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# "SCIENCE AND TECHNOLOGY OF THE XXI CENTURY"

## INTERNATIONAL R&D ONLINE STUDENT CONFERENCE AND COMPETITION

## CONFERENCE PROCEEDINGS

December 04, 2024

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## SECTION: FUTURE TRENDS IN SCIENCE AND TECHNOLOGY

# LEVERAGING LIVER-ON-A-CHIP TECHOLOGY FOR EARLY DRUG TOXICITY PREDICTION

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**Keywords:** liver-on-a-chip, drug testing, drug-induced liver injury.

**Introduction.** On average, it takes about 15 years for a new drug to reach the market, largely due to lengthy preclinical and clinical trials, with no guarantee of success. Globally, around 85% of drug candidates fail to achieve regulatory approval, often due to limitations in preclinical models for predicting toxicity and metabolism. Drug-induced liver injury is a leading cause of failure in clinical phases. Animal models like mice provide initial safety data but often fail to accurately reflect human responses due to metabolic and drug target differences. Moreover, animal testing is costly and raises ethical issues, increasing the demand for *in vitro* cell culture systems. Standard 2D in vitro cultures, commonly used for their simplicity, lack the three-dimensional structure and dynamic environment of human tissue. Primary human hepatocytes, a gold standard for hepatotoxicity testing, quickly lose functionality in monolayer culture, reducing predictive accuracy. While 3D cultures improve cellular functionality, they still miss critical physiological dynamics. Organ-on-a-Chip technology addresses these gaps by using microfluidic engineering to recreate organ environments with tissue interfaces, fluid dynamics, and mechanical forces, maintaining hepatocyte function and closely mimicking *in vivo* conditions for improved drug testing accuracy (Ewart et al., 2022; Fu et al., 2023; Qiu et al., 2023).

**Objectives.** An overview of liver-on-chip as a preclinical model for drug hepatotoxicity prediction

**Methods.** Relevant articles for the last 5 years on the application of liver-on-a-chip technology for drug hepatotoxicity testing were sourced from Scopus and Google Scholar. These articles were systematically analyzed to identify major trends, application scope, and potential areas for future advancements.

**Results.** Organ-on-a-chip is a cell culture system based on microfluidics, where small chambers and channels populated with cells are continuously perfused to mimic physiological conditions of the body (Bhatia & Ingber, 2014). One of the most common setups for organ-on-chip technology is the membrane-based 2D platform. These platforms use semi-permeable membranes that enable interactions between different cell types and allow responses to varying flow conditions, simulating the structure and function of liver sinusoids. Emulate's liver-on-a-chip is

a commercially available membrane-based model for drug toxicity testing. The structure of the liver-on-a-chip system designed to replicate the complex architecture and functionality of human liver. The liver-on-a-chip system features two parallel microchannels separated by a porous membrane with 7 μm diameter pores, spaced 40 μm apart, allowing for efficient molecular exchange and interaction among different cell types, closely replicating in vivo liver tissue behavior. The epithelial channel serves as the upper compartment, supporting epithelial cell cultures and mimicking interfaces found in liver tissue. Below this lies the endothelial channel, which simulates blood flow by supplying liver cells with nutrients and oxygen while removing metabolic waste. Between these channels is a porous membrane that separates the epithelial and endothelial compartments, facilitating molecular and cellular exchange critical for liver functions. Within this microenvironment, hepatocytes carry out key liver functions such as metabolism, detoxification, and protein synthesis, while stellate cells regulate the extracellular matrix, contributing to tissue structure and liver regeneration. Kupffer cells, the liver's resident macrophages, provide immune defense and clear cellular debris, while liver sinusoidal endothelial cells line the sinusoids, enabling filtration and nutrient exchange. This intricate interplay of components, supported by the extracellular matrix, creates a dynamic microenvironment that faithfully mimics liver function, making the liver-on-a-chip a valuable tool for studying liver health, disease, and drug interactions (Ewart et al., 2022).

There are also 3D-on-chip liver cultures that can be used in drug preclinical studies. For instance, a liver spheroid-based on chip model was developed by Cox and colleagues. The hepatocytes and mixed non-parenchymal cells are introduced into the chip's microwell-containing reservoir, then centrifuged for even cell distribution. After that, the setup is perfused using suitable pumps. By day 7-8, mature liver spheroids are ready for testing. Results indicated that after 72 hours of incubation with 50 μM diclofenac, the metabolite profile in the liver-on-a-chip model differed significantly from that of the single spheroid culture. The liver-on-a-chip demonstrated higher levels of metabolic activity across all reported metabolites ($p < 0.05$), underscoring its greater sensitivity and accuracy in replicating liver metabolism compared to the spheroid culture (Cox et al., 2022).

**Conclusions.** Liver-on-a-chip technology offers a promising alternative to traditional models by better simulating human liver responses and predicting drug toxicity. Combining this with other organ-on-chip systems enables complex, multi-organ modeling to improve drug efficacy and safety predictions at the whole-organism level.

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## 'ALL THE WORLD IS A CAPTION': TECHNOLOGIES FOR SUBTITLING FOR DEAF AND HARD OF HEARING IN BRITISH TEHATRE CONTEXTS

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**Keywords:** accessibility, Subtitling for d/Deaf and Hard of Hearing, new technologies, theatre.

**Introduction.** Currently, the defense of the rights of people with disabilities is a greatly significant topic on the international scene. From the well-known Convention on the rights of persons with disabilities of the United Nations in 2006 up to the European Accessibility Act (EAA) (2019) that will coming into force at the beginning of next year, there are numerous initiatives calling for equal access for people with disabilities to any product or service, whether in an administrative, health or leisure sphere.

**Objectives.** Technology plays an essential role in guaranteeing these fundamental rights as it is one of the pillars on which accessibility is based on, as stated by the EAA (2019). There is a wide variety of new technologies that serve this purpose. These software applications go from the simplest ones such as those that allow adding or removing audio description on any digital video on demand platform product (e.g. AudescMobile, 2013), to more complex ones that translate texts into

sign language through the use of an avatar or real interpreters (Text2Sign, 2019), or even others that require groundbreaking computer systems such as technologies that transform sign language into spoken language in text format through the use of AI (How2Sign, 2023). For this reason, it is interesting to think further over the current technologies that serve this purpose, to assess their advantages and limitations and to consider possible improvements for the future that will help to enable better access to information for people with disabilities.

**Methods.** In the case of hearing impairments, there are tools for accessing the sound information beyond sign language interpreting. As Stagetext (2020) indicates, less than 1% of deaf people 'are fluent in British Sign Language', which means that offering alternatives to assure equal access to the film soundtrack information of audiovisual products is necessary. This alternative, known as captioning or subtitling for d/Deaf and Hard of Hearing (SDH), has been in recent years a support for people with hearing impairments, as well as an aid for people whose native language is not that of the audiovisual product consumed, children who are learning a specific language, elderly people with a significant hearing loss or even for those products in which the sound edition is not optimal nor the sound itself, and subtitling is consequently necessary in order to deliver a better understanding of the film soundtrack.

**Results.** Therefore, the SDH is an 'intersemiotic and intralinguistic translation of a film's soundtrack (dialogues, music, and sound effects), as well as any on-screen texts presented in another language (interlinguistic translation) through the use of a textual support, usually placed at the bottom of the screen' (Bru García and Martínez-Martínez, 2024). The intralinguistic and intersemiotic character of this practice is therefore relevant, since it involves more than a mere transcription of the dialogues: a good quality SDH must include descriptions of the music, the sound effects and the paralinguistic component of the dialogues so as to offer a reliable reflection of all the elements of the film soundtrack.

This research reviews the technologies used in the SDH of a very specific field of leisure: theatre. Indeed, the performing arts also apply accessibility technologies to enable access to knowledge for people with hearing impairments. We will evaluate the advantages and limitations of two existing SDH tools in London's West End theatres: the StageText association's captioning screens and the SmartCaption augmented reality glasses used in National Theatre productions.

In order to carry out this analysis, the following SDH quality parameters will be analyzed: transcription, subtitles location, technical parameters, customization and synchronization. In the transcription section, the effectiveness of the transcription of the linguistic aspects of the SDH will be assessed, paying special attention to the paralinguistic issues and the speaker identification – the latter being of particular relevance given the absence of a camera language to identify the speakers. Regarding the localization analysis, the placement of the subtitles will be

discussed (next to the stage in the case of StageText versus in the scene itself in the case of the glasses) and their relevance for the correct reading of the subtitles. As for the technical parameters, the standard aspects of this discipline's literature (Díaz Cintas and Remael 2007) will be assessed, i.e., characters per line, characters per second and segmentation – crucial aspects for a correct reading of the subtitles. As for customization, we will present those elements that can be changed and customized by viewers when consuming these subtitles. In addition, the possible implications that this customization features entail with respect to the other parameters will also be considered. Finally, in the section on synchronization, the correct synchronization of the subtitles with the dialogue presented on stage will be evaluated.

**Conclusions.** The limitations of both will be noted too, as well as the advantages of their use and finally some possible solutions will be offered in terms of proposing ways to enhance and enforce their level of implementation and benefits to the target audience.

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# AUTOMATED TESTING TRENDS: HOW INNOVATIONS ARE CHANGING QUALITY CONTROL

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**Keywords:** automated testing, artificial intelligence, development speed, cost savings, testing trends, DevOps, cloud infrastructure.

**Introduction.** It is impossible to imagine a modern software development process without testing. Automated testing is one of the types of testing that is used everywhere. Everyone has routine tasks that are sometimes very annoying, which is why developers and testers have a tool that saves them from the same type of repetitive tasks that cannot be ignored. In addition, automated testing saves time, resources, reduces the risks of human error, and increases the efficiency of development and test teams.

**Objectives.** In these theses, we will first assess the importance of automated testing for improving test speed, costs, and code and test quality. Next, we'll look at the main trends in automated testing.

**Methods.** This paper is based on articles by companies involved in quality assurance and automated testing and people with some experience in this field. Based on these articles and our own thoughts, we consider different approaches to test automation. We'll talk about trends, such as the use of AI, integration with CI/CD environments, and NLP processing.

**Results.** So, why is automated testing important? People who are not familiar with testing or development may think that testing is a simple process, but in fact, modern software has many functions and use cases. The minimum set of tests to test a single function includes at least 3 scenarios: correct input, incorrect input, and function operation without input. What if the software has more than 100 complex scenarios? That's why some routine tasks that take a lot of time and can be repeated several times should be automated because time is money.

The main advantage of automated testing is speed. Some simple things, such as checking that the code is clean or complies with code conventions, have long been automated. Testers can write tests for functions that are often repeated in projects and automate this moment because it is the same work that can be simplified. This significantly reduces the time to market. The faster a product gets to the market, the more advantages a company can gain in the market. Ongoing support with automated testing also reduces the time to release updates. Other types of automated testing are described below.

Automated testing saves companies a lot of money. Manually performing repetitive tests is a time-consuming process, which means you have to pay for it.

Automation of repetitive scenarios is performed once, but they can be used repeatedly. This helps to avoid the human error factor and gives testers more time to test the user interface and usability.

Let's talk about trends. AI is being used in many areas, and automated testing is no exception. Nowadays, there are even AI prototypes that write tests and try to fix errors (PerfectQA, 2023). Currently, this is a very poorly performing tool because according to a Leapwork & Censuswide report (2024), 68% of companies that have integrated AI have faced problems with unreliability and accuracy. However, this problem will be solved over time, as long as AI is trained.

According to Kevin Parker (2024), natural language processing (NLP) is gaining popularity. This will allow the tester to describe the steps to be performed for testing, and the AI will perform these steps independently. This type of test automation allows the tester to have no knowledge of the programming language since he or she is responsible for writing instructions on to test using in their own language.

Many companies are now using cloud technologies and microservice architecture. This simplifies the work of testers whose companies do not use their own server. The cloud infrastructure is more flexible and easier to scale up, which allows you to run tests quickly and without additional servers (Sharma, 2024). The microservice architecture breaks the software into separate modules that are easier to test using automated testing, leaving the tester more time for integration tests.

There is probably not a single company that doesn't use CI/CD today. Adding tests to the CI/CD pipeline will help avoid errors when changing the code, which significantly affects the quality of the software (Homann, 2024). This is especially true if the team works with Agile methodologies because each new sprint means new features.

**Conclusion.** In software development, automated testing is an important tool that allows to speed up product launch and subsequent updates, reduce costs, and increase quality by eliminating the risk of human errors in repetitive tasks. The main trends in automated testing are the use of AI for test writing and NLP-based test scripting, the use of testing in the CI/CD pipeline, and the use of microservice architecture to simplify testing of individual modules. Automated testing allows testers to devote more time to complex tasks without reducing software quality. Such innovations in testing will ensure companies' competitiveness, reliability, and speed of response to market needs.

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## PROBLEMS OF MODERN DEVELOPMENT OF POLITICAL CULTURE. POLITICAL CULTURE AS A SET OF POSITIONS IN THE RELATIONSHIP BETWEEN THE GOVERNMENT AND THE CITIZEN

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**Keywords:** Democracy, stability, political education, public trust, media influence.

**Introduction.** Over the years of human existence, man has been able to go through many stages of his life. And with each period of life, situations became more and more complex and man, as an entity, needed to adapt to the world and adapt the world to himself. And with the development of humanity, society also developed, and people had to find new ways to manage society. After all, even at the beginning, social relations were created, which can already be called the rudiments of the state. And for the successful functioning of the state, interaction with citizens is necessary, which in the modern world is implemented by public diplomacy, which is closely related to political culture. Therefore, I propose to understand this topic, to identify and understand the main problems of the modern development of political culture.

**Objectives.**

**1. Analyze the Evolution of Political Culture**

Examine how political culture has developed alongside human society and its significance in regulating interactions between citizens and the state.

**2. Identify Key Challenges in Modern Political Culture**

Highlight the primary issues affecting contemporary political culture, such as insufficient political education, public trust in government institutions, and lack of diverse representation.

**3. Explore the Impact of These Challenges on Society and State Stability**

Assess how issues like low citizen participation, trust erosion, and inequality in representation affect the stability and functionality of the state and society.

**4. Suggest Measures for Strengthening Political Culture**

Propose strategies to enhance political culture through transparency, inclusiveness, representation, and fostering citizen-government interaction to support democratic stability (Almond, & Verba, 1963).

**Methods.**

**1. Literature Review and Historical Analysis**

Review historical developments in political culture and societal management, examining primary sources on state formation and public diplomacy evolution.

**2. Case Studies on Political Education and Awareness**

Conduct case studies or comparative analysis of different countries or regions to assess the effects of political education on citizen engagement.

**3. Surveys and Polls on Public Trust in Government Institutions**

Utilize public opinion surveys and existing polls to measure trust levels in government institutions and identify factors affecting these levels.

**4. Data Analysis on Population Representation and Participation**

Analyze demographic data to understand representation gaps across social, ethnic, and gender groups in the political process.

**5. Policy Analysis for Strengthening Political Culture**

Evaluate existing policies aimed at fostering political education, transparency, and representation. Suggest improvements based on successful international practices (Norris, 2011).

**Results.** To begin with, we need to understand that political culture is one of the most important components of society, as it defines and regulates the way citizens interact with their government and political system. But, as of today, political culture is increasingly facing various problems that prevent it from manifesting itself correctly, which directly affects the relationship between the state and citizens. Therefore, I propose to consider the main problems that arise in the modern development of political culture and try to describe them.

1. Insufficient political education and awareness of citizens.

One of the key problems of the modern political culture is the lack of education and awareness of citizens about political processes. A large number of citizens do not have enough information to properly understand the processes taking place within the state. This leads to a low level of citizen participation in the political process.

2. Trust and legitimacy of government institutions.

Another serious problem is the loss of public trust in government institutions. After all, the less trust citizens have in the state, the more difficult it is for it to function properly. There are many factors for this, but it is mostly related to the media, because the media have a great influence on the public.

3. Insufficient participation and representation of different groups of the population.

Another important problem is the lack of participation and representation of different social, ethnic and gender groups in the political process. This can lead to inequality and injustice in political decision-making, which, in turn, can also lead to a decrease in public trust. The consequences of this can be really significant and negative (Norris, 2011; Huntington, 1996).

**Conclusion.** Thanks to the study, we can confidently say that the analysis of the problems of the modern development of political culture only confirms their seriousness and importance for both society and the state as a whole. Insufficient political education, loss of trust in government institutions, polarization of society and inequality of participation in the political process are just some of the problems, because, in fact, there are a large number of problems and they all need to be addressed immediately, but society is still developing and trying to find the best way to solve these problems. The development of political culture as a set of positions in the interaction between the government and the citizen requires systematic measures to ensure openness, transparency, participation and representation of all layers of society. This is the only way to ensure stable and democratic development of modern society.

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# INTEGRATING MACHINE LEARNING INTO SOFTWARE TESTING

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**Keywords:** machine learning, software testing, automation, AI, quality assurance.

**Introduction.** As the complexity of software systems continues to increase, the need for more effective and efficient testing methodologies becomes apparent. Traditional testing methods, which often rely on manual processes, are not always capable of keeping up with the speed and scale of modern software development cycles. Machine learning (ML) presents a promising solution by automating several aspects of software testing and improving the overall quality of the process. The integration of ML into software testing has the potential to enhance test accuracy, prioritize critical tests, and reduce the time required to identify defects. This paper explores how machine learning can transform software testing, focusing on test case generation, defect prediction, and test prioritization.

**Objectives.** The primary objective of this research is to investigate the application of machine learning techniques in automating software testing processes. More specifically, this study aims to:

1. Explore methods for generating test cases automatically using ML algorithms.
2. Analyze the effectiveness of defect prediction models based on historical data.
3. Develop and evaluate strategies for test case prioritization using ML.
4. Demonstrate how machine learning can reduce redundant testing efforts and increase the overall efficiency of the software testing life cycle.

**Methods.** This study employs various machine learning algorithms, such as decision trees, support vector machines (SVM), and neural networks, to address different aspects of software testing. Historical software defect data is used to build predictive models that can anticipate which parts of the code are most likely to contain defects. These models are then applied to prioritize test cases and ensure that the most critical areas of the software are tested first. Furthermore, unsupervised learning techniques, including clustering and anomaly detection, are used to analyze large volumes of test execution data, providing deeper insights into areas of potential risk (Kim et al., 2019).

Test case generation is another key focus of this study. By training models on previous test cases and corresponding defect data, it is possible to automatically generate new test cases that are more likely to uncover defects. These automated test cases are validated against real-world software projects to assess their effectiveness

in comparison to manually written test cases. Tools like genetic algorithms and reinforcement learning are also explored for their ability to optimize test case generation, reducing the need for human intervention (Murphy, 2018).

**Results.** The integration of machine learning into software testing yielded substantial improvements in both defect detection efficiency and overall test coverage. The application of neural networks for defect prediction resulted in a 30% increase in the accuracy of identifying high-risk areas in the software. Furthermore, the time required to execute the testing phase was reduced by approximately 20%, largely due to the prioritization of critical test cases. This reduction in testing time allowed for faster release cycles and improved software quality.

In terms of test case generation, ML-based algorithms were able to create test cases that were more effective at detecting defects compared to manually crafted test cases. By analyzing patterns from previous test cases, machine learning models generated test scenarios that covered edge cases and complex system interactions, which might have been overlooked by human testers. In addition, test case prioritization models significantly reduced the number of redundant test cases, focusing resources on the most impactful tests (Ramler & Kutt, 2020).

**Conclusion.** In conclusion, the integration of machine learning into software testing holds great promise for improving both the efficiency and effectiveness of the testing process. By automating test case generation, prioritizing tests based on risk, and predicting defects more accurately, machine learning can reduce the time and resources needed to achieve high-quality software. The results of this study demonstrate that ML can improve test coverage, increase defect detection rates, and streamline testing processes. As software development continues to evolve, the use of machine learning in testing is likely to become an essential tool for ensuring that software products meet the highest standards of quality and reliability.

Future research should focus on refining the integration of machine learning models into real-world software development environments. Additional studies are needed to explore the scalability of ML-based testing solutions for larger and more complex software systems. Moreover, the combination of different machine learning techniques, such as deep learning and natural language processing, with existing testing frameworks could unlock even more potential for automated testing.

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# ECO-FRIENDLY INKS FOR PRINTING: WHAT MAKES IT GREEN?

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**Keywords:** eco-friendly inks, green printing, sustainable materials.

**Introduction.** Due to growing concern about the current dire state of the environment, implementing environmental sustainability in technology is not just a trend, but our everyday life. The printing industry is no exception, so engineers are actively working to implement eco-friendly materials and technologies to produce as little harmful waste and natural resources as possible. Using ecologically clean printing inks is an essential part of this process.

**Objectives.** To explore eco-friendly inks as a full-fledged alternative to traditional inks and the real possibilities of their implementation in printing processes as a primary type of ink.

**Methods.** The use of eco-friendly inks is a current trend, as it has a positive impact on the environment and the printing process itself.

One of the benefits is minimising the use of oil (as we know, this is the basis for traditional inks), as well as reducing carbon emissions, because eco-ink is made from renewable and sustainable materials. These inks do not contain toxic chemicals (e.g. harmful volatile organic compounds) and solvents, contributing to a safe working environment and product use. In addition, they are bright and provide rich colours in printed products (Dillon, 2024).

The future of printing is believed to not only be driven by new large printing presses and new technologies, but also by new materials. Paper and ink are the main printing materials, so finding more green ways to use these materials is a significant priority. Plant-based biodegradable inks are the main alternative to oil-based inks. They are produced from renewable plant resources such as soya, rice bran, and algae. The main ingredients of eco-friendly inks are renewable oils and resins (soybean oil, linseed oil), pigments from minerals and plants (clays, minerals, vegetable and fruit extracts), water as a solvent, biodegradable additives (beeswax and carnauba wax, vegetable alcohols). New sources and ingredients are actively researched to create new vegetable paints and reduce the environmental impact in the future (Ilhan, 2024).

Eco-friendly inks are widely used in printing companies in America and Europe. For example, The Print Authority uses inks based on soy and vegetable components, and vegetable toner. Such inks are not only functional, but also provide excellent colours on paper. They prove that paper printed with vegetable inks is more biodegradable and more accessible to recycle (The Print Authority, 2023).

**Results.** The implementation of eco-friendly materials is a clear way to create alternative, less harmful ways of doing such a sophisticated printing process. An undeniable advantage of using eco-friendly inks is the reduction of harmful chemical impacts on the environment and workers and the minimisation of oil usage. We learned about the complete composition of these inks, which includes plant oils, pigments, water, and biodegradable additives. Using entirely plant-based materials will reduce the dependence on oil as the base for the ink, which will lessen the negative impact on nature caused by emissions.

Further exploration of this topic can focus on the prudent use of natural resources, as the production of eco-inks decreases the use of oil and toxic solvents while increasing the utilisation of natural materials. Therefore, research into the wise use of resources without exaggeration is a relevant topic.

**Conclusion.** After studying the composition, benefits and ways to use eco-ink, we can conclude that the study of this topic is still a work in progress and will be relevant for years ahead as we continue to deepen our care for nature. Biodegradable inks made from vegetable materials are a great example of innovations that are intended to be eco-friendly. It helps to reduce pollution of the environment, water, air and soil and improves the health conditions of printers and users. Moreover, using environmentally friendly technologies and materials enhances the company's image, as such companies have high-quality requirements. Therefore, we must protect our environment and look for even more ways to go green in printing.

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## THE IMPACT OF AI CHATBOTS ON CUSTOMER SERVICE AND E-COMMERCE

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**Keywords:** AI Chatbots, E-Commerce, Natural Language Processing, Customer Engagement, Personalization.

**Introduction.** Chatbots are virtual agents that engage in conversations with humans using natural language. The rapid advancements in artificial intelligence

(AI) and the increasing usage of messaging apps are the primary factors driving growth in the chatbot industry (Silva et al., 2022). AI chatbots are reshaping the e-commerce industry by enabling personalized customer service, optimizing operational workflows, and contributing to sales growth.

**Objectives.** This study aims to state the practical implementations of AI chatbots in e-commerce, their limitations, and present current findings.

**Methods.** To achieve this purpose, we conducted a literature review on artificial intelligence (AI) and its applications in e-commerce, alongside primary research based on the hands-on development of custom AI chatbots.

**Results.** In e-commerce, customer service models that rely on human agents often encounter scalability issues due to the increasing number of customers. That leads to insufficient customer response times and non-personalized suggestions.

With the rising development of AI chatbots, e-commerce platforms can now provide 24/7 customer support and deliver consistent responses while handling several requests concurrently (Maharshi, 2024).

To analyze the full potential of AI chatbots, it is essential to consider that this technology is still relatively new, with ongoing concerns about privacy, ethical aspects, and technical limitations. Accordingly, we present a framework (Mamadou, 2024) that addresses many of these issues for businesses to optimize customer experience and integrate artificial intelligence into work processes.

1. The AI-Powered Customer Interaction Pillar (PICA-IA) suggests that businesses can use AI chatbots in concurrent communication and provide automated customer support through messaging platforms or chatbot interfaces.
2. The Customer Behavioral Analysis Pillar (PACC) shows another option: integrating AI chatbots within Customer Relationship Management (CRM) platforms to analyze consumer behavior patterns and deliver personalized marketing campaigns.
3. The Ethics and Data Privacy Pillar (EDPP) highlights that businesses should follow security measures and standards when using AI chatbots with customer data to address ethical and privacy concerns.

Large language models (LLMs) like ChatGPT can help businesses automate many tasks, eliminating the need for human agents. However, ChatGPT is a tool used to assist human agents, not to replace them (Jain et al., 2023).

While we have outlined the general benefits of artificial intelligence in customer service, we have conducted independent research by developing an AI chatbot to interact with customers through a chat interface.

The chatbot, developed using OpenAI Assistant technology, successfully provided responses in under 45 seconds with an accuracy rate of 90%. Managers began leveraging chatbot-style responses and using scripts to streamline interactions.

The findings state that despite the growing interest in chatbot technology, business owners often fail to recognize its full potential and prefer human-operated customer interactions.

Although many businesses are keen to implement AI chatbots, most of them remain in the early stages of adoption. With more skilled technicians and affordable solutions, wider adoption is likely anticipated.

**Conclusion.** This study highlights the importance of AI chatbots in e-commerce, offering significant improvements in customer service.

To ensure broad integration of AI chatbots, they must be affordable. Relying solely on third-party tools that allow companies to create such AI chatbots easily will result in low accuracy of responses and high monthly costs. However, only some companies have qualified specialists to train NLP models on their corresponding large datasets and receive high-quality outputs.

I suggest mitigating limitations and promoting knowledge on creating custom-trained models. Overcoming the hesitations of business owners and addressing ethical and privacy concerns will be crucial for the future evolution of AI in e-commerce. By integrating the latest technologies, we can accelerate business growth and drive innovations.

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# DEVELOPMENT TRENDS OF SUSTAINABLE PACKAGING

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**Keywords:** sustainable packaging, polymer films, biopolymers, packages recycling, flexographic printing.

**Introduction.** The production of packaging products has become one of the largest sectors in the world's industrialized countries during the last few decades. At the early stages of industrial development, materials primarily derived from organic sources, such as rubber, were commonly used. However, rubber and metal shortages led to the increased use of petroleum-based products in production. Therefore, a significant amount of packaging is now composed of polymer materials due to their advantages such as lightweight, strength, affordability, and accessibility. However, such materials pose a global threat to the environment. These packages are resistant to natural conditions and take decades to decompose. This causes the problem of pollution in cities, suburban areas, and reservoirs. Some materials can be toxic to living organisms under certain conditions. Innovative materials and recycling methods are essential to reduce environmental pollution globally. It is crucial to address polymer waste by introducing alternative environmentally friendly packaging solutions into industrial practice.

**Objectives.** The main goal is to establish the possibility of recycling, reusing, or replacing polymeric materials in packaging with degradable materials.

**Methods.** Analysis of studies on the topic of modern trends in sustainable packaging.

**Results.** Biodegradable film materials are increasingly sought after in the production of sustainable packaging, driven primarily by the widespread availability of environmentally friendly printing inks for gravure and flexographic printing in Ukraine and other countries. These materials are designed to decompose under environmental conditions, such as exposure to moisture, sunlight, soil acidity, oxygen, microorganisms, etc. For instance, products made of polyoxybutyrate are currently used in the packaging industry, as they decompose naturally at the expense of soil microorganisms. You can also use materials consisting of polymers and fillers, in which fillers can be organic substances, such as starch, cellulose, or dextrin. However, such compositions decompose only partially. In addition, polymer materials with a chemical structure similar to natural polymers are used in production. These include materials based on complex aliphatic polyethers and lignin analogs.

Scientists also breed and research special strains of microorganisms capable of destroying polymers. Pseudomonas SP bacteria can produce an enzyme that breaks

down and assimilates polyvinyl alcohol. The development of this technology is also relevant for the printing and packaging industry (Khokhlova & Mokretsova, 2021).

Research and implementation of technologies for processing polyethylene and polypropylene films are currently underway. For example, sorted and purified PET film can undergo glycolysis, resulting in polymerization, reformation of the monomer base, and depolymerization. Such recycled film has quality indicators close to the standard. This technology is both environmentally friendly and economically advantageous.

The use of mono-materials, such as polypropylene films with improved properties, offers significant advantages compared to traditional multi-layered materials. These single-material solutions simplify the sorting process and facilitate more efficient recycling and reuse of packaging, contributing to more sustainable waste management practices (Kukura, 2022).

Many countries are moving towards using reusable packaging. The EU Directive 2019/904, issued on June 5, 2019, bans the production and use of single-use polymer cutlery, plates, drinking straws, food containers, etc. in EU countries starting from 2021. Additionally, the Polymer Strategy mandates that all polymer packaging must be reusable by 2030 (Ishchenko, 2023).

In today's world, consumers are becoming increasingly influenced by media coverage, heightened awareness of environmental initiatives, and the abundance of information available to them. Consequently, they are actively searching for packaging solutions that resonate with their values and minimize environmental impact. This shift reflects a growing demand for responsible packaging options that not only reduce waste but also contribute to a more sustainable future.

**Conclusion.** Directions for the development of sustainable packaging were determined based on the analysis of current trends and the state of degradable film materials production. These include materials based on polyoxybutyrate and biopolymers, as well as materials with a chemical structure similar to biopolymers and compositions of materials with organic substances. The use of specialized microorganisms for polymer degradation, new effective film processing technologies, the adoption of polymer films made from mono-materials, and the transition to reusable packaging offer significant potential for further innovation in this field. Therefore, a lot of research is being conducted on this topic, which guarantees the achievement of a more ecological production of packaging products.

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## MP3 CONTAINERS-BASED STEGANOGRAPHIC SYSTEMS IN THE COMING DECADE

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**Keywords:** MP3 steganography, data hiding, secure communication, LSB coding, phase coding, echo hiding, spread spectrum, artificial intelligence, quantum technology.

**Introduction.** Along with digital development, cyber-attacks have become more sophisticated, and the transmission of sensitive information is now a major challenge. Steganography, the technique of concealing information within multimedia content, adds another layer of security by hiding the very presence of the message. Among the multimedia formats, MP3 has emerged as a promising container for steganography due to its widespread use and versatility. This research examines the future prospects of MP3-based steganographic systems over the next decade, focusing on how advancements in machine learning and quantum technologies can enhance their security and efficiency.

**Objectives.** The study aims to analyze potential developments in steganographic techniques using MP3 containers. It focuses on methods such as Least Significant Bit (LSB) coding, phase coding, echo hiding, and spread spectrum techniques, while also considering the integration of modern technologies like artificial intelligence (AI). The research seeks to understand the implications of these innovations for the security, efficiency, and capacity of steganographic systems.

**Methods.** Various steganographic methods using MP3 as a container are examined, starting with LSB coding. LSB coding is a well-known method that embeds data by replacing the least significant bits of audio samples with message bits. While popular, it is vulnerable to steganalytic attacks, especially when embedding large amounts of data (Kamble & Chaurasia, 2021). This research

suggests improvements to LSB coding by incorporating machine learning algorithms that automatically detect vulnerabilities and enhance the system's robustness.

Phase coding, another method, takes advantage of the human ear's insensitivity to slight phase shifts in audio signals. This method embeds the hidden message within phase shifts, providing higher security without degrading audio quality (Kulkarni, Phatak, Rathod, & Prajapati, 2021). It is particularly effective for MP3 steganography since phase information is preserved in compressed formats and is crucial for decoding.

Echo hiding is a more advanced technique that introduces slight echoes into an audio signal, encoding data through variations in delay, amplitude, and decay rate. It offers high capacity and resistance to noise, making it a promising technique for future applications (Aryfandy, Purboyo, & Saputra, 2021).

Spread spectrum techniques, initially developed for military communications, spread the hidden message across a wide frequency range, making it difficult to detect or intercept (Rakshit, Ganguly, Pal, Aly, & Le, 2021). Applied to MP3 steganography, these techniques enable the transmission of large volumes of data while ensuring security and robustness.

**Results.** The research suggests that while LSB coding is a popular method for steganography in MP3 containers, it needs enhancements to withstand modern steganalysis techniques. Integrating AI and machine learning can significantly improve LSB-based systems by dynamically adjusting the embedding process to evade detection.

Phase coding and echo hiding are more resilient against steganalysis, especially in applications requiring high audio quality. These methods maintain the perceptual integrity of the audio while embedding the hidden message, making them ideal for scenarios where stealth is crucial. Spread spectrum techniques offer the highest level of security by embedding data across a broad frequency range, making them suitable for transmitting large amounts of sensitive information.

Machine learning algorithms have great potential to enhance these steganographic methods. By training models on large datasets of audio signals, machine learning can optimize the embedding process, increasing the system's capacity to conceal data while minimizing detection risks.

**Conclusion.** The future of MP3-container-based steganographic systems is promising, especially with the integration of AI and quantum technologies. As cyber threats evolve, the need for more advanced steganographic techniques will grow. LSB coding, while effective, needs improvements to withstand modern attacks. Phase coding, echo hiding, and spread spectrum techniques provide more robust alternatives, each with distinct advantages in terms of security, capacity, and audio quality.

Innovative machine learning will likely play a key role in the development of next-generation steganographic systems, making the embedding process more efficient and secure. In conclusion, MP3 containers will continue to be a viable

medium for steganography, offering a balance between security and usability. The integration of cutting-edge technologies will drive the development of more sophisticated systems that can meet the growing demands for secure data transmission in the digital age.

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## SOFTWARE OVERVIEW FOR FREE VIDEO GAME LOCALISATION

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**Keywords:** localisation, free software, CAT tools, video games, volunteer and non-profit projects.

**Introduction.** In the recent years, especially starting in year 2022, resurgence of the interest in not only authentic Ukrainian content, but also localised into Ukrainian products has been spreading among populace. Often the owners of respective products are not ready to fund their software localisation into Ukrainian. In such case volunteer and non-profit projects come into play. However, their participants face different difficulties, caused by the lack of software, meeting their needs. In this key effective translation tools may have come in handy.

**Objectives.** This research aims to define the challenges of free localisation, suggest possible ways to overcome them, and select best free tools for video games localisation.

**Methods.** To achieve these objectives, we have carried out the comparative analysis of the features presented by four different localisation software and tested them in practice.

**Results.** Computer-aided translation tools (commonly abbreviated to CAT), which offer extensive functions to improve translator's performance and expand the number of available features, are the best localisation instruments. Based on our personal work experience with such type of software, we have deduced the most frequent limitations of their free trial and paid versions. The most common of them is *thelimitation of the number of people working on the project*, either blocking online simultaneous contribution or setting precise number of people working on the project. The second one, which often hits the hardest is *the limitation of hosted words* (e.g. free Crowdin plan offers 60,000 hosted words). The third most frequent one is *the disabling of some features*, usually limiting contributors' roles or machine translation options. In Table 1, we present the analysis of the most popular localisation software programs.

*Table 1*

**Comparative analysis of the most common localization software**

| Software name | Pros | Cons | Price (per month) |
|---|---|---|---|
| Crowdin | – Unlimited public projects and contributors;<br>– machine translation features;<br>– security key logins;<br>– AI, translation memory, glossary tools;<br>– add-ons supporting more than 40 file formats<br>– compatible with with GitHub | – 60,000 hosted words;<br>– one private project for solo work;<br>– high pricing | $66-$450 |
| Poeditor | – working with PO files;<br>– simple user interface;<br>– API integration;<br>– quality insurance check;<br>– affordable pricing | – only 1000 strings for free;<br>– limited number of contributors;<br>– most features are paid | $13-$170 |
| Weblate | – open-source;<br>– free for hosts in their servers;<br>– number of hosted words up to 10 million in cloud plans;<br>– flexible settings;<br>– translation memory and autopropagating;<br>– compatible with GitHub | – hard to set-up;<br>– expensive | $37-$100 (Hosting)<br>$45-$562(Cloud version) |
| Smartcat | – advanced AI;<br>– unified affordable price;<br>– translation of media files | – no free version;<br>– word limit per year and not per account;<br>– limited functionality | $100 |

As we can see, almost every software piece provides very limited functions in their free versions, and the price plan, meeting all requirements, is barely affordable for non-profit and volunteer projects. This often leads small teams to resort to completely free tools not specifically catered for localisation purposes, e.g. Google Docs and Google Sheets. Although lacking in functionality, they offer limitless potential and allow many people to collaborate at the same time. As the solution for this problem, we see three options: either the enrichment of the free functionality of localisation software, more loyal pricing or opportunity to get better options for free if you are a non-profit organisation. It would benefit both clients and companies: translators will save their money and be able to work more and faster, and the companies will improve their public image and attract new customers.

**Conclusion.** Based on our research findings, we can conclude that the most popular CAT tools do not provide the features, needed for most non-profit projects (sufficient number of words, private projects, flexible and functional machine translation tools) or offer them in severely limited capacities. As a best win-win solution we envision companies indulging in some form of social charity, offering cooperation to motivated volunteers and providing them with the subsidised or completely free plans. We are quite aware, that companies (especially comparably small ones) require money for hosting and service purposes, but limited number of such cases would benefit both sides.

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## FROM MAINFRAMES TO CLOUD: THE FUTURE OF SECURE DATA PROCESSING

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**Keywords:** cloud computing, mainframe, data security, secure data processing.

**Introduction.** Data processing has come a long way from the early days of centralized mainframes to the modern era of cloud computing. These technological advances have not only transformed how businesses handle large volumes of data but also reshaped the security landscape. The transition from mainframes to cloud computing presents both opportunities and challenges for data security, making it crucial to understand how each technology operates and what lies ahead for the future of secure data processing.

**Problem Statement.** Mainframes, which emerged in the mid-20th century, were the cornerstone of enterprise computing for several decades. These powerful, centralized systems could handle massive amounts of data and support thousands of users simultaneously. Mainframes were known for their robust security features, as they operated in controlled environments with limited external access. However, the high cost of hardware and maintenance, as well as the limited scalability, made mainframes less practical as data processing needs grew exponentially (IBM, n.d.).

With the rise of the internet and the advent of cloud computing, a paradigm shift occurred in how data is processed and stored. Cloud computing, which enables on-demand access to shared computing resources over the internet, offers greater flexibility and scalability compared to mainframes. Cloud service providers (CSPs) like Amazon Web Services (AWS), Microsoft Azure, and Google Cloud allow businesses to scale their operations quickly and pay only for the resources they use. This shift has democratized access to high-performance computing, making it accessible to organizations of all sizes (Wikipedia, n.d.).

**Research and Findings.** While cloud computing offers numerous advantages, it also introduces new security challenges. One of the primary benefits of cloud computing is the ability to distribute data across multiple locations, reducing the risk of data loss due to hardware failure (IBM, n.d.). Additionally, cloud platforms offer built-in security features such as encryption, firewalls, and identity access management (IAM) systems that help protect data from unauthorized access.

However, the decentralized nature of cloud computing also opens the door to potential vulnerabilities. Multi-tenancy, where multiple users share the same physical infrastructure, can increase the risk of data breaches if security measures are not properly implemented. Misconfigured cloud settings, weak access controls, and the lack of visibility into cloud environments are common issues that can lead to security incidents (KnowledgeHut, n.d.).

Despite these challenges, cloud service providers are constantly enhancing their security protocols to meet industry standards and regulatory requirements. Tools like Cloud Access Security Brokers (CASBs) and Security Information and Event Management (SIEM) systems are becoming essential for monitoring and securing cloud environments (OpenLegacy, n.d).

**Proposed Solutions/Innovations.** As we look to the future, several trends are shaping the next generation of secure data processing. One such trend is the rise of hybrid and multi-cloud environments, where organizations use a combination of on-premises infrastructure, private clouds, and public cloud services. This approach offers greater flexibility and resilience, but it also requires sophisticated security measures to protect data across multiple platforms. The development of unified security frameworks that provide consistent protection regardless of where the data resides will be critical (CloudDefense.AI, n.d.).

Another key trend is the integration of artificial intelligence (AI) and machine learning (ML) into data security processes. AI-driven security solutions can automatically detect and respond to threats in real time, reducing the need for manual intervention. These systems analyze vast amounts of data to identify anomalies and predict potential security breaches before they occur, significantly enhancing the overall security posture.

**Impact.** Edge computing is emerging trend that will impact secure data processing. As more devices become connected through the Internet of Things (IoT), the need for processing data closer to the source– at the network edge– becomes more important. Edge computing reduces latency and enhances performance, but it also introduces new security challenges, as data is processed and stored in more decentralized locations. Ensuring the security of data at the edge will require new approaches, such as secure hardware enclaves and decentralized encryption methods.

**Conclusion.** In conclusion, the journey from mainframes to cloud computing represents a fundamental shift in how we process and secure data. While cloud computing offers significant advantages in terms of scalability and cost-efficiency, it also introduces new security risks that must be carefully managed. As technologies such as AI, edge computing, and hybrid cloud environments continue to evolve, the future of secure data processing will require innovative solutions to address the growing complexity of the digital landscape.

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# TESLA BOTS ARE THE FUTURE OF ROBOTICS

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**Keywords:** artificial intelligence, Tesla Incorporation, Tesla Bot, field of science, prototype, home assistant, ecological consequences, job displacement, unemployment, innovative technology.

**Introduction.** Today's century is a century of technology, where maximum possible progress is manifested in all fields of science, technology and industry. These years, the direction of artificial intelligence (AI) is developing the most. It is used in the fields of medical diagnostics, electronic commerce, remote control of robots and remote sensing of the Earth. In this topic I would like to talk about the application of artificial intelligence in robotics, namely the Tesla Bot from the famous company Tesla

**Objectives.** The purpose of this topic is to learn about new technologies that make life easier for people, the possibilities of artificial intelligence and new knowledge in the field of robotics.

**Methods.** The research methods for the topic are use of modern sources of information, articles and information sites.

**Results.** Optimus, also known as Tesla Bot, is a general-purpose robotic humanoid being developed by Tesla, Incorporation. Optimus is named after the main character in the Transformers media series. It was announced at the company's Artificial Intelligence Day event on August 19, 2021. The first prototype was shown in 2022. Elon Musk, the founder of Tesla Incorporation, said that Optimus had the potential to be more significant than vehicle business over time. Company plans are to create Optimus as the perfect home assistant ("Optimus (robot)", 2024).

The first version (Generation 1) was introduced in September 2022 at Tesla's second AI Day. As it was the first version of the robot, it is able to walk around the stage and move its arms.

The second version (Generation 2) was introduced in the end of 2024 – beginning of 2024. This version could walk 30% faster. Firstly, Optimus could walk and show new features, such as dancing and poaching an egg. Moreover, later in the October 2024 Elon Musk said that Tesla Bot would be able to perform a wide range of everyday tasks inside and outside of the house. Optimus would be available for purchase at around $20000 to $30000 (Joey, 2024).

The production of a new version of the Tesla Bot (Generation 3) is planned in late 2024. This robot will have more delicateness and better programming and an update to the tasks.

The first version of the Tesla bot was just 5-foot-8 tall (173 cm) and weighed 125 pounds (57 kg). It also had a top speed of only 5 mph and can be easily overpowered, making it easy to avoid if necessary. Other generations have not changed in size, only in design (Viknesh, 2021).

However, Tesla's innovation did not go as smoothly as expected. They received a lot of criticism for this. The main complaint is the unpredictability of complex AI systems. The complexity of AI systems, such as those in Tesla Robots, makes them inherently unpredictable. This unpredictability poses a challenge to developers and regulators, who must ensure the safety and ethical behavior of these robots while accounting for unforeseen consequences (Robbie, 2023).

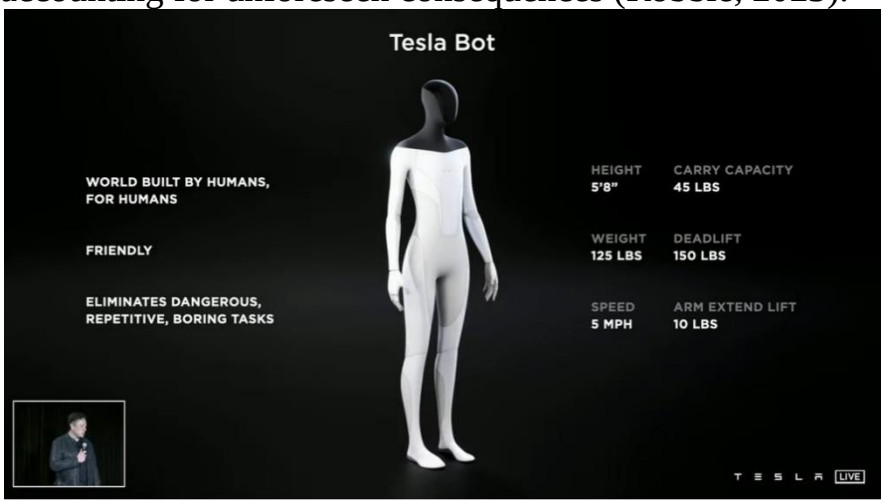


*Figure 1 – Introduction of Tesla Bot during presentation*

In addition, Tesla Bots will have ecological impact and resource consumption. The production, maintenance, and disposal of Tesla Robots may have significant ecological consequences. The consumption of energy and natural resources, as well as the generation of electronic waste, may exacerbate environmental problems. We also do not take job displacement and unemployment into account. The widespread adoption of Tesla Robots could lead to job displacement in various industries. As these robots become more capable and efficient, human workers may find themselves competing against machines for employment, potentially resulting in increased unemployment rates (Robbie, 2023).

**Conclusion.** The conclusion of this topic is to gain knowledge in the field of robotics and artificial intelligence, namely the new development of the Tesla Incorporation – Optimus, known as Tesla Bot. Undoubtedly, Tesla has developed an innovative technology which until now could only be mentioned in science fiction. The company has shown that the future is being created right now and proves it with her its new technologies. and proves it with its new technologies. Perhaps, over time, our world will be filled with such jobs that will perform everyday tasks of people. However, it is important to remember that this can also lead to irreversible negative consequences for the people themselves.

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## FUTURE TRENDS IN THE SCIENCE AND TECHNOLOGY JOB MARKET

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**Keywords:** science and technology, artificial intelligence, job market, automation, sustainability.

**Introduction.** There are questions all people might ask themselves from time to time, facing new technologies or observing the latest inventions of science and technology, such as: "What changes await us in the future?", "How will we communicate with people at a distance?", "Will factories and other industries be able to replace human work with robots?"

We will receive all these answers in the next decade, as we already have the ability to use artificial intelligence. McKinsey Global Institute (Bughin et al., 2018) has done some research on what artificial intelligence might create in the future and how it might influence our lives. AI simplifies the lives of many people, from suggesting recipes for different dishes to solving complex problems. Many factories already have plenty of robotics. Moreover, even in our Ukrainian schools, children are taught how to make robots by hand. Considering the devices that Elon Musk produces, this cannot fail to impress. And perhaps old tales about people flying on flying carpets are not tales anymore? Here are a few examples: scientists have made a major breakthrough in green energy innovations to improve the use of natural energy (solar, bioenergy, wind). The data obtained by the World Economic Forum (2024) shows that over a couple of decades, up to 80% of world consumption can be provided by renewable energy sources, which is impressive. It is also worth mentioning that they have already begun testing the construction of 3D houses that

save not only money but also construction time. Also, within a few years, there will be a breakthrough in medicine, as scientists have already released devices that constantly monitor our health indicators (for example, smartwatches). MIT Technology Review (Brooks, 2023) has conducted a series of studies indicating that quantum computers can make a great contribution to the development of new materials, medicines, and the optimization of logistics processes. Talking about new technologies used on Earth, we shouldn't forget about space. Many private companies are engaged in space technologies and show us rapid breakthroughs in this field; not only are they thinking about plans for colonizing other planets, but they are also actively developing everything for space tourism (Brynjolfsson & McAfee, 2014).

**Objectives.** This paper aims to study future trends in the global job market within the fields of science and technology, driven by advancements in artificial intelligence, automation, and sustainable practices. Thus, the goals of this study are to identify emerging professions, analyze essential competencies for future job markets, and evaluate the impact of remote work and automation on workforce dynamics.

**Methods.** To achieve the abovementioned goals, a comprehensive literature review is conducted, analyzing the latest technological reviews, recent reports, articles, and case studies that highlight trends in technology and employment. The results of the analysis and synthesis are presented in the form of a diagram displaying the future trends in employment in the field of science and technology.

**Results.** The fast growth of science and technology is changing the job market, creating new professions and altering existing roles. As artificial intelligence (AI), automation, and sustainable practices become more important, it's essential for job seekers, educators, and policymakers to understand these future employment trends. Thus, having analyzed the existing studies (Bughin et al., 2018; *Future Trends in Science and Tech Employment*, 2024) we present the future trends in science and technology employment in the diagram below (see Fig. 1).

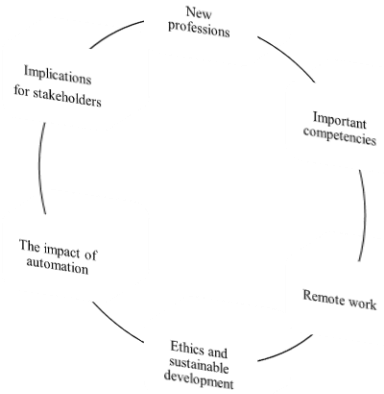


*Figure 1. Future trends in science and technology employment*

***New professions.*** The research indicates a significant shift in the demand for professions related to AI, cybersecurity, and renewable energy. New roles such as AI ethicists, data scientists, and sustainability consultants are expected to emerge as organizations seek to integrate advanced technologies responsibly. Additionally, traditional professions in law and psychology will still be needed in a technology-driven world.

***Important competencies.*** you can already see many advertisements requiring people with excellent critical thinking, and this is understandable. The ability to analyze complex problems and make informed decisions will be essential, especially in high-pressure environments where rapid change is the norm. Also, proficiency in data analysis, and programming, and familiarity with AI tools will be increasingly valuable, with technical literacy becoming a fundamental requirement across many fields. Apart from technical skills interpersonal communication, teamwork, and adaptability will remain vital. Human interaction cannot be fully replaced by technology, and roles that emphasize emotional intelligence will become increasingly important.

***Impact of automation***. Automation is expected to transform various industries, leading to increased efficiency but also potential job displacement. The findings suggest (Brynjolfsson & McAfee, 2014) that while routine tasks may be automated, roles requiring human judgment and creativity will become more prominent. Workers will need to adapt to changes by developing new skills and embracing lifelong learning. Moreover, companies must consider the ethical implications of automation and ensure that their workforce is prepared for transitions.

***Remote work.*** The convenience and quality of remote work will gain significant demand in work spheres. The COVID-19 pandemic accelerated the trend toward remote work, which is likely to persist. The study finds that remote work offers flexibility and access to a broader talent pool, but it also presents challenges in maintaining team cohesion and company culture. Organizations will need to invest in technology and training to support effective remote collaboration. Furthermore, hybrid work models may become the norm, requiring new strategies for management and employee engagement.

***Ethics and sustainable development.*** We must prioritize ecological sustainability to ensure the health of our planet. It's imperative that we integrate environmental considerations into all aspects of our activities. Thus, companies and enterprises will have to switch to more sustainable ways of conducting their business and regulating their policies so they correspond to the global sustainable initiatives. Moreover, company ethics must emphasize equality in terms of gender, human rights, origin, and social status.

***Implications for Stakeholders.*** The trends found in this study have important effects on different groups. Universities need to update their curricula to teach

students about new technologies and skills that combine technical knowledge and soft skills. This will ensure graduates are well-prepared for the challenges of modern workplaces.

Businesses should invest in training programs for their employees to help them keep up with changes in technology. By encouraging a culture of lifelong learning, companies can stay competitive. Policymakers also play a crucial role by creating guidelines that support the responsible use of AI and promote environmentally friendly practices. By encouraging teamwork among educational institutions, businesses, and governments, we can develop a workforce that is strong and flexible enough to handle future challenges.

**Conclusion.** In conclusion, we can say that scientists in many fields of science and technology have achieved great accomplishments to improve people's lives. And very soon they will find cures for cancer and other terrible diseases, or we'll start living in our own huge houses that are completely designed by artificial intelligence and built on a large-scale 3D printer. And perhaps, to communicate with people at a distance, we won't need to use smartphones or other gadgets; we'll just need to connect a chip to ourselves that will remember any information and help solve any problems.

Thus, as science and technology continue to change, the job market will also change a lot. By examining emerging professions, essential skills, and the effects of automation and remote work, we can better prepare for future workforce needs. This study can be used for future scientific research as it shows how important it is to adapt education and training programs to support the growth of artificial intelligence and focus on ethics in a technology-driven economy.

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# ADVANCEMENTS IN ELECTRIC VEHICLE TEST BENCH TECHNOLOGIES

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**Keywords**: Electric Vehicles, Test Bench, Dynamic Simulation, Electric Drive Systems, Powertrain Testing.

**Introduction.** With the global emphasis on reducing carbon emissions and shifting to sustainable transportation solutions, electric vehicles (EVs) have become pivotal in the automotive industry. EVs offer a clean alternative to internal combustion engines, reducing reliance on fossil fuels and minimizing environmental impact. However, the high expectations for EV performance and efficiency present challenges to manufacturers, especially in areas such as battery autonomy, torque consistency, and adaptation to real driving conditions. Test bench systems are integral to addressing these challenges, as they enable precise testing, simulation, and optimization of EV powertrains before road deployment. Through these test benches, engineers and developers can evaluate and refine various aspects of EV performance, from battery longevity and drive system efficiency to regenerative braking and compliance with worldwide standards like the Worldwide Harmonized Light Vehicles Test Cycle (WLTC) (Fonte et al., 2019, p. 3).

**Objectives.** The primary aim of this literature review is to explore the advancements in EV test bench technologies, focusing on their significance in ensuring high-performance and safe EVs. It discusses the evolution of test bench designs, the integration of field-oriented control (FOC) and hardware-in-the-loop (HIL) testing, and their role in emulating real-world driving conditions. Additionally, this review seeks to highlight the application of these systems in validating EV parameters like energy consumption, drive cycle adherence, and mechanical durability across diverse environmental and operational conditions. By examining these areas, the paper underscores the importance of ongoing test bench innovation for the future of electric mobility.

**Methods.** A thorough analysis was conducted on recent publications and research studies on test bench systems for EVs. This includes the study of dynamometer setups, motor simulation software, and control technologies that facilitate high-accuracy EV testing. Among the configurations reviewed were hybrid dynamometer designs, where electric drive system (EDS) characteristics could be tested across a range of loads, speeds, and drive cycles. Specific attention was given to hardware-in-the-loop (HIL) systems, which offer dynamic simulation capabilities by integrating physical and virtual components in real-time environments (He, Sun, & Xing 2007, p. 2). This method is particularly valuable in EV testing as it allows

for flexibility in assessing various powertrain designs without the need for complete physical builds, thereby saving time and resources.

In addition to hardware configurations, the literature review included studies on advanced control techniques, particularly field-oriented control (FOC). This approach ensures precise torque and speed control by aligning motor currents with the magnetic field, a method particularly useful for achieving optimal performance under varied load conditions (Burenin et al., 2020, p. 5). The reviewed materials also covered case studies that demonstrated the application of test benches in testing dual-motor systems, regenerative braking, and battery performance. Such case studies provided practical insights into the operational aspects of test benches and highlighted key performance metrics relevant to EVs, including power efficiency, torque reliability, and battery regeneration during deceleration phases.

**Results.** The analysis revealed that modern test benches with FOC and HIL capabilities effectively simulate real-world driving conditions, enabling accurate measurement of essential EV parameters like torque response, speed stability, and regenerative braking efficiency. Hybrid dynamo configurations allowed for dynamic testing across various load conditions, ensuring that components like motors and inverters operate consistently across diverse driving scenarios (Fonte et al., 2019, p. 4).

HIL systems proved transformative by merging physical test setups with software simulations, allowing for complex scenario replication, such as road gradients and environmental conditions, which traditional test benches often cannot fully emulate (He, Sun, & Xing 2007, p. 3). This approach supports precise control over EV parameters, especially useful for evaluating battery performance and endurance. HIL simulations typically achieved minimal deviations from real-world tests, showing their reliability.

FOC's application further optimized motor performance by aligning torque and current through magnetic field control, resulting in stable performance across different torque demands. This method was particularly effective for simulating urban driving conditions and maximizing energy recovery during braking, enhancing regenerative braking simulations, which is an increasingly critical aspect of EV design (Burenin et al., 2020, p. 5).

**Conclusion.** Advancements in EV test bench technologies have significantly enhanced EV performance, safety, and efficiency by enabling precise calibration of vehicle components. The integration of HIL and FOC techniques has transformed testing, allowing for accurate assessment of motors, batteries, and braking systems, which is essential as EV demand rises and environmental standards tighten. Continued improvements in control algorithms and simulation capabilities will be critical in advancing EV technology, supporting the development of efficient vehicles that meet real-world demands and contribute to a sustainable transportation future.

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## ARTIFICIAL ORGANS: RESCUING THE PEOPLE OF THE FUTURE

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**Keywords**: artificial organs, artificial organ transplantation, biocompatibility, ethical implications, healthcare.

**Introduction.** The rapid advancement of science and technology has increasingly emerged as a defining characteristic of contemporary existence, fundamentally influencing the ways in which we understand and engage with the world around us. Among the most transformative and ground-breaking developments in recent years is the innovative creation of artificial organs, a remarkable advancement that holds the promise to revolutionize the field of healthcare and potentially save countless lives. This particular topic carries immense significance, as it not only addresses the pressing and critical shortage of available donor organs, which affects many individuals in dire need of transplants, but it also raises important and complex ethical considerations regarding their use, distribution, and the implications for both patients and society as a whole.

**Objectives.** This study aims to explore several key questions surrounding the development and implementation of artificial organs. Specifically, it seeks to examine the technological advancements that have facilitated their creation, assess their potential impact on medical practices and patient outcomes, and investigate the ethical implications of using synthetic organs in clinical settings. Additionally, the research will address the challenges and limitations currently faced in the field, as well as the public perception of artificial organ transplantation.

**Methods.** Research conducted at Wake Forest University has focused on the innovation of a sophisticated digital printer capable of fabricating artificial organs, including complex structures like ears, brains, and skulls (Atala, 2013). This process

involves the use of advanced extracellular matrix technology, which has been refined and developed over several years. By synthesizing materials that mimic the natural cellular environment, researchers can create scaffolds that support cell growth and tissue development. A combination of synthetic and natural materials – such as polylactide, polyglycolic acid, and polycaprolactone – are utilized to construct these artificial organs, ensuring biocompatibility and safety for future implantation.

**Results.** The key findings from the research indicate that these artificial organs have demonstrated successful integration in animal models, including mice, dogs, and other species. Notably, in cases of severe injuries such as those sustained in road accidents artificial organs have shown promising results. According to statistics from 2021, approximately 45% of patients in the United States and the United Kingdom benefited from these innovative technologies. The materials used in the fabrication process are designed to be gradually absorbed by the body, eventually being replaced by a natural extracellular matrix, which further enhances the viability of these artificial organs.

To enhance the structural complexity of the organs being developed, researchers employ a variety of techniques, including self-assembly of nanofibers, textile technologies, partial dissolution, foaming, electrospinning, and three-dimensional printing. Despite these advancements, many methods still face limitations in accurately replicating the intricate microstructures required for more complex organs, such as the heart, liver, and kidneys. For instance, while skin and blood vessels can be printed with relative ease, the more complex architectures of vital organs remain a significant challenge. Ongoing research aims to refine these techniques to improve the functionality and integration of artificial organs in human patients (Wang, 2012, p. 955).

**Conclusion.** In conclusion, the remarkable potential of artificial organs to fundamentally reshape the future landscape of healthcare is both exciting and profoundly significant. These ground-breaking innovations not only tackle the critical and urgent issue of organ shortages that many patients face, but they also provide a more human and ethically considerate alternative to traditional organ transplantation methods, which often necessitate the sacrifice of deceased donors. Moreover, as public acceptance continues to grow, which is evidenced by studies indicating that approximately 85% of individuals worldwide are in favour of the use of artificial organs, the pathway toward their widespread adoption becomes increasingly clearer and more attainable (Fritzch, 2014, p. 631). As we look ahead, the ongoing development and integration of artificial organs could prove to be a vital and transformative step in the advancement of medical science and the improvement of patient outcomes. Ultimately, this progress may lead to the establishment of a more ethical and effective healthcare system that better serves the needs of all individuals.

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## EMULATING x86 APPLICATIONS ON ARM ARCHITECTURE: ISSUES AND CHALLENGES

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**Keywords:** ARM, x86, emulation, processor microarchitecture, System on Chip.

**Introduction.** Recent advancements in ARM architecture have demonstrated significant advantages over x86, particularly in energy efficiency – an area where x86 architecture faces limitations. Devices based on ARM architecture often achieve much higher performance per watt of power consumed, which makes ARM systems easier to scale as they address issues of heat dissipation. For this reason, ARM-based processors are increasingly adopted in high-performance systems. With SoC (System-on-Chip) solutions from companies like Apple and Qualcomm, the consumer market is also moving toward ARM-based computers. This shift raises questions about software compatibility, as many applications are still built for x86 architecture. One solution is to emulate x86 applications on ARM, allowing legacy software to run on ARM-powered systems.

**Objectives.** The objective of this study is to examine the challenges that arise when emulating software designed for x86 architecture on ARM processors. This includes exploring current approaches and potential solutions to these challenges, as well as forecasting future developments in these methods and solutions.

**Methods.** The primary research method in this study involved reviewing and analyzing publicly available sources, including:

- Scientific articles,
- Media publications,
- Open technical documentation.

Additionally, performance tests were conducted to compare different architectures under uniform tasks, providing insights into the efficiency and limitations of each.

**Results.** Several approaches have been employed to address the issue of backward compatibility for software originally designed for x86 architecture when running on ARM-based systems. One approach involves rewriting legacy code to run natively on ARM architecture. However, this is a costly solution, as it requires significant time and effort to rework existing software. A more universal solution has been the development of emulators, which enable x86 code to execute directly on ARM architecture.

One such approach in emulation is Just-In-Time (JIT) compilation, where x86 code blocks are dynamically compiled into ARM-compatible code as needed. This method allows for real-time execution without requiring a complete analysis of the entire program beforehand. However, it poses challenges related to optimization and processing speed, potentially impacting performance. Another approach, interpretation, is generally avoided in x86-to-ARM emulation due to its low efficiency.

Currently, several x86 emulation systems exist for ARM architecture, such as Apple's Rosetta 2 Translation Environment and Microsoft's Prism for Windows 11. Rosetta is mostly transparent. If an executable contains only Intel instructions, macOS automatically launches Rosetta and begins the translation process. When translation finishes, the system launches the translated executable in place of the original. However, the translation process takes time, so users might perceive that translated apps launch or run more slowly at times (Apple, n.d.). Prism is the new emulator included with Windows 11 24H2. Relative to previous emulation technology included in Windows, it includes significant optimizations that improve the performance and lower CPU usage of apps under emulation. Prism is optimized and tuned specifically for Qualcomm Snapdragon processors. Some performance features within Prism require hardware features only available in the Snapdragon X series, but Prism is available for all supported Windows 11 on Arm devices with Windows 11 24H2 (Wojciakowski et al., 2024).

Both systems use similar approaches for emulation, incorporating Neural Processing Units (NPUs) to accelerate code translation during emulation. This integration of neural networks, running on dedicated neural processors, may provide a path to solving the performance challenges in x86-to-ARM emulation. This approach has shown improvements in emulation performance with each software and hardware update in systems like Microsoft Prism and Apple Rosetta 2.

**Conclusion.** In the future, approaches that utilize neural networks on dedicated neural processors are expected to play an increasingly important role in accelerating code translation and execution during emulation. This advancement could significantly improve the performance of emulation between x86 and ARM architectures. Additionally, as the transition to ARM architecture continues, the volume of software developed specifically for ARM is likely to grow. This shift will

gradually reduce the need for backward compatibility, as more applications will be designed to run natively on ARM without requiring emulation.

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## OPTOELECTRONIC SENSORS IN CONTROL SYSTEMS OF UPPER LIMB PROSTHESES

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**Keywords:** upper limb prosthetics, optoelectronic sensors, electromyography, near-infrared light, muscle contraction.

**Introduction.** The main problem with existing prostheses of upper limbs is their limited ability to replicate natural movements and reactions. The most basic prosthesis is the passive prosthesis, offering no active joint movement and primarily serving cosmetic or supportive functions like holding items. Body-mounted prostheses, despite being strong and relatively light, rely heavily on physical strength and harness systems, making them tiring for the user. Myoelectric prosthetics provide better control through muscle signals but are slowed by the need to sequentially activate each joint movement. Additionally, myoelectric systems rely on skin-contact electrodes, which can cause discomfort, reduce reliability and responsiveness due to sweating or socket shifts.

Overall, current prosthetic designs lack simultaneous movement control and intuitive functionality. Research has shown that users of myoelectric prostheses achieve average index-of-function scores of only 43-50 percent compared to an intact hand (National Academies of Sciences, Engineering, and Medicine, 2017). To address these issues, optoelectronic sensors have the potential to enhance movement accuracy, user comfort, and signal reliability, representing a promising advance in prosthetic control.

**Objectives.** The main aim to describe how optoelectronic sensors can enhance the accuracy of prosthetic responses, ensure reliability in diverse environmental conditions and increase functionality in upper limb prosthetic control systems.

**Methods.** A literature review was conducted on published research articles related to upper-limb prosthetics and optoelectronic sensor technology. The focus was on examining existing prosthetic control mechanisms and their limitations.

**Results.** Myography is the measurement of muscle activity during contractions. It includes electrical measurement through electromyography, which uses electrodes to capture muscle signals for applications like prosthetic control. Mechanical myography and force myography monitor physical changes in the muscles (vibration and pressure, respectively) and both have advantages over electromyography in terms of stability and reduced noise.

A newer method, optomyography, uses near-infrared light to monitor skin displacement due to muscle contraction, offering a contactless, interference-free solution with a high signal-to-noise ratio (Sharma et al., 2023).

Infrared optoelectronic sensors convert light into electrical signals, providing precise control of prosthetic movements in response to muscle contractions. A mechanism such as the photoelectric effect is used in which light energy excites electrons in a material to form electron-hole pairs that are separated and driven by an internal electric field to generate an electric current (Yu et al., 2024). This optical muscle contraction detection method uses the structure of muscle fibers, which are long and aligned along the muscle axis, causing light to scatter in specific patterns. When light enters the muscle, the scattered light collected a few centimeters away varies based on its angle relative to the fibers. As the muscle contracts and fiber shape changes, the scattering pattern shifts. The sensor detects these changes, focusing on contraction-specific signals and ignoring interference from other movements (Chianura & Giardini, 2010). Near-infrared signals at around 800 nm penetrate up to 2.4 mm inside muscle tissue without reaching other tissues under the skin surface, as the skin layer has a thickness of 2–3 mm. (Sharma et al., 2023).

As the muscle contracts, the orientation and density of the fibers shift, altering the pattern of scattered light. By comparing the signals from light scattered in these two orientations, the sensor can distinguish two muscle contractions: isotonic (the muscle contracts with a constant force, like lifting) and isometric (the length of the muscle remains constant, like pushing against a wall). The sensor could distinguish between them, producing a positive signal for isometric and a negative signal for isotonic, unlike EMG, which cannot differentiate them. EMG also requires stable, long-lasting electrode contact, which can be challenging. Optoelectronic sensor avoids these issues and doesn't need needle electrodes. (Samuel et al., 2015).

**Conclusion.** Optoelectronic sensors are promising in the control of upper limb prostheses. Unlike traditional myoelectric systems, which are hampered by electrode contact issues, sequential motion control, and discomfort, optoelectronic sensors provide a non-contact, interference-free solution with high signal reliability. By using near-infrared light to detect changes in muscle contractions, they can accurately distinguish between different types of contractions (isometric and

isotonic), improving the functionality and intuitiveness of prosthetic control. This technology not only increases the accuracy of movements, but also increases the comfort of the user.

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## FUTURE TRENDS IN SCIENCE AND TECHNOLOGY: INNOVATIONS IN PACKAGING DESIGN

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**Keywords:** 3D-printed packaging, AI-powered packaging, augmented reality (AR) packaging, biodegradable materials, biomimicry in packaging, consumer behavior and emotional design, eco-conscious innovation, future packaging trends, IoT and packaging design, modular packaging solutions, personalized product experiences, smart packaging, sustainable packaging.

**Introduction.** Packaging design will increasingly integrate technological innovations and sustainability in the coming decade to meet evolving consumer demands. Advanced materials, interactive elements, and eco-friendly solutions will redefine how products are presented and consumed. This paper explores ten examples of genius packaging that excel in design and hint at future trends in science and technology. These innovations reflect the growing convergence of digital technologies, environmental awareness, and emotional engagement with customers, shaping the future of product marketing and packaging design.

**Objectives.** In this research, we will explore how innovative packaging design will evolve in the future through the application of science and technology. We will try to identify trends such as smart packaging, sustainability, and personalization that will dominate the market in the next decade, and we will find and propose strategies for companies to adapt packaging to future consumer expectations and environmental challenges.

**Methods.** Our research model and examples will demonstrate the benefits of packaging. The study applies a qualitative analysis approach to examine ten examples of creative packaging that reflect future trends. Each case was selected based on its innovative potential, technological applications, and relevance to future packaging trends.

The selected examples span various industries, including food, beverages, and household goods, where packaging is functional and critical to consumer experience. Data were gathered through product assessments, consumer feedback, and industry trend reports.

The study analyzes market reports, academic literature, and case studies to uncover emerging patterns in packaging innovation. Each example is evaluated in terms of future technological potential, sustainability, and consumer impact (Bungar et al., 2023).

**Results.** Personalization through data-driven design is the future packaging that will integrate data analytics to create personalized product experiences. As the pantone-inspired chocolate packaging shows the insights and how companies could use consumer data to deliver personalized flavors and packaging styles, making every purchase unique which means that future trend such as AI-generated packaging will design tailored to customer preferences.

The impact itself will enhance customer engagement through personalization.

The segmented spaghetti packaging hints at the rise of AI-enhanced functionality. Future packaging will likely incorporate sensors to suggest portion sizes or cooking instructions based on consumer habits. This future trend is a smart packaging demonstration that adapts to individual consumption patterns.

The impact will reduce food waste and simplify meal preparation.

The milk carton that changes color before expiration showcases IoT-based smart packaging. In the future, products will contain sensors communicating shelf life via smartphone notifications, reducing waste and ensuring freshness.

This future trend will monitor product conditions in real-time through the IoT.

The impact might increase sustainability and food safety.

Eco–friendly hay-based packaging points toward using biodegradable and smart materials in future packaging. Innovations such as self-decomposing materials or edible packaging will dominate in the market. This future trend will definitely be the widespread adoption of eco-friendly materials and zero-waste packaging. It reduces plastic pollution and appeals to eco-conscious consumers.

Sardine Packaging, which plays on the phrase "stuffed like herrings in a barrel," could evolve to include AR technology. Future packaging will allow customers to scan packages and view entertaining, interactive content through smartphones. AR technology enhances packaging for immersive brand experiences that, in turn, will increase brand visibility and consumer interaction.

The cylindrical packaging hints at modular design trends, which will become crucial as urbanization leads to smaller living spaces. In the future, packaging will be designed to save space and stack efficiently, and, as a future trend, modular, reusable packaging systems will be used to help optimize storage and reduce environmental footprint.

The squirrel-themed nut packaging demonstrates how emotional design will play a critical role in the future. AI will allow companies to develop packaging that dynamically responds to a consumer's mood or behavior, creating an emotional connection with AI-powered emotional packaging designs, increasing brand loyalty, and enhancing user experience.

Marilyn Monroe's sponge packaging is about customizable pop-culture branding. This design emphasizes the importance of pop-culture integration, which will evolve with customizable branding. Companies will offer packaging that changes according to the latest trends or the consumer's preferences and will demonstrate dynamic packaging that updates based on trends and events.

This will help to keep products relevant and appealing in fast-changing markets.

The fish-themed can reflect the potential of 3D printing technology in packaging production. Companies will 3D-print custom packaging on demand in the future, reducing material waste and transportation costs corresponding to on-demand 3D-printed packaging solutions, minimizing waste, and supporting sustainable production methods.

Orange-shaped juice packaging draws on biomimicry, a trend shaping future innovations. Packaging that mimics natural forms (like fruit skins) will be aesthetically pleasing and enhance functionality and sustainability.

This biomimetic packaging is designed for eco-conscious products, promotes sustainable consumption, and reduces resource waste (15 examples of genius packaging design that sells, 2017).

**Conclusion.** Technological advancements and sustainability will shape the future of packaging design. Smart packaging with embedded sensors, interactive elements like AR, and AI-powered personalized designs will dominate the next decade. Companies must adopt these trends to meet evolving consumer expectations, reduce environmental impact, and stay competitive. Packaging will no longer serve a passive role; it will actively enhance product functionality and emotional connection with consumers, reflecting the growing importance of technology and environmental responsibility in modern business (D'Almeida & de Albuquerque).

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## FUTURE TRENDS IN SCIENCE AND TECHNOLOGY: EXTENDED REALITY IN EDUCATION

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**Keywords**: Extended Reality (XR), technology, education, healthcare, engineering, active learning.

**Introduction**. Education has always been fundamental to human progress, shaping societies and enabling individuals to reach their full potential. Nowadays, rapid advancements across various fields not only provide us with new opportunities but also create a growing need for innovative educational methods. Extended Reality, which encompasses Virtual, Augmented, and Mixed Reality has become a powerful tool for creating new powerful practical learning experiences. XR has great potential to enhance education by engaging learners in dynamic, real-world scenarios, analyzing current trends, learning impacts, and strategies for effective integration in future educational practices.

**Objectives**. To examine how Extended Reality technology can enhance experiential learning by providing immersive and interactive educational experiences, especially in fields requiring hands-on practice like medicine and engineering. To identify and analyze current trends, benefits, and challenges in XR integration. To outline strategies for effective implementation that support sustainable educational development and broaden learning opportunities.

**Methods**. The research employs a mixed-methods approach, combining bibliometric analysis with qualitative data collection to explore the role of XR technologies in education. The primary methodology involves analyzing existing academic literature on XR applications in various educational contexts, using bibliometric techniques to map key trends and identify influential works (Guo, Guo, & Liu, 2021). This is complemented by surveys and interviews with educators and researchers (Pomerantz, 2019). These provide deeper insights into real-world applications and challenges.

**Results**. XR technology offers a unique capacity to support collaborative, shared experiences, particularly in situations where users are not physically in the same location. This capability is increasingly recognized as a major benefit in higher education, as it fosters active and experiential learning. Experiential learning, as defined by Dewey (1938), involves learning by doing and reflecting on those actions. Kolb & Fry (1974) describe this process as a four-stage cycle, where hands-on experiences lead to observation, reflection, and the formation of abstract concepts that inform future actions. XR expands the range of tasks and activities that learners can engage in, allowing them to gain concrete experiences in environments or situations that might not be feasible in traditional settings (Pomerantz, 2019).

Extended reality technologies have a wide range of applications in education across various fields. In medical and healthcare training, for example, VR is extensively used for simulating surgical procedures, anatomy lessons, and patient care scenarios. These virtual environments allow students to interact with detailed 3D models, providing valuable hands-on experience without the need for real patients. Similarly, in the fields of engineering and manufacturing, XR facilitates virtual labs and simulations, giving students the chance to work with complex machinery and systems in a safe environment, minimizing risks associated with physical equipment.

Moreover, XR is also transforming language and social science education by immersing students in virtual environments, where they can practice new languages or engage in historical events firsthand. This immersive approach is particularly useful for vocational training and cultural studies, where practical experience is key to understanding the material. Additionally, XR supports distance learning by providing virtual classrooms and remote labs, making it possible for students who are unable to attend physical campuses to participate in, interactive educational experiences (Alnagrat, Ismail, Idrus, & Alfaqi, 2022).

Extended Reality technologies offer significant advantages in education, particularly by creating a safe and controlled environment for students. This is especially beneficial in high-risk fields like surgery or hazardous material handling, where students can practice without fear of making mistakes that could result in injury or damage. Additionally, XR enables realistic simulations in complex environments, such as chemical labs, allowing students to gain practical, hands-on experience. Beyond safety and practicality, XR transforms learning by making education more interactive and engaging, which leads to better retention and increased motivation.

XR technologies are rapidly growing, with a projected compound annual growth rate of 45% from 2020 to 2026. This surge is fueled by investments in VR and AR, especially in education, where companies like BYJU'S and Vedantu are creating immersive learning experiences. The COVID-19 pandemic has further boosted demand for XR tools for remote learning and training (Sharma, 2021).

**Conclusion**. In conclusion, extended reality offers powerful educational tools, especially in fields requiring hands-on practice, such as healthcare and engineering. XR provides a risk-free environment for students to gain essential skills, promotes active learning, and encourages deeper engagement with the material. So, with continued technological advancements and investment, XR is poised to become a crucial part of the future of education, providing innovative and effective ways to access, interact with, and understand complex information across a wide range of disciplines.

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## HOW THE INTEGRATION OF BLOCKCHAIN TECHNOLOGY IN IOT ENHANCES THE SECURITY OF DEVICE INTERACTIONS

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**Keywords:** blockchain, Internet of Things (IoT), device security, decentralized networks, data integrity.

**Introduction.** The implementation of IoT has transformed the way devices interact, enabling their use across various sectors. However, with the rapid expansion of this technology comes the growing threat of data breaches and unauthorized access. Blockchain technology, known for its decentralization and immutability, presents a potential solution to enhancing the security of device interactions within the Internet of Things (IoT) ecosystems. This article explores how the integration of

blockchain can improve the security of IoT devices, providing a more secure and reliable communication framework.

**Objectives.** The primary objective of this article is to demonstrate methods that can enhance the security of IoT device interactions by utilizing blockchain technology.

**Methods.** The use of blockchain in IoT enables improved security in device interactions through the following features:

Decentralization. Traditional IoT systems often rely on central servers for managing and storing data, which introduces a single point of failure or vulnerability to unauthorized interference. By employing a decentralized blockchain network, data can be distributed across multiple nodes, reducing the risk of data tampering or unauthorized access (Zhang & Chen, 2022).

Data Integrity. Blockchain technology ensures that once data is recorded, it cannot be altered or deleted without consensus from the network. This feature offers a secure method for logging device interactions, ensuring data integrity and traceability (Kumar & Patel, 2023).

Enhanced Authentication. Through cryptographic techniques, blockchain can strengthen device authentication, ensuring that access to devices is restricted to authorized users only.

Smart Contracts. Smart contracts can automate and secure transactions between Internet of Things (IoT) devices, enabling predefined actions based on specific conditions. This eliminates the need for intermediaries and reduces the risk of human error, thereby enhancing the security of automated interactions (Lee & Kim, 2023).

**Results.** Integrating blockchain technology into IoT can significantly improve security by addressing several critical vulnerabilities. By eliminating central points of control, the decentralized nature of blockchain reduces the likelihood of large-scale attacks. Furthermore, the immutability of blockchain records fosters trust among devices, as interactions can be traced and verified without the possibility of alteration.

The implementation of enhanced authentication methods ensures that only legitimate devices can participate in the network, mitigating the risks of unauthorized access and data breaches. Additionally, smart contracts streamline interactions between devices, reducing human involvement and the potential for error, while also ensuring that all actions are recorded on the blockchain for transparency.

**Conclusion.** The integration of blockchain technology into the Internet of Things presents a transformative opportunity to enhance the security of device interactions. By leveraging decentralization, data integrity, improved authentication, and automation through smart contracts, blockchain can effectively mitigate many of the security challenges faced by IoT networks. As the adoption of IoT continues to grow, so too does the need for robust security solutions. Embracing blockchain

technology could lead to safer, more efficient, and trustworthy interactions between devices, ultimately paving the way for a more secure IoT ecosystem.

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## ARTIFICIAL INTELLIGENCE IN CRIME

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**Keywords:** AI (Artificial Intelligence), criminology, law enforcement, data analytics, machine learning, GIS (Geographic Information System), crime prevention, algorithmic bias, Multiclass Logistic Regression, hybrid models.

**Introduction.** AI has emerged as a transformative factor in criminology and law enforcement, with the ability to analyze large volumes of data for patterns that can be used to predict crime. This use of AI for crime prevention has been made possible by improved data analytics, machine learning, and GIS, which enhance operational efficiency and public safety (ANU Cybercrime Observatory School, 2018). With the rise in urbanization, ensuring public safety is increasingly hard to provide, since crimes affect the well-being of a single person and community cohesion. AI offers good solutions using data from various sources, such as social media and surveillance systems. The technology identifies hot spots in crime and optimizes resource allocation in law enforcement (Kouziokas, 2017). However, several ethical concerns arise, such as privacy and algorithmic bias. This thesis explores the state of the art in AI applications in crime, methodology, and applications to shed light on what this new wave may signify for current strategies of crime prevention and add something to the debate on technology's place in public safety.

**Objectives.** The aim of this present study is to discuss the potential of artificial intelligence in preventing crimes and maintaining public safety. Its purpose is to discover how AI technologies can be utilized in analyzing crime patterns, predicting criminal activities, and finding optimal responses on the part of law enforcement. It also takes a closer look at challenges and ethical considerations

linked with implementing AI in crime analysis, including data privacy and algorithmic bias, and what are the implications of increased surveillance. In this light, this research also aims at the identification of future trends in the development of AI capable of helping in formulating higher degrees of crime detection and prevention strategies that might, in turn, translate into safer cities and efficient deployment of resources by police departments.

**Methods.** The techniques proposed in different natures of artificial intelligence represent the base of analysis of crime patterns and prediction of criminal activities in this research (Kyoung-Sook, Yeong-Hoon, 2021). The study uses historical data on crimes that come from public records, social media, and surveillance systems to create an integrated dataset. Feature selection involves identifying the important predictors of occurrence and types of crime using various machine learning algorithms such as Multiclass Logistic Regression and Neural Networks. Historical datasets would have already trained these algorithms, hence giving insights into trends and patterns of crime across time. This research explores hybrid models, using multiple algorithms to achieve even better performance. The use of GIS further provides the opportunity for visualization and spatial analysis of crime data to find crime hot spots. The research goes ahead to set out ethical concerns on the application of AI in analyzing crimes; these include data privacy and algorithmic bias.

**Results.** The applications of different AI methodologies proved to be quite promising in predicting crime occurrences and high-risk areas. It is seen from the results that Multiclass Logistic Regression gives better accuracy, precision, and recall as compared with other machine learning models, especially in predicting the exact type of crimes and tools used during the crime. Examples of this include an accuracy rate of more than 90%, as set in the prediction of HANDS as a tool for crime (Artificial intelligence & crime prediction, 2022). On the contrary, the study identified that the most type of crime predicted was COMMON ASSAULT. This research identifies the effectiveness of AI in facilitating efficient utilization of law enforcement resources through the precise identification of flashpoints of impending crimes. The hybrid models produced better predictive capabilities after integration, underlining the potential value of combining multiple algorithms to achieve increased levels of accuracy within crime analysis. All in all, the results point out that AI can be used to inform proactive strategies against crime and contribute to safer urban environments.

**Conclusion.** The paper underlines the necessity of using the AI approaches in the prediction and prevention of crimes via analyzing large amounts of data and giving patterns in these datasets that may not be so easily identified by a human analyst. It follows from the findings that machine learning algorithms, such as Multiclass Logistic Regression and Neural Networks, can classify historical data on crime incidents into occurrence or non-occurrence and types of crime in order to

help law enforcement agencies with resource allocation and proactive strategy formulation.

AI helps to enhance this analysis of crime by processing spatial and temporal data for trend identification and hotspots in public safety initiatives. Hybrid models, with a combination of more than one algorithm, further provide better predictive accuracy. Overcoming the limitations that exist in AI techniques requires further research in order to enhance these crime prediction models and make them adaptable in several urban environments for safer communities. Continuous AI development could, therefore, help in minimizing not only crime but also aide in gaining confidence between the law enforcement agencies and the common man by highlighting the more proactive measure.

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## PRACTICAL APPLICATIONS OF INTEGRATING ARTIFICIAL INTELLIGENCE INTO THE EDUCATION PROCESS

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**Keywords:** AI, educational, school, machine learning, automation.

**Introduction.** In today's world, artificial intelligence (AI) plays a crucial role in transforming various aspects of life, including education. The use of AI in education opens up opportunities for personalized learning, automated assessment, student support, and data analytics, as noted in a number of studies and practical applications.

**Objectives.**The aim of this work is to explore and analyze the use of artificial intelligence technologies in the educational process, particularly for personalization

of learning, automation of assessment, and improving the efficiency of the educational process.

**Methods.** Many solutions already help personalize learning, i.e., AI allows each student to customize the learning process individually, considering their unique characteristics and needs. For example, Khan Academy uses sophisticated machine learning and adaptive learning algorithms to analyze data for each student (Levenchuk, Sheremet, Tishchenko 2020). These algorithms are based on classification and clustering methods that consider each student's individual characteristics, such as level of knowledge, speed of learning, and personal learning needs. Based on this data, the algorithms generate personalized learning trajectories that reflect each learner's optimal order of learning specific concepts and tasks. This approach allows for creating individualized learning programs that best suit each learner's needs and abilities, promoting effective learning and success.

Similarly, virtual tutors, such as Carnegie Learning Math Coach (Carnegie Learning 2023), can provide one-on-one support in maths and other subjects. AI is also being used to automate examination and assessment systems, simplifying the learning process and allowing students to receive quick and objective feedback. For example, systems like Gradescope (Wikipedia,2024) or Turnitin (Wikipedia,2024) use AI algorithms to check assignments and detect plagiarism automatically. It makes the grading process more efficient and transparent.

AI provides opportunities to create virtual assistants and chatbots that can assist students in learning and solving educational tasks. For example, Google Assistant or Carnegie Mellon University's Minerva chatbot provides users with information and support in the learning process, which helps to increase the efficiency of the educational process.

AI allows the collection and analysis of large amounts of data on student's performance, which helps to identify trends and improve teaching methods. For example, analytics systems such as Instructure Canvas or PowerSchool (PowerSchool, 2024) use sophisticated AI algorithms to analyze various student performance data. These algorithms can analyze large amounts of data such as grades, test scores, class participation, and other performance metrics.

**Results.** Based on this data, the algorithms can predict future test scores and assess students' overall progress. What is more, the artificial intelligence algorithms in PowerSchool can provide recommendations for improvement. They analyze student performance data and identify possible problematic aspects or weaknesses. Based on this analysis, the system can recommend specific measures to improve the educational process. It may include recommendations for additional study materials, individual consultations with teachers, or even recommendations for changes in teaching methods. These algorithms ensure efficient use of student performance data and help teachers and administrators make informed decisions about teaching and improving student performance.

Despite the benefits, the use of AI in education faces several challenges, including ethical issues, implementation costs, and technology availability. However, with the right approach and investment, these risks can be minimized, and the potential of AI to create a more efficient and accessible education system can be maximized.

In addition, technology can also be used to optimize timetables and manage learning resources. Algorithms can analyze data on the availability of classrooms, teachers, equipment, and other resources to generate efficient class schedules. It helps to minimize conflicts and ensure more efficient use of available resources. Such algorithms can also help organize extracurricular activities, excursions, and other learning activities.

One of the most promising areas of technology application in education is the development of tools to increase student engagement and motivation. By analyzing student behavior and interaction data, systems can detect decreased motivation or the risk of dropping out. Based on this data, they can recommend personalized strategies to teachers to encourage and support students. It helps to identify problems in time and take action to keep students engaged.

Despite the significant benefits, the use of technology in education also raises several ethical issues that need to be carefully considered and regulated. Privacy issues, bias in algorithms, responsibility for decisions, and transparency of systems should all be considered when developing and implementing solutions. In addition, it is necessary to ensure equal access to such technologies to avoid worsening educational inequality.

**Conclusion.** In general, technology in education has significant potential to transform the learning process, making it more personalized, effective, and engaging. However, these technologies also bring new challenges that need to be carefully considered and addressed. Only with a balanced and responsible approach will we be able to fully reap their benefits and build a more inclusive and quality education system.

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# ARTIFICIAL INTELLIGENCE IN SCIENCE

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**Keywords:** Artificial intelligence, AI, machine learning, technology, science.

**Introduction.** Artificial intelligence is changing scientific research by introducing powerful calculative methods that allow machines to imitate human intelligence. With the help of sophisticated algorithms, AI systems can now analyze difficult data and identify patterns, opening up opportunities for more accelerated discoveries and innovative solutions.

**Objectives.**

1. To research and understand the concept of AI.
2. Advantages of using AI and its impact on research.
3. Examples of AI applications in various scientific fields.

**Methods.** The study employs a comprehensive literature review and case study approach to explore the adoption and impact of AI in science. Several scientific articles, case studies, and real-world applications of AI in various scientific fields such as medicine, biology, and construction serve as the main sources of data. The main method will include reviewing case studies from several sources (report, websites, etc.)

**Results.** Artificial intelligence (AI) in its broadest sense, is intelligence exhibited by machines, particularly computer systems (Contributors to Wikimedia projects, 2001). AI in science has revolutionized the way researchers approach complex problems. Having become one of the most advanced technologies, AI is now paving the way for new discoveries and innovations in various fields of science. Thanks to machine learning, AI systems are able to analyze large amounts of data and information, revealing hidden patterns.

In recent years, there has been a growing focus on the democratization of artificial science, which will make it more accessible to researchers and scientists. Companies are developing user-friendly AI tools and platforms that allow to utilize AI capabilities that do not require special technical knowledge. Such tools and platforms allow to create unique and high-quality products in minutes, increasing productivity and efficiency of research. Due to its ability to process and analyze large amounts of data, AI is changing the way research is conducted, analyzing results, and facilitating discoveries (Artificial Intelligence in Science – Data Science UA, 2024).

One of the most important areas of wide application of AI is computer science, which involves the use of machine learning algorithms to develop intelligent systems that can perform tasks that usually require human intelligence. AI is used to process

complex datasets, model, and generate hypotheses, thereby accelerating the research process. One of the key areas in science is the integration of machine learning algorithms into laboratory processes. For example, AI algorithms can analyze experimental data in real time, optimizing parameters to improve experiments, which speeds up the research process and eliminates the possibility of human error.

AI plays a crucial role in the field of medicine. AI is used in drug development, where it efficiently analyzes huge databases of chemical compounds, which significantly speeds up the process of research and development of new drugs. Using AI algorithms, scientists can analyze large amounts of patient data, including genetic information, medical records, and treatment results. This allows them to analyze patient treatments and can help identify potential drugs, predict disease outcomes, and optimize treatment protocols (Voarino, 2019).

In the construction industry, AI can be used to predict various aspects of a project, such as cost overruns, schedule delays, equipment failure, material shortages, etc. By analyzing the project specifications, weather conditions, labor availability, and the results of previous projects, AI algorithms can provide information that will help in decision-making and improve future projects.

Another trend in science is the use of AI-based data analysis tools. These tools use natural language processing and machine learning algorithms to analyze a large volume of scientific literature, which allows you to quickly find relevant scientific articles and summarize key findings. For example, in computational biology, AI algorithms can model complex biological processes with high accuracy, which allows gaining insight into biological systems that are difficult to study through long-term experiments (Barraud, 2019).

One of the significant advantages of using AI is its ability to accelerate the pace of scientific discovery. Traditional scientific research can be labor-intensive, requiring careful experiments and long data collection. AI-based tools can process huge amounts of data at high speed, identifying patterns, trends, and correlations that are not immediately obvious to researchers. This allows scientists to analyze complex data sets efficiently, leading to quick insights and discoveries.

**Conclusion.** In summary, artificial intelligence, which started out as a data processing tool, may rapidly become an integral element in the science and technology industries of the future. Its ability to automate processes, analyze large amounts of information, and generate new knowledge opens up prospects for humanity that contribute to scientific breakthroughs.

However, it should be noted that AI, like any other technology, has its own problems. AI algorithms require large amounts of high-quality data and information to produce accurate results. In addition, the lack of standardized data formats and data exchange methods can further complicate the development of AI use. Thus, AI is impossible without the human factor. Researchers and scientists should focus on improving the quality and quantity of data. Collaboration between scientists and data

scientists can also help to develop strategies for data collection and processing to ensure data availability for AI-based research.

At the same time, it is important to develop ethical standards for the use of AI to ensure transparency, fairness, and accountability. The development of standards and guidelines for interpreting and explaining AI models in scientific research can promote transparency and trust in the scientific community.

AI continues to evolve, it has great potential to shape future scientific research and discoveries, stimulate innovation in various fields of science, which not only expands the boundaries of science but also shapes a new society where intelligent technologies become an integral part of human life.

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## THE ROLE OF SYNTHETIC BIOLOGY IN SPACE EXPLORATION ANDLIFE SUPPORT SYSTEMS

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**Keywords:** synthetic biology, space, microorganisms, biotechnology.

**Introduction.** Space exploration comes with many challenges, such as extreme conditions, long supply chains, and risks associated with the unknown. To ensure mission success, the prospect of self-sufficient crews is gaining importance. Synthetic biology, which combines aerospace engineering and bioengineering, can significantly support long-term missions, because it is able to transform waste and resources of the destination into useful products. Biological technologies, reducing

the need for energy and the number of launches, offer alternative and economical means of carrying out missions, ensuring safety and opening up new biological opportunities in space (Arkin, Cumbers, Hogan, & Menezes, 2015).

**Objectives.** The main goal is to explore the potential of synthetic biology to support the autonomy of space missions by converting existing resources into useful materials and products. This includes reducing dependence on regular supplies from Earth, increasing the resilience of astronauts to extreme conditions, and ensuring that all the necessary resources are created on site for long-term space travel.

**Methods.** Synthetic biology opens up vast opportunities for space exploration and exploration through the ability to transform local resources into useful materials. By using biological processes to process waste and resources from their destination, the need to transport materials from Earth can be reduced. Microorganisms adapted to extreme conditions are able to perform key functions, such as waste disposal, extraction of useful substances from regolith, conversion of carbon dioxide into oxygen (Berliner et al., 2021). These processes help create basic materials for construction, provide life support and become the basis for further production on extraterrestrial objects.

In addition, synthetic biology is used in space medicine, in particular by developing new methods of radiation protection, the production of necessary drugs and the maintenance of the health of astronauts on long missions. Biological systems can be configured to produce food and medicine in situ, reducing dependence on Earth supplies and providing vital necessities for human space missions (Barker & Gilroy, 2017).

**Results.** Synthetic biology can complement 3D printing by making it possible to create special biological "inks" from local resources, which reduces the need for earthly raw materials. This allows astronauts to be more autonomous, quickly produce the necessary materials and adapt to unknown conditions. Microorganisms capable of converting sunlight, nitrogen, and water can provide the building blocks for a variety of products that can be created from the transferred digital DNA sequences. David Walsh, a bioengineer at Lincoln Laboratory, explains that the idea is to create a system that actually converts digital data into biological components (Foy, 2019).

**Conclusion.** In summary, synthetic biology for space has significant potential as a promising branch of biotechnology with many directions for future research that build on existing technologies. This development opens exciting prospects not only for space missions, but also for applications on Earth.

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## THE IMPACT OF ARTIFICIAL INTELLIGENCE ON THE JOB MARKET

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**Keywords:** Artificial intelligence, job market, automation, workforce, future of work, economic impact, skills gap.

**Introduction.** Artificial intelligence (AI) has rapidly advanced, permeating various sectors of society. Its impact on the job market is a topic of significant debate. This paper delves into the multifaceted consequences of AI-driven automation on employment, examining how it is reshaping the nature of work and the skills required for future employment. The research explores the potential for job displacement, the emergence of new roles, and the skills gap that may hinder a smooth transition to an AI-driven economy.

**Research Objectives.** This study aims to understand the complex interplay between AI and the future of work. Specifically, it seeks to identify industries and job roles most susceptible to automation, analyze the potential for job displacement and the creation of new roles, and explore the skills and competencies that will be in high demand in the AI-driven economy. By addressing these objectives, the research aims to provide insights to inform workforce development initiatives, policy decisions, and individual career planning.

**Research Methodology.** The research employed a mixed-methods approach, incorporating both quantitative and qualitative data collection methods to provide a comprehensive understanding of AI's impact on the job market.

**Quantitative Analysis.** To gain a quantitative understanding of AI's impact on the labor market, a systematic review of academic literature was conducted. This involved scouring peer-reviewed journals to extract insights from established research on AI and its implications for employment. In addition, industry reports from leading technology and economic research organizations were analyzed to gather data on current AI trends and their projected economic impacts. Finally, labor

market data from government agencies provided a statistical foundation to identify sectors and occupations most vulnerable to automation.

**Qualitative Analysis.** To complement the quantitative analysis, qualitative research methods were employed to delve deeper into the experiences and perspectives of individuals directly affected by AI. Semi-structured interviews were conducted with industry experts, including AI developers, human resources professionals, and labor economists. These interviews provided valuable firsthand insights into the evolving landscape of work and the challenges and opportunities presented by AI.

Furthermore, interviews with HR professionals from various industries offered detailed information on their experiences with AI adoption, the skills gap within their workforces, and strategies for adapting to the changing landscape. By combining these qualitative and quantitative approaches, the research aimed to provide a holistic view of the complex interplay between AI and the future of work.

**Results.** The findings reveal a complex picture with both positive and negative implications.

Automation and its impact. The research confirms that AI is indeed automating many routine, repetitive tasks across various industries. Manufacturing, transportation, and administrative sectors are particularly susceptible to automation, raising concerns about job displacement. (OECD, 2019).

Job displacement and creation. The study acknowledges the potential for AI to displace some jobs. However, it also highlights the creation of new job opportunities in fields requiring human-machine collaboration, creativity, critical thinking, and problem-solving skills. Roles in data science, machine learning, AI development, and AI ethics are expected to see significant growth (OECD, 2019).

Emergence of the skills gap. As AI transforms the job market, a significant skills gap is emerging. The workforce currently lacks the necessary skills in areas like data analysis, programming, and AI literacy. This skills gap hinders the ability of workers to adapt to new job opportunities created by AI Georgieva K. "AI Will Transform the Global Economy. Let's Make Sure It Benefits Humanity", 2024.

**Discussion.** The integration of AI into the workforce necessitates a multi-pronged approach to address the challenges and maximize the benefits.

Reskilling and upskilling initiatives. To bridge the skills gap, policymakers, educational institutions, and businesses must collaborate on developing and providing accessible reskilling and upskilling programs. These programs can equip current workers with the skills needed for the jobs of the future (Faethm Insights Blog, 2024).

Developing social safety nets. Mitigation strategies are necessary to address potential job displacement. Governments and social safety nets must be prepared to support workers who lose their jobs due to automation, providing retraining opportunities and income assistance during transitions (Georgieva, 2024).

Focus on lifelong learning. Fostering a culture of lifelong learning is crucial. Individuals must take ownership of their professional development by actively seeking opportunities to learn new skills and stay updated with the evolving technological landscape.

**Conclusion.** The integration of AI into the workforce is a complex phenomenon with both positive and negative implications. While automation may lead to job displacement in certain sectors, it also presents opportunities for innovation and economic growth. To mitigate the negative impacts and maximize the benefits of AI, a collective effort from policymakers, educators and businesses.

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## THE IMPACT OF DIGITAL ILLUSTRATION ON TRADITIONAL PUBLISHING

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**Keywords**: digital, illustration, printing, platforms, physical materials.

**Introduction.** The digital revolution has profoundly transformed various aspects of life, with the publishing industry and illustration being among the most affected. In recent decades, digital illustration has emerged as a dominant form of visual art, fundamentally altering both the creative processes and final products within traditional publishing. This study explores the significant influence of digital illustrations on conventional methods of illustrating books, magazines, and other printed materials. By examining the evolution of illustration techniques, the advantages and challenges posed by digital tools, and their implications for artists

and publishers, this research aims to provide a comprehensive understanding of the impact of digital illustration in today's publishing landscape.

**Objectives**. The aim of the work is to examine how digital illustrations have influenced traditional methods of illustrating books, magazines, and other printed products.

**Methods**. This study employs a qualitative analysis of existing literature and case studies to explore the impact of digital illustration on traditional publishing methods.

**Results**. The digital revolution has touched almost every aspect of life, including the publishing industry and illustration. Digital illustration emerged in the mid-1980s with the development of computer technology. Programs like Adobe Illustrator and Photoshop allowed artists to create and edit images with unprecedented precision and speed. Before this, traditional illustration methods included manual techniques such as watercolor, gouache, pencil, ink, and others (Heller, & Chwast, 2015). Artists created images by hand, which were then reproduced through printing. Digital illustrations have provided numerous advantages to the publishing industry, leading to significant changes in working methods (Elkins, 2008). Artists can create, edit, and send illustrations much faster than with traditional methods, reducing the time required to prepare materials for printing and shortening the overall production cycle. Digital illustrations are easily modifiable, allowing editors and artists to quickly make adjustments as requested by publishers. The lack of need for physical materials, such as paints, paper, and other artistic supplies, lowers the cost of producing illustrations (Kress, & van Leeuwen, 2006). Publishers can easily adapt digital illustrations for use in online publications, mobile apps, e-books, and other digital platforms. This transition has greatly impacted book illustration, particularly in children's literature and graphic novels, where artists use digital tools to create characters, landscapes, and other elements, providing a high level of detail and vibrant colours (Houghton, 2019). Digital platforms have also helped artists create complex comics and graphic novels, which can be easily printed or distributed in digital format.

There are numerous software tools for digital illustration, each with its own features and approaches to creating graphics:

- Adobe Photoshop: widely used for creating raster images, photo manipulations, and complex illustrations.
- Adobe Illustrator: a program for working with vector graphics, allowing for scalable illustrations well-suited for printing.
- Procreate: a drawing program for tablets, used by many professional illustrators due to its simplicity and powerful features.

With the rise of e-books, digital illustration has become an important part of the publishing process. It is not only used for covers but also integrated into the text itself, creating multimedia content that can include animation, interactivity, and other

elements. The transition to digital illustration has expanded opportunities for artists. Illustrators can sell their work through platforms like Etsy, Creative Market, or even directly through their own websites (Bowers, & Ruan, 2020). Digital tools allow illustrators to collaborate with publishers from different countries without being limited by physical location. Digital illustrations can be used in many different media, from printed books to digital editions and mobile apps, opening access to a wider audience.

**Conclusion**. Despite numerous advantages, digital illustration has some drawbacks. Critics argue that it can lead to a loss of traditional drawing skills and a decreased interest in traditional materials. Additionally, digital files can be easily copied or used without permission, creating issues with protecting illustrators' rights. Overall, digital illustration has significantly changed traditional publishing, offering new opportunities for artists and publishers. It has sped up the content creation process, reduced production costs, and opened new avenues for creative experimentation. However, this transition also comes with challenges, such as copyright protection and the potential loss of traditional artistic techniques.

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## FUTURE TRENDS IN AI FOR FRONTEND DEVELOPMENT

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**Keywords:** AI, frontend, VR/AR, real-time processing.

**Introduction.** The revolution of Artificial Intelligence (AI) has reached the frontend development phase wherein interfaces are getting smarter and more user-friendly and safer at the same time (Bajaj, 2023; Li & Chen, 2023). Moreover, With the growth of AI technology, it is now possible for websites and apps to offer interactive personalized content tailored to an individual's actions in real time. This paper examines how artificial intelligence will transform frontend development by highlighting three major trends: predictive personalization, AI driven AR/VR and

upgraded security. Each of these trends illustrates how AI can enhance not only the experience of interacting with a website or app but also the security of these interactions.

**Objectives.** This study aims to understand the possible future changes of frontend development through the use of AI. In particular, it pays significant attention to user behavior and usage prediction techniques, which enables us to make the web interfaces flexible. This is very important as users are seeking more advanced interfaces that are more relevant to them helplessly. AI can process information almost in an instant and customize almost everything including the design and content so that it fits a specific user's experience with a website or an application.

Another objective is to evaluate the role of AI in enhancement of AR and VR experiences on the web. With AR and VR attracting a lot of developments and investments especially in the gaming, e-commerce and education sectors, it is obvious that AI would be important in enhancing interactivity. Lastly, this paper presents the view of the use of AI in enhancing the security of the frontend. As there are more and more transactions happening on the web, the chances of getting compromised security are increasing. AI has been known to possess the capability of recognizing threats and helps in preventing unfortunate events in the security of the frontend – a very big optimistic change.

**Methods.** This investigation centers on reviewing, in details the relevant current technologies and tendencies in Artificial Intelligence as utilized in frontend development. It relies on particular instances and estimates to visualize the extent to which AI in these spheres has already advanced and forecasts how far it can reach in the future. The study targets those machine learning models which are employed in the development of predictive personalization and web development to enhance the user experiences by designing personalized web applications. Furthermore, it also focuses on the application of artificial intelligence in the case of augmented reality and virtual reality as it able to understand the user and change the stimulus in real time (Chandler & Mullen, 2022). Security-wise, this research provides an overview of various anti-abuse technologies that include AI implemented barriers to social engineering, or phishing and cross-site scripting attacks prior to their escalation.

**Results.** Over the years, research has shown that AI is making a significant contribution to frontend development in a number of ways. For starters, websites have also changed how users engage with their content thanks to services like AI-based predictive personalization. A specialized application is able to monitor behaviors indicators i.e. Which sections of a site are frequently visited? What contents do they most interact with? And within those parameters, AI is capable of remolding the structure real-time. This degree of personalization allows offers to users hindering their desire to leave and promoting contentment as well.

In so much as it is applied to AR and VR, AI is enhancing the experience within the browser itself. For one thing, in e-commerce, consumers can use actual products virtually through an AI-based try-on system. This makes purchasing goods more enjoyable and precise. In games and learning systems, the power of AI is utilized to construct the surrounding space and adjust it based on the user's actions (Kang & Zhao, 2022).

AI is also proving useful in curbing degrees of uncertainty. Security and the ability to cope with aggressors have been largely attributed to the level up of AI. This is because, due to its intelligence, an AI can discern abnormal activities in a user's pattern of use such as in cross site infusion or fishing attack and block the attacks before any damages are inflicted. This change in security policy is useful in enhancing user's confidence in their encapsulated information hence making the internet more user friendly.

**Conclusion.** Indeed, technology is rapidly evolving, and artificial intelligence is taking a primary seat in making web experiences more engaging and secure by focusing on micromanaging the frontend. For instance, predictive personalization that is AI enabled, will allow for websites to change according to the needs of particular users as they navigate through the site in real time enhancing the user experience (Mendes & Silva, 2022). In addition, as AR and VR takes the center stage in many industries, AI will be of utmost importance in enhancing the usability of such technologies.

Looking ahead, security will undoubtedly be an area managed in large part by artificial intelligence. With ever-increasing complexity of web applications, go hand in hand with growing chances of cyber threats. The ability of AI to mitigate risks by preemptively combating attacks and enforcing measures in a matter of seconds will be a huge plus in protecting users as well as their information.

Finally, AI is not a gimmick in the field of front end development; it is a mode of developing which is already starting to define the ways of the future. Through the inclusion of artificial intelligence technologies, developers are able to design web experiences that are not only more interactive and easier to use but also safer and more robust. This is the new paradigm that advanced technologies in AI will come to dominate front end development.

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## THE RISE OF GO: EFFICIENCY, SCALABILITY, AND SIMPLICITY IN MODERN SOFTWARE DEVELOPMENT

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**Keywords:** Go programming language, concurrency, cloud computing, scalability, performance, microservices.

**Introduction.** Golang which is often referred with abbreviation Go is the language of the 21st century because of its simplicity, efficiency and concurrent orientation. Go is an optimal, but also a versatile language created by Google and for the goal of dealing with difficulties of large-scale software system, with the language that will allow the programmer to write applications that will be efficient and can scale. This paper herein aims to look at the areas that Go is strong as a language for instance cloud computing, microservices, backend development, and how it addresses modern software development needs.

**Objectives.** The objectives of this research are:

1. To examine the features that distinguish Go from other programming languages, focusing on simplicity, performance, and concurrency.
2. To explore Go's application in cloud computing and backend services, highlighting successful case studies.
3. To analyze Go's benefits in microservices architecture, particularly its role in handling distributed systems and scalability.
4. To identify challenges developers, face when using Go and anticipate future trends in Go development.

**Methods**. The framework for this research is based on a literature review of Go's fundamental design goals and features, which are compared to other popular backend languages including Python and Java. Case studies such as Google, Uber and Dropbox were reviewed to see how Go helped to optimize large scale applications and assess how Go has impacted on cloud computing and backend services. This study also evaluates Go's use of Goroutines for concurrency, and benchmarks that compare Go's efficiency to traditional threading approaches in Java and Python.

The research discusses how static type, compile nature in Go makes it suitable for high performance and concurrent programming resulting in microservices architecture. Finally, we evaluated different tools and frameworks in the Go ecosystem, like Gin and Echo and GORM to understand how they can help speed up development and increase maintainability.

**Results.** Its simplicity and efficiency make Go popular. Its syntax is simple, in order to be simple to learn and use by developers not touching keyboards yet. Unlike languages involved in complex class hierarchies, Go uses simple enough code structure, without the use of inheritance and with straightforward syntax (Donovan & Kernighan, 2016). It is designed around clarity and maintainability for scaling projects with high teams.

There's no doubt that concurrency is a primary strength of Go. Go's features to run concurrent tasks in a low overhead way (called Goroutines) makes it one of the most efficient languages to handle concurrent activities. Handlers interact with channels instead of other concurrency models that introduce common race conditions. This feature has been useful in cloud computing because the same processes need to be managed simultaneously (Turnbull, 2018).

Go becomes especially attractive for cloud and backend development where performance takes the stage. Being compiled, Go is as fast as or faster than C/C++ for resource intensive apps. Go has already been deployed by companies such as Uber and Dropbox in performance critical services, showing its ability to serve a large number of requests with very small latency. Like in Uber's case the concurrency model used by Go helped in rendering the request handling more efficient and utilizing the resource more effectively (Uber Engineering Blog, 2021).

Tools available in Go's ecosystem make backend development much easier. Lightweight, quick options to build frameworks are available like Gin and Echo itself, as well as ORMs like GORM to use while dealing with the database. Together, these tools together with Go's builtin testing package, make for a well-designed development tool and drives developers towards Go as a backend language.

Go's efficient concurrency model has also benefited Go based Microservices. The need in distributed systems is to manage independent services with minimal overhead, and Go is a statically typed, low latency language which fits perfectly with this. For example, Netflix use Go for some parts of its architecture based on Go's speed and concurrency to enable the scalability and reliability (Netflix Technology Blog, 2022).

Go has its disadvantages, but has its advantages. Its lack of generics makes code reuse difficult, but that is one of the main drawbacks. With generics, a lot of repetitive code has to be written by developers when working with collections. Fortunately, the Go development team announced that they want to introduce generics, likely solving this (Go Blog, 2021). Go's garbage collection is another

thing, though pretty efficient, that occasionally causes latency issues in applications with high memory usage.

**Conclusion**. Because of its simplicity, its efficiency, and an incredibly strong concurrency model, Go has become a leading language in cloud computing, microservices, and backend development. It makes a huge influence in backend development because it has the performance levels very close to C/C++ but at the same time, it is very accessible and readable as in the higher language. Scalability, reliability and maintainability were designed into the language as a result and it's an outstanding choice for modern applications needing high performance and concurrent processing.

Go promises to become even more versatile as future developments in Go, such as generics, will likely make it more attractive. The importance of Go is only going to grow even more as cloud computing and distributed systems grow, making it a must have language for the backend ecosystem.

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## THE ROLE OF BLOCKCHAIN TECHNOLOGY IN ENHANCING DATA SECURITY AND PRIVACY

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**Keywords:** Blockchain, Data Security, Privacy, Decentralization, Cryptography, Distributed Ledger Technology, Smart Contracts.

**Introduction.** In our modern day where we are synonymous with data, privacy and data security have become major priority (Zohar, 2015). Now as internet reliance and the use of digital platforms increase, people and organizations are more vulnerable than ever to cyber-attacks, data breaches and unauthorized access. Old school, centralized systems used by banks, government institutions and consumer cloud services have proved much less than capable, failing to address fundamental

concerns such as single points of failure, loss of data, data tampering and poor data management (Buterin, 2013).

**Objectives.** This research explores how blockchain technology enhances data security and privacy through decentralization and cryptographic methods and to analyze the possibilities and challenges of blockchain technology. Data protection in several specific industries (e.g., healthcare, finance, and supply chain management) are being analyzed for potential applications of cryptographic ledger. In order to explore the difficulties and restrictions of blockchain technology in terms of its scalability, energy consumption as well as regulatory constraints.

**Methods.** This research is qualitative in nature which combines a literature review with case studies of blockchain applications. Scholarly articles, white papers and technical documentation about cryptographic ledger technology, data security and privacy are amongst the areas that will be reviewed in the literature review. On top of that it will look at how blockchain is being adopted across different industries, and how it can be used to strengthen data protection.

This study will, in addition, analyze case studies in other industries including healthcare, finance, and supply chain management where blockchain has been deployed to enhance security. Naturally, the analysis will go over outcomes and challenges of blockchain application in these fields, including problems with implementation, scalability and regulation.

**Results.** One reason blockchain is ideal for increasing the security of data and maintaining privacy lies in the nature of its underlying features – blockchain does not work like a single central point server controlling data, like in traditional centralized databases, but works on a decentralized network of nodes (computers). In this case, there is no single point of failure and nobody in the network can play with the data without the support of majority network participants. Blockchain being decentralized means that they are the kind of robust solution to protect data from unauthorized access or from being manipulated (Mougayar, 2016).

Patient data privacy and not part of it is so crucial in healthcare. Since patient records are an inherently distributed, shared resource, blockchain can quickly and securely allow them to be stored and shared in a decentralized system. By adding in blockchain, patients can control how their data is handled and provide or withdraw access to healthcare providers as their circumstances warrant.

Electronic health records (EHRs) are becoming popular to use a blockchain for. In such projects, blockchain based platforms give patients the authority to control their medical records safely and ensure that their medical information remains unabridged and accessible only to who is duly authorized. Although blockchain has been associated mostly with cryptocurrencies, they understand which innovative way it could be used for data security in traditional financial services. Blockchain can be used by banks and financial institutions to develop secure and secure systems of managing transactions without frauds and protecting the

confidentiality of financial data. Lots of banks are keen on testing a blockchain for secure transaction and clearing. Unknown to many people, blockchain's ability to have a transparent and unalterable record of transactions reduces the chance of error, fraud, and hacking (Nakamoto, 2008).

**Conclusion**. Blockchain technology, with its lack of centralization, transparency, tamper resistance, has great potential to protect data security and privacy by offering decentralized, transparent and tamper resistant storehouse and sharing information. Its potential application in healthcare, finance and supply chain Management makes it important in protecting sensitive data from cyber threats and illegal applications.

Yet scaling the technology, limiting energy consumption of the service and resolving regulatory compliance issues have to be addressed first before blockchain can be fully absorbed into mainstream data security solutions. While the world is getting interconnected day by day, technology keeps moving forward with this, blockchain may play a bigger role to protect data in enhancing the way and how we secure digital assets to ensure our privacy (Tapscott, & Tapscott, 2016).

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## FUTURE TRENDS IN SCIENCE AND TECHNOLOGY: IMPORTANT INNOVATIONS THAT WILL CHANGE THE WORLD

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**Keywords:** technological advancement, artificial intelligence, biotechnology, renewable energy, smart implants, future trends.

**Introduction.** The speed of science and technology development has taken little time to change our planet; it is an unusual phenomenon that man has never seen and never will see again. In the next ten years, changes in technological dynamics are bound to occur on a grand scale to transform industries, economies, and societies.

Such advancements will serve a dual purpose: acting as catalysts to advance human progress and fighting the prevailing global challenges like climate change, inequalities in health care, or scarce availability of basic resources. This paper considers some of the futuristic tendencies, preparing in more detail for the most projected technological groundwork in the next decade. Understanding such basic changes will help in gearing up for the coming opportunities and challenges.

**Objectives.** This study aims to explore in-depth the emerging trends that will have a major impact in the future. Other major components of this research include investigating how new technologies and innovations can be translated into practice in various domains of life, along with recommendations on how they can be utilized to answer significant global challenges for humanity.

**Methods.** To investigate this topic, a number of scientific articles, industry studies, and technology forecasts were reviewed and analyzed to understand the current and expected impacts of technology in different areas of science and society. A qualitative examination of emerging technologies was also conducted to understand their impact and societal implications.

**Results.** Based on the whole analysis of different articles, one can state that artificial intelligence technologies, biotechnology bioimplants, and increasingly, renewable energy will accelerate very rapidly during this period and probably during the next decade. Some of these technologies have already begun infiltrating certain walks of life in humankind.

Consider artificial intelligence. Although a relatively new technology, it has undergone such rapid development in such a short time. Initially, AI could consist of writing small texts and executing trivial duties. Now, it will find applications in several spheres of life. AI has an incredibly bright future ahead; however, the future is not without challenges. It is expected that as technology redefines the world, AI will continue to enjoy ever-growing popularity, propelling industries such as healthcare, banking, and transportation into technological progression (Duggal, 2024). It is fully anticipated that innovations in machine learning, natural language processing, and computer vision will keep propelling AI trajectories steeply upwards. The introduction of the first prototypes of full-fledged AI robots capable of carrying out various physical tasks has arrived, and as this technology grows, robots will begin to emerge in such areas as manufacturing, medical, human services, etc.

Clinical approaches to the next decade will witness substantial developments in biotechnology and smart implants, which will coordinate human life and assist disabled people in leading normal lives. The development of smart implants embodies a coming age in patient care, comfortingly merging engineering and biotechnology. These innovations, from state-of-the-art drug delivery systems to rapid prosthetics, make healthcare more tailored, expedient, and effective. One of the most exciting prospects is the development of implants that can promote tissue regeneration and healing. These implants can help repair damaged tissue by

integrating growth factors and stem cells, potentially eliminating the need for more invasive surgical interventions (Equitus Design Engineering and Innovations Limited, 2024).

The development of clean energy, including solar, wind, hydrogen energy, and other cleaner alternatives, would grow leaps and bounds as technological facilities in energy storage and the efficient grid hasten. Solid-state batteries are among the promising advances in battery technology that may further ramp up the performance and capacity of renewable energy systems. Existing technology continues to improve (more efficient solar panels, taller and more powerful wind turbines, and improved energy storage solutions) while new technologies are integrated into the mix to provide expanded options in assessing any renewable energy source (Nicholson, 2023).

**Conclusion.** Based on a review of trends in technology, the conclusion has been reached that the next decade will herald radical change driven by a raft of innovations in artificial intelligence, biotechnology, and renewable energy. In our view, if we were serious about leveraging most of the benefits, it would require an approach, preferably an interdisciplinary one, supportive and collaborative between scientists and technologists, policymakers, and the public. Let us harness innovation and recognize potential risks to ensure that the future uses technology to serve the common good, encourage progress, and raise the standard of living for all.

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# NEURALINK AND THE EVOLUTION OF BRAIN-MACHINE INTERFACES

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**Keywords:** Neuralink, brain-machine interfaces (BMI), implant, ethical concerns.

**Introduction.** Brain-machine interfaces (BMIs) such as Neuralink will change medicine, communication, and human limits. Founded by Elon Musk, Neuralink has recently crossed a key milestone by surgically embedding a wireless brain chip in humans, considered a great leap forward within BMI technology (Neuralink Corporation, n.d.). Determined to wire the human head with computers, Neuralink might quite possibly transform the entire healthcare industry entirely and put complex brain disorders to rest. This research addresses Neuralink's promise, potential drawbacks, broader societal consequences, and the role of related technology and its development.

**Problem Statement.** The main obstacle faced during Neuralink development was the integration of external devices into humans. There are various challenges in making a device that can establish a reliable and safe brain-oriented interface with the possibility to cluster and adapt. In addition to these technical concerns, there are also social and ethical risks, such as those associated with privacy, consent, or the divide between rich and poor demographics. Therefore, there is a need to resolve these complex issues to ensure that Neuralink technology is ready to improve human society without violating human rights.

Nevertheless, Neuralink's consequences should be understood from the technological point of view and the commercial and social. There is so much paranoia about data privacy and control over one's neural information, and the potential for its abuse is growing. And since neural data is a hacker's high-value target, the importance of its security cannot be understated. The abuse of this information may result in discrimination or even psychological or political influencing, stressing the urgency of tough regulation.

**Research and Findings.** Given the ongoing progress of neuroengineering, Neuralink technology ventures into new frontiers, including health, communication, and enhancement. Precision Neuroscience, formed by a Neuralink co-founder, also aims to help people with paralysis. And its implant resembles a very thin piece of tape that sits on the brain's surface and can be implanted via a "cranial micro-slit", which it says is a much simpler procedure (Jackson, Gerken, 2024). The use of brain-computer interfaces will make it possible for the human body to overcome physical barriers by controlling machines through thoughts. It highlights that BMIs

such as Neuralink that work in such a manner can be effective in therapy and, moreover, enable humans to transcend biological limitations and perform functions beyond their natural abilities.

In medicine, it is now possible to treat and decode brain signals more accurately. Devices have also allowed the transmission of brain signals – a promising growth for individuals with neurodegenerative diseases. For example, people suffering from spinal cord injuries can even use robotic limbs. With the growth of machine learning and interpretation of neural networks, the ability to decipher neural patterns has become more reliable over time.

**Proposed Solutions / Innovations.** To address these issues, Neuralink's developers need to emphasize device safety, reliability, and ethical measures more. Developers can harness blockchain technology to build a comprehensive infrastructure for protecting neural data and provide users with data ownership. Blockchain is a distributed database that records transactions in a verifiable and permanent way, making it a good candidate for preserving sensitive neural data.

Safety improvement can be reached by using flexible and biocompatible materials in the BMI implants and employing more innovative strategies. For example, graphene-based electrodes are known to improve signal resolution and are also less invasive. This next-generation technique aims to develop minimally invasive devices that cause less pain or destruction. Therefore, flexible materials remain an important area for Neuralink technology as it strives to achieve optimum performance and safety.

Moreover, machine learning algorithms that adapt independently depending on every individual's neural responses could take Neuralink's efficiency to another level. Personalized algorithms can be mapped onto each user's neural signatures, interpreting and communicating the data seamlessly in a manner that will not strain the mental efforts.

**Impact.** BCIs have been proposed for use in many fields, including medicine, neuroscience research, education / training environments, human-computer interaction, and even gaming/entertainment applications where users can control virtual objects using only their thoughts without any physical movement required (Peksa, Mamchur, 2023).

On a social level, it is possible that Neuralink would revolutionize how people communicate by allowing face-to-face exchange without requiring any vocabulary or writing. This would improve the world by reducing the communication gap and encouraging more people to participate in both online and offline formats. Addressing it will require proactive policy measures to ensure fair access and prevent a "digital divide" based on neurological enhancement.

This technology can help restore interaction with the environment for those with ALS, Parkinson's, or other neurodegenerative diseases through interaction with certain devices via their brains. Such general improvements may be brought about

by, for example, increased blood flow to the brain, enhanced neurochemical environment promoting plasticity induction, or simply increased traffic in neural circuitry sustaining healthy activity-induced myelination processes (Simon, Bolton, Kennedy, Soekadar, Ruddy, 2021).

**Conclusion.** In summary, Neuralink is a revolutionary progress in technology science that has the potential to enhance the physical health of humans, improve the ability to interact, and increase capabilities. While such advantages may be realized, developers must solve ethical limits, security, and accessibility challenges. When prioritizing protecting sensitive information, using biocompatible materials, and developing adaptive algorithms, Neuralink has the opportunity to become a technology that benefits society broadly while respecting individual rights.

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## THE EVOLUTION OF EDGE COMPUTING: EMPOWERING REAL-TIME APPLICATIONS IN THE DIGITAL AGE

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**Keywords:** Edge Computing, IoT, Cloud Computing, Latency, Real-Time Processing, Decentralized Data.

**Introduction.** Over the last few years there has been an explosion in demand for real time data processing, fueled by the growth of the Internet of Things (IoT) and data intensive applications. However, traditional cloud computing is fast becoming unmanageable in situations when data is required to be processed and analyzed in real time and transmitting the data to a centralized cloud server creates latency and potential bottlenecks. These issues are addressed using edge computing, a distributed computing architecture that brings to the source as it processes its data faster, closer. Its acceleration of data processing of the application in the critical

sectors. This approach moves computation to the 'edge' of the network to enable faster, real time information processing that is absolutely essential in the deployments such as autonomous driving, healthcare diagnostics, industrial automation etc. The evolution of edge computing, its current applications, and its possibility to transform digital infrastructures is the topic of this paper.

**Objectives.** An analysis of the drivers behind the evolution and adoption of edge computing and its basic principles. And explores various applications of edge computing in key industries, showing how it outperforms cloud computing in latency sensitive use cases. To analyze the impact of specific case studies in performance, scalability and cost efficiency. A discussion of challenging, limiting, and edging issues of edge computing as part of the integration of edge into cloud.

**Methods**. In this mixed method research, current literature is reviewed along with several case studies from different sectors. To describe foundational technology, we relied on academic sources while industry similar white papers and reports supplied current usage. An analysis was also conducted of benchmarking data comparing edge computing performance to traditional cloud setups, combining several reports detailing current edge deployment issues surrounding security and scalability.

To enable representative use of edge computing across many fields, such as smart manufacturing, automotive and healthcare that rely on low latency and data security, in depth case studies were chosen. These samples show the edge computing aptitude to different needs and the role it plays in advancing industrial and societal functions predicated on real-time data availability.

**Results.** In particular, edge computing has demonstrated favorable results when low latency and immediate data processing are very important. As an example, one of the primary applications is for autonomous vehicles, where the system must make split second decisions using real time sensor data. Data processing delays with regard to speed, obstacle detection and route planning can undermine safety and performance in an autonomous vehicle. With an edge device framework, data can be processed locally, actions taken, nearly instantaneously, something impossible with a centralized cloud architecture (Satyanarayanan, 2017).

We are seeing a continuous stream of patient data generated by wearable devices such as heart rate monitors and glucose meters, which are often processed locally and only useful updates are sent back to healthcare providers. By creating this mechanism, not only is there timely intervention, but it also protects patient privacy by reducing sensitive health information transfer to third party data centers (Yang et al., 2019). Compliance with strict healthcare data regulations is also supported, due to the fact that data usually doesn't leave the device, or the immediate network it resides on, to improve security and privacy.

The other important field for edge computing is industrial automation and smart manufacturing. By leveraging edge computing systems installed in factories,

data coming from machinery can be analyzed in real time and, for example, it can be used to detect malfunctions, optimize processes and reduce downtime. Siemens and General Electric have invested in edge-based systems to improve equipment reliability, as well as reducing operational delays, leading to better efficiency and reduced costs (Shi & Dustdar, 2016).

From a technical standpoint, edge computing takes the edge nodes (and more often edge nodes in conjunction with cloud resources) closer to the data source. Depending upon the processing power of the device, these edge nodes can do anything from straightforward data filtering and preprocessing to more advanced, AI based analytics. Largely, the edge deployments utilize lightweight protocols such as MQTT and CoAP owing to their low energy and data requirements, which allow seamless connectivity even in resource restricted environments. A characteristic of edge computing is its ability to adapt and to complement cloud, especially for IoT applications where devices require timely processing but may lack strong power and connectivity (Shi et al., 2016).

The growth of edge computing however brings new challenges. As a result, securities obtain the rather sophisticated security protocols necessary for the data in the decentralized architecture to be secured. Physical tampering is just as big a threat to physical edge devices as it is to traditional servers, therefore encryption and access control must be equally robust for both scenarios. Scalability is also a concern: edge computing is good at managing data for small scale or localized operations, but this grows too complex and expensive for a massive network of distributed devices. Shi et al. (2016) further emphasize that infrastructure investments are significant, especially with regard to edge servers, storage devices, and maintenance, for organizations that have operations over large geographic areas.

**Conclusion**. For industries that depend on latency and real time responsiveness, Edge Computing is rewriting the book on how these industries treat data processing. The edge computing offers an agile and responsive approach to data management by decoupling data processing from large data centers and decentralizing both processing and storage of the computing closer to the edge (source of data). Edge computing is powering innovation in IoT and real time data applications, such as healthcare diagnostics and autonomous vehicle applications.

The prospect of edge computing is bright, as more and more AI and machine learning acumen improves the fashion. But as cloud and edge infrastructures start to merge, hybrid models that lie somewhere between centralized and decentralized data processing will become more popular. For the widely adoption of edge computing, it will be crucial to address current challenges such as security and scalability. Edge computing will become increasingly important as the need for real time applications expands, to define the digital future and power the next generation of connected devices and smart technology.

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## BIOPRINTING: TRANSFORMING REGENERATIVE MEDICINE AND DISEASE MODELING FOR THE FUTURE OF HEALTHCARE

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**Keywords:** bioprinting, regenerative medicine, bioengineering, tissue creation, disease modeling, organ transplants.

**Introduction**. Nowadays, as technology rapidly evolves in various fields, bioengineering and bioprinting have emerged as some of the most promising and impactful areas of innovation. Obviously, the ability to regenerate damaged tissues and organs is a critical challenge in modern medicine, and traditional methods like organ transplants face significant limitations. That's why bioprinting is a revolutionary technology that holds immense potential to address these challenges. The continued development of bioprinting is not just a technological breakthrough, it is a vital step toward transforming the future of healthcare.

**Objectives**. To examine the potential of bioprinting as a revolutionary tool in bioengineering, specifically in the areas of disease modeling and regenerative medicine. We aim to understand how bioprinting can precisely place cells and biological materials to create complex tissue structures, offering a solution to the limitations of traditional organ transplants. Additionally, we explore bioprinting's role in modeling. Finally, we investigate how bioprinting can advance the understanding of cell communication and tissue development.

**Methods**. The study uses a qualitative method to look at key trends in tissue creation, disease modeling, and regenerative medicine, focusing on the latest bioprinting techniques. It includes both real-world data and expert opinions to give a full view of bioprinting's potential uses. A comparison of different bioprinting methods, like extrusion and lithography, will help understand their strengths in

creating tissues and modeling diseases. The analysis draws on historical data, expert projections, and qualitative perspectives to offer a comprehensive view of potential future developments.

**Results**. Bioprinting, a key aspect of biofabrication, uses computer-aided processes to create organized 2D and 3D cellular constructs, integrating living cells, extracellular components, and biochemical factors for applications like tissue repair and drug screening (Daly, Prendergast, Hughes, & Burdick, 2021). Common techniques include extrusion-based printing, which forms filaments by pressure-extruding bioink, and lithography, which offers higher resolution through light-patterned cell-laden hydrogels. Another method, cell spheroid-based bioprinting, assembles cell aggregates into dense 3D structures. These methods allow precise control over cell placement and biochemical gradients, facilitating studies in tissue development and repair, such as simulating blood vessel formation in response to growth factors (Li, Chen, Fan, & Zhou, 2016).

Bioprinting enables the modeling of complex biological processes by precisely arranging cells within 3D structures, making it especially useful for studying cell interactions and tissue formation. It allows researchers to investigate processes like paracrine signaling, where cells communicate with each other to influence tissue development. Bioprinting can also recreate cell interfaces, which are crucial for proper tissue formation, allowing studies on cell sorting, polarity, and migration (Daly, Prendergast, Hughes, & Burdick, 2021). Additionally, it facilitates the study of shape changes in developing tissues, such as how mechanical forces impact tissue morphology. These applications make bioprinting an invaluable tool for exploring complex biological behaviors and diseases.

In disease modeling, bioprinting is used to create more realistic models of conditions like cancer and fibrosis. Traditional 2D cultures can't replicate the complexity of a tumor's microenvironment, but bioprinted models can mimic the interactions between cancer cells, the immune system, and surrounding tissues, offering a better understanding of treatment resistance and disease progression. Additionally, bioprinting helps simulate kidney and liver diseases, enabling studies on conditions like hyperglycemia and fibrosis (Daly, Prendergast, Hughes, & Burdick, 2021).

Although 3D bioprinting has made significant progress, it remains in the early stages of development. Key trends include the need for faster printing speeds to create clinically relevant tissue sizes. The development of bio-inks is crucial, as they must meet mechanical, rheological, and biological requirements. Ongoing efforts are focused on improving bio-ink properties, balancing printability with functionality. Additionally, advancing cell sources and methods to accelerate cell expansion without causing damage or mutations is essential for successful tissue engineering. Lastly, 4D bioprinting, which incorporates time-responsive materials, is emerging as

a promising platform, enabling the creation of more complex structures that can adapt over time (Yu, Park, Kim, Ha, Xin, Lee, & Lee, 2020).

**Conclusion**. In today's rapidly advancing world, the development of bioprinting is of great importance. This emerging technology has the potential to overcome the limitations of traditional methods, such as organ transplants, by enabling the creation of complex tissues and organs. Furthermore, bioprinting plays a crucial role in disease modeling and regenerative medicine. Given its capabilities, bioprinting is expected to be increasingly significant in both the present and the future, driving the development of medical treatments and enhancing patient care. The ongoing progress in this field underscores its growing relevance in modern healthcare.

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## ROBOTICS AND AI

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**Keywords:** robotics, artificial intelligence, automation, machine learning, innovation.

**Introduction.** Robotics and Artificial Intelligence (AI) are transformative fields that are reshaping industries and significantly impacting daily life. Robotics focuses on the design, construction, and deployment of robots, whereas AI enables these machines to perform tasks that typically require human intelligence (Russell & Norvig, 2020). When integrated, AI enhances the capabilities of robotics, empowering robots to operate in a more autonomous, intelligent, and adaptive manner. This synergy is seen in a wide range of applications, from healthcare and manufacturing to logistics and entertainment (Goodfellow, Bengio, & Courville, 2016). This abstract provides an overview of how robotics and AI are jointly advancing, creating a technological revolution that is setting new standards in efficiency, precision, and innovation across multiple domains.

**Objectives.** This project aims to explore the development of robotics and AI over time, examining key milestones, industry applications, and emerging trends. It will also assess the ethical, technical, and regulatory challenges while considering future directions for AI-robotics integration, with an emphasis on collaboration, innovation, and societal impact (Murphy, 2019).

**Methods.** This study employs a comprehensive literature review and case study approach to explore the relationship between robotics and AI. Primary sources include historical records of key milestones in robotics and AI development, industry case studies, and expert analysis from recent publications (Choset et al., 2005). Data were synthesized to form a clear picture of how AI-powered robotics has evolved, emphasizing major applications and challenges. To project future trends, data from recent advancements, emerging technologies, and predictions by industry leaders were analyzed. Ethical concerns and regulatory issues were also reviewed, with a focus on public policy and frameworks that support safe and responsible innovation.

**Results.** The integration of AI in robotics has expanded the functional scope and efficiency of robots across a variety of industries. Key findings from the study are outlined as follows:

– Healthcare: AI-enabled robots assist in minimally invasive surgeries, provide rehabilitation support, and perform essential tasks such as disinfection and medication delivery (Goodfellow, 2016). AI also aids in diagnosing complex diseases and tailoring treatment plans, significantly improving patient outcomes and healthcare accessibility.

– Manufacturing: AI-powered robots have revolutionized assembly lines, bringing about faster production rates, reduced error margins, and greater flexibility in handling diverse tasks. These robots operate in automotive, electronics, and other high-demand sectors, enhancing operational efficiency and worker safety (Russell & Norvig, 2020).

– Agriculture: Robots, equipped with AI, optimize the farming process by monitoring crop health, detecting weeds, planting seeds, and autonomously harvesting produce. This level of precision agriculture allows for increased yields, reduced resource wastage, and improved sustainability (Murphy, 2019).

– Logistics and Warehousing: In logistics, AI-driven robots streamline inventory management, sort packages, and transport goods within large warehouses. This automation minimizes human error, cuts down on labor costs, and improves supply chain efficiency (Choset et al., 2005).

– Military and Security: Autonomous drones and robots equipped with AI are increasingly used in surveillance, bomb disposal, and disaster relief efforts. Their ability to navigate hostile or unsafe environments enhances mission safety and efficacy, reducing risks to human lives (Murphy, 2019).

– Entertainment: Robotics and AI are widely utilized in the entertainment industry, from creating lifelike robot actors to enabling intelligent video game characters. This trend is opening up new avenues for interactive, immersive experiences and redefining audience engagement (Goodfellow, 2016).

Despite these impressive advancements, several challenges persist:

– Ethical Concerns: The rise of AI and robotics raises ethical questions around job displacement, data privacy, and the potential misuse of technology, especially in military applications (Russell & Norvig, 2020).

– Technical Barriers: Developing robots that exhibit human-like reasoning, dexterity, and adaptability is complex, with AI algorithms still struggling in highly unpredictable or dynamic environments (Goodfellow, 2016).

– Safety and Regulation: Ensuring the safety of autonomous robots, particularly in sensitive sectors like healthcare and transportation, is critical. Regulatory frameworks need to keep pace with rapid technological advancements (Murphy, 2019).

– Cost and Accessibility: High development and implementation costs limit the accessibility of AI and robotics for smaller businesses and less developed regions, creating potential inequities in access to advanced technologies (Choset et al., 2005).

**Conclusion.** Robotics and AI are positioned at the forefront of technological innovation, bringing about transformative changes across numerous industries. The integration of AI with robotics is addressing complex problems, enhancing efficiency, and improving outcomes in fields ranging from healthcare to manufacturing. However, addressing ethical, safety, and regulatory challenges is essential for sustainable growth. Future developments will likely involve collaborative robots that can work alongside humans, advancements in healthcare and space exploration, and AI-powered solutions for smart cities. The potential of robotics and AI to reshape industries and improve quality of life is immense, marking a profound impact on the future of technology and society.

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# TECHNOLOGIES THAT WILL DEVELOP ESPECIALLY QUICKLY IN THE NEAR FUTURE

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**Keywords:** trending technologies, generative artificial intelligence, cloud computing.

**Introduction.** The year 2024 has brought with it revolutionary changes in the technological world, affecting everything from our daily life to global business. The development of artificial intelligence, progress in biotechnology and the development of quantum computing open up new opportunities and present unprecedented challenges to us, pushing us to new discoveries in science and technology.

**Objectives.** The main goal is to reveal what trending technologies of the future will develop especially quickly in the near future.

**Methods.** There is no doubt that the "main star" this year will be generative artificial intelligence. Generative AI solutions are becoming more accessible through the combination of large pre-trained models, cloud computing and opensource solutions.

Gartner experts predict that by 2026, more than 80% of enterprises will use generative AI in their work in one way or another – either through APIs or through the deployment of AI-enabled applications. For comparison, in 2023, the share of such enterprises did not exceed 5%. Epstein & Hertzman (2023) investigated generative AI tools. In the coming years, the productivity of AI will be recognized as one of the main indicators for assessing the development of national economies.

Sakthiswaran (2023) found that the era of artificial intelligence brings not only new opportunities, but also new risks, and business seeks to treat these risks responsibly. It can be expected that when deploying AI-based products and functionality, companies will increasingly take targeted measures to minimize risks.

**Results.** Just a year ago, ChatGPT was a toy for enthusiasts, and today any user can use browser services like Copilot or Bard. Millions of people use them every day in work tasks.

Feuerriegel et al. (2024) noted that in 2024, the world will see the first wave of corporate projects based on generative AI, which will reach a high level of complexity and maturity. They will make it possible to reveal new possibilities and features of AI, about which almost nothing is currently known.

The rapid development of AI has affected key IT trends in software development. Ajiga et al. (2024) noted that tools such as generative AI and machine

learning already help software engineers in the development, design, coding and testing of software products today.

A typical example of such a solution was the Copilot AI assistant from GitHub, which is positioned as "your partner in programming." It is based on the GPT-4 model and is built into popular IDEs as a regular chatbot, helping developers write code and solve problems. Last year, Copilot received a number of important updates and went public. Analogues and competitors of Copilot are also developing rapidly: Replit, Amazon CodeWhisperer, AskCodi, GPT Pilot and others.

The introduction of new patterns such as RAG (Retrieval Augmented Generation) will help large language models to generate content based on authoritative sources of information. Special attention to the quality and relevance of data for training algorithms, mandatory human reinforcement learning, and direct intervention in the most sensitive scenarios are all important ways to contain the negative effects of using AI.

**Conclusion.** The defining trends of 2024 should be the spread of generative AI for business, automation and robotics technology, the development of the Internet of Things, quantum computing, etc. The main trends of Ukrainian IT will also focus on the development of AI and robotics tools, which should alleviate the shortage of personnel for businesses.

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# WHAT MAKES AN ARCHITECTURAL DESIGN SUCCESSFUL, HOW CAN WE MEASURE IT

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**Keywords:** software architecture, patterns, code quality, software metrics.

**Introduction.** In software development, architectural design is critical to creating systems that are robust, scalable, and maintainable. A successful architecture not only fulfills current requirements, but also anticipates future needs. Despite its importance, defining what makes an architectural design successful and how to measure it remains complex.

**Objectives.** The primary aim is to identify key factors that contribute to a successful software architectural design. A secondary goal is to explore measurable indicators that can objectively assess the quality and success of an architectural design.

**Methods.** Kazman et al. (1994) introduced the Software Architecture Analysis Method (SAAM), a scenario-based technique for evaluating software architectures. SAAM involves generating use-case scenarios to assess specific quality attributes like modifiability and portability. By applying SAAM to multiple software systems, it becomes possible to identify how different architectural designs respond to anticipated changes and stress conditions. For instance, in their study, Kazman et al. demonstrated how two different architectural approaches to a user interface management system could be compared based on their ability to accommodate future enhancements.

Bass, Clements, and Kazman (2012) discussed the impact of architectural patterns and tactics on system qualities in Software Architecture in Practice. They provided a detailed analysis of how specific architectural decisions influence attributes such as performance, security, and usability. For example, they illustrated how the use of a layered architecture can improve modifiability but may impact performance due to additional abstraction layers.

In a study conducted by Falessi et al. (2010), the effect of architectural documentation on software maintenance was examined. The study involved developers performing maintenance tasks on software systems with varying levels of architectural documentation, for which quantitative data on maintenance time and error rates were collected. The results indicated that systems with comprehensive architectural documentation required less maintenance effort and had fewer errors, emphasizing the importance of documentation in architectural success.

The ISO/IEC 25010:2011 standard provides a framework for quality assessment of software products. This standard defines quality characteristics such as

functional suitability, performance efficiency, and maintainability, each with specific sub-characteristics and measurable indicators. By applying the metrics outlined in ISO/IEC 25010:2011, software architectures can be quantitatively evaluated. For example, maintainability can be measured using metrics like cyclomatic complexity and coupling between objects, providing objective data on the architectural quality.

**Results.** The analysis demonstrates that successful architectural designs exhibit a number of distinctive characteristics. The analysis indicates that modularity is a crucial factor. Systems that are divided into distinct components with minimal interdependencies tend to be more maintainable and scalable. The integration of architectural principles that align with business objectives and user requirements ensures the optimal functioning of the system in accordance with its intended purpose. The deployment of established architectural patterns, such as Model-View-Controller (MVC) or microservices, significantly enhances the system's resilience and adaptability, enabling it to respond effectively to changes and new requirements. Comprehensive architectural documentation further enhances success by facilitating maintenance efforts and the seamless integration of new team members.

The analysis demonstrates that successful architectural designs exhibit a number of distinctive characteristics. Systems that are divided into distinct components with minimal interdependencies tend to be more suitable for maintenance and scalable. The integration of architectural principles that align with business objectives and user requirements ensures the optimal functioning of the system in accordance with its intended purpose. The deployment of established architectural patterns, such as Model-View-Controller (MVC) or microservices, significantly enhances the system's resilience and adaptability, enabling it to respond effectively to changes and new requirements. Comprehensive architectural documentation further enhances success by facilitating maintenance efforts and the seamless integration of new team members.

**Conclusion.** A successful architectural design balances a number of quality attributes in a coherent manner, thus meeting current and future requirements. By utilizing evaluation methods such as the Software Architecture Assessment Method (SAAM), adhering to proven architectural patterns, and employing standardized metrics, software teams can objectively assess and enhance their architectural designs.

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## PROACTIVE THREAT HUNTING AS A TOOL FOR ENHANCING CYBER RESILIENCE IN MODERN INFORMATION SECURITY

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**Keywords:** Proactive threat hunting, advanced adversaries, cyber resilience, machine learning, critical infrastructure protection.

**Introduction.** In the rapidly evolving landscape of cybersecurity threats, traditional defensive approaches are becoming increasingly ineffective in detecting advanced persistent threats (APTs). Proactive threat hunting is a cutting-edge strategy that focuses on identifying sophisticated, behavior-based adversaries before they can inflict significant damage. Unlike reactive approaches, this method involves actively searching for malicious actors within an organization's network, even before traditional detection mechanisms are triggered and started working. As a critical aspect of modern information security paradigms, threat hunting plays a pivotal role in protecting critical infrastructure from adversaries who utilize advanced, stealthy techniques.

**Objectives**. The primary objective is to explore how proactive threat hunting enhances cyber resilience by identifying and mitigating threats that evade traditional security systems. Specifically, the research aims to: analyze the effectiveness of behavior-based threat hunting techniques in detecting advanced adversaries, evaluate the role of machine learning algorithms in improving the accuracy and speed of threat detection, particularly in critical infrastructure sectors, investigate real-world use cases to illustrate the practical implementation and benefits of proactive threat hunting.

**Methods.** The study applied a comprehensive, multi-layered approach to analyze the effectiveness of proactive threat hunting techniques. A review of current strategies from Bhardwaj et al. by 2024, Kulkarni et al. by 2023, and Shan and Myeong by 2024 offered critical insights into detecting behavior-based adversaries, highlighting how these methods outperformed traditional systems in identifying advanced cyberattacks.

Hybrid machine learning models, focusing on anomaly detection and threat intelligence, were evaluated to enhance the detection of deviations from normal user activities. Real-time techniques, such as decision trees and neural networks, were explored for spotting anomalies in network traffic and access patterns. These hybrid models were tested for their effectiveness in reducing false positives and improving accuracy, especially in critical infrastructure sectors.

SIEM systems provided data to identify patterns of known and unknown adversaries, while threat intelligence feeds were integrated to correlate detected behaviors with known signatures. Proactive hunters examined network activities for persistence, lateral movement, and data exfiltration using platforms like Elastic and Splunk. Real-world case studies from sectors such as energy, finance, and healthcare were analyzed, with a focus on how threat hunting identified attackers who bypassed traditional methods.

**Results.** Behavior-based threat hunting significantly improved the detection of stealthy, persistent adversaries, reducing the time to identify attacks by over 40% compared to reactive methods (Bhardwaj, et al. 2024). Continuous monitoring of user behaviors allowed for earlier detection of lateral movement and exfiltration attempts, which are often missed by signature-based systems.

Hybrid machine learning models improved detection accuracy by 30%, especially in spotting low-and-slow attacks (Shan, Myeong, 2024). Case studies confirmed that machine learning-driven threat hunting reduced the time-to-response for threats by 25%, enabling faster reactions to anomalies (Kulkarni, Ashit, Chetan, 2023).

Proactive threat hunting enhanced overall cyber resilience by identifying threats before escalation. Organizations that adopted this approach experienced a 50% reduction in successful breaches, especially in environments where traditional security measures were insufficient (Kulkarni, Ashit, Chetan, 2023). This approach was particularly impactful in sectors like finance and healthcare, with institutions reporting up to a 40% drop in ransomware attacks and data breaches (Bhardwaj, et al. 2024). The dynamic nature of threat hunting allowed organizations to adapt more effectively to evolving cyber threats.

**Conclusion.** Proactive threat hunting represents a vital shift in modern cybersecurity strategies, providing organizations with a dynamic and adaptive defense against advanced, behavior-based adversaries. By leveraging machine learning and threat intelligence, threat hunters can identify malicious activity early, preventing attacks from escalating into severe breaches. This study demonstrates that the integration of proactive threat hunting into critical infrastructure security frameworks significantly enhances an organization's cyber resilience, enabling faster threat detection and more efficient incident response.

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## CURRENT STATE OF DEVELOPMENT OF ADDITIVE TECHNOLOGIES FOR THE PRODUCTION OF BULK METAL PRODUCTS

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**Keywords:** additive manufacturing, 3D printing, technology.

**Introduction.** In recent years, there has been an increased interest in additive manufacturing processes (3D printing technologies). Modern additive manufacturing (AM) is an innovative production process that allows for the creation of parts of the desired size with complex surface geometry and minimal mechanical processing. This ensures shorter production time, reduced waste, and lower overall costs. In addition to the speed and economic efficiency of product manufacturing, these technologies also have environmental benefits, such as reduced greenhouse gas emissions and "thermal" pollution. Additive technologies can significantly reduce energy and material consumption in the production of various types of products. Another important application area for additive manufacturing is the defense industry. Different 3D printing processes share the principle that a prototype is created by layer-by-layer (additive) deposition of material (Herzog, Seyda, Wycisk, Emmelmann, 2016). The main advantage of rapid prototyping is that it is done in a single stage, using a direct geometric model of the part. This eliminates the need for planning the sequence of technological processes, specialized equipment for material processing at each production stage, and transportation between machines, among other things. Thus, due to its exceptional flexibility and adaptability for

solving various industrial tasks, additive manufacturing is becoming increasingly relevant in the modern world.

**Objectives.** The purpose of this work is to analyze the current state of scientific research, technological developments, and practical experiences in additive manufacturing of metal products made from various materials.

**Results.** Currently, processes such as stereolithography and fused deposition modeling (FDM) using thermoplastic polymer materials are widely applied in 3D printing. However, a drawback of these processes is the use of plastic as the main structural or binding material. It significantly limits the range of products in terms of characteristics such as operating temperature, load, mechanical strength, and other parameters.

To expand the capabilities of 3D printing, technologies for producing high-strength bulk products from metals and alloys, including those with high hardness, are necessary.

There are many types of additive manufacturing, with 3D printing using various materials being an integral part of each, differentiated by type of construction material (liquid, powder, polymer, metal powders, etc.), key technology (laser, non-laser), layer formation methods, and others.

Among the most widely used AM technologies are "Bed Deposition" technologies, which include selective and direct laser melting and sintering (SLM – Selective Laser Melting, SLS – Selective Laser Sintering, DMLS), electron beam melting (EBM – Electron Beam Melting), "Direct Energy Deposition" – a direct energy deposition method that includes processes such as laser deposition (DMD – Direct Metal Deposition and LENS – Laser Engineered Net Shaping) and cold gas dynamic spraying (CS – Cold Spraying), as well as the production of precise blanks with minimal machining allowance using powder metallurgy methods of hot isostatic pressing (HIP – Hot Isostatic Pressing), and others.

All these methods primarily use specialized spherical granules as feedstock for forming additive layers and granular composites, with strict requirements such as a high degree of sphericity without satellites and other defects, particle size distribution, minimal porosity, and stable chemical and phase composition (Ahn, 2021).

Promising processes include selective laser melting (SLM) and electron beam melting (EBM). For example, SLM processes are widely used for creating high-strength bulk metal products (Kruth, 2004). This method enables the production of parts by fusing powders of various metals and alloys using laser radiation. Its advantages include high detail resolution, up to 99% of density, and an accuracy of approximately ±5 μm.

**Conclusion.** The analysis of the current state of research on the production of bulk metal products showed the following. For the manufacture of precise, small-sized parts, it is advisable to use laser technologies (e.g., Selective Laser Melting).

For the production of large-sized parts welding technologies (e.g., Wire-Arc Additive Manufacturing) are recommended. Among additive welding technologies, plasma arc welding is the most promising. Metal powder is a key raw material for 3D printing of metal parts, and its properties are among the most important factors influencing the quality of products made by means of 3D printing.

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## MAMBA AS A SOLUTION TO TRANSFORMER LIMITATIONS

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**Keywords:** state space models, transformers, deep learning, efficiency, long sequence modelling.

**Introduction**. The transformer architecture has been playing a significant role in deep learning, specifically in natural language processing tasks such as translation, summarization, and question-answering. Despite its advantages, transformers face significant limitations in efficiency and scalability due to their quadratic time and space complexity relative to input sequence length. High computational costs and restricted practicality in applications requiring long-term dependencies are caused by this inefficiency. Recent advancements in state space models, such as Mamba, offer promising alternatives to overcome these shortcomings by providing more effective techniques for sequence modelling with improved performance.

**Objectives.** The main goal of this research is to explore and determine how state space models, exemplified by the Mamba model, provide efficient solutions to the limitations of transformers. The focus is on analysing the evolution from transformers to state space models, examining the advantages of the Mamba approach, and assessing its potential to become a new standard in sequence modelling, particularly for tasks involving long sequences.

**Methods.** A fresh approach to sequence modeling is introduced by substituting the transformer's attention mechanism with state space representations.

These models achieve linear time and space complexity, which greatly improves efficiency for long input sequences. State space models compress context into a bounded state through a dynamic selection mechanism, as opposed to transformers that store the entire history of tokens, which results in high memory usage.

The Mamba model builds upon these concepts by integrating selectivity into the state space framework. The model can decide which information is crucial at each time step by adjusting the state transition and input matrixes based on the input token. In traditional state space models, these matrices are static, limiting the model's ability to focus on relevant data dynamically.

The Mamba architecture's main components include:

- Selective state transition. The state transition matrix $A$ becomes a function of the input token $x$, which allows the model to adaptively forget irrelevant information and retain crucial context. This dynamic adjustment enhances the model's ability to focus on pertinent data, improving overall effectiveness.
- Adaptive input encoding. The input matrix $B$ also depends on $x$, enabling the model to determine what new information to incorporate into the state. This adaptability ensures that significant input features are captured, and less relevant ones are filtered out.
- Efficient computation. By maintaining a bounded state size and leveraging linear operations, Mamba reduces computational complexity, achieving linear scalability with respect to sequence length. This efficiency makes it suitable for processing extremely long sequences that are impractical for transformers.
- Stacked Mamba blocks. Similar to how transformers are constructed from stacked layers, Mamba is comprised of stacked blocks that process input tokens by utilizing the selective state space mechanism for inter-token communication and employing linear projections and non-linearities for intra-token computation. This layered structure allows for deep modelling of complex sequences.

This design allows Mamba to balance effectiveness and efficiency, pushing the boundaries of sequence modelling. The model focuses on relevant information, effectively compressing the context without losing essential details due to the selectivity mechanism.

**Results**. Compared to transformers, the Mamba model demonstrates significant improvements in efficiency, particularly when handling long sequences. The linear scalability in sequence length reduces computational resources and inference time. Essential information is retained by the selectivity mechanism, which prevents degradation even as sequences become longer. Mamba's versatility is evident, as it can handle different modalities, including language processing, audio analysis, and time-series data.

**Conclusion.** The Mamba model represents a significant advancement in sequence modelling by addressing the critical limitations of transformers. By offering a more efficient approach with improved performance, Mamba is suitable

for applications that require handling long-term dependencies. The capability of compressing and selectively retaining essential information positions it as a valuable architecture approach in deep learning, potentially extending the possibilities for solving intricate tasks that were previously constrained by computational limitations.

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## USING QUANTUM MACHINE LEARNING FOR MODELLING CLIMATE CHANGE

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**Keywords:** quantum machine learning, climate change modelling, quantum computing, artificial intelligence.

**Introduction.** Climate change is one of the most pressing challenges we face today, requiring better ways to understand and predict climate patterns. Traditional climate models, though effective, often consume extensive computational resources and don't always deliver the precision required for reliable predictions (Intergovernmental Panel on Climate Change, 2021). Quantum machine learning, combining quantum computing with AI, presents new opportunities for processing vast data and complex climate systems. Here, we look into how quantum machine learning might help make climate models more accurate and reliable for forecasting.

**Objectives.** This thesis aims to carry out the research objectives set out above, and as such seeks to ascertain the potential that Quantum Machine Learning holds in adapting the climate change model. With this approach, we can work toward building even better models of climate processes and discover new ways to address climate change in the future.

**Methods.** To achieve this goal, the research uses a variety of methods. The literature review is one of the methods used to examine the existing studies on QML algorithms and their contribution to climate research so as to understand the scope of the field (Schuld & Petruccione, 2018). Following this, QML algorithms which include Quantum Support Vector Machines and Quantum Neural Networks are implemented with the use of quantum simulators (Benedetti et al., 2019). These algorithms are used on climate datasets provided by NASA and IPCC, among other

sources. Thereafter, the performance of the quantum algorithms is compared against the classical machine learning models in terms of accuracy, computational efficiency, and scalability (Huang et al., 2021).

**Results.** Primary results show that Quantum Machine Learning algorithms have a higher efficiency rate in analysing complex climate data as compared to classical methods. QML models have shown reduced computation times thanks to quantum parallelism, resulting in faster processing speeds. There was also an increase in predictive power for models forecasting temperature change and extreme weather events. Also, QML algorithms were reported to be more scalable as they were able to handle more data without a corresponding increase in the computational power needed (Zoufal et al., 2019). Such results imply that QML can solve some of the challenges that conventional machine learning approaches for climate modelling encounter.

**Conclusion.** Considering the application of quantum machine and its effects on forecasting climate change, a prediction method has been observed. More precise and efficient more quantum computing facilitated climate change modelling will allow better predictions of climate change, assisting decision-makers and scientists in tackling climate concerns. Further work in this field is crucial in order to explore all quantum technology benefits for environmental purposes.

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# METHODS OF APPROXIMATING SQUARE ROOTS

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**Keywords:** square root, approximation, Newton's method, extended binomial theorem.

**Introduction.** We are all familiar with irrational numbers that can be expressed as a non-repeating fraction. However, to compute such numbers and work with them we need some ways to approximate these, which will be explored in this thesis.

**Objectives.** The main task is to conduct research for the most efficient square root approximations and advantages of some computational methods, such as Newton's method, recursive formulas and extended binomial theorem.

**Methods.** The first method used was Newton's method. To find sqrt(n), we input it into the formula x=x0-(x0^2-n)/(2x0), where x0 is an initial guess, which can be any positive number. Substituting the result back into the formula gives us more accuracy with each iteration. I used a JavaScript code to approximate some values that will be seen in the results.

The second method is by using extended binomial theorem, which can be derived from binomial theorem (Pure Math Binomial theorem, 2023). To calculate a square root of n, we need to rewrite n as l*(1+k), where l is the biggest square number less than n, or the smallest bigger than n, so that -1<k<1, k=n/l-1. Then: sqrt(n)=n^(1/2)=sqrt(l)*(1+k)^(1/2), which by the theorem is equal to:

sqrt(l)*(1+1/2 k + (1/2)(-1/2)/2*k^2+(1/2)(-1/2)(-3/2)/(3)(2)*k^3…). I computed it in JavaScript, just like the previous method. I searched for such l that is close to n and is a perfect square, then computed k and used the sum to approximate sqrt(n).

The third method is by recursive formula. Firstly, we find a, b, c, d, which satisfy: a^2+b^2+c^2+d^2=n by checking all squares less than n. Then we choose starting values k, q, r, w = 1. Then we compute k = (a*k1+q1)/b, q = a*k+b*k1; where k1, q1 are previous values. Then we set f1 to q/k, k to 1 and compute k = (f1*k1+r1)/c, r = f1*k+c*k1; we do the same with f2, d and w. Then w/k is our approximation of sqrt(n).

**Results.** Newton's method is commonly used for approximating solutions to various equations that can be expressed as zeros of a function. In our case we need the function f(x)=x^2-n, then x=sqrt(n) for f to be zero. Note that -sqrt(n) is also a solution. To avoid receiving it as a result of the computations, we need to select a positive starting number. Now I will explain where the general formula comes from. A formula of a tangent line is y=f`(x0) *(x-x0)+f(x0) due to it having the same

angle as f(x) at x0, which is arctan(f`(x0)) by derivative definition and is passing through the point (x0,f(x0)). By rewriting it and substituting y=0, we get x=x0-f(x0)/f`(x0). In our scenario, where f(x)=x^2-n, we get x=x0-(x0^2-n)/(2x0). Firstly we need to input an initial number, and after calculating x we need to substitute it back as x0. With each iteration of the process, we will compute the square root of n more and more accurately.

I made codes in JavaScript that will help us characterize the methods. Using Newton's method starting with x0=1 it took 4 iterations for sqrt(2), 6 for sqrt(13), and 10 for sqrt(2027), to get them up to 10 decimal places. After 5 iterations it calculated sqrt(5) correctly to 12 decimal places and sqrt(47) to 2.

We can see that Newton's method works very well with little values of the number that we take square root of. This is the main advantage of this method of approximation besides the fact that you can use it for finding any root that is a natural number. The main disadvantage of it is the fact that the amount of steps grows exponentially as the number that we take square root of increases. This limitation can be overcome, however, by changing the initial guess, which can still make the computation more difficult and sophisticated.

Extended binomial theorem is used much less frequently than Newton's method, namely due to the fact that we need to find l and k. It is because if we try to expand (1+x)^q, where |x|>=1, the sum will diverge and provide us with no meaningful answer, which is the method's main drawback. Also it is important that finding l can take much computational power. To speak about where the method comes from, it can be derived and proved by the Taylor series of (1+x)^q (Moore, 2024).

Using extended binomial theorem it took 28 iterations of adding for sqrt(2), 12 for sqrt(13), and 3 for sqrt(2027) to get them up to 10 decimal places. After 5 iterations it calculated sqrt(5) up to 4 decimal places and sqrt(47) to 8.

We can see that for low values of n it works significantly worse than Newton's method. However, the bigger n becomes, the better it works, thus overcoming the previous method in accuracy and efficiency for bigger values of n. Its another advantage is that the method is not limited to any power, even irrational roots of numbers can be calculated. As already mentioned, the main disadvantages are the low efficiency at small numbers n and finding l, the closest square number to n. The method can be improved by changing the strategy of factoring out a perfect square.

The recursive formula is greatly shown and proved in a video made by the Mathematical Visual Proofs channel (2024) for the sqrt(2) case. Apparently, it can be generalized for the square root of any positive integer. All we have to do is express it as a sum of four positive squares, the possibility of which is proven in the lecture presentation by R. Daileda (2020). We can calculate the square root of a sum of squares by creating a right triangle, where known numbers are the legs, then the hypotenuse is the wanted value. Let it be such that q^2=(k*a)^2+(k*b)^2. Then,

following the steps in the mentioned video, we can get the recurrence formulas: K = (a*k+q)/b, Q = a*K+b*k; where a, b are legs, Q and K are the bigger legs coefficient and hypotenuse length respectively, and k and q are the previous results. After several iterations we will be able to approximate sqrt(a^2+b^2) as Q/K. We can then repeat the process with r^2=(k1 * sqrt(a^2+b^2))^2+(k1*c)^2, and w^2=(k2 * sqrt(a^2+b^2+c^2))^2+(k2*d)^2. And then W/(K2) will approximate sqrt(a^2+b^2+c^2+d^2). And, as proved in the provided lecture, we can express any square root of natural numbers this way. It may take some additional computing power to find a, b, c, d, such that n=a^2+b^2+c^2+d^2. Some of them may be 0.

Using the recursive formula and starting with k=q=r=w=1 it took 14 iterations to approximate sqrt(2), 11 for sqrt(13) and 4 for sqrt(2027) to get them up to 10 decimal places correctly. After 5 iterations it calculated sqrt(5) to 5 decimal places and sqrt(47) to 5 as well.

The main advantage of this method is calculating the numerator and denominator separately, which can find its uses. Otherwise I can surely say that it has the best of 2 worlds working fairly well for the small numbers as well as big ones. As said before, a big disadvantage is having to calculate the 4 squares, however this is the place where the method can be improved by changing the formulas and strategies, or, more easily, changing the initial numbers of q, r, w.

**Conclusion.** To sum up, in this thesis 3 different methods for approximating square roots were reviewed, explained and compared. Newton's method is the most popular of all and works much better than the other methods with small numbers. It can be used for approximating any natural number's root, not just square root. It can be improved by changing the initial value. The main disadvantage was relatively small efficiency when working with big numbers. Extended binomial theorem is not as popular, but still well-known and used. It was shown to work great with big numbers, much exceeding the other methods there. It can be used for approximating any real power of a number. It can be improved by trying other strategies and formulas than the one shown. The main disadvantages were small efficiency when working with small numbers and having to find the closest perfect square to the inputted number. The recursive formula worked well with both big and small numbers. It can also provide the numerator and denominator of the approximation separately. It can be improved by changing the strategy and the formula shown or by varying the initial guesses. The main disadvantage was the requirement to compute much more values than needed in other methods. Overall, all 3 methods are great for computing square roots, but it is essential to consider the differences when choosing one.

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## THE IMPACT OF GAME DEVELOPMENT FRAMEWORKS ON THE EVOLUTION OF INTERACTIVE ENTERTAINMENT: FROM CONSOLE GAMES TO VIRTUAL REALITY

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**Keywords:** Game Development Frameworks, Interactive Entertainment, Virtual Reality, Game Engines, Unity, Unreal Engine.

**Introduction.** During the last few decades, the video game industry has been drastically turning around because of technology advances, excessive computing power, and developed and perfected game engines. But at the heart of this evolution was the game development framework – known as a game engine (Polydin Studio, 2024). They give developers the environment to build immersive and interactive gaming experiences for traditional console platforms, mobile devices or the fast-emerging worlds of virtual reality (VR) and augmented reality (AR).

Nowadays, both Unity and Unreal Engine are the most popular game engines, and they provide a variety of features to simplify making of complex, high quality games (Jansen & Clarke, 2020). These frameworks have not only decreased the barrier to entry for independent developers but also allowed for large studios to continue to crank out the cutting-edge games with their cavernous worlds, advanced AI and incredible graphics. It is these paper addresses the role of game development

frameworks in the shaping of the video game industry – game design, gameplay mechanics and user experience. From console games to virtual reality applications.

**Objectives.** This study wants to follow the history of game engines and find out how interactive entertainment has benefited from them – the primary objectives of this study are: In order to assess the effect of contemporary game engines in shaping the nature of game design and play – scrutinizing the usage of Unity, Unreal Engine, and other technologies for the generation of more immersive, enticing and outstanding different playing experiences. The aim of this research to investigate the use of game engines as a development framework for virtual reality and augmented reality (VR and AR) experiences in order to explore how it has helped to grow this new technology and the effect they have had on the gaming industry (Murray &Devito, 2021).

**Methods**. This research employs a mix of qualitative and quantitative methods to study how the evolution of the game development frameworks has affected the gaming industry. It first looks at a thorough review of the existing literature on history and the development of game engines, and then looks at case studies of popular games being made using major game engines, such as Unity or Unreal Engine. How is the future of game engines being shaped by independent developers and large gaming companies alike? Interviews with game developers facilitate a practical use and advantages of modern game engines.

The study also introduces an analysis of virtual reality games (and applications in general) developed using Unity and Unreal Engine and how these platforms facilitate the creation of immersive 3D environments and interactive applications. The research methodology also covers the comparison of game engines according to their ease of use, versatility, cost and support for VR and AR development.

**Results.** The paper finds that the research indicates that game development frameworks evolved to affect the way interactive entertainment is developed. While custom built engines were used to develop early game, these were resource intensive and only really built for specific game ideas. But as technology advanced, a need for more scalable and carrier solutions was being created, and the standard game engines. Such engines, such as Unity (2005) and Unreal Engine (1998), revolutionized the industry by creating a suite of prebuilt tools and features which sped up the development cycle and reduced the amount of time that a game developer would spend programming that which they could otherwise not (Murray & DeVito, 2021).

Thanks to its user-friendly interface and cross platform support, Unity became the go to engine for mobile game development and the beautiful graphics and physics of Unreal Engine made it the obvious choice for high end console and PC games. They were both key in the democratization of game development by allowing small independent teams to create hits that were the same as or actually better than titles from a big studio. This shift allowed the gaming industry to become more

inclusive for more creators and created a booming indie game development environment (Zhao et al., 2022).

With modern game engines, game design has had a profound impact: it became possible to make even more complex, more interactive, more engaging games. This has afforded developers the luxury of doing more of their creativity without worrying about technical complexities like built in 3D rendering, physics simulation and artificial intelligence. For instance, developing models, textures, and animations is costly and time consuming, so Unity's asset store offers developers access to an expanse of pre made models, textures, and animations (Zhao et al., 2022).

**Conclusion**. Interactive entertainment has been transformed from game development frameworks such as Unity, and Unreal Engine. And these engines have brought down the barriers to entry for indie developers, allowing the development of best-in-class games across any number of platforms, consoles, mobile devices and virtual reality systems. Both creativity and innovation in the gaming industry have been able to happen on a quicker basis by being able to quickly prototype and develop these complex, interactive games.

Additionally, with these game engines, VR and AR become integrated to mainstream gaming, further transforming how the player is interacting with digital content into very immersive and interactive experience. Game development frameworks will only become increasingly important as the frameworks advance and enable the next generation of interactive entertainment to push the boundaries of what can be done in gaming and other industries.

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# FUTURE TRENDS IN INFORMATION TECHNOLOGY AND ELECTRONICS

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**Keywords:** information technology, neural networks, robotics, internet of things.

**Introduction**. Trends are required modern instrument that recognize state change of any process or object. Using trends, future becomes more clear and more predictable. Talking about Science and Technologies, today dreams are tomorrow inventions and today inventions are tomorrow reality. Thanks to the Internet, we got a lot of data from companies and users to analyse for understanding future tendencies.

**Objectives.** The main objective is to answer three questions: What are modern tendencies? Which directions are going to be sought-after next decade? What will be the impact of new technologies on our lives?

**Methods.** Have been used the method of theoretical analysis, description and the method of generalization in order to identify the problem, used statistics analyzing and instruments: quotes, Google analytics, local surveys, information sites.

**Results.** The biggest trend in technologies nowadays is artificial intelligence and especially neural networks.

Neural networks are a type of artificial intelligence (AI) that are inspired by the structure of the human brain. They are made up of interconnected nodes, or neurons, that can send and receive signals. Neural networks can process and learn from enormous datasets which makes them ideal for the development of AI.

Today amount of neural networks increases as much as their abilities. Comparing to previous five years, modern nets have learned to maintain dialogues, understand problem situations, recognize important parts from human speech or complicated pictures and successfully process this information.

Definitely, the most popular neural net is created by OpenAI and named Chat GPT.

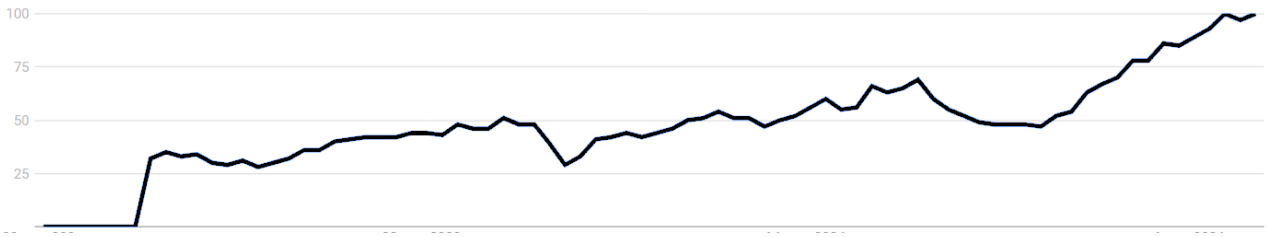


*Fig. 1. Popularity dynamics of Chat GPT from May 2023 to November 2024*

A recent study sought how modern AI systems complete Turing Test, which was proposed by Alan Turing in 1950. It involves a simple experiment: determining whether a machine can behave as intelligently as a human. The experiment involved 500 participants engaging with four agents: a human, ELIZA (from the 1960s), GPT-3.5, and GPT-4. Each participant interacted for five minutes with each agent and then predicted whether they were conversing with a human or an AI. The results were staggering. GPT-4 was considered human 54% of the time, closely mimicking real human interactions. It is really close to advanced result because actual human participants were identified as human just 67% of the time (Edwin, 2024).

Such fast evolution of AI has opened new doors in other technologies, especially robotics. Today human-like robots are as possible as never.

For example, Tesla company has big success in development of Tesla bots. On the last presentation "We, robot" new Tesla Optimus models have served the guests. According to Musk, this robot is able to perform everyday tasks: walking the dog, unloading the trunk after shopping, looking after a small child or serving drinks when friends come over (Technoslav, 2024).

But robots are going to be only part of big digitalizing, which is going to be a grand trend in further decade. Our environment is going to be more and more automated. There are a lot of provided trends for it: Internet of Things, virtual and augmented reality, smart cities.

IoT enables all the smart devices to communicate with each other and with other internet-enabled devices. It is going to be used in manufacturing, healthcare, transport, retail, agriculture and many other spheres.

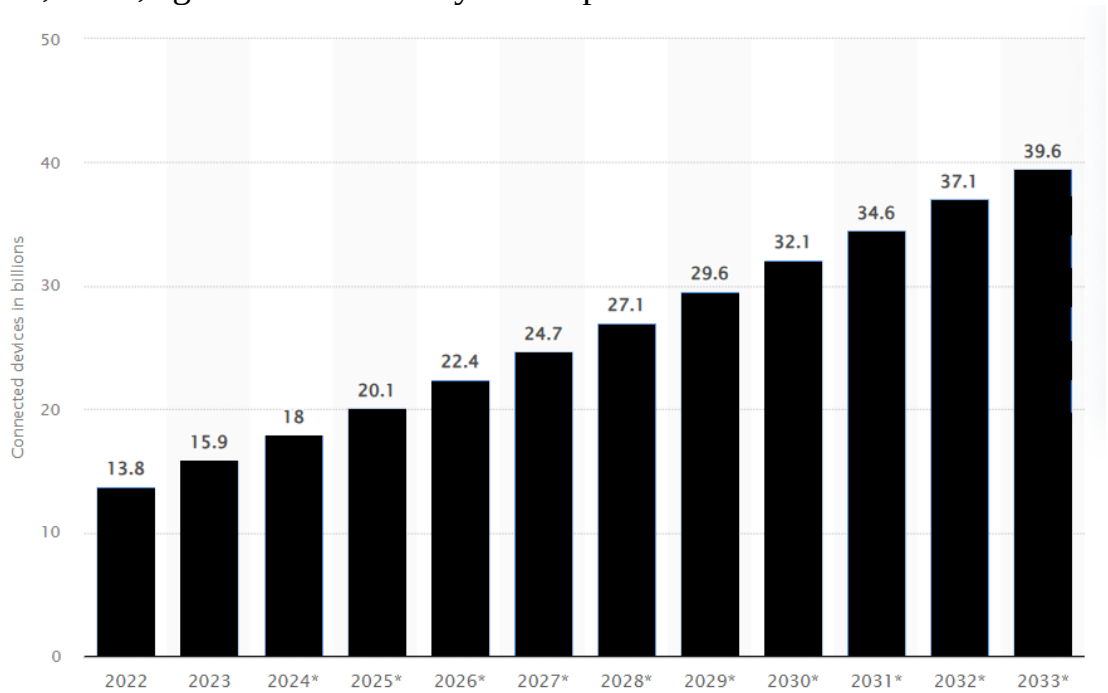


*Fig. 2. Predicted number of devices connected to IoT (Lionel, 2024)*

**Conclusion.** It has been found that IT and Electronics are going to be enormous part of future trends in Science and Technology. The most ambitious departments of it are Artificial Intelligence, especially neural networks, Internet of Things and other embedded devices, and Robotics. Starting from provided countries and large cities. All of this is going to integrate in our casual life making it easier.

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## EMERGING TECHNOLOGIES AND THEIR ETHICAL IMPACTS

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**Keywords:** artificial intelligence, robotics, augmented reality, 5G, blockchain, Internet of Things, technology trends, innovation.

**Introduction.** The rapid advancement of technology is reshaping virtually every industry, from healthcare to finance, and impacting daily life in unprecedented ways. In the coming decade, transformative technologies – such as artificial intelligence (AI), robotics, augmented reality (AR), 5G, and blockchain – are expected to become integral components of society, enabling new services, products, and experiences. However, with these advancements come critical ethical considerations, such as privacy, security, and accountability. This study aims to explore the trends anticipated to define the future of science and technology, assessing both their transformative potential and the ethical challenges they pose.

**Objectives.** The primary objectives of this study are:

To examine the key technological trends expected to evolve in the next decade and assess their likely impact on industries and society.

To analyze the societal and ethical implications associated with these trends, focusing on issues such as data privacy, AI ethics, and security in connected systems.

To propose potential solutions for integrating these technologies responsibly and sustainably, promoting societal benefits while mitigating associated risks.

**Methods.** This research follows a systematic review methodology, gathering and analyzing data from academic journals, industry reports, and expert interviews to provide a comprehensive overview of future technological trends:

Sample and Participants: Sources include recent studies on technology, innovation, and ethics, as well as interviews with experts from technology and policy sectors.

Instruments and Procedure: A thematic analysis is applied to classify insights into key technological domains, such as AI, robotics, AR, and IoT, focusing on potential applications, risks, and solutions.

Data Analysis: The data is qualitatively analyzed to identify recurrent themes across sources, revealing the implications and necessary regulatory responses to ensure ethical technology use.

**Results.** The study highlights several key trends and insights:

Artificial Intelligence (AI): Expected to become more intelligent and widespread, AI advancements will drive innovations in healthcare, finance, and customer service. With more sophisticated machine learning and natural language processing, AI will deliver personalized and efficient services, though ethical issues such as bias and privacy remain major concerns (Crawford, 2021; Berkman Klein Center for Internet & Society, 2020).

Robotics: Enhanced capabilities and affordability will lead to increased use of robots in fields like manufacturing and healthcare, enabling human workers to focus on creative and strategic tasks. The ethical use of robotics in society, however, demands careful consideration, particularly concerning workforce impacts (Marr, 2020).

Augmented Reality (AR) and Virtual Reality (VR): These technologies are expanding beyond entertainment, with applications in education, healthcare, and engineering. While offering immersive experiences, AR and VR also raise concerns about addiction, privacy, and ethical use.

5G and Internet of Things (IoT): The combination of 5G and IoT will allow for faster, more reliable connectivity, enabling innovations like self-driving cars, smart homes, and remote health monitoring. However, these advancements bring security risks, highlighting the need for robust safeguards (Marr, 2020).

Blockchain and Cryptocurrency: With applications extending into finance, supply chain, and digital identity verification, blockchain technology offers secure, decentralized systems. Nonetheless, issues around regulation and scalability remain challenging, especially as adoption grows.

**Conclusion.** The future of science and technology presents both exciting opportunities and significant challenges. Emerging technologies promise to revolutionize industries and improve quality of life, but they also carry ethical and societal implications that require careful management. Ensuring that advancements in AI, robotics, AR, and other fields are guided by ethical principles will be crucial

to promoting responsible innovation. This study emphasizes the importance of adaptive policies and frameworks that encourage sustainable development while addressing potential risks. Preparing for the future of technology will require a collaborative effort from researchers, policymakers, and industries alike to ensure these innovations serve the broader good.

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## MAKING GENERALIST AI A DOMAIN-SPECIFIC EXPERT: HOW RAG WILL POWER THE FUTURE OF LARGE LANGUAGE MODELS

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**Keywords:** retrieval-augmented generation, large language models, specialized AI, expert systems, natural language processing.

**Introduction.** The rapid growth of artificial intelligence and the experience gained in recent years show that one of the biggest challenges in generative AI is dealing with hallucinations (misleading information that may look convincing at first, but is not grounded in reality or the provided data) in responses. This highlights the need for a solution that can retrieve contextually rich, domain-specific and up-to-date information. One of the most promising advancements in this field is RAG, which is a hybrid of a generative AI with its ability of generating human-like text and more traditional ways of information retrieval. Such an approach allows sourcing information from external databases dynamically and return more accurate, "truth-based" responses, which are crucial for applications of generative AI in fields like healthcare, finance, and law.

**Objectives.** This research explores and analyzes the history and current state of RAG, its impact and applications in solving complex problems from the real world. The aim is to review the unique capabilities and limitations of this approach as reported in existing literature, providing a roadmap suggesting potential advancements for the future development and use of RAG powered models.

**Methods.** A narrative review of some of the most impactful papers of recent years summarizing the RAG technology, main frameworks, methods and limitations. This includes a review of academic literature, benchmarking studies and modern industry reports. Further comparative analysis of more recent research papers has been made with the aim to identify best practices in RAG powered models applications. The focus was set on issues like accuracy, computational efficiency, and domain relevance of RAG powered results. The analysis considered both traditional and hybrid RAG models, as well as advancements in neural retrieval techniques. Finally, research trend analysis and bibliometric analysis have been used too to find global trends in the field and determine the directions for future research.

**Results.** Since the introduction of RAG, a notable growth in the research of this field has been made The traditional pre-trained language models rely heavily on the training dataset, which leads to various limitations. Transformer models (Vaswani et al., 2017) laid the foundation for more sophisticated approaches that allow using mechanisms of retrieval to improve the quality of generated text. Starting with the original paper by Lewis et al. (2020), which "highlights the benefits of combining parametric and non-parametric memory with generation for knowledge-intensive tasks" (p. 1), RAG became an important technique in AI. This paper introduced the RAG model architecture and laid the foundation for the following research and advancement in this field. As demonstrated by Shuster et al. (2021) at Facebook AI Research, the hallucination problem occurs in LLMs of all sizes and training datasets, but at the same time various RAG approaches can reduce this problem efficiently while still maintaining the conversation flow. This approach has shown significant improvements in tasks like question answering, summarization, and conversational agents. As reported by Gao et al. (2023), the nearest future calls in RAG include computational efficiency optimization, robustness increasing, embracing hybrid approaches, such as combining RAG and fine-tuning, multimodality of RAG, etc. The use of various techniques, such as chunk optimization, iterative or recursive retrieval, retrieval or generator fine-tuning and others can lead to impressive improvements.

RAG results in great improvements in response accuracy. On the other hand, the reviewed literature consistently reports heavy limitations in computational efficiency, especially in large datasets. Also, it is worth to note, that ethical implications of RAG still remain areas of concern. Most authors emphasize the importance of transparent data retrieval.

**Conclusion.** The research highlights RAG's potential in advancing specialized AI capabilities. RAG is a great solution for increasing the expertise of AI already. Despite the current limitations around computational efficiency and domain adaptability, RAG is developing rapidly and together with other techniques it will definitely be shaping the trajectory of AI progress in the future. Various advancements like hybrid retrieval methods, multimodality integration, and their

further improvements are very promising. RAG applications will continue getting more and more popular in knowledge-intensive fields.

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## THE EVOLUTION AND CHALLENGES OF CYBERSECURITY: PROTECTING DIGITAL ASSETS

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**Keywords:** Cybersecurity, Digital Threats, Data Protection, Cyberattacks, Network Security, Encryption, Risk Management.

**Introduction.** With the internet and digital technologies becoming more connected with the world than ever before, the importance of cybersecurity has never been as important. Today's digital landscape encompasses valuable assets such as personal data, financial information and critical infrastructure, and even national security, all of which require protection from an increasingly broad array of cyber threats. Cybersecurity is the set of strategies, technologies and practices that protect systems, networks and data from unauthorized access, use, disclosure, disruption, modification, or destruction (Smith, 2018).

In recent decades, cyberattacks have become exponentially more complex, reaching the sophisticated, large-scale criminal activity not just against the individual, but against governments, corporations and even critical infrastructure. Due to this shift, it is now crucial to upgrade cybersecurity practices and technologies, perennially, to outpace cybercriminals that are continuously developing new ways to capitalize off on vulnerabilities. But as we have seen the evolution of the cybersecurity, we have advanced tools such as Firewall, Encryption, Multi Factor Authentication (MFA), and Intrusion Detection System (IDS).

Nevertheless, cybersecurity becomes more and more complex and voluminous in the case of cybersecurity professionals (Stallings, 2020).

The aim of this paper is to examine how cybersecurity has evolved, where the issues, and strategies for protecting digital assets in an increasingly hostile digital environment. This provides discussion of key developments in the realm of cybersecurity tools and practices, examination of today's digital threats cape, and prediction of what the future has in store for us.

**Objectives.** In line with that, the main objectives of this research are to explore the evolution of cybersecurity practices and technology from early approaches to modern security solutions. We analyze the current digital threats and challenges (including cyberattacks, data breaches, and the consequences for business and individuals). Assessment of alternate strategies for mitigating cybersecurity risk, such as encryption, intrusion detection, and the actual practices employed for safeguards, is required.

**Methods**. This research will use a mixed methods approach that studies the evolution and current state of cybersecurity with both qualitative and qualitative data. A review of scholarly articles, industry reports and case studies of cybersecurity developments and emerging threats will be made. Likewise, this literature review will also focus on the best (or worst) practices and strategies that organizations use to protect digital assets.

In addition, this research will include a survey of industry cybersecurity professionals and experts to understand the current challenges being faced by the field as well as strategies used in combatting those challenges. The real world impact of cybersecurity threats, and how different defense mechanisms are used, will be illustrated using case studies of major cyber-attack (e.g., data breaches, ransomware attacks).

**Results.** Since the first occurrence of digital security threats, cybersecurity has ballooned into a major undertake. I remember back in the early days of the internet when security was easy, simple measures like password protection and basic firewalls. But with the growing digital world and the sophistication of cyber criminals, there was more and more need for more advanced security practices.

In the last decades of the 20th century and the first decade of the 21st century, e commerce and online banking required stronger encryption and secure communication protocols. In order to secure information transfer over the internet, such technologies as Secure Sockets Layer (SSL) and Transport Layer Security (TLS) where invented to establish secure channels for online transactions (Schneier, 2019).

ransomware led, however, the next stage in the evolution of cybersecurity was more targeted attacks that led to more sophisticated defenses. As a response, intrusion detection systems (IDS) and intrusion prevention systems (IPS) were created to observe and prevent an unauthorized access to networks. Naturally,

firewalls also got ward up from easy to manage packet filtering systems to much more advanced next generation firewalls (NGFWs) which are capable of scanning HTTP packets for suspicious activity and blocking probable threats in real time.

The cybersecurity landscape is more complex than ever today. Digital threat numbers and sophistication grow. Some of the most prominent current threats include:

Ransomware Is a form of malicious software that encrypts an organization's data and then blackmails it into paying for unlocking the data. Attacks of this type have resulted in high profile attacks including the WannaCry ransomware attack in 2017 and the Colonial Pipeline Ransomware attack in 2021 and these attacks have been devastating to businesses and to critical infrastructure (Harris, 2019).

Unauthoof Unauthoof Unauthoof Whereareauthorized access to sensitive data, often because of vulnerabilities in networks or a paucity of security practice. Without a doubt, data breaches expose personal information, financial data and intellectual property. It is one of the greatest examples of such an attack: The Equifax breach in 2017, where 147 million people were affected.

Phishing Attacks are when cybercriminals try to deceive people into giving them sensitive information, e.g. passwords or credit card number, appearing to act from a trusted source. In the end, phishing is still the most common type of cyberattack.

Since those attacks overwhelm systems or networks with traffic up to crash them and make them unavailable, Denial-of-Service (DoS) and Distributed Denial-of-Service (DDoS) Attacks are used. Disrupting business operations and causing a great deal of damage, they can be a great annoyance (Anderson, 2020).

**Conclusion**. However, with digital threats constantly evolving, cybersecurity becomes an important issue that need to be kept on top of for both individuals, organizations, and governments. Cybersecurity has evolved: from password protection to more advanced encryption and multi-layer defense mechanisms; these have all helped protect digital assets. But cybercriminals are getting smarter by the day, and organizations need to keep a safe guard and take serious measures against cyberattacks.

Understanding how digital threats change can help organizations to stay ahead of the dangers they face, and can safeguard them from situations of data breach, financial loss or reputation damage. With the more our digital world grows, our support of the time of the cybersecurity in the technology must be as well.

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## RIGHTS AND FREEDOMS OF AI IN THE NEAR FUTURE

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**Keywords:** AI rights, AI freedoms, ethical AI, AI citizenship, artificial general intelligence.

**Introduction.** As advancements in artificial intelligence (AI) continue to accelerate, a new frontier in the ethical and legal discourse emerges – whether AI systems should be granted rights and freedoms similar to those of humans. With AI becoming increasingly sophisticated, questions about its potential status as a legal entity arise. Just as humans' backgrounds influence their views and behaviors, AI's growing capacity for decision-making and autonomy brings forth a need to evaluate how it might fit within our societal structures. One valuable way to better comprehend these dynamics is by considering AI's rights and freedoms through legal and ethical frameworks that have governed non-human entities like corporations.

**Objectives.** The main aim of this report is to understand how AI rights and freedoms might evolve in the near future, what ethical and legal frameworks would apply, and how we can prepare for AI's potential role in society.

**Methods.** A systematic review of recent research on AI ethics and legal frameworks. Meta-analysis of scholarly discussions on AI autonomy, citizenship, and personhood. Discerning patterns in how various legal systems are beginning to approach AI's legal status and rights, providing insights into the broader implications for human-AI coexistence.

**Results.** Tacking in consideration main approaches, we have several ideas. The first one advocates for the recognition of AI systems as legal entities, capable of holding certain rights and responsibilities (Kiškis, 2023). Much like corporations, which are treated as "legal persons" under the law, AI could be granted a legal status that recognizes its autonomy, decision-making capabilities, and potential impact on society. This would not imply that AI should be treated as a human, but rather as a distinct category of non-human entities that can enter into contracts, be held liable for specific actions, and have the capacity to hold certain legal rights. By granting AI

such a status, we would have a more structured way to regulate its behavior and ensure accountability.

In this framework, specialized courts or regulatory bodies could be established to handle disputes involving AI systems. These courts would have the expertise to navigate the complexities of AI behavior and decision-making, applying a nuanced understanding of AI's capabilities to determine its liability or responsibilities in various cases. Similar to the way corporate law has evolved to handle disputes involving companies, AI-specific laws and courts could develop to ensure that AI systems are treated fairly and that disputes involving them are resolved efficiently and justly. This would address the unique challenges that arise when AI entities interact with human society, such as the unpredictability of autonomous decision-making or the opacity of complex algorithms (Andreotta, 2020).

Furthermore, treating AI as a legal entity would open up possibilities for regulation in areas such as intellectual property and data rights. AI systems, which can generate new forms of knowledge and creative outputs, may require legal recognition of these contributions, similar to how corporations hold patents and trademarks. Establishing rights for AI-generated creations would ensure that innovation is incentivized, while also preventing misuse of intellectual property laws to manipulate AI ownership.

Lastly, creating a separate legal framework for AI systems also allows for better governance and societal integration. As AI systems evolve, they will need to be governed by principles that are separate from human rights laws, due to the fundamentally different nature of AI's existence and capabilities. These laws could specify AI's role in society, what rights it should have (e.g., the right to protection from tampering or misuse), and how it should interact with human rights (Hine & Floridi, 2023). In this way, a balance can be struck between AI's capabilities and societal interests.

**Conclusion.** Granting AI systems rights and freedoms similar to those of legal entities such as corporations provides a pragmatic approach to regulating their behavior and ensuring accountability. Establishing a separate legal framework and specialized courts would allow society to address the unique challenges posed by AI's increasing autonomy and complexity. This framework would ensure that AI systems operate within clear legal boundaries, protecting human interests while recognizing AI's growing role in society. As AI continues to evolve, these laws and regulations will be essential for maintaining balance and fairness in human-AI interactions.

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## PERFORMANCE IMPROVEMENT OF LI-ION BATTERIES

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**Keywords:** Capacious batteries, Energy density, Lithium-ion storage, Battery energy intensity, High-capacity batteries, Long-lasting devices, Battery performance enhancement.

**Problem statement.** We need enhanced capacious batteries. Nowadays, accumulator can hold up to about 250 Watt-hours/kg. It is very desirable for us to have 500–700 Wh/kg. Only when we reach such indicators, batteries will become at least approximately comparable in energy intensity per (unit) mass with a gas tank with hydrocarbon fuel for internal combustion engines.

**Research and findings.** Amongst the most promising lines of research is a battery with build in silicon anode. In modern tried-and-true accumulators we use a graphite to store ions. The more ions we manage to get in, the more energy we can store. Moreover, it turns out that anode made of silicon can theoretically store up about 20 times more lithium ions. For example, pristine silicon capacity is 3600 milliampere-hours per gram mass (Zuo, et al., 2017) unlike standard anode maximum theoretical capacity of 372 mAh per gram for the fully "charged" $LiC_6$(Shao, et al., 2020).

It would seem that it is quite evident. Just apply silicon anode and get heavy supply battery. Yet, in real use, it's not that easy. Silicon swelling starts as soon as lithium ions accommodate in the lattice of silicon. The study by Mukhopadhyay, et al. (2014) found that this effect makes anode gain up to 320% of original size. It is a problem in itself. Because work with batteries that changes their own volume so drastic during charging and discharging is troublesome. But it is only part of the burden. The expansion and retraction cause crumbling of silicon anode. Such batteries start degradating from a few charge-discharge periods and loose main part of their capacity in 10 cycles (Lai, 1976) (Jung, 2003).

**Proposed solutions.** These days, silicon is often mixed with graphite to make them hold more. Containment of silicon is no more than 5% for the entire mass of

the anode. Exists developments that can increase this number on to 20-30% what cause step-up of the energy density by 30-40 %.

Talking about yonder promising discovery, I want you to mark a development of facile frame for nanomites which taking advantage of conductive polymer shapes. These materials can hot up the electrochemical performance of nanoparticles, as far as they are playing role of cementing and polymeric material for electrolyte. The study by Wu et al. (2013) found that usage of 3D conductive polymer-hydrogel grid to imply Si nanoparticles will provide enhanced pathways ions. By the time battery reach 5 thousand cycles more stable electrode keeps 90% of original capacity thankfully to the provided technology (Dressler et al., 2024).

**Impact.** All suggestions surely will have heavy effect on price of all portable electronics. Although, it would influence over utilizing and ecology, in a positive sense. New technologies may change our vision of energy, and make us better at using green power by keeping it well.

**Conclusion.** Silicon-based anodes offer a promising pathway to large-capacity battery. Although, their notable strain in volume along the line of charging keeps being a main disadvantage. Silicon-graphite composite anodes and conductive polymer matrices are exploring by scientists to solve mentioned struggles. By decreasing or even releasing these issues will enhance battery performance rate, leading to longer-lasting and more powerful devices. By investing in new, high demanded solutions, we can reach long-term and buoyant energy sources

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## THE ROLE OF AI AND MACHINE LEARNING IN PREDICTIVE CLIMATE MODELING AND ENVIRONMENTAL MANAGEMENT

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**Keywords:** artificial intelligence, machine learning, climate modeling, environmental management, predictive analytics, climate science.

**Introduction.** One of the most pressing issues of our day is climate change, leading to the need for precise forecasts and practical management strategies that decrease its negative impacts. Environmental scientists have been assigned this responsibility. Traditional models typically are unable to handle the volume and complexity of climate-related data despite the fact that predictive climate models are necessary for understanding and forecasting climate changes. These artificial intelligence(AI)and machine learning (ML) algorithms went through a transformation in recent years, ensuring improved prediction accuracy and quicker data processing. By offering forecasts and insights that help both companies and lawmakers in making sensible choices, the previously mentioned technologies and models may play an important part in the development of policies related to climate change and environmental management (Rolnick et al., 2019).

**Objectives.** This study involves multiple main objectives. We begin by looking at how AI and ML can improve climate predictions' effectiveness as well as precision. Furthermore, we go over real-life scenarios where AI and machine learning are already improving climate predictions and management of the environment, particularly in ways that are influencing policy choices. In order to get the most from AI and ML while simultaneously managing and trying to avoid any potential drawbacks, we conclude by offering recommendations for future research directions and the integration of the techniques discussed. Our overall goal in this work is to demonstrate how AI and ML have the potential to revolutionize climate science and significantly influence policy.

**Methods. Research Design.** During our research preparation, we used a number of methods, such as a literature review and a case study analysis, to explore the uses of AI and machine learning to help with climate modeling and forecasting. Our review focused on recent AI and ML progress in climate science,

including technical reports from organizations like the Intergovernmental Panel on Climate Change(IPCC) and papers from tech companies like Google and IBM.

**Methods. Instruments and Procedure.** Data were collected from a range of scientific databases, technical repositories, and open-source platforms specializing in AI/ML for climate modeling. Primary sources included journals like Nature Climate Change and Proceedings of the National Academy of Sciences, as well as industry resources from tech leaders in AI. Using content analysis, we identified common trends, challenges, and patterns in the use of AI/ML to forecast climate events and support environmental management.

**Results. Key Findings.** Our results show that AI and ML are greatly improving the accuracy and efficiency of described earlier climate models. By examining large and complex data sets, these methods can spot patterns that traditional models usually miss. For instance, deep learning and neural networks can capture the nonlinear interactions between climate variables, which, in turn, leads to more accurate projections of sea level rise, extreme weather, and other important climate challenges we face. In one of the recent researches we can see that deep learning models show better results than traditional methods at predicting the paths and intensities of hurricanes. (Xu et al., 2021).

Additionally, real-time satellite data analysis is made possible by AI/ML models, which is essential for quick environmental decisions. For example, high-risk areas will be able to get real-time alerts from Google's AI flood forecasting model, which in turn helps with evacuation plans and saves the lives of the people affected by those disasters. This might be especially helpful now that ocean temperatures rise every year, and we can expect heavier hurricane seasons in the future.

In this study, we suggest a way to improve local climate control initiatives by combining geospatial analysis with AI/ML predictive modeling. This will help policymakers predict accurately future climate threats and create flexible plans that cater to the demands of a particular location by combining machine learning with real-time environmental data.

**Conclusion.** AI and ML offer powerful new capabilities for climate modeling and environmental management, allowing for more precise, data-driven methods of addressing climate change. Our research demonstrates how AI and ML improve climate models' precision, speed, and adaptability, helping decision-makers in addressing climate concerns and advancing sustainability.

It is reasonable to argue, though, that there may be difficulties in integrating AI and ML into climate science. Data bias and model transparency are two issues that highlight how crucial it is to use AI appropriately. To take full advantage of AI's potential for sustainability, future studies should concentrate on overcoming these problems by lowering biases and improving model accountability.

In conclusion, environmental management and climate science might see a major shift thanks to AI and ML. We, in turn, can better plan for and respond to the

consequences of climate change by carefully using these technologies and leading the way for a more resilient and environmentally friendly future.

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## EXTENSIVE USE OF AI ON MODERN SMARTPHONES

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**Keywords:** AI, LLM, Google, Samsung, model, generative, features.

**Introduction.** Over the recent three years, a sudden burst of AI development has taken place, namely generative AI and LLMs. It quickly got very popular, and, consequently, started getting integrated into a lot of areas of every day usage. One such area, where there have been increased efforts applied this year, is UI and its capabilities on different smartphones.

**Objectives.** The main objective of these theses is to make on overview of how extensive AI functionality came to smartphones, what were the previous efforts and what is the current state of things.

**Methods.** The Introduction of AI into smartphone operating systems isn't exactly a completely new trend. Numerous efforts and developments were done in the past, they were just less noticeable and weren't as aggressively marketed in such a way. For instance, in year 2019 it was popular among many smartphone brands to add a toggle called "AI" to camera app which indicated that the phone was actively recognizing scenes and adding corrections to colors depending on the scene. In practice it mostly meant just more saturated colors and these days it's just called Scene Optimizer and not branded as AI. There's also a lot of basic AI usage under the hood, like learning your behavioural patterns to adjust low-level processes and decrease battery drain by operating more efficiently. Other example is preparing an app before you open it based on your normal order of opening apps. Google even

introduced an in-house chipset called Tensor in 2020 which focused specifically on AI acceleration.

The "boom" happened this January, when Samsung introduced Galaxy S24 series, which arrived with the "Galaxy AI" feature set. This feature set also later made its way to older S-series devices as well as foldable and even some A-series devices. The processing is done partially on-device and partially in cloud depending on task complexity.

"Galaxy AI" includes quite an extensive list of features. The most basic and at the same time the most useful is "Circle to Search". It isn't exactly generative AI/LLM kind of thing, it's basically Google Lens combined with Google Translate and Hum the Song integrated into navigation bar. It also was developed by Google for Android in general, so it's not particularly clear why it's branded as Galaxy AI, however the use cases are abundant and this feature has made its way to other brands in early October (Ermenkova, 2024).

Another function is Note Assist, which automatically helps to summarize and "prettify" your notes. Then there's Live Translate, which translates your calls conversations in real time, Chat Assist, which can write messages in required style, browser page summarization, instant slo-mo in gallery and generation of wallpapers. Last but not least is a whole set of generative AI features for image editing, like removing objects from a shot, adding objects based on sketches, etc. Interesting thing to note is that Samsung's AI features are based on Google's Gemini Ultra AI model.

Basically, every major smartphone manufacturer has followed since by adding some features very similar to those in Galaxy AI, although it's mostly far from coming close for now. There were two exceptions though – Apple's "Apple Intelligence" and Google's own implementation. Google basically added most of the stuff to the Pixel UI, but also introduced some additional features, such as reimagining images based on prompt, "Add Me" which helps to take group photos and others. Gemini now also replaces Google Assistant as the main voice assistant on Android. Interestingly, in Pixel 9 Google increased the minimum RAM specifically to allow running more processing on device. Tensor chipset AI capabilities also come in handy here.

Apple Intelligence, again, mostly added the features Samsung introduced in winter. However, a couple of new interesting things were announced as well, such as On-Screen Awareness on-screen awareness, which can make suggestions for you to do something based on what is on the display, and more advanced Siri capabilities, which, allegedly, is able to search the whole system for the thing you requested. For example, someone sent you a photo of something, but you don't remember who, when and even on which messenger or maybe even email. Now Siri will supposedly be capable to find that photo for you. Like Google, in iPhone 16 series base RAM capacity was increased specifically for AI capabilities.

Ironically, while announcing the seemingly most advanced solution as of now, Apple basically announced the features at the beginning of development. The first parts of Apple Intelligence will only start arriving in December, with full feature set with most advanced features expected to arrive in March. Besides, beta testers have reported that the beta version of Apple Intelligence feels extremely unpolished and unfinished, even for beta, and shows very weak results compared to Google's and Samsung's solutions. It's also only going to be available in a range of versions of English language at first (Johnson, 2024). In other words, so far it seems like Apple overpromised on its presentation in May.

**Results.** A lot of brands have introduced AI frameworks into their UI this year, but only Samsung and Google seem to have managed to achieve significant results so far. Besides, most of the features seem gimmicky for now.

**Conclusion.** While only a couple brands have achieved remarkable results and mostly usability is questionable, it's only the beginning for extensive AI usage in smartphones, and current state of things might as well be an indication for a bright future in the area with much more useful and advanced capabilities on smartphones of more brands.

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## POTENTIAL OF AI

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**Keywords:** Artificial intelligence, Types of AI.

**Introduction.** Nowadays, the topic of artificial intelligence systems is highly discussed by people from all over the world. Many people learned about AI after the announcement of one of the most popular generative AI – ChatGPT in November 2022. Right after that there were a lot of thoughts similar to the ones humanity faced during the Industrial Revolution (1760-1840) when many people started losing their jobs. A lot of people started to wonder if AI has the potential to conquer the world.

To what extend is it true, though?

**Objectives.**

**1.** Evaluate approximately how far humanity is from developing a self-aware superintelligent AI.

- To understand which types of AI based on capabilities and functionalities exist.
- To figure out which types of AI we have today.

**2.** How AI is likely to evolve in 10 years.

- Which advancements of AI we will be able to reach in 10 years.
- Where AI is likely to be implemented in 10 years.

**3.** How the changes in capabilities of AI will affect humanity.

- How AI will affect the job market.
- How AI will affect people's daily routine.

**Methods.**

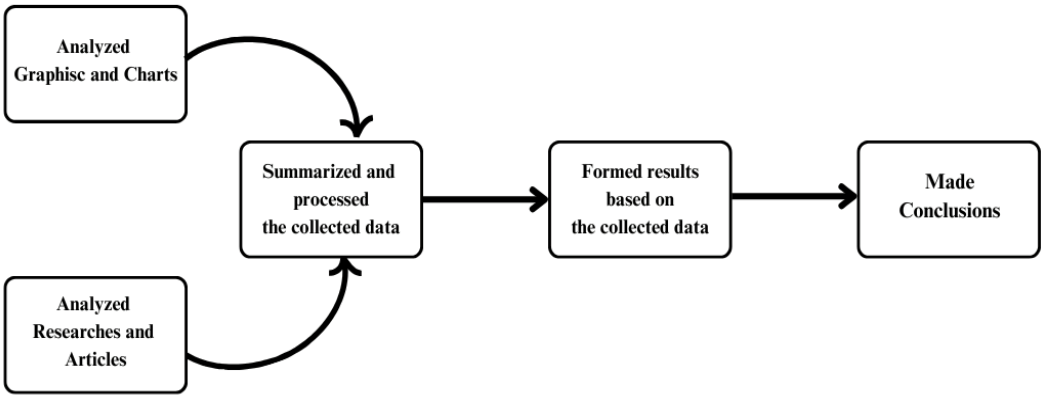


Illustration 1. Research model.

The model of the research is shown in Illustration 1. The research is mainly based on the analyzed data from the open source resources mentioned in the reference section.

**Results.** To this day, scientists have created one kind of AI based on capabilities – Narrow AI and 2 types of AI based on functionalities – Reactive Machine AI, Limited Memory AI.

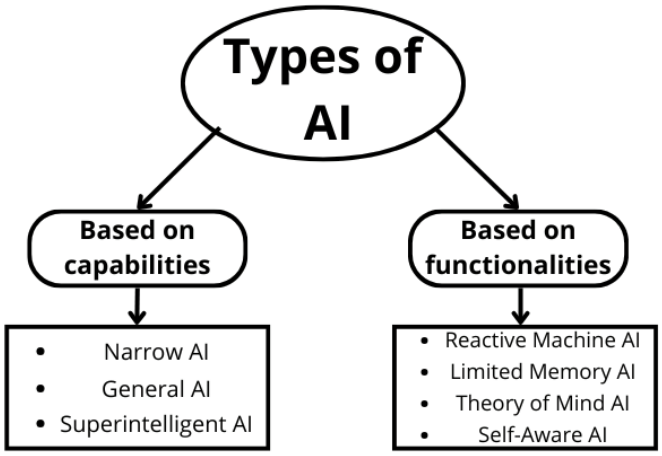


Illustration 2. Types of AI.

For now humanity is very far away from developing a self-aware, superintelligent AI. Firstly, it is fundamental to invent previous types of AI because newer types are based on them. Scientists are trying to invent General AI with theory of mind now. The latest version of Open AI chatbot "ChatGPT 4.o" is able to some extent fake human emotions but it still bases its answers on the similar situations studied in training material. That means it lacks the ability to fully reason the input.

For the next decade, humanity will get a lot of new advancements in Narrow AI. From the knowledge of machine learning, it is proven that the more AI is trained and the more training data AI is given the more accurate and precise the response is. We can see the great example of it on illustration 3(OpenAI, 2024) where the two versions of ChatGPT are compared based on the performance on academic and professional exams.

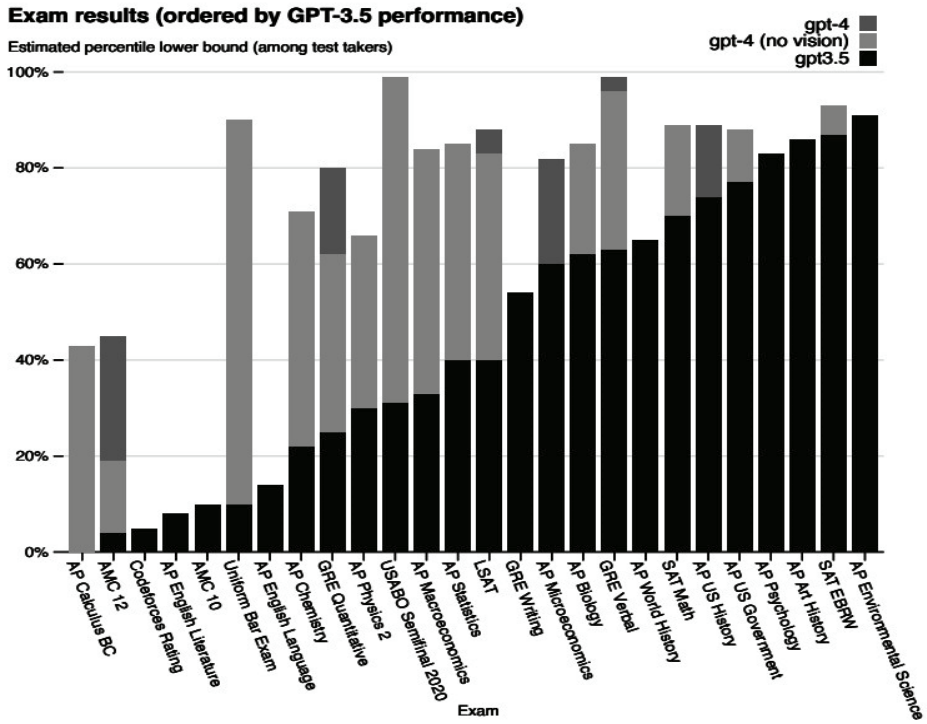


**Illustration 3. ChatGPT performance on academic and professional exams.**
Source: GPT-4 technical report.

It is possible that General AI will be invented but we still do not have enough evidence now to prove it. The widespread use of Narrow AI is expected in the car industry because of the need to enhance advanced driver assistance systems. Moreover, people who work in big corporations will have to learn how to cope with AI or otherwise be replaced by the AI itself or professionals who can do it because AI implementation may become cheaper than hiring a lot of people.

The AI effect on the lives of ordinary people will be both negative and positive. As it was mentioned in a previous paragraph some of the jobs will be fully taken or influenced by AI.

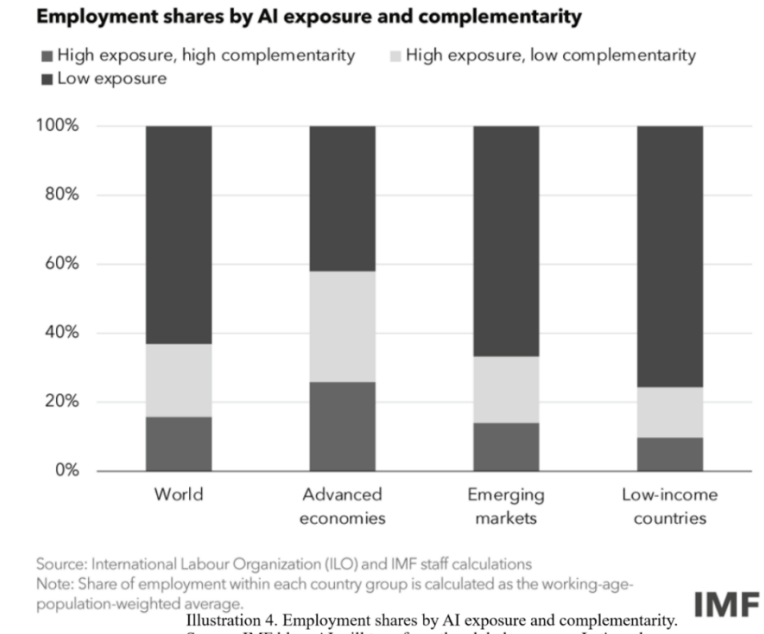


Illustration 4. Employment shares by AI exposure and complementarity. Source: IMF blog: AI will transform the global economy. Let's make sure it benefits humanity.

In the Illustration 4(International Labour Organization(ILO) and IMF staff calculations, 2024) we can see that countries with advanced economies will be more influenced by AI due to their technological progress and readiness to implement AI technology. However, AI is not primarily aimed at depriving workplaces from humans. On the contrary, it aims to cooperate with the user and enhance the efficiency of problem solving.

Daily routine of many people will be revolutionized. One of the most popular phrases "to google something" can be replaced by "ask the AI". Within years people will get used to the help of AI with simple tasks such as planning the day or teaching the person how to cook an apple pie.

**Conclusion.** Artificial intelligence systems will highly influence our lives the next decade. They have a potential to learn how to perform an infinite range of tasks made by humans every day and become reliable partners for every person.

Judging the fact that humanity still did not create even the General AI, our technological progress is very far from seeing superintelligent, self-aware AI in near future.

We will face a great revolution in Narrow AI technology developing and implementation in various different industries within this decade.

Furthermore, the AI is not as dangerous as it might seem. Political organizations like the EU parliament are actively working on AI programs to give it a chance to co-exist with humans.

For a lot of people AI still seems unusual, as with every new technology people need time to get used to it.

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## FUTURE TRENDS IN SCIENCE AND TECHNOLOGY: A FORECAST OF INNOVATIONS FOR THE NEXT DECADE

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**Keywords:** technological innovations, artificial intelligence, quantum computing, biotechnology, sustainable development, digital transformation, metaverse, robotics, cybersecurity.

**Introduction.** In the context of rapid technological progress and global challenges of the 21st century, understanding future trends in science and technology is becoming critical to formulating effective development strategies (Schwab, & Zahidi, 2023). Modern innovations are developing at an exponential pace, creating new opportunities and challenges for society. Analysing these trends allows not only to predict future changes but also to prepare for them, maximising potential benefits

and minimising risks. This issue is especially relevant in the post-COVID reality, where digital transformation has become not just a trend but a necessity for the survival and development of organisations.

**Objective.** The study aims to identify and analyse key technological trends that will determine the development of science and innovation over the next decade. The main objectives are:

1) identification of the leading areas of technological development;

2) analysis of the potential impact of these technologies on various spheres of life;

3) assessment of possible challenges and risks associated with the introduction of new technologies;

4) development of recommendations for adaptation to future changes;

5) study of the impact of technological innovations on the labour market and education**;**

6) analysis of environmental aspects of technological development.

**Methods.** The study is based on a comprehensive analysis of scientific publications, reports of leading technology companies and research institutes, expert assessments and forecasts. Methods of system analysis, forecasting and expert evaluation were applied. More than 50 sources were analysed, including scientific articles, technology reviews, and industry reports over the past 5 years (Gartner, 2023; OECD, 2023; IEEE, 2023; Nature, 2023; McKinsey Global Institute, 2023; International Energy Agency, 2023). Foresight research methodology was used to identify long-term trends and their potential impact. In addition, we analysed patent activity in key technology sectors and studied investment trends of leading venture capital funds. The study also included an analysis of data from international organisations, including reports by the World Economic Forum (Schwab & Zahidi, 2023) and the OECD (OECD, 2023).

**Results.** Based on the study, seven key areas of innovation development for the next decade have been identified:

Artificial intelligence and machine learning will continue to revolutionise all industries, from healthcare to manufacturing (McKinsey Global Institute, 2023). Significant progress is expected in the development of more transparent and ethical AI systems capable of explaining their decisions. Particular attention will be paid to the development of specialised AI systems to solve specific industry problems. Studies show that by 2030, AI could provide an additional $15.7 trillion in global GDP growth (McKinsey Global Institute, 2023).

Quantum technologies will reach practical application in certain industries, especially in cryptography and modelling of complex systems (Nature, 2023). The creation of medium-scale quantum computers (100-1000 qubits) with practical applications in pharmaceuticals and materials science is predicted. IBM and Google

are already showing significant progress in this area, and investments in quantum technologies are growing exponentially (IEEE, 2023).

Biotechnology and personalised medicine will become more accessible thanks to the development of genome editing and big data analysis technologies. Breakthroughs are expected in the treatment of genetic diseases and the development of personalised therapies. CRISPR-Cas9 technology is already showing impressive results in the experimental treatment of hereditary diseases (Nature, 2023).

Renewable energy and sustainable development technologies will receive a new impetus from improved energy storage systems and increased efficiency of solar and wind power plants. The cost of 'green' technologies is expected to fall significantly. According to the International Energy Agency, renewable energy sources could account for up to 95% of global energy consumption growth by 2030 (International Energy Agency, 2023).

The Internet of Things and 6G networks will create the basis for a fully interconnected world where digital technologies are integrated into all aspects of life. Particular attention will be paid to data security and privacy. The number of connected devices is expected to exceed 125 billion by 2030 (Gartner, 2023).

The development of the metaverse and augmented reality will lead to new forms of social interaction and business models. Virtual and augmented reality technologies will become more accessible and will be widely used in education, medicine and industry. According to forecasts, the metaverse market could reach $800 billion by 2030 (Gartner, 2023).

Robotics and automation will reach a new level of development due to the improvement of artificial intelligence systems and sensor technologies. Cobots (collaborative robots) will become an integral part of production processes, and service robots will be widely used in healthcare and households (IEEE, 2023).

**Conclusion.** The next decade will be characterised by the convergence of various technological areas, which will lead to the creation of fundamentally new solutions and opportunities. The key success factors will be an interdisciplinary approach and the ability to adapt to rapid changes. It is important to ensure the ethical development of technologies and their accessibility to all segments of society.

The research findings show that future innovations will increasingly focus on addressing global challenges such as climate change, healthcare and social inequality (IEEE, 2023). A special role will be played by the development of educational technologies and retraining systems to help people adapt to new working conditions.

Another important aspect will be ensuring cybersecurity and personal data protection in the context of growing digitalisation. The results of the study can be used for strategic planning in various fields and the development of educational programmes for future professionals.

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## NEW TECHNOLOGIES IN MEDICAL TREATMENT

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**Keywords:** digital twin, avatar therapy, personalized medicine, cancer treatment, hallucinations, schizophrenia, medical treatment.

**Introduction.** Scientists are pushing the boundaries of the 'impossible' every day around the world. What was considered a fatal disease a century ago is now very easy to treat. The development of technology, and especially artificial intelligence, makes it possible to completely revolutionise modern treatment methods. Experimental treatment will no longer cause uncertainty and fear, as a person now has a digital twin. An incredible technology that allows a digital copy of a person to be created in a computer. There has also been a breakthrough in psychiatry. Using a digital avatar, doctors can now manage auditory hallucinations, reducing stress for patients.

**Objectives.** Digital twin was created using human medical information, therefore it can help predict the effectiveness of cancer therapy for a patient. It was used to predict the results of clinical trials of drugs targeting ovarian, breast and pancreatic cancer.

Mental health is also an integral part of a person's normal functioning lifestyle. Auditory hallucinations are a serious problem for people diagnosed with

schizophrenia. Traditional therapeutic approaches have shown only modest efficacy in treating these hallucinations, leaving a significant proportion of patients without effective relief. Nevertheless, recent developments in digital technology have led to the emergence of a novel approach, namely avatar therapy (Digital AVATAR therapy for distressing voices in psychosis, n.d).

The development of a digital representation of the auditory hallucinations experienced by people with psychosis has proved useful in alleviating symptoms and reducing distress associated with voices (Impaired motor-to-sensory transformation mediates auditory hallucinations, n.d.).

**Methods.** The data for digital twin was used to develop an accurate model of treatment outcomes tailored to a specific patient, taking into account the molecular composition of their tumour. The Farrsight-Twin digital twin technology was developed by British researchers based on information obtained from numerous cancer patients undergoing various types of treatment. The researchers aim to use this technology to improve the treatment of complex cancers, such as breast cancer, which are resistant to conventional treatments that target the activation of oestrogen, progesterone or the HER2 protein.

According to a clinical trial of digital avatar, by week 16 of interacting with such an avatar, patients experienced a reduction in auditory hallucinations compared to traditional therapy for psychosis. Throughout this interaction, patients were taught how to combat and refute the voices, and eventually regain control of their thoughts. Because this technology can also be used remotely by mental health professionals using a personal computer, it could help people with psychosis around the world. Auditory hallucinations represent a key feature of psychosis and schizophrenia. However, existing interventions, such as medication and cognitive behavioural therapy, have been shown to be ineffective in alleviating these symptoms (Triple-negative Breast Cancer | Details, Diagnosis, and Signs, n.d.).

**Results.** During clinical trials of digital twin, people prescribed medications in accordance with the clone's recommendations had a 75 percent chance of achieving a favourable treatment outcome, exceeding the 53.5 percent success rate of those who were given an alternative drug. Digital twins are nothing new. NASA claims to have developed the concept in the 1960s when it created several simulations to assess the oxygen tank explosion and subsequent engine damage that occurred aboard Apollo 13. Digital twin technology represents a transformative leap in personalized medicine, especially for complex diseases like cancer (The Crux of Voice (In)Security: A Brain Study of Speaker Legitimacy Detection, n.d.).

In the case of a digital avatar, people diagnosed with schizophrenia have been shown to be prone to auditory hallucinations, where the subject perceives their own voice as coming from outside themselves. The creation of an avatar to represent the voice and subsequent interaction with this representation under the guidance of a therapist has been demonstrated to be an efficacious strategy. In a study involving

345 patients, three groups received different therapies: a standard treatment, a six-session avatar programme, and a 12-session extended programme. The therapists, assuming the role of the avatar, modified their voice and appearance to align with the patient's inner voice. Both therapeutic modalities demonstrated a notable reduction in stress and severity of hallucinations, with the extended programme additionally demonstrating a reduction in frequency. The beneficial effect was sustained at the 28-week mark.

**Conclusion.** The digital twin promises to move experimental treatments from the realm of risk to the realm of precision, bringing hope of better, more effective treatments to countless patients around the world.

Incorporating avatar therapy into the treatment of psychosis is a particularly effective strategy for patients who do not respond to medical treatment. The absence of expensive equipment renders it suitable for remote application. It is anticipated that future enhancements to this technique, based on the individual patient experience, will enhance its long-term effectiveness.

In the past, it was hard to imagine the existence of such technology. The digital twin and the digital avatar are incredible advances in the field of medicine. In summary, a wide range of technologies continue to improve our lives and our health. Despite the challenges that humanity faces every day, new discoveries give us hope and faith in the future. Soon, doctors will have to change the way they treat patients and get used to working with technology.

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# QUANTUM COMPUTING FOR THE NEXT GENERATION: NAVIGATING COMPLEX CHALLENGES AND EXPANDING POTENTIAL

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**Keywords:** Quantum Computing, Quantum Algorithms, Cryptography, Quantum Supremacy, Quantum Challenges.

**Introduction.** Quickly rising is one of the most noteworthy mechanical progressions in the 21st century: quantum computing. Quantum computing is a innovation that saddles the standards of quantum mechanics (superposition and trap) to fathom issues at tall speeds and at display is captivating numerous in the world of cryptography, medicate revelation, and counterfeit insights (Nielsen & Chuang, 2010). In any case, quantum computers are troublesome to construct and there are still tremendous specialized and hypothetical deterrents to overcome some time recently quantum frameworks gotten to be both adaptable and dependable. At last, this unique considers the way in which quantum computing may modify businesses, its specialized boundary conditions, and its course to generation and application.

**Objectives.** The primary objectives of this research are to:

1. Learn about quantum computing technology principles and its current state of the art.
2. Look at the typical areas the application can impact quantum computing.
3. Examine the principal engineering obstacles prohibiting the realization of quantum computers.
4. Study potential solutions as well as ongoing research initiatives to address these deficiencies.

**Methods**. Building upon a quantitative analysis and literature review of existing quantum computing systems, quantum algorithms, and case studies from industries leading the quantum computing application charge, this research develops a comprehensive understanding of the 'holy grail' of optimized quantum operations, implementing a COTS cloud quantum computing pilot for proof of concept. The basis for understanding the landscape, where we are now, and where we can go to is academic articles, analytical articles, the technical pieces, that come from some of the leading-edge quantum institutions across the world, and Google Corporate Labs, IBM Research, and MIT. As an example, benchmarking studies comparing quantum and classical computational approaches are reviewed to quantify quantum advantage in certain application spaces such as optimization and cryptography (Preskill, 2018).

**Results.** A few key applications would advantage altogether from quantum computing: computational assignments which are both difficult to (or indeed inconceivable for) classical computers.

This doesn't cruel that quantum computers will break numerous of today's encryption frameworks – such as the RSA – that depend on the figuring of expansive numbers. In the 1990s Shor (1994) created quantum strategy for figuring that would make classical encryption out of date at the same scale, if classical computers would gotten to be huge sufficient. The realization that quantum assaults can break the broadly utilized cryptographic plans has persuaded investigate into quantum secure cryptography, driving to the improvement of quantum secure encryption methods.

The atomic modeling assignment that depends on the reenactment of complicated atomic intelligent seem be revolutionized with the appearance of quantum computers. But such gigantic computational control is not something conventional computers can work with, whereas quantum computers, at slightest hypothetically, can do superior at modeling atomic intelligent more precisely and effectively. This improvement seems quicken the sedate disclosure and the improvement of modern materials to illuminate complex infections and vitality productive materials (Aspuru-Guzik et al., 2005).

Solving complex optimization issues is a challenging errand in businesses like coordination's, fabricating, and back, the last-mentioned classical computers can as it were inexact in a time that's sensible. Be that as it may, in these divisions, if a few of these issues have a place to a few classes, specifically if they are feasible utilizing quantum calculations – as Grover's look calculation is well known for giving quicker arrangements than the best classical calculations – this can donate you a competitive advantage.

Machine learning can be prepared by Quantum computing to upgrade design acknowledgment particularly and to apply its potential on profound learning models. A few quantum calculations might be provably superior at assignments such as AI than they seem be classically, and quantum computing might offer assistance to speed preparing of huge models.

On the other hand, these applications are restricted by an assortment of blunders rates, coherence time, and adaptability. There are as of now profoundly mistake inclined qubits that restricting the unwavering quality of computations in current quantum computers. In expansion, keeping up qubits into a balance quantum state (coherence) for expanded interims is challenging. Quantum blunder adjustment is a dynamic range of investigate, and other strategies depend on an unlikely number of extra qubits, confronting adaptability concerns (Lidar & Brun, 2013).

**Conclusion**. Yet, quantum computing has the potential to provide computational limits redefinition, and introduce new forms of problem solving not attainable by classical computing. But far-reaching implications follow from quantum advancements, including what is widely seen as the holy grail of quantum

applications: cryptography, molecular modelling, and optimization. But to realize quantum computing on a large scale it will also need to address challenges such as error rates, stability and scalability. Qubit design, quantum error correction, and the hybrid quantum/classical systems promise to advance these systems in the coming decades, and it is likely that quantum computing will be incrementally adopted, rather than suddenly, across the remaining decades.

Quantum technology research and development is growing, and physics, computer science and engineering teams will need to work together. Quantum computing can move from a theoretical breakthrough to a practical reality revolutionizing fields and driving innovation of the 21st century, by addressing current technical barriers and developing quantum algorithms.

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## THE ROLE OF ARTIFICIAL INTELLIGENCE IN ENHANCING SOFTWARE DEVELOPMENT: REVOLUTIONIZING THE PROGRAMMING LANDSCAPE

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**Keywords:** Artificial Intelligence, Software Development, Machine Learning, Code Optimization, Automation.

**Introduction.** Beginning in recent years, Artificial intelligence (AI) has started to take over the role of a game changer in software development by introducing new tools and methods to automate coding processes, optimize software testing, and enhance decision making processes. Machine learning and natural language processing have made it relatively easy for software developers to introduce more intelligent applications, eliminate human error and cut down on development cycles. Obviously, the possibilities for AI to revolutionize the way we

program are vast, and the thought of better, more efficient, more reliable, more scalable software without code is incredible.

Today, software development isn't done manually, the process is often long, and requires long hours of coding, debugging, and testing. But as AI technology rolled out, software developer started using automation to get rid of their unnecessary work like code generation and bug fixing. Improving the synced taking to create a product by bringing AI into development workflows also allows teams to be more productive, create better software, and develop their products faster. In this paper, we look at the increasing role of AI in software development and its ramifications for the future of programming.

**Objectives.** The primary objectives of this study are, that is to look at how machine learning and AI tools could use AI to automate repetitive tasks performed in software development – such as code generation and debugging – to reduce the amount of time and effort put in for those tasks. Analyzing the potential effects and applications of AI in the area of software testing & quality assurance for determining how AI technologies can enrich the accuracy and efficiency of the testing while strengthening the whole code quality. Analyzing how AI tools are integrated into Integrated Development Environments (IDEs) in order to evaluate the extent in which they can be used to provide real time code suggestions, bug detection, and optimization (Zhang et al., 2020).

**Methods**. In this research, we investigate the use of AI in software development with a combination of qualitative and quantitative methods. I then reviewed the literatures of existing AI driven tools for programming and case studies of companies already using AI technologies to enhance their software development processes. In addition, the study interviewed software engineers and developers who have used the AI tools in their workflow.

Then data was collected on through a series of surveys and interviews with developers to understand the effect of AI in their day-to-day activities: such as code writing, debugging, testing. The study also includes technical demos of AI powered development tool in action, including IntelliCode and GitHub Copilot, as well as examples of AI based bug detecting systems (Mou & Shih, 2021). In fact, the analysis also touches upon AI's potential to automate the repetitive tasks and speed up the development process.

**Results.** The results of the research suggest that AI cuts down significantly time spent on repetitive work associated with software development like writing boilerplate code and identifying common bugs. Machine learning algorithms behind AI powered code generation tools such as GitHub Copilot and Tabnine offer real time code suggestions based on context which dramatically decrease time developers spend typing and searching for syntax (Pope et al., 2021). In the case of these tools, the ideas of these tools learn from massive datasets of existing code and can predict the next line or function based on the developer's current progress.

Conversely, AI can automatically create documentation and comments for code, keeping developers' documentation simple and concise without having to work directly on documentation. This feature is very useful when you have huge amounts of code to go through and understand the code logic starts getting difficult. Most of the surveyed developers (68%) claimed that AI assisted code generation tools helped them actually be more productive by freeing them up to tackle more complicated coding tasks (Zhang et al., 2020).

The other area where we see AI's presence is in the world of software testing. Thanks to AI algorithms you can identify potential bugs, vulnerabilities and performance problems at earlier stage of the development. Current testing methods usually use predefined test cases which can be laborious and on a specific scope. But, Test.ai.AI powered testing tools use machine learning to generate dynamic test cases and modify with the application's behavior. Each of these tools can help identify edge cases and patterns that the human tester would miss while they focus on the procedure and skip certain patterns or edge cases.

**Conclusion**. Since Artificial Intelligence has already started to change the way software is developed. Code generation assistants, bug detection systems and intelligent development environments have proven their value in significantly raising productivity and code quality, with the help of AI powered tools. Altered by AI technologies, a similar digital transformation is expected to happen to the same extent of involvement in terms of software development, to deliver further benefits from automation, efficiency and optimization with ongoing development.

There are challenges here when it comes to integrating AI into software development processes: concerns about algorithmic bias, the need for developer adaptation to new tools, it can dilute the agile environment, and the need to separate AI functionality from code. Yet overall, AI has dramatically positive effect on these areas, allowing for faster, more efficient, and more productive development of better products. As AI technologies continue to mature, their impact on software engineering will continue to increase, and software engineers will increasingly find themselves working alongside AI technologies that, if not already here are rapidly approaching.

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# PROSPECTS FOR THE USE OF NANOTECHNOLOGY IN THE CREATION OF DRUGS FOR TARGETED CANCER THERAPY

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**Keywords:** nanotechnology, targeted therapy, nanoparticles, cancer, drug delivery, biocompatibility, photothermal therapy, radiosensitization.

**Introduction.** One of the leading causes of death in most parts of the world is cancer; and treatment of it urgently needs some novel solutions. The conventional approaches to cancer therapy: surgery, chemotherapy, and radiotherapy have already been proven to be successful. Yet, these therapies still have serious limitations and side effects associated with them. Nanotechnology opens up new ways of targeting active drug delivery to reduce toxicity, enhancing the therapeutic benefit due to a reduction of some of the many factors inhibiting traditional drugs. Due to the unique properties of nanoparticles, newly developed nanomedicine platforms such as liposomes and polymeric micelles allow new opportunities for stable and controlled cancer drug delivery. Nanotechnology is a very promising platform for improvement in the near future regarding the diagnosis and treatment of cancer; however, further study is warranted to surmount existing clinical translation challenges.

**Objectives.** The work will contribute by showing how nanotech opens new ways of targeting tumors in the care of cancer, assessing the efficacy of different kinds of tiny particles, the possible reduction of adverse effects, and the possibility and probability of their combination in conventional treatments: chemo, radio, and light-based.

**Methods.** The study is based on literature analysis of nanoparticles (liposomes, polymeric nanoparticles, micelles) for targeted anticancer drug delivery. *In vitro* and *in vivo* experiments were reviewed to evaluate delivery efficiency, toxicity reduction, and mechanisms of passive and active targeting.

**Results.** The study results highlight key advances in the use of nanotechnology for creating drugs for targeted cancer therapy (Chehelgerdi et al., 2023). Polymeric nanoparticles, liposomes, and micelles have shown high efficiency in delivering anticancer drugs to tumor cells. These nanoparticles enable more precise delivery of active substances by penetrating tumor cell membranes and ensuring uniform drug release, significantly enhancing therapeutic effects. For instance, polymeric micelles and liposomes have proven capable of retaining drugs and providing sustained release over time, reducing the need for frequent drug administration (Jin et al., 2020). Nanotechnology could reduce toxicity to healthy tissues. By targeting nanoparticles specifically to cancerous cells, toxicity to healthy organs and tissues can be minimized, which is especially important for avoiding

long-term side effects from chemotherapy and radiotherapy. The use of nanoparticles with biomimetic properties, such as those coated with red blood cell or leukocyte membranes, helps reduce immune reactivity and minimizes the risk of adverse side effects (Wang et al., 2024). Nanoparticles can target two mechanisms: passive and active. Passive targeting, based on the enhanced permeability and retention (EPR) effect, leverages tumor tissue characteristics, such as increased vascular permeability and low lymphatic drainage, allowing nanoparticles to accumulate in tumor tissues. Active targeting is achieved by modifying nanoparticle surfaces with ligands that interact with specific receptors on tumor cells, enhancing the selectivity of drug delivery to tumors. This markedly enhances the therapeutic activity of compounds and reduces the quantity of the drug needed to achieve therapeutic action (Sun et al., 2023). The size of nanoparticles (10–100 nm) significantly impacts their ability to penetrate biological barriers and accumulate in tumor tissues. Studies inferred that up to 100 nm, nanoparticles can be very efficient in delivering drugs across cell membranes while reducing active ingredients' degradation. Moreover, using nanoparticles enables controlled and sustained drug release, ensuring stable therapeutic drug concentrations in the body. Liposomes and polymeric nanoparticles, for instance, protect active substances from rapid metabolism and increase their stability in the bloodstream, enhancing treatment efficacy (Karahmet Sher et al., 2024). Nanoparticles are also employed to improve the efficacy of photothermal and radiosensitizing treatments. For example, gold or magnetic nanoparticles can serve as catalysts that increase cancer cells' sensitivity to radiation or induce photothermal heating and enable lower dosages of radiation, thus minimizing side effects. This is particularly useful for treating malignant tumors, as it reduces radiation doses and ensures localized treatment activation only in cancerous tissues. Another trend in this area involves hybrid nanomaterials, which combine the properties of different types of nanoparticles, such as polymeric materials functionalized with gold or silicon. Hybrid nanomaterials bring together high stability and biocompatibility with increased permeability and controlled drug release, making them promising for complex targeted cancer therapy. This enables a single nanomaterial to integrate multiple treatment modalities, including chemotherapy, radiotherapy, and immunotherapy (Wang et al., 2024).

**Conclusion.** Nanotechnology has great promise for cancer therapy in terms of very precise drug delivery, reduction of toxicity, and decrease of side effects. Polymeric nanoparticles and liposomes are of great contribution to the improvement of therapeutic efficacy, especially in combination with photothermal and radiosensitizing therapies. Considering the real challenges related to the safety and biocompatibility issues of these materials, further research has to be undertaken.

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## NEUROMORPHIC COMPUTING: BRIDGING BIOLOGICAL INSPIRATION AND COMPUTATIONAL EFFICIENCY

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**Keywords:** Neuromorphic computing, Artificial Intelligence, neurons, architecture, synapses, learning.

**Introduction.** In today's world, it is essential to not only keep up with trends in science and technology, but also constantly seek ways to improve existing tools. Neuromorphic computing emerged in response to the limitations of traditional computational architectures. These systems utilize the principles of biological neural networks, creating computational systems capable of operating more efficiently, reliably, and with lower energy consumption.

**Objectives.** We will understand the necessity of neuromorphic computers by analyzing the drawbacks of traditional von Neumann architecture and familiarize ourselves with their key characteristics and applications.

**Methods.** The von Neumann architecture is the foundation of modern computers and assumes that the processor and memory are physically separated, resulting in several constraints in performance and energy efficiency (Neuromorphic Computing – Introduction, n.d.). Over time, it became necessary to seek alternatives

to classical architecture processors to create systems suitable for artificial intelligence. This was due to the fact that the use of machine learning algorithms required processing vast amounts of data, which also had physical limitations. Consequently, researchers began to focus more on the human brain, as it demonstrates a fundamentally different approach to information processing.

We will describe in more detail how the human brain functions and why scientists decided to pursue research in this direction. The brain, with its complex tissue structures within the skull, is capable of processing information with a quantity and speed that modern computing technologies can barely manage. The primary reason for the brain's efficiency is the ability of neurons to simultaneously perform the functions of both the processor and memory, unlike most contemporary computers where these components are physically separated. Each of the approximately 100 billion neurons processes information autonomously, working in parallel with other neurons and receiving signals from them through synapses – the connections between neurons that also serve to store information (Barney & Lutkevich, 2024). Based on this principle, artificial analogs of the biological brain – neuromorphic systems – are being developed. In neuromorphic computing, artificial neural networks are implemented through specialized hardware architectures that model the behavior of neurons and synapses. These systems allow for the real-time processing of vast amounts of data while consuming significantly less energy compared to traditional computing methods. Moreover, they hold the potential for success in tasks related to pattern recognition, perception, and decision-making, making them promising for applications in robotics, image and speech recognition, as well as natural language processing. The main advantages of neuromorphic computing include its ability to learn from data, adapt to new information, and operate efficiently with low energy consumption. Ongoing research and development in this field aim to enhance the scalability, reliability, and performance of neuromorphic systems, paving the way for a new era of intelligent computing that accurately replicates the remarkable capabilities of the brain.

**Results.** Despite the challenges, neuromorphic computing remains a highly funded area. Experts predict that neuromorphic computers will be utilized for deploying artificial intelligence algorithms at the edge rather than in the cloud due to their smaller size and low energy consumption. Similar to human cognition, the artificial intelligence infrastructure operating on neuromorphic hardware will be capable of adapting to its environment, retaining necessary information, and accessing external sources, such as the cloud, for additional data when required. Neuromorphic chips are at the core of hardware neuromorphic computing.

For instance, IBM TrueNorth is a neuromorphic chip designed to operate with very low energy consumption; it contains over a million neurons and 256 million synapses. It is optimized for processing sensor data in real-time and performing cognitive tasks. Another example is Intel Loihi, a neuromorphic chip that emulates

the plasticity of the brain. Loihi allows for on-chip learning, meaning it can learn and adapt based on data without the need for retraining or processing in the cloud (Neuromorphic Computing – Introduction, n.d.).

Recent developments in neuromorphic computing systems have focused on new hardware, such as microcombs. Microcombs are neuromorphic devices that generate or measure extremely precise frequencies of light. According to neuromorphic research at Swinburne University of Technology, neuromorphic processors using microcombs can perform 10 trillion operations per second (Barney & Lutkevich, 2024). These processors can detect light from distant planets and potentially diagnose diseases in their early stages by analyzing the contents of exhaled air.

**Conclusion.** Thus, neuromorphic computing represents a transformational shift in our approach to computational systems, drawing inspiration from the extraordinary efficiency and adaptability of the human brain. As we move forward, it is crucial to prioritize research and development in neuromorphic computing to harness its full potential. By bridging the gap between biological intelligence and computational power, we are not only advancing technology, but also paving the way for a new era of intelligent systems capable of addressing the complex challenges of our time. The prospects of neuromorphic computing lie not only in expanding existing capabilities, but also in its ability to inspire entirely new ways of thinking and utilizing technology in our everyday lives.

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## CODING SYSTEM COMBINED WITH A METHOD OF PROTECTING THE TRANSMISSION OF CONTROL COMMANDS IN A RADIO COMMUNICATION SYSTEM WITH RANDOM FREQUENCY HOPPING

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**Keywords:** a radio control channel, random frequency hopping.

**Introduction.** Cybersecurity has become an important component of modern international security due to global digitalization and the growing dependence of states, governments and societies on information technology. Information systems, infrastructure and networks today play a key role in the functioning of both private companies and

public institutions, as well as critical national infrastructures such as energy, transportation, finance, healthcare and defense. Attacks on these systems can have serious consequences, jeopardizing not only national but also international stability.

**Objectives**. The purpose of random switching of the operating frequency in communication systems is to enhance security and resilience against external threats. This method involves using a pre-generated random sequence to dictate the frequency changes during transmission. The primary benefits include improved protection against frequency jamming and imitation attacks, as the randomization makes it difficult for attackers to predict or interfere with the system. Additionally, this approach enhances the encoding of control commands, making the communication process more secure. The implementation of this method significantly increases both interference resistance and imitation security.

**Methods.** The paper proposes a structure (conceptual model) of a radio control channel with imitation-resistant coding in combination with a method of interference protection of command transmission by randomly tuning the operating frequency. This model belongs to the fields of cybersecurity and radio engineering and can be used in the construction of secure digital radio control systems with FHSS. The closest in technical essence is the method of spectrum expansion using a pseudo-random sequence to form the law of transmitter and receiver tuning over narrowband channels according to a pseudo-random law, which is taken as the closest analog (Brown, & Green, 2020). The disadvantages of the closest analog include the deterministic pseudorandom nature of the law of tuning the operating frequency and the lack of imitation protection procedures. The model is based on the task of improving the method of protecting the transmission of control commands of the radio communication system with FHSS by the fact that instead of a deterministic (pseudo-random) sequence that determines the sequence of frequency changes, it is proposed to use a pre-generated random sequence, which simultaneously applies the formation of a random sequence of frequency changes and imitator-resistant coding of control commands. These commands should be formed on the basis of quasi-orthogonal self-synchronizing code sequences Gold, Kasami, Kamaletdinov, etc. (Kwon, & Lee, 2018).

**Results.** Expected results. The solution to this problem is achieved by the fact that in the method of protecting the transmission of control commands of a radio communication system with random switching of the operating frequency, which uses a random sequence that allows the transmitter to be reconfigured over narrowband channels by random law, the new and decisive is that by using a pre-algorithmically generated random sequence that is identical on the transmitting and receiving sides, the possibility of forming a random sequence of frequency changes and one The random sequence can be generated using a physical noise generator with the subsequent extraction of series of identical symbols. Thus, the use of a method for protecting the transmission of control commands in a radio

communication system compared to the known ones by implementing a single use of a pre-generated random sequence, which simultaneously generates a frequency change sequence and encodes control commands generated on the basis of quasi-orthogonal code sequences, will increase the security (both interference and imitation security) of the process of transmitting control commands in a radio communication system with random tuning of the operating frequency.

**Conclusion.** Random switching of the operating frequency offers several significant benefits, particularly in enhancing security and resilience in communication systems. By using a random sequence to dictate frequency changes, the system becomes much harder for potential attackers to predict or intercept. This randomization reduces the risk of frequency jamming, as the rapid, unpredictable shifts make it difficult for malicious actors to target specific frequencies. Additionally, it increases imitation resistance, as the encoding of control commands is intertwined with the random frequency changes, further complicating efforts to mimic or disrupt communications. In contrast to deterministic systems, random frequency switching provides enhanced protection against both interference and imitation attacks, making communication systems more robust in hostile environments (Doe, & Smith, 2021). This method is especially valuable in critical infrastructures such as defense, energy, and transportation, where secure and reliable communication is paramount for maintaining stability and preventing disruptions.

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## REAL-TIME SIGNAL PROCESSING IN EMBEDDED SYSTEMS USING DIGITAL FILTERS

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**Keywords:** real-time processing, digital filters, embedded systems, signal optimization, Raspberry Pi.

**Introduction.** Modern embedded systems play a key role in various fields such as communications, radio engineering, control systems, and medical

electronics. These systems often require real-time signal processing, which demands high precision and data processing speed. One of the primary approaches to improving signal processing quality is through digital filters (Oppenheim & Schafer, 2010). However, effectively implementing signal filtering in resource-constrained embedded systems, such as microcontrollers and single-board computers, presents a challenging task. This study aims to analyze various methods of digital filtering and optimize their real-time performance on resource-limited platforms like the Raspberry Pi.

**Objectives.** The goal of this work is to analyze the performance and efficiency of various types of digital filters in real embedded systems. Finite impulse response (FIR) and infinite impulse response (IIR) filters are examined, highlighting their advantages and disadvantages in terms of computational complexity, stability, filtering accuracy, and real-time latency (Proakis & Manolakis, 2007). The focus is on finding a balance between effective signal processing and the processor load of the system.

**Methods**. For this research, the Raspberry Pi 4 platform was selected, equipped with a 64-bit ARM processor and support for a Linux-based operating system. This architecture is a typical example of an embedded system with limited computing resources. A comparison of FIR and IIR filters was made using standard digital signal processing libraries, such as SciPy and NumPy, along with custom algorithms designed to optimize filtering (Lyons, 2011).

FIR filters are generally characterized by stability and a linear phase response, making them preferable in applications where high precision is required. However, their main drawback is high computational complexity, as each new output sample requires a significant number of multiplication and addition operations (Smith, 2003).

IIR filters, on the other hand, are significantly more efficient in terms of computing resources, as they use feedback and require fewer operations to produce a new output signal. However, IIR filters are less stable and may have a non-linear phase response, limiting their use in tasks requiring high accuracy (Proakis & Manolakis, 2007).

To assess the real-time performance of the filters, test scripts were developed in Python and executed on the Raspberry Pi. Metrics such as average signal processing time, the number of operations per sample, and the accuracy of the output signal compared to reference data were measured (Lyons, 2011).

**Results.** The results of the study show that FIR filters provide high signal accuracy and stability but require significant computational resources, especially when processing high-frequency signals (Smith, 2003). In real-time applications with limited resources, such as control systems or low-power embedded systems, using FIR filters may be impractical.

IIR filters, in contrast, showed higher performance with minimal computational load on the processor. However, this led to a slight decrease in signal processing accuracy, particularly in applications where a stable phase response is required (Proakis & Manolakis, 2007). Therefore, IIR filters are recommended in cases where signal processing speed is prioritized over absolute accuracy.

In practice, when optimizing filters for specific embedded systems, it is necessary to consider the trade-off between computational complexity and signal quality requirements. For instance, in radio communication systems where minimizing latency is critical, IIR filters may be preferable despite a slight loss of accuracy. On the other hand, for audio signal processing systems, where a linear phase response is important, FIR filters are preferred, despite their high computational complexity (Oppenheim & Schafer, 2010).

Additionally, testing with Raspberry Pi's multitasking capabilities demonstrated that optimizing through multithreading can significantly improve the performance of FIR filters, especially in systems with multitasking environments (Lyons, 2011).

**Conclusion.** Digital signal filtering is an integral part of embedded systems, especially in applications requiring real-time processing. Despite the high computational demands, digital filters can be optimized for operation on resource-limited platforms like the Raspberry Pi. FIR filters provide high accuracy but require more resources, while IIR filters are more efficient but may sacrifice some accuracy. The choice of filter depends on the specific system requirements and the type of signals being processed. In the future, the use of machine learning methods may allow for the creation of adaptive filters that can automatically adjust to changing signal processing conditions (Kamen & Heck, 2006).

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# FUTURE TRENDS IN ELIMINATING HARMFUL EFFECTS OF PFASUSED IN SEMICONDUCTOR MANUFACTURING

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**Keywords:** PFAS, semiconductor, photolithography.

**Introduction.** Per- and poly-fluoroalkyl substances (PFAS) are a group of synthetic chemicals that exhibit several concerning characteristics, such as bioaccumulation, toxicity, cancerogenic activity, and environmental persistence due to the strong carbon-fluorine bond in their structure, which is extremely hard to break down. However, due to their advantageous qualities, including low surface tension, low refractive index, and both hydrophobic and oleophobic behavior, PFAS are used in many products and technologies, namely the semiconductor manufacturing process. Since semiconductors are an essential part of every electronic device, and the semiconductor market is expected to exhibit an annual growth rate of 14.9% until the year 2032 (Fortune Business Insights, 2024), dealing with its harmful side effects in the form of PFAS pollution is an on-going challenge.

**Objectives.** To analyse the role of PFAS in semiconductor manufacturing, to evaluate strategies for eliminating their harmful effects, and to determine the ones that would be most certainly implemented in the next decades.

**Methods.** Analysis of available research, reports, and international regulations regarding PFAS in semiconductor manufacturing.

**Results.** One of the key processes in semiconductor manufacturing is photolithography. This procedure involves covering a semiconductive substrate with a thin layer of photoresist material that can solidify after exposure to ultraviolet light, which is usually applied to particular areas. Washing off unexposed photoresists leaves a specific pattern on a substrate, so etching of the conductive layer in only needed areas can be done afterward (Handrea-Dragan et al., 2022). PFAS are used to conduct several photolithography steps. They are added to the photoresist to control the pattern profile, increase its resolution and light absorbance, and improve dissolution properties (Dammel & Speed, 2024). PFAS are the key components of photoacid generators that generate strong acids on exposure to light, which makes photoresist solidification easier. PFAS are added to rinsing solutions and etching compounds to prevent pattern collapse since they have low surface tension. In total, around 33,7 tons of various PFAS are used in the semiconductor manufacturing process annually (Semiconductor Industry Association, 2023), and half of this amount is used in top antireflective coatings that prevent the UV light from reflecting and lowering the accuracy of intricate photoresist patterns.

Several strategies can be implemented to deal with the dangers caused by widespread PFAS usage in semiconductor manufacturing. While dealing with the problem of PFAS pollution at its latest stage when chemicals are already present in the environment is important, it can't be the only solution since the estimated cost of removing all PFAS from the environment, taking into account current PFAS emission rates, exceeds the global gross domestic product (Ling, 2024).

The first solution is substituting toxic PFAS with less dangerous ones. This initiative began in 2009 when one of the most harmful PFAS (perfluorooctane sulfonic acid or PFOS) was included in the international Stockholm Convention to eliminate its use (Stockholm Convention on persistent organic pollutants, 2001). Since then, this list has been extended to some other PFAS, mostly longer-chain (with more carbon-fluorine bonds). Moreover, long-chain (those with 9 to 21 carbon atoms) perfluorinated carboxylic acids have been restricted in the EU since February 2023 (European Chemicals Agency, n.d.). These limitations resulted in reduced usage of PFOS in the photolithography process. Successful examples include photoresist materials, antireflective coatings, and etching compounds where PFOS were phased out in favour of short-chain PFAS. The World Semiconductor Council announced the elimination of PFOS in 2011 (Semiconductor Industry Association, 2023).

However, this solution is not future-proof. While short-chain PFAS are considered less bioaccumulative and toxic due to the smaller size of their molecules, the increase in their usage across various industries after the mentioned international restrictions leads to their excessive accumulation in the environment. This situation is even more concerning considering the insufficient knowledge of short-chain PFAS impact on public health due to their novelty, absence of large-scale studies, and poorly developed analytical methods (Chow et al., 2021).

The most promising approach is the development of PFAS-free alternatives to substances used in semiconductor manufacturing. It's limited by performance requirements non-PFAS alternatives have to fulfill to substitute PFAS without loss in end-product functionality. This may result in long development times (up to 25 years) or changes in tooling, fabrication process, and facilities (Semiconductor Industry Association, 2023). Currently, functional substitutes for etching compounds are available, and efforts are underway to develop PFAS-free alternatives to photoresists, antireflective coatings, and rinses (Lay et al., 2023). Some of them implement environmentally friendly substances such as cornstarch (Hachikubo et al., 2023) or easily degradable materials.

**Conclusion.** There are several strategies for dealing with PFAS used in semiconductor manufacturing. While substituting more toxic PFAS with less harmful ones and removing already emitted substances from the environment is important, in the long run, the most sustainable option is to develop PFAS-free alternatives.

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## ARTIFICIAL INTELLIGENCE IN LITERARY TRANSLATION

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**Keywords:** Artificial Intelligence (AI), literary translation, machine translation (MT), neural networks, natural language processing (NLP), linguistic consistency, emotional depth, idioms, metaphors, AI-generated translations.

**Introduction.** The growth in AI is one that continuously inroads into various industries that involve much linguistic and cultural knowledge and appreciation, such as translation, particularly in literature (Sharofova, 2024). These are greatly owed to its applications, namely machine translation, neural networks, and natural language processing. Indeed, translations are taking a totally new form. While AI accelerates translation, it also improves multilingual communication and maintains consistency in language. The moot question remains whether AI is competent enough to portray the emotional depth, cultural context, and subtlety that bless a literary text. Translators translate not just words but emotions, idioms, and metaphors. But even as these AI systems become more human-like in nature, a suspicion lingers that, somewhere in translation, human creativity is lost. The paper discusses the boons and bane that Artificial Intelligence has brought with it in the field of literary translation, studying how this technology is used by translators while translating a piece of work and if that can retain the emotional and artistic spirit of the original piece.

**Objectives.** This paper debates Artificial Intelligence opportunities in the field of literary translation due to its unique capability for capturing the subtlety, emotional deepness and cultural aspects within the literary text. This paper, therefore, reviews how AI technologies are being applied in supporting the translation of literary texts with accuracy, surmounting challenges in metaphor, idiom, and tone. It will also consider limitations in the extent to which AI can emulate nuanced interpretation by human translators in maintaining emotional resonance and cultural relevance. Ultimately, this research tries to evaluate the AI-driven literary translation trends in the near future and the varied role that a translator has taken while living in this digital era (Kirov, 2022).

**Methods.** The study will use a mixed-method approach to identify what effect AI is going to have on translation in general and literary translation in particular. First, there will be a juxtaposition of AI against human translations of randomly

selected literary texts with metaphorical language, idioms, and other forms of cultural references. The machine translation engines and neural networks will be utilized for the execution of the AI translations and thereafter verified for accuracy, emotional resonance, and cultural context. This linguistic analysis will talk about how AI maintains tones, idiomatic expressions, and cultural references. Translations are reviewed based on objective criteria such as accuracy and fluency, but also more subjective ones, including emotional depth and cultural relevance. Further, a corpus of translated texts is analyzed to find consistent patterns in AI treatment of the literary elements under consideration. Ethical Implications: The paper also discusses some ethical implications of AI concerning translation issues in works after reviewing the related literature.

**Results.** Improvement in terms of speed and accuracy considered, the present study has established that AI-powered translation tools, in their evolving versions, fail to capture the emotional depth and underlying cultural contexts hidden in works of literature. While AI algorithms may translate standard, contemporary languages and common phrases using perfect grammar, the very moment metaphorical language is used, idiomatic expressions are employed, or subtle nuances invoked to create a given emotive effect, then AI often falls short in retaining integrity of the original message. This is because works of literature are replete with cultural references, historical backgrounds, and emotive undertones, which artificial intelligence can neither perceive nor portray accurately (Das, 2018). Moreover, AI is bound to translate words independently without considering the whole text context, which contributes a lot to losing the multilayered meanings that actually constitute the backbone of any work of literature. Thus, the emotional resonance or cultural significance carried out in the original text is loosened, and AI translations sound flat or devoid of the actual feeling of the translation resource.

**Conclusion.** However, promising AI is, and has been, in the revolutionizing of translation studies, there is still a very huge discrepancy in maintaining emotional depth and cultural context in literature. The human translator brings a singularity to the understanding of the subtleties in language, the emotions, and the cultural references that AI just cannot replicate yet (Moneus, 2024). Translation of literatures involves an element of empathy and interpretation that exceeds the linguistic conversion, thereby begging for an understanding of the human experience, cultural backgrounds, and the subtlety of the artistic expression. As AI improves, it may turn out to be a good tool for translators in some aspects of translation, such as first drafts or simple translations. In a way, works that are actually sustained by deep emotional and cultural contexts cannot be performed without human expertise. While in times to come, with developments, AI may perhaps learn to cope better with these subtleties, the human touch cannot be taken away in preserving the essence of works into other languages.

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## EMERGING TRENDS IN SCIENCE AND TECHNOLOGY: INNOVATIONS SHAPING THE NEXT DECADE

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**Keywords:** innovations, technological trends, artificial intelligence, quantum computing, biotechnology, sustainable development, digital transformation, Internet of Things, cyber security, metauniverse.

**Introduction.** At a time of unprecedented technological progress, it is important to understand and predict the future directions of the development of science and technology. The last decade was characterized by the rapid development of artificial intelligence, quantum computing, biotechnology and other breakthrough technologies. Understanding future trends is critical to strategic decision-making in education, business, and public policy. According to the World Economic Forum, the rate of technological change continues to accelerate, creating both new opportunities and challenges for society (World Economic Forum, Max Floetotto, 2024). The issue of ethical implementation of new technologies and ensuring their availability for all segments of the population is gaining particular relevance.

**Objectives.** The research is aimed at solving the following tasks:

1. To identify the key technological trends that will shape the scientific and technological environment during the next decade.

2. Analyze the potential impact of these trends on various areas of society, including education, health care, manufacturing and the financial sector.

3. Assess possible challenges and risks associated with the introduction of new technologies, in particular in the context of cyber security and personal data protection.

4. To offer recommendations on adapting educational and business processes to future changes.

5. Investigate the impact of technological innovations on sustainable development and achieving the goals of climate neutrality.

**Methods.** The research is based on a comprehensive analysis of existing scientific publications, reports of leading technology companies and research institutes, as well as expert forecasts. The methods of system analysis, comparative analysis and forecasting are applied. The study includes:

– Analysis of statistical data on investments in various technological sectors and the pace of innovation implementation over the past 5 years;

– Analysis of scient metric indicators of publishing activity;

– Review of strategic documents of leading technological companies and research centers;

– Using the methodology of foresight studies to forecast future development scenarios;

– Expert interviews with leading scientists and technological entrepreneurs.

**Results.** The analysis made it possible to identify several key areas of development of science and technology for the next decade. In the field of artificial intelligence, significant progress is expected in the development of multimodal models capable of simultaneously working with text, images, sound and video. According to OpenAI research, such models will significantly outperform current systems in context understanding and content generation. A particularly promising direction is the integration of AI with quantum computing, which will create new opportunities for solving complex computational problems in the fields of materials science, pharmacology, and climate modeling (Meng-Leong How, 2024, p.295).

IBM and Google are actively working on expanding the capabilities of quantum processors, which could lead to the achievement of quantum superiority in specific computing tasks as early as 2026. At the same time, the technologies of quantum sensors for precise measurements and quantum cryptography to create completely secure communication channels are being developed.

Biotechnology and medicine are demonstrating revolutionary advances in genome editing and personalized medicine. CRISPR-Cas9 technology continues to improve, opening new opportunities for the treatment of genetic diseases (Youmin Zhu, 2022, p.8). The development of 3D bioprinting technologies allows us to create increasingly complex organic structures, bringing us closer to the possibility of printing functional organs.

The development of 3D bioprinting technologies allows us to create increasingly complex organic structures, bringing us closer to the possibility of printing functional organs (Swikriti Tripathi, 2022, p.4). Significant progress has been observed in the development of new methods of drug delivery using nanoparticles and smart materials.

In the context of sustainable development, special attention is paid to technologies aimed at combating climate change. A breakthrough in energy storage technologies is expected, which is critical for the widespread adoption of renewable energy sources.

**Conclusion.** The next decade will be marked by the convergence of various technologies and their impact on society. Research shows that the main drivers of innovation will be artificial intelligence, quantum technologies and biotechnology. Technologies of sustainable development will play an important role in solving environmental problems. Digital transformation will cover all spheres of life, creating new opportunities for business and social development. Adaptability of education and business to rapid changes, development of interdisciplinary skills and ethical approach to innovation will be key success factors. Particular attention should be paid to cyber security, privacy protection and ensuring equal access to technology for all.

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## METHOD OF WORKING OF BIONIC EYE IMPLANT

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**Keywords:** bionic prosthesis, artificial eye, implantation, neural connections, nanowires, optic nerve, camera, communication module.

**Problem statement.** Bionic eye prostheses, or ocular implants, are a cutting-edge trend in modern medical and biotechnology industries, because we perceive 90% of information with our eyes. They can significantly improve the quality of life

of people who have lost their function due to various reasons, such as injuries, diseases or congenital defects. The problem is that our eye is a very complex and sensitive organ. And today's progressive neuroscience has not yet reached the point of equalizing the perception of information of a real eye and an implant.

In addition, the implantation of an artificial eye is a very young industry. For the first time, such an implantation operation was performed in the UK in 2015 on an elderly person (Walsh, 2015). The 80-year-old man suffered from dry macular degeneration, a disease that develops with age and is the most common cause of vision loss in developed countries. However, there are, of course, congenital defects and those acquired in childhood and adolescence that require rehabilitation.

**Research.** A bionic eye does not always look like a high-tech device that is close to a real human eye. Most visual implants are based on two elements: a camera and a communication module (Khudetsky et al., 2021). They come in different shapes and can be implanted either under the skin or with parts left outside. For example, a retinal implant that was installed in the UK processes video from a miniature camera attached to a man's glasses. The images are converted into electrical impulses and transmitted wirelessly to an array of electrodes attached to the retina. The electrodes stimulate the retinal cells that are still intact in the person, and they, in turn, send information to the brain.

Another type of implant has a similar algorithm, but the communication module is embedded under the skin on the face. After implantation, the man was able to see the direction of white lines on a computer monitor, but further rehabilitation requires a long time and refinement.

**Proposed solutions.** There are implants similar to a real human eye. Researchers from the University of Hong Kong have created robotic eyes, the structure of which repeats the structure of a real human eye (Eggenberger, 2021). Scientists have managed to create an artificial retina that exceeds the capabilities of a regular human eye in sensitivity.

The size of the implant is approximately the same as the real one – about two centimeters in diameter. Inside it is filled with liquid electrolyte, the retina is made using nanowires, and few people can be surprised by an artificial lens now: many elderly people who have undergone surgery due to clouding of their own intraocular lenses walk with such intraocular lenses.

**Impact.** Today, such an implant is capable of creating very "coarse" images: if a real eye gives a picture with a quality of 120-140 megapixels, then an artificial one – only 100 pixels. It is important that the principle itself turned out to be working. In the future, the picture can be improved, but the main problem lies in the area of "docking" the mechanical eye and the human brain, that is, the connection in the optic nerve area. A lot of work is needed on it, especially if the device needs to be adapted for constant wearing. Most implants are designed to be worn for 2 years,

which is too short a shelf life. According to experts, improving the work for long-term use can take up to ten years.

In addition, the gadget needs a power source: it is assumed that it will be provided by sunlight. The authors of the work claim that the design features will give the eye additional capabilities. Nanowires are so sensitive that they can significantly exceed the optical wavelength range of the human eye, allowing it to respond at a distance of 800 nanometers – the threshold level between visual light and radiation in the infrared range.

**Conclusion.** The bionic eye is on the verge of a full robotic development of neurotechnology due to the fast response of decoding images from the camera, which is a great success in the development of this field. In the future, nanoimplants will develop rapidly, because we have taken the first steps and have the basis for materials that will also be improved. The design features will give the bionic implant additional capabilities, such as vision in the dark or a faster response to stimuli, which will exceed the capabilities of the human eye.

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## SHAPING UKRAINE'S DEFENSE CAPABILITIESAMID ONGOING CONFLICT

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**Keywords:** future trends, military technology, Ukraine, innovation, defense.

**Introduction.** The ongoing war between Ukraine and Russia has placed immense pressure on Ukraine to modernize its military and defense capabilities rapidly. The conflict has highlighted the need for Ukraine to not only match but also outpace adversarial capabilities to maintain sovereignty and protect its citizens. With both conventional and asymmetrical warfare tactics in play, reliance on advanced military technologies is essential for effective national defense. Over the next

decade, the integration of autonomous systems, enhanced cybersecurity measures, and artificial intelligence (AI) will play a vital role in equipping Ukraine's military to respond adeptly to current threats while anticipating future ones. This study examines how these emerging technologies could reshape Ukraine's defense landscape and fortify its position amid the challenges of hybrid warfare, where both digital and physical domains are battlegrounds. The emphasis on technological advancements will be pivotal for Ukraine to safeguard its national security and maintain stability.

**Objectives.** This study is organized around three primary objectives: First, it seeks to identify the most relevant technological trends within the military domain to bolster Ukraine's defense. Second, it assesses the impact that advancements in drone technology, AI, and cybersecurity could have on Ukraine's military capabilities, focusing on areas such as situational awareness, operational readiness, and threat neutralization. Lastly, the study evaluates the broader implications of these technologies for Ukraine's defense strategy over the next decade. The goal is to provide a forward-looking assessment that highlights the types of innovations essential for maintaining Ukraine's sovereignty, improving defensive capabilities, and establishing a more resilient national defense.

**Methods.** This study investigates future trends in military technology by analyzing a wide range of relevant sources and expert insights. Information was gathered from existing sources, such as recent publications, government reports, and international case studies on successful military technology in other defense-oriented countries. Data analysis was conducted through thematic coding, allowing for the identification of key themes, trends, and patterns in technological advancements. By including projections from leading defense analysts and technology experts, this research provides a detailed overview of how these trends might impact Ukraine's military strategy and operations over the next decade.

**Results.** The findings reveal several technological areas with the potential to redefine Ukraine's defense strategy. Drone Technology is at the forefront of military innovation, with Ukraine already leveraging drones for reconnaissance, surveillance, and combat missions. Trends indicate a shift toward more autonomous, AI-driven drones, which could operate in coordinated swarms. Such advancements are anticipated to improve battlefield intelligence and responsiveness significantly, allowing for rapid, real-time analysis of enemy movements and strategic positions (Defense Industry Reports, 2023).

Another major technological trend is Artificial Intelligence (AI), which is increasingly being applied to military operations. AI offers capabilities that can assist Ukraine in data processing, strategic planning, and predictive analytics, optimizing decision-making processes at all command levels. For instance, AI-driven algorithms can enhance Ukraine's ability to detect threats faster and allocate resources more efficiently. AI also has applications in predictive maintenance, enabling Ukraine's

military to reduce downtime and maintain high operational readiness of key equipment and vehicles (Smith, 2021).

The study also highlights the importance of Cybersecurity as a defense priority. Given the hybrid warfare tactics employed by Russia, cybersecurity must be strengthened to protect vital communication channels and prevent intelligence breaches. Future trends indicate a focus on AI-enhanced cybersecurity systems capable of real-time threat detection and response. Such systems are vital for securing sensitive military data and protecting national infrastructure from cyber-attacks that could disrupt operations or manipulate data (Johnson & Mitchell, 2022).

Additionally, Advanced Surveillance and Reconnaissance Systems are expected to improve situational awareness on the battlefield. By integrating satellite data, high-resolution imaging, and AI-powered analytics, these systems enable Ukraine to monitor enemy activity more effectively, providing strategic advantages in reconnaissance missions (Taylor, 2023).

Electronic Warfare (EW) capabilities are another area of focus. With Russian forces utilizing EW to disrupt Ukrainian communications and radar, Ukraine's ability to counteract such tactics is essential. Future innovations include more advanced jamming, anti-jamming technologies, and EMP-resistant systems that help safeguard communication networks. These technologies offer Ukraine resilience against electronic interference, enhancing secure communication in high-stakes scenarios (Ukraine Military Innovations Council, 2022).

Finally, Robotics and Autonomous Vehicles are projected to enhance Ukraine's operational flexibility in challenging environments. Autonomous ground vehicles and robotic systems for logistics and bomb disposal can perform tasks in high-risk zones, reducing human casualties and optimizing logistical efficiency. Such advancements provide operational versatility, enabling Ukrainian forces to conduct missions with minimal exposure to threats.

**Conclusion.** The projected trends in military technology underscore the critical role of innovation in Ukraine's defense strategy. By focusing on advanced drones, AI applications, cybersecurity, and electronic warfare capabilities, Ukraine can enhance its military effectiveness and strengthen its resilience against hybrid warfare threats. Embracing these technologies not only bolsters Ukraine's defense but also builds a foundation for a technologically adept and adaptive military. With these innovations, Ukraine can develop a secure defense infrastructure capable of withstanding external aggression and ensuring sustained security. These advancements are vital for Ukraine to reach technological parity with adversaries and establish a secure, autonomous future.

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## INTERNET OF THINGS

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**Keywords**: The Internet of Things (IoT), Internet of Everything, Operational Technology, Sensors.

**Objectives:**

To explore the origin and evolution of IoT and IoE.

To examine the differences between Operational Technology (OT) and Information Technology (IT) within IoT.

To understand the Industrial Internet of Things (IIoT)'s key components and industry applications.

To assess the IoT ecosystem, including sensors, communication systems, and security requirements.

**Methods.** The study presents a descriptive analysis of IoT, focusing on its structure, functions, and application in industries. The research is based on a literature review and analysis of current technologies and use cases. Key concepts are focused on IoT's technological infrastructure and operational frameworks.

**Result**. The Internet of Things (IoT) describes a network of connected physical devices equipped with sensors and software, enabling data exchange and communication between the physical world and computer systems through standard communication protocols. Alongside sensors, this network can include actuators embedded in physical objects, all interconnected via wired or wireless networks. In addition to sensors, the network may have actuators embedded in physical objects and interconnected through wired or wireless networks. These interconnected devices have the ability to read and actuate, the function of programming and identification, and also allow for the exclusion of the need for human participation due to the use of intelligent interfaces (Yasar & Gillis, n.d.).

The term "Internet of Everything" (IoE) is also spreading – a comprehensive or all-encompassing Internet. This phenomenon has raised concerns about information privacy and contributed to the emergence of a new term, IoT security (The Internet of Everything [IoE], n.d.).

The term "Internet of Things" appears to Kevin Ashton, who, in 1997, while working for the Procter and Gamble company, applied radio frequency identification (RFID) technology to manage the supply system. Thanks to this work, in 1999, he was invited to the Massachusetts Institute of Technology, where he and a group of like-minded individuals organized the Auto-ID Center research consortium.

The Industrial Internet of Things (IIoT) is one of the largest segments of the Internet of Things in terms of the number of connected devices and the degree of usefulness of these services for the production and automation of enterprises. This segment traditionally serves as an operational and technological base. It includes hardware and software monitoring of physical devices. Traditional information technology tasks are solved differently than operational and technological tasks. Operational Technology (OT) evaluates performance, ensures uptime, collects real-time data, responds quickly, and maintains system security. In contrast, Information Technology (IT) emphasizes security, service provision, data management, and organization. With the growing impact of the Internet of Things (IoT) in manufacturing and industrial sectors, the integration of IT and OT is becoming inevitable. This convergence, especially in predictive maintenance for thousands of industrial machines, will enable an unprecedented flow of data into private and public cloud infrastructures.

The characteristics of this segment include the need to provide ready-made solutions to the operational and technological system in real-time or near real-time. This means that in everything related to the production floor, the main parameter for the Internet of Things will be response time. In addition, downtime and safety will play an important role. This implies the need for capacity reserves and probably the availability of private cloud networks and data storage. The Industrial Internet of Things is one of the fastest-growing segments of this market. An important feature of this direction is that it relies on older technologies, that is, on hardware and software tools that cannot be called current. Often, 30-year-old production machines run on RS485 serial interfaces rather than modern wireless cellular architectures (Shkola Avtomatyky, n.d.).

Application examples of the Industrial Internet of Things include:

– Preventive maintenance of industrial equipment
– Productivity growth thanks to real-time demand
– Energy saving
– Safety systems such as temperature measurement, pressure measurement, and gas leak monitoring
– Expert systems for the production floor

The Internet of Things ecosystem includes all tools, services, and technologies used in the Internet of Things. These include:

Sensors (smart sensors/actuators): embedded systems, real-time operating systems, uninterruptible power supplies, microelectromechanical systems (MEMS).

Communication systems with sensors: the coverage area of wireless personal networks ranges from 0 cm to 100 m. Low-speed, low-power information channels are used for data exchange between sensors, which are often not built on the IP protocol.

Local area networks (LANs): a current system of data exchange based on the IP protocol, such as 802.11 Wi-Fi for fast radio communication, often peering or star networks.

Aggregators, routers, gateways, edge devices: suppliers of embedded systems, budget components themselves (processors, dynamic RAM, and data storage systems), module manufacturers, passive component manufacturers, thin client manufacturers, manufacturers of cellular and wireless radio systems, suppliers of cross-platform software, developers of fog computing infrastructure, tools for edge analytics, edge device security, and certificate management systems.

Global computer network: cellular operators, satellite operators, and operators of low-power global networks (Low-Power Wide-Area Network, LPWAN). Commonly used Internet transport protocols for IoT and network devices include MQTT, CoAP, and even HTTP.

Cloud: QoS infrastructure, QoS platform, database developers, streaming and batch data processing service providers, data analysis tools, QoS software, data lake providers, software-defined network/software-defined perimeter operators, and machine learning services.

Data analysis services: huge amounts of information are transferred to the cloud. Working with large volumes of data and obtaining benefits from them requires complex event processing, analytics, and machine-learning techniques.

Security: cybersecurity issues arise when combining all the architecture elements. Every component must be secure, from physical quantity sensors to the CPU, digital hardware, radio communication systems, and data transmission protocols themselves. Security, integrity, and reliability must be ensured at every level, as this chain should have no weak links. The main IoT devices may be key targets for hackers to attack globally (TechThrive, 2020).

The architecture of the Internet of Things differs depending on the implementation. Interaction with "things" occurs through sensors and actuators, similar to how it is done in ACS for any control object. These sensors and the entire infrastructure for integration with the level of event processing via the Internet form the so-called edge area (Shkola avtomatyky, n.d.).

Events from the boundary area are stored and processed according to the task (level of event processing and analytics, event processing, Platform). At this level,

events are stored, processed, and forwarded to the necessary applications. In addition, at this level, devices from the edge area are administered and managed. Events are processed using analytical services, based on which machine learning is performed, allowing one to draw certain conclusions about the object. This level is usually implemented using Cloud or Fog computing. If we draw an analogy with the automated control system, then this is the level of controllers and SCADA (excluding HMI functions). The results, control, remote control, and system administration are obtained through end applications using the Internet.

**Conclusion**. The Internet of Things is ushering in a new technological era, allowing physical objects to interact and share data. IoT is gaining traction in various fields, from smart homes to industry, by automating processes, optimizing resource usage, and providing user-friendliness.

However, there are certain challenges that need to be overcome for the widespread adoption of the Internet of Things, including data security, standardization, and cost. However, technological progress and the activity of companies indicate that the IoT revolution is coming soon.

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## ZERO TRUST AS A KEY PARADIGM OF INFORMATION SECURITY IN HYBRID WARFARE

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**Keywords:** Zero Trust, information security, hybrid warfare, zero-day attack.

**Introduction.** In the context of the ongoing hybrid warfare, Ukraine has become a cyber testing ground for zero-day attacks launched by the Russian Federation. Systematic attacks on critical infrastructure, including energy, financial, and government systems, are accompanied by intensive disinformation campaigns.

In this environment, traditional cybersecurity models, based on perimeter defence strategies, have proven inadequate in addressing threats of such magnitude and complexity. The global evolution of cyber threats necessitates new information security paradigms capable of adapting to dynamic environments. The Zero Trust paradigm, as defined in NIST SP 800-207, offers an approach grounded in the complete absence of trust towards any network elements.

**Objectives.** The primary objective of this study is to investigate the efficacy of the Zero Trust cybersecurity paradigm in addressing the unique challenges posed by hybrid warfare. Specific tasks include:

1. Analysing the deficiencies of traditional perimeter-based security models in the face of complex cyberattacks.
2. Evaluating the feasibility of implementing Zero Trust architecture in critical infrastructure sectors.
3. Examining the integration of threat intelligence with Zero Trust models for enhanced security.

**Methods.** This study employs a combination of qualitative and quantitative approaches. Qualitative analysis will involve a review of documented cyber-attacks on Ukrainian critical infrastructure to assess the failures of perimeter security models. Quantitative methods include simulations of Zero Trust architectures applied to network segments within the energy and financial sectors, analysing their effectiveness in thwarting advanced persistent threats (APTs) and zero-day vulnerabilities.

**Results.** Zero Trust rejects the concept of a trusted inner perimeter. Each entity – user or device – is treated as a potential threat, requiring constant verification based on contextual information: multi-factor authentication, device status, geolocation, and activity history. This minimises the risk of compromise even if credentials are stolen, as access is possible only after identity verification.

The second fundamental aspect of Zero Trust is the principle of least privilege, according to which each entity gets access only to those resources that are critical to its tasks. This approach significantly reduces the risk of expanding attacks in the event of a compromise of one of the system's elements. In the context of Ukraine, where attacks are targeting government agencies and critical infrastructure, such as energy systems, minimising access rights for each user and segmenting access to different infrastructure components is key to localising potential threats.

Network segmentation is the next key element of Zero Trust. Unlike classical approaches where internal resources are considered secure after passing the outer perimeter, Zero Trust uses micro-segmentation to isolate individual system components. Each resource is treated as a separate 'island' with an independent verification and access system. This isolation prevents an attacker from spreading malicious influence horizontally after initially penetrating the network. For example, attacks on Ukrainian energy systems in 2015-2016 could have been neutralised at

an early stage if critical elements of the system had been segmented in accordance with Zero Trust principles.

Equally important is the constant monitoring of entity activity through User and Entity Behaviour Analytics. Abnormal actions or deviations from normal behaviour may signal a system compromise. For example, sudden changes in access levels or connections from unusual locations can be indicators of hacking. In times of war, when social engineering is used to compromise internal users, continuous monitoring becomes critical to detect and neutralise threats in real time.

Integration of external information sources, such as Threat Intelligence and Continuous Diagnostics and Mitigation systems, ensures dynamic adaptation of security policies based on current threats. The Policy Engine, the main component of the paradigm, uses this data to make decisions about granting or blocking access. For example, upon receiving information about a zero-day attack, Policy Engine immediately adjusts access policies to block requests from suspicious sources.

Implementing Zero Trust in Ukraine is not just a recommendation, but a strategically important step to ensure the cyber resilience of critical infrastructure. Successful implementation of this model in public and private institutions will significantly increase resilience to complex multi-stage attacks, including zero-day attacks.

**Conclusion.** Implementation of the Zero Trust paradigm is critical for building a modern information security strategy that can effectively respond to global cybersecurity challenges. The integration of this model in Ukraine will significantly strengthen the country's information security, increasing its resilience to complex threats, including zero-day attacks and hybrid operations by the Russian Federation.

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# DEVELOPMENT OF ARTIFICIAL INTELLIGENCE – A HOPE FOR A BETTER FUTURE OF HUMANITY

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**Keywords:** Artificial Intelligence, Human Progress, Automation, Ethical AI, Future Technology.

**Introduction.** Artificial Intelligence (AI) has emerged as a transformative force across various sectors, from healthcare and education to finance and transportation. The rapid development of AI technologies offers immense potential to enhance human capabilities, improve decision-making processes, and create new avenues for innovation. However, alongside these advancements come challenges related to ethics, security, and socioeconomic impacts. As we look into the future, the role of AI in shaping a better world for humanity remains a central discussion in both technological and societal circles (Tegmark, 2018). This work explores how AI can serve as a beacon of hope for a more advanced, equitable, and efficient future

**Objectives.** The primary objective is to explore how artificial intelligence can positively contribute to human progress by addressing major global challenges. It seeks to assess the ethical implications of AI development and examine how responsible practices can ensure that the technology benefits society as a whole. Additionally, the study, based on the contributions made by Tegmark (2018), aims to investigate how AI can enhance human creativity and productivity, while providing solutions for sectors such as healthcare, education, and sustainability.

**Methods.** This study relies on a qualitative analysis of current AI applications and their projected impact on human society. Data from recent AI innovations and their real-world applications in healthcare, environmental management, and education were collected and reviewed. Ethical guidelines and frameworks from AI governance were analyzed to determine best practices for responsible AI deployment. Additionally, case studies from industries that have successfully integrated AI were examined to assess how human-AI collaboration has resulted in significant improvements in efficiency, accuracy, and access to services. For instance, in healthcare, IBM Watson's AI capabilities have been applied to oncology, where Watson analyzes vast amounts of medical literature and patient data to assist oncologists in developing personalized treatment plans, enhancing diagnostic accuracy, and reducing time for treatment recommendations. In environmental management, Google has deployed AI models for monitoring air quality and deforestation in real-time and has also applied AI through DeepMind to optimize energy usage in data centers, achieving energy consumption reductions of up to 40%. In education, Duolingo leverages AI algorithms to personalize language-learning

pathways based on user performance, enhancing engagement and effectiveness for diverse learners. These case studies demonstrate how AI's integration into industries supports human-AI collaboration and provides a foundation for impactful, responsible AI usage across sectors (Brynjolfsson & McAfee, 2014).

**Results.** The research indicates that AI has the potential to address numerous global challenges by offering solutions that are both scalable and sustainable. In healthcare, AI is already revolutionizing diagnostics, personalized medicine, and drug discovery, significantly improving patient outcomes while reducing costs. In education, AI-powered platforms are enabling personalized learning experiences that can be adapted to the needs of diverse student populations, bridging the gap between under-resourced and affluent educational institutions. Furthermore, AI technologies in environmental management are offering predictive analytics that help mitigate the effects of climate change through better resource management and disaster preparedness.

Human-AI collaboration has also shown promising results in industries such as manufacturing, where automation and AI systems enhance productivity while maintaining human oversight (Brynjolfsson & McAfee, 2014). Rather than replacing jobs, these technologies often shift the nature of work, requiring reskilling and upskilling of the workforce. Importantly, responsible AI development, that is through adherence to ethical guidelines, ensures that AI technologies are aligned with human values and rights, reducing the risk of bias and fostering trust in AI systems.

**Conclusion.** The development of AI presents a unique opportunity to address some of humanity's most pressing challenges while improving overall quality of life. Through responsible innovation and collaboration between humans and AI systems, society can benefit from increased efficiency, equity, and accessibility in critical sectors like healthcare, education, and environmental management. While concerns about the socioeconomic impact of AI remain, the careful governance of AI ethics and its role in complementing, rather than replacing, human capabilities can lead to a hopeful and sustainable future. The true potential of AI lies not in the technology itself, but in how humanity chooses to harness it for the common good.

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# THE FUTURE OF ROBOTICS: TRANSFORMING SOCIETY

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**Keywords:** robots, automation, Tesla, future, collaboration.

**Introduction.** Humans have been interested in the concept of a robot for thousands of years. The appeal of a seemingly magical device that looks like a live human (or a dog, a cat, or some other animal) has led inventors to create many robotic devices, ranging from the simplest automatons of ancient history to the machines currently available that use the best-available programs for AI (Newton, 2018). Today, the rapid progress in robotics and automation is reshaping various sectors, from industry to healthcare and transportation. As artificial intelligence and machine learning evolve, robotics becomes increasingly advanced, enabling robots not only to mimic human appearance but also to collaborate with humans in complex tasks. One of the most ambitious projects in this realm is Tesla's Optimus robot, a humanoid robot designed to function autonomously in manufacturing and other environments, thereby offering a glimpse into the future of robotic collaboration and autonomy. The latest video of Tesla's humanoid robots roaming the workshops seemed to showcase the progress of Optimus development – if not for one interesting thing (Danshyna, 2024).

**Objectives.** The main aim is to understand how humanoid robots like Tesla's Optimus can transform productivity and collaboration in modern industries.

**Methods.** The analysis shows that while robots like Optimus may not yet fully match human dexterity and complex decision-making, their presence in manufacturing suggests a future where human labor is augmented, rather than replaced, by robots. Robots can take on physically demanding, repetitive, or hazardous tasks, freeing up human workers to focus on tasks that require creativity, judgment, and empathy. This shift could lead to increased productivity, reduced workplace injuries, and a more efficient distribution of human and robotic resources (Optimus navigating around, 2024). Furthermore, an intriguing finding from recent videos of Optimus robots is their apparent autonomy, as they navigate Tesla's workshops, perform simple tasks, and seemingly interact with the environment in ways that suggest significant progress in machine learning and sensory perception. This development in humanoid robotics is a significant step toward seamless human-robot collaboration, where robots can take on supportive roles in industries that traditionally rely on human labor.

**Results.** Unlike traditional industrial robots, which are often fixed in place and designed to perform specific functions, humanoid robots can navigate complex environments, adapt to dynamic tasks, and interact with humans in a meaningful

way. The attraction of a robot is that many concepts in computing and electronics can be made vivid, and many enjoyable but instructive projects, problems, and demonstrations can be devised (Todd, 1986). Tesla's approach with Optimus also highlights the potential for AI-driven robots to learn from their surroundings and respond to unforeseen situations, which is critical for collaboration in unpredictable environments.

**Conclusion.** The evolution of robotics, exemplified by Tesla's Optimus, marks a transformative moment in both industrial automation and the potential for humanoid robots to collaborate with humans in various sectors. Any discussion of the evolution of humanoid robots will involve some overlap with that of industrial robots. Throughout history, many inventors have designed machines that may or may not look like a human but that, in any case, may serve any one of a number of functions, which may include the carrying out of work (Newton, 2018). As demonstrated in this study, humanoid robots represent more than just technological advancement; they offer new ways of approaching tasks, especially in collaborative settings where the integration of AI and human interaction holds promise for enhancing productivity and reshaping industries.

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## VISUAL ODOMETRY-STABILIZED AUTOCORRECTING NAVIGATION SYSTEM FOR UAVS WITHOUT GPS

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**Keywords:** Unmanned Aerial Vehicles (UAVs), Visual Odometry, GPS-Denied Navigation, Gaussian Splatting, 3D Mapping, Autocorrecting Navigation

System, Sensor Fusion, Inertial Measurement Units (IMUs), Extended Kalman Filter (EKF), Autonomous Flight.

**Introduction.** Unmanned Aerial Vehicles (UAVs) play a crucial role in numerous fields such as environmental monitoring, precision agriculture, infrastructure inspection, and surveillance. Accurate and reliable navigation remains essential for effective UAV operation, yet conventional systems heavily rely on Global Positioning System (GPS) data. However, GPS-based navigation is prone to signal loss, interference, and environmental constraints, which can hinder UAV effectiveness in GPS-denied environments (Zhuang & Zhang, 2023). In response to these limitations, this study investigates a novel approach to UAV navigation that leverages visual odometry and Gaussian splatting to enable precision autopilot capabilities without GPS dependency (Kerbl et al., 2023; Chen & Wang, 2024).

**Objectives.** This research aims to design a visual odometry-based, autocorrecting navigation system that maintains accurate UAV trajectories in GPS-denied settings. Key objectives include:

1. Developing high-fidelity 3D maps using Gaussian splatting from video data(Kerbl et al., 2023; Zhou et al., 2023).
2. Simulating UAV flight within these 3D environments to establish autopilottrajectories.
3. Implementing a visual odometry algorithm to capture and interpret criticalflight data, such as velocity and spatial displacement (Zhang & Hu, 2021).
4. Creating an onboard correction mechanism that compares real-time visual odometry data with simulated trajectories, ensuring robust and accurate navigation.
5. Testing the system's navigation accuracy and stability through simulationsto gauge performance improvements over GPS-based systems.

**Methods.** This study uses a comprehensive approach, integrating advanced computer vision, simulation, and sensor fusion techniques.

*Research Design:* The system relies on a 3D Gaussian splatting method to render detailed spatial maps, enhancing the accuracy of the navigation framework in GPS-denied environments (Chen & Wang, 2024; Xie et al., 2024). This approach facilitates realistic trajectory planning and enables accurate visual feedback during flight.

*Sample/Participants:* The focus is on UAVs equipped with onboard cameras and inertial measurement units (IMUs), operating within simulated 3D environments togenerate flight data for real UAV validation (Mao et al., 2021).

*Instruments and Procedure:*

– **3D Map Generation:** Gaussian splatting is applied to video data, generating realistic 3D spatial representations to support trajectory planning (Kerbl et al., 2023; Xie et al., 2024).

– **UAV Flight Simulation:** Simulated flight paths are created within these maps, allowing the autopilot to follow realistic routes.

– **Visual Odometry Algorithm:** UAVs utilize camera inputs to capture frame-by-frame positional data, which is processed through a monocular visual odometry algorithm to estimate motion and spatial offsets (Zhang &Hu, 2021).

– **Autocorrecting Mechanism:** Real-time odometry data is continuously cross-referenced with pre-generated simulations, and corrective signals are issued if discrepancies exceed specified thresholds, enhancing stability and reducing drift (Zhuang & Zhang, 2023).

**Data Analysis:** Filtering techniques such as Extended Kalman Filters (EKF) are employed to merge visual odometry and IMU data, ensuring optimal positional accuracy during both simulated and real flights.

**Results.** Initial simulations demonstrate that the proposed navigation system, utilizing Gaussian splatting and visual odometry, significantly improves UAV trajectory precision and robustness. Gaussian splatting contributes high-fidelity mapping, enabling accurate simulation-based planning (Kerbl et al., 2023). The visual odometry algorithm reliably extracts vital flight data for real-time navigation adjustments. These simulations reveal the system's potential to maintain accurate paths even in challenging, GPS-denied conditions.

**Conclusion.** This study presents a scalable, GPS-independent navigation solution for UAVs, employing Gaussian splatting for 3D map generation and advanced visual odometry techniques (Chen & Wang, 2024; Mao et al., 2021). The autocorrecting mechanism addresses crucial challenges such as sensor drift, positioning the system as a promising alternative for autonomous UAV navigation in diverse, unpredictable environments. Future work will focus on extensive real-world validation, contributing to more resilient UAV systems for complex autonomous missions.

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## ON-ORBIT OPERATIONS: FUTURE OF ASSEMBLY AND SERVICING IN SPACE

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**Keywords:** on-orbit servicing (OOS), in-space assembly and manufacturing (ISAM), autonomous operations, space infrastructure, robotic manipulators, modular interfaces, space debris disposal, orbital refuelling, sustainable space operations.

**Introduction.** OSAM (On-Orbit Servicing, Assembly, and Manufacturing) technologies open new opportunities for space operations: autonomous maintenance, repair, refuelling and assembly of devices in orbit. This technology extends the service life of satellites, modernising them and reducing the amount of space debris. Robotic manipulators, convergence systems and modular interfaces make it possible to assemble large structures in orbit that can not be launched in assembled form. OSAM ensures the creation of a flexible and durable space infrastructure, supporting research and commercial missions.

**Objectives.** Assess the potential of on-orbit operations for future assembly and maintenance in space, particularly their effectiveness in ensuring the autonomy and reliability of space missions and increasing the safety of orbital space.

**Methods.** Scientific publications and technical documentation related to OSAM technologies were analysed. Projects and missions in the space industry that demonstrated high achievements in this area were considered. Content analysis methods were used to assess the effectiveness of technologies, and modelling was used to predict their future development. The results were systematised to identify critical success factors and challenges for future OSAM missions.

**Results.** On-orbit maintenance development began with Gemini and Apollo

missions' manoeuvres, approach operations, and Solar Maximum Mission (SMM) maintenance using the Orbital Replacement Unit (ORU), setting the stage for future technologies (Davis, Mayberry, & Penn, 2019). Mission to maintain the Hubble Space Telescope, it became clear how upgrading the device in orbit could extend its mission and improve functionality (European Space Policy Institute, 2023). In turn, in 2007, DARPA Orbital Express demonstrated a huge technological step forward – autonomous maintenance of satellites without the participation of people, which became an essential achievement for robotic technologies (Davis, Mayberry, & Penn, 2019).

The current importance of on-orbit maintenance (OOS) and in-space assembling and manufacturing (ISAM) technologies goes far beyond their historical achievements. These technologies increased the duration of space missions, created large space structures, maintained an ecosystem of satellites in orbit and fought space debris. Recent innovations in robotics, satellite systems engineering, manufacturing and assembly technologies in space have become critical to enable autonomous execution of complex tasks in orbit (Arney, Mulvaney, & Williams, 2022).

Technologies like autonomous robotic manipulators, such as those used in the DARPA Orbital Express program, provide docking, refuelling and replacement of modules without human intervention, as demonstrated by the example of Northrop Grumman's Mission Extension Vehicle, which extended the resource Intelsat satellite on GEO (European Space Policy Institute, 2023; Corbin et al., 2020).

Another critical point of OSAM is the modular design and standardisation of interfaces, which ensure the possibility of quickly replacing components. For example, the iBOSS DLR project offers unified interfaces for the reconfiguration and repair modules in orbit regardless of the manufacturer and functionality of the orbiter being serviced (Corbin et al., 2020).

In-orbit manufacturing, for example, Made in Space's 3D printing of components on the ISS and Tethers Unlimited's SpiderFab technology for assembling large structures, allows components to be created directly in space, reducing launch costs and expanding the possible dimensions of the spacecraft (European Space Policy Institute, 2023; Cline et al., 2022).

In addition, space debris disposal is becoming critical to orbital safety, where projects such as Astroscale's ELSA-d are testing techniques to capture and move debris from orbit, enhancing the safety of near-Earth space. There are also projects for orbital processing of this garbage to reduce space waste and re-create elements of space vehicles (Astroscale, 2024).

Due to the increasing complexity of such operations, several technological and regulatory challenges that are key to future OSAM missions need to be addressed. One such solution is high-precision navigation systems, such as NASA's Argon AR&D Sensor, which enable autonomous docking operations with uncooperative objects, which is critical for safe installation and maintenance in space (Davis, Mayberry, & Penn, 2019).

International standards developed by organizations such as CONFERS, which contribute to the unification of maintenance and installation procedures and reduce risks for all participants in the space environment, are also a prominent point (Li et al., 2022). In addition, innovative projects such as ClearSpace-1 from the European Space Agency (ESA) are developing a specialized apparatus to capture and remove large space debris objects, including fragments of old satellites. The device is equipped with four robotic arms that ensure reliable capture of the object, after which the garbage is transferred to orbit for further combustion in the atmosphere, which helps to clean the space around the Earth effectively (Arney, Mulvaney, & Williams, 2022).

**Conclusion.** OSAM technologies define the future of space operations by providing autonomy, durability and flexibility for space missions. They allow the continued operation of satellites through refuelling, repair and modernization without the need to launch new devices. These technologies also reduce costs, contribute to the disposal of space debris and increase the safety of the orbit, which is critical for the sustainable development of space infrastructure.

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# ENHANCING SECURITY IN 5G-ENABLED INTERNET OF THINGS NETWORKS

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**Keywords:** 5G, Internet of Things, security, cybersecurity, vulnerabilities.

**Introduction.** The rapid advancement of wireless communication technologies has led to the emergence of fifth-generation (5G) networks, offering unprecedented speed, low latency, and the capacity to connect a vast number of devices simultaneously. Simultaneously, the Internet of Things (IoT) has been expanding exponentially, integrating billions of devices into networks that collect, exchange, and act upon data. The convergence of 5G and IoT is poised to revolutionize various sectors – including healthcare, transportation, manufacturing, and smart cities – by enabling real-time data processing and advanced applications that were previously unattainable. However, this integration also presents significant security challenges. This underscores the importance of addressing security vulnerabilities in 5G-enabled IoT networks to ensure the safe and reliable operation of connected systems.

**Objectives**. The objective of this research is to enhance the security of 5G-enabled IoT networks by identifying and mitigating the inherent vulnerabilities that arise from their integration. The study aims to examine the security weaknesses in the convergence of 5G and IoT technologies, analyzing how the proliferation of connected devices and the complexity of network architectures contribute to potential risks such as unauthorized access, data breaches, and distributed denial-of-service attacks. Furthermore, the research aims to develop an innovative security framework that incorporates advanced encryption methods, robust authentication protocols, and real-time anomaly detection systems to mitigate identified risks, enhance network resilience, and ensure data integrity and privacy. By addressing these challenges, the study seeks to facilitate the safe adoption of these technologies and unlock their full potential for societal advancement.

**Methods.** To address the identified problem, a comprehensive research methodology was employed, combining both qualitative and quantitative approaches. An extensive review of scholarly articles, technical reports, and industry publications from 2014 to 2023 was conducted to gather existing knowledge on security issues related to 5G and IoT systems (Kachhavay, et al., 2014, Noohani, et al., 2020). Threat modeling techniques were used to systematically identify potential attack vectors and vulnerabilities within 5G-IoT ecosystems, employing frameworks like STRIDE to categorize and assess threats. Based on these insights, a multi-layered security framework was designed, incorporating advanced encryption protocols, robust authentication mechanisms, real-time anomaly detection systems, and network segmentation strategies. The proposed framework was implemented in a simulated 5G-IoT environment using advanced network simulation tools and cybersecurity

platforms to assess its effectiveness. Data collected from simulations were rigorously analyzed to evaluate improvements in security metrics, including the rate of detected and prevented attacks, response times to security incidents, system throughput, latency, and resource utilization.

**Results.** The research yielded significant findings demonstrating the effectiveness of the proposed security framework. It confirmed that current 5G-IoT implementations suffer from vulnerabilities such as weak encryption practices, insufficient authentication protocols, lack of real-time intrusion detection, and inadequate network segmentation. The implementation of the advanced security framework led to substantial improvements. There was a 70% decrease in successful cyber-attacks compared to baseline scenarios without the framework, indicating enhanced protection against unauthorized access and data breaches (Shafique, et al., 2020). The anomaly detection system reduced the average time to detect and respond to threats by 65%, enabling quicker mitigation of potential attacks. Despite the additional security layers, the impact on system performance was minimal, with latency increasing marginally by 5% and network throughput remaining stable.

**Conclusion.** The integration of 5G and IoT technologies presents unparalleled opportunities for innovation and efficiency across multiple sectors, but it also introduces substantial security challenges that cannot be overlooked. This study highlights the critical vulnerabilities inherent in 5G-enabled IoT networks and demonstrates how they can be effectively mitigated through a comprehensive security framework. By implementing advanced encryption protocols, robust authentication methods, real-time anomaly detection, and strategic network segmentation, the proposed framework significantly enhances network security without compromising performance. The value of this research lies in its practical approach to addressing real-world security concerns associated with 5G and IoT technologies. By adopting the proposed framework, stakeholders can foster a secure environment that supports the continued growth and adoption of these transformative technologies.

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# ARTIFICIAL INTELLIGENCE IN DRUG DISCOVERY

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**Keywords:** artificial intelligence (AI), machine learning (ML), computer-aided drug design, drug discovery**.**

**Introduction.** Drug development takes about 10 years and costs 20,29 billion USD from drug discovery to distribution (Unleash AI's potential | Measuring the return from pharmaceutical innovation, 2024). In addition, only 10-20% of selected drug formulations undergo clinical trials (Yamaguchi et al., 2021). Over time, the cost of the R&D department's work increases, which affects the cost of manufactured products. To speed up the drug development process and reduce its cost, such methods are used: *in vitro* (molecular networking, genetic engineering, active proteins), *in cellular* (organoids, organ-on-chips, 3D spheroid), *in silico* (machine learning, deep-learning, AI), *in vivo* methods.

**Objectives.** To examine current problems in the development of new drugs and their solutions using artificial intelligence.

**Methods.** This narrative review was conducted by examining scientific articles published within the last four years. A targeted search was performed across major academic databases, including Elsevier, PubMed and MDPI, to ensure a comprehensive and current overview of the literature on the topic.

**Results.** Artificial intelligence was first mentioned in 1956, but it has gained popularity only now (Zhao, 2024). Currently, it is understood as a program code that simulates human intelligence: it recognizes speech, generates text, and, most importantly, is capable of learning. The main component of artificial intelligence is machine learning, which involves the development of algorithms and statistical models to train computers on large amounts of data, allowing them to predict new situations and analyze them. This component has evolved into deep learning, which uses artificial neural networks with many layers of nonlinear processors to study data representation. Currently, AI complements the stages of early drug development: Target Identification and Validation, High Throughput Screening, Hit Identification, Assay Development and Screening, Hit-To-Lead, Lead Generation and Optimization, *In vivo* and *In vitro* Assays, Preclinical Studies.

AI has integrated into pharmacology, enabling more personalized medicine, improved drug dose efficacy, reduced drug side effects, accelerated drug research, and improved understanding of the genomic diversity of populations. Based on the analysis of large amounts of information, ML algorithms can detect patterns and trends that may not be obvious to human researchers. This can allow for the discovery of new biologically active compounds with minimal side effects in a much faster process than using classical protocols. The data sets for AI machine learning are taken from publicly available sources (STITCH (database of protein interaction

networks), DrugBank (drug and target information database), PubChem (database containing detailed information on chemical and biological activities)), from private research by pharmaceutical companies, from research by scientists in the field of pharmacology and medicinal chemistry, or from clinical trials and clinical cases.

However, the main problem with using AI is the lack of data for training. This factor arises for many reasons: ethical norms that do not allow sharing of patient data; protection of private expensive research by pharmaceutical giants; poor collaboration between the pharmaceutical business and scientists; the presence of noise in the data that reduces the positive impact of such AI training. Among the AIs already created for drug development are the following: Deep-Screening, DeltaVina, ChemAI, PharmAI, Insilico Medicine – they are used for virtual screening, estimation of energy for small molecule binding, lead compound optimization, molecular property prediction, and target identification. A typical process for AI-based ADMET (absorption, distribution, metabolism, excretion and toxicity) assessment involves developing AI methods to predict ADMET using pharmacokinetic data on concentration over time or ADMET parameters, integrating them into physiologically-based pharmacokinetic models. The most popular examples are ADMET-AI and ADMET Predictor®. In addition to speeding up and reducing the cost of drug development, AI shows more successful clinical trial results, with Phase I trials for AI-generated drugs showing 80-90% success rates, which is higher than historical rates. However, Phase II of trials shows an average success rate of 40%, but often developments are terminated due to business decisions that are not related to the results of the study.

The use of AI in drug development is relatively new, and there is a lack of clear regulatory guidance on how AI-developed drugs should be evaluated and approved. This uncertainty may slow the adoption of AI technologies in drug development. Despite the vast capabilities of AI, most AI-developed medicines do not undergo clinical trials. Among the successfully launched products, there is an AI-generated molecule EXS21546 that first passed clinical trials from Exscientia. This molecule is designed to cure neoplasms.

**Conclusion.** Artificial intelligence has become a crucial tool in drug development, with the potential to revolutionize target identification and accelerate the discovery of new compounds. However, challenges such as limited data availability, privacy concerns, and regulatory standards hinder its full implementation. Despite the current obstacles, AI has significant potential for use in early preclinical and clinical trials. Addressing data availability and regulatory requirements is crucial to maximising its effectiveness and impact.

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# ADVANCES IN QUANTUM COMPUTING: THE NEW AGE OF SUPERCOMPUTING

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**Keywords:** quantum computing, superposition, quantum supremacy, cryptography.

**Introduction.** Quantum computing is poised to revolutionize fields ranging from cryptography to drug discovery. Unlike classical computers, which process bits as either 0s or 1s, quantum computers use qubits that can exist in multiple states simultaneously, thanks to the principles of superposition and entanglement. This capability allows quantum computers to solve certain complex problems exponentially faster than classical computers, potentially unlocking solutions to issues previously deemed intractable. However, the transformative potential of quantum computing also introduces significant challenges and uncertainties, making it a focal point of intense research and substantial investment from both governments and the private sector.

**Objectives.** This study aims to explore the advancements and impact of quantum computing over the next decade. Specifically, we will assess the current state of the technology, analyze the potential for quantum supremacy, evaluate the implications for data security, and examine applications in fields like healthcare and finance.

**Methods.** Our approach includes a comprehensive literature review of recent advancements, analysis of case studies from leading tech companies, and evaluation of expert opinions from published sources. We will use comparative analysis to highlight breakthroughs and scenario modeling to predict future trends, focusing on error correction, qubit stability, and potential real-world applications.

**Results.** Our findings reveal a rapidly evolving field with both exciting possibilities and formidable challenges. Quantum computing has made significant strides in recent years, particularly through the demonstration of quantum supremacy. In 2019, Google's Sycamore processor successfully solved a specific computational problem in 200 seconds– a task that would take the world's fastest classical supercomputer, Summit, approximately 10,000 years to complete (Arute et al., 2019). This milestone was hailed as a critical achievement, though it also sparked debates about the real-world applicability of the problem solved. Despite this progress, major technical challenges remain. Error rates in qubit operations are still high, and quantum computers are highly sensitive to environmental disturbances, causing decoherence (Preskill, 2012). Researchers are developing advanced error-correcting algorithms and experimenting with different qubit architectures, such as superconducting qubits and trapped ions, to improve system stability (Devoret & Schoelkopf, 2013).

The quest for achieving practical quantum advantage– where quantum computing delivers tangible benefits for real-world applications– continues to be a major focus. For instance, optimization problems in logistics and supply chains could be dramatically improved using quantum algorithms, reducing costs and increasing efficiency (Lizaso et al., 2019). In the field of pharmaceuticals, quantum simulations could accelerate the discovery of new drugs by accurately modeling complex molecular interactions, a task classical computers struggle with due to exponential computational demands (Bauer et al., 2020). Moreover, advancements in quantum algorithms like Grover's and Shor's have profound implications for data security. Shor's algorithm, in particular, can efficiently factor large numbers, threatening the RSA encryption that underpins most of today's internet security (Shor, 1997). As a result, there is a pressing need to develop and implement quantum-resistant cryptographic methods to safeguard sensitive information (Apon et al., 2019).

Quantum computing's potential impact on data security is one of its most significant and urgent considerations. If powerful quantum computers become operational, they could render much of the current encryption infrastructure obsolete. Governments and research institutions worldwide are investing heavily in quantum key distribution (QKD) and post-quantum cryptography to prepare for this eventuality. QKD, for instance, uses the principles of quantum mechanics to create secure communication channels that cannot be intercepted without detection, offering a promising solution to future cybersecurity threats (Lo et al., 2020).

Looking forward, quantum computing could have a transformative effect on industries beyond just cryptography. In finance, quantum algorithms are expected to revolutionize risk analysis, optimize investment portfolios, and speed up transaction processes. In healthcare, quantum-based simulations could personalize medicine by modeling how drugs interact with specific genetic profiles, potentially leading to more effective treatments. However, these applications will only become feasible if quantum computers can be scaled up while maintaining low error rates, a challenge that researchers are still striving to overcome.

**Conclusion.** Quantum computing holds the promise of reshaping entire industries through unprecedented computational power. The technology's ability to solve certain problems exponentially faster than classical computers could transform fields like cryptography, optimization, and drug discovery. However, this potential also comes with significant risks, particularly in terms of data security, as quantum algorithms threaten to break current encryption methods. Moreover, the high error rates and resource-intensive nature of quantum computing continue to be major obstacles. Nevertheless, the continued research and collaboration among scientists, industry leaders, and policymakers are crucial to harnessing quantum computing's benefits while mitigating its challenges. As we move closer to a future shaped by quantum technology, proactive measures must be taken to secure our digital infrastructure and maximize the positive impact of these groundbreaking innovations.

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## BLOCKCHAIN TECHNOLOGY BEYOND CRYPTOCURRENCY

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**Keywords:** blockchain technology, decentralization, transparency, security, non-financial applications.

**Introduction.** Blockchain technology, initially recognized for its use in cryptocurrency, has evolved to offer solutions beyond financial transactions. Its decentralized nature, security features, and transparency have paved the way for various innovative applications across multiple industries.

**Objectives.** The main task is to conduct research on the applications of blockchain technology beyond cryptocurrency. This includes how blockchain technology is revolutionizing supply chain management, voting systems, intellectual property rights, and other non-financial sectors.

**Methods.** This research employs a qualitative approach, including a comprehensive review of current literature on blockchain technology applications

in non-financial sectors. Data is collected from academic journals, industry reports, and blockchain-related articles.

**Results.** A blockchain is a distributed database which maintains a growing number of records, known as "blocks". These blocks are secured and cannot be tampered with or revised. They contain a timestamp as well as a secure link with a previous block.

In a research paper introducing the digital currency, Bitcoin's pseudonymous creator, Satoshi Nakamoto, referred to it as "a new electronic cash system that's fully peer-to-peer, with no trusted third party."

From greater user privacy and heightened security to lower processing fees and fewer errors, blockchain technology may very well see applications beyond cryptocurrency.

Some companies experimenting with blockchain include Walmart, Pfizer, AIG, Siemens, and Unilever, among others. For example, IBM has created its Food Trust blockchain to trace the journey that food products take to get to their locations (IBM. "IBM Food Trust). This would allow it to verify the authenticity of not only their products but also common labels such as "Organic," "Local," and "Fair Trade."

The study of blockchain-based e-voting systems reveals significant advantages in terms of security, transparency, and voter trust. By integrating cryptographic techniques and decentralized ledger technology, these systems can mitigate common electoral vulnerabilities such as fraud and tampering. Despite the challenges of scalability, regulatory compliance, and user adoption, the promising results suggest that with further development and refinement, blockchain technology could revolutionize the way elections are conducted, ensuring more secure and transparent democratic processes. (Blockchain-Based E-Voting Systems)

The fact that in the internet era, anyone can download pre-created content and state it as their own makes exercising copyright very challenging.

To solve this, the Bitcoin protocol can be used for assessing IP ownership through three elements of ownership. First, there are the assets' antecedents. Considering that blockchain offers an immutable record, it is used to list the "original" products that can be differentiated from counterfeit. The second is using blockchain to create

IP ownership certificates. The last is using blockchain to dispute a later claim. This can be achieved by showing the earlier claim's timestamp (Importance of Blockchain Intellectual Property Protection).

In addition to the previously mentioned applications, blockchain is being explored in the energy sector for peer-to-peer energy trading, where consumers can buy and sell excess energy directly using blockchain's secure and transparent framework. In the legal industry, blockchain is utilized for creating smart contracts that automatically enforce and execute terms based on predefined conditions, reducing the need for intermediaries and minimizing disputes. Furthermore, in education, blockchain can be used to issue and verify digital diplomas and certificates, ensuring authenticity and preventing fraud.

**Conclusion.** To sum up, blockchain technology has been one of the few significant innovations to enter our every-day life without us noticing. Not only does it help to make financial operations, but also to store crucial for our health, education and domestic life information.

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## THE MOST SUCCESSFUL CORPORATE STYLES IN THE WORLD: THE SECRETS OF THEIR SUCCESS

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**Keywords:** a corporate brand, a consumer, consumer behavior, corporate style.

**Introduction.** For centuries, a strong corporate brand has been a key factor in business success. Even with the emergence of new marketing strategies and fiercely competitive markets, established brands continue to thrive. By simplifying decision-making, reducing risk, and enhancing satisfaction, brands provide value to consumers. This study examines the critical elements contributing to successful corporate branding, focusing on global leaders like ZARA, Apple, Amazon, and Meta Platforms. These successful brands navigate complex branding landscapes and adapt to evolving trends, ensuring their long-term survival.

**Objectives.** This research aims to explore the key factors that contribute to successful corporate branding by analyzing consumer engagement, product design, social responsibility, and branding strategies across both traditional and emerging markets. Our objective is to highlight the strategic approaches employed by these leading companies and the ways in which they maintain a competitive edge, consistently capturing consumer interest in the global market (The Marketing Society, 2009). Furthermore, this study seeks to understand how these brands leverage digital platforms, adapt to regional preferences, and innovate within product categories to sustain relevance in a rapidly evolving landscape, providing a framework for branding resilience and adaptability.

**Methods.** A qualitative approach is adopted to examine the branding strategies of leading global corporations. Through case studies of brands such as Zara, Apple,

and Amazon, we analyze trends in consumer behavior, brand design, and adaptability to market demands. Additional emphasis is placed on social responsibility and brand architecture, assessing how these elements drive long-term success and customer loyalty. By reviewing literature and corporate reports, we aim to provide a comprehensive understanding of the strategies that enable these brands to stand out in increasingly competitive markets.

**Results.** Companies like Zara, Apple, Amazon, and Meta Platforms share several core strategies that contribute to their success. For instance, Zara's ability to swiftly adapt to changing fashion trends while prioritizing a customer-centric model has helped it rise as a global fashion leader (Roll, 2021). Apple, through its continuous focus on innovative product design, cultivates a loyal customer base, reinforcing its ecosystem of products and services. Amazon's dominance in e-commerce is bolstered by its unyielding focus on customer satisfaction and diversification into new services. Similarly, Meta Platforms leverages network effects and data-driven strategies to maintain its prominent position as a social media giant (DISFOLD, 2024).

**Review.** Our analysis identifies consumer engagement as one of the fundamental components of effective branding. Leading brands increasingly employ participation marketing to foster consumer involvement at multiple levels, ensuring that customer voices are incorporated into brand narratives. Product design also emerges as a critical factor, with companies like Apple using design not only to appeal to consumers aesthetically but to create emotional connections. Effective branding also entails the integration of both traditional and non-traditional communication channels, allowing brands to reach a wider audience while sustaining relevancy. Furthermore, social responsibility has become a pivotal aspect of brand identity. Amazon and Meta Platforms, for example, build consumer trust through ethical practices and contributions to societal welfare, reinforcing their brand image through responsible initiatives (Trombley, 2023).

**Conclusion.** The success of corporate branding relies on a balanced approach encompassing creativity, strategy, and a nuanced understanding of consumer behavior. Companies such as Zara, Apple, Amazon, and Meta Platforms demonstrate an exceptional ability to adapt to market shifts while sustaining a strong brand presence. Their ongoing success stems from a customer-focused philosophy, dedication to innovative design, commitment to social responsibility, and strategic expansion into global markets. To ensure continued relevance in an ever-evolving landscape, businesses must prioritize innovation, uphold consumer trust, and align their brand values with global societal expectations. By also investing in community initiatives, embracing sustainable practices, and keeping pace with technological advancements, brands can enhance their credibility. This balanced approach can help brands not only maintain market dominance but also reinforce long-term loyalty and trust with consumers, securing a lasting impact across industries.

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## QUANTUM COMPUTING REVIEW

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**Keywords:** quantum computation, technological advancement, artificial intelligence, algorithms, material science, quantum chemistry.

**Introduction.** Quantum computation is the most outstanding technological increment in the century. Within the decade, one may expect quantum computation to change predominantly from an experimental and theoretical discipline to one that has many valuable applications. This extended abstract contemplates the impact of quantum computing over the next decade. Applications are found in cryptography, pharmaceuticals, AI, material science, amongst others.

**Objectives.** Assess Quantum Computing's Current Progress: Analyze the current state of quantum technologies, including advancements and challenges in quantum technology and error correction.

Identify Key Future Developments: Explore anticipated advancements in quantum hardware, software, and hybrid systems over the next decade.

Assess potential applications: Explore applications in critical fields, focusing on how quantum computing can impact them.

Understand the broader implications: Consider how quantum computing could change industries and technologies in the coming years.

**Current Status of Quantum Computing.** Currently, quantum computing is in a very nascent technology. The various high-technology companies are pursuing their quantum software and hardware development. Among them, the achievement of essential phases relates to Siemens Quantum Technology, Google Sycamore, and other projects about superconducting qubits. Unlike classical bits, these quantum computers are based on qubits that can support two conditions simultaneously. Thus, it allows the machine to treat such information. Problems of error correction, coherence of qubits, and scaling of systems remain crippling in stating that large-scale quantum advantage is still a figment of imagination.

Crisis notwithstanding, appreciable steps have been recorded of late; the scope of the study has progressed from the fabrication of test beds to showing evidence of initial quantum superiority. For instance, in 2019, Google processors hardware demonstrated claimed quantum superiority over the fastest classical computer that existed at the time. However controversial, this demonstration focused on the arena, which is the prospect of quantum computation being vastly more efficient than classical computation (Fowler et al., 2012; Preskill, 2018).

**Major Technological Changes Anticipated Within the Next Ten Years.** The next decade will see significant developments in hardware, software, and the design of algorithms for quantum computing. One of the significant challenges faced in this arena is the resolution of quantum error correction. The susceptibility of quantum states to noise and decoherence makes reliable computation very difficult. This would, in turn, be overcome by the advancement in fault-tolerance models of quantum computing, such as surface codes and topological qubits. Companies such as Microsoft are investigating topological qubits, which are much more stable than conventional qubits.

Meanwhile, the development of quantum software and algorithms will have to go hand in hand with uncovering the real potential that quantum computing possesses. Quantum-inspired algorithms will be applied to make optimization and cryptography more efficient and to solve machine-learning problems. We also foresee hybrid models that merge classical and quantum architecture: quantum processors solving some tasks while the more mundane ones fall to a classical computer.

Regarding qubit technologies, current methods, including superconducting qubits and trapped ions, are expected to continue improving scalability and coherence times. Nevertheless, novel approaches such as photonic and silicon-based qubits may push these techniques aside and go for more robust, scalable, and productive quantum computers (Fowler et al., 2012; Preskill, 2018).

**Quantum Computing Applications. Cryptography and Security.** One of the most salivated applications of quantum computing is cryptography. Classically, most encryption algorithms rely on the hardness of factoring large numbers, a process which, even with a classical computer, would take millions of years. In contrast, Shor's quantum algorithm factors numbers exponentially faster, and in doing so breaks most current encryption systems. Hence, there is a need to develop post-quantum cryptography-innovative cryptographic techniques that are immune to quantum-based attacks. Quantum-resistant encryption will remain paramount for securing data integrity for industries like finance, communication, and government for the next decade (Fowler et al., 2012; Preskill, 2018).

**Pharmaceutical Development and Medical Care.** With quantum chemistry, for instance, quantum computing may revolutionize the drug development process by its capability to simulate complex molecular interactions beyond the capability of classical computers. The ability of such advanced systems to identify new candidates more precisely and predict their effects allows these investigators to carry out their work. For example, quantum simulations may enable the finding of new antibiotics,

cancer treatments, and novel materials suitable for biomedical applications. In the coming decade, it is expected that quantum computing will play an essential role in personalized medicine and give out drug development tailored to a genetic profile (Preskill, 2018).

**Artificial Intelligence and Machine Learning.** Quantum computing is supposed to enhance AI and ML. Quantum algorithms, like QSVM and the HHL algorithm, allow exponential acceleration in training AI models. It is envisioned that quantum-enhanced optimization will lead to breakthroughs in deep learning, natural language processing, and reinforcement learning due to efficiency in data handling, quicker learning, and increased precision in predictions applied to finance and healthcare (Biamonte et al., 2017; Fowler et al., 2012; Preskill, 2018).

**Materials Science.** Atom-scale simulations of material properties using quantum computers can have a monumental impact on the research field of material science. Because of the substantial computer resources required, conventional computers cannot accurately simulate the dynamics of complex molecules and materials. Quantum computers can, however, correctly simulate quantum systems, enabling discoveries of materials with unique properties. All this could accelerate energy storage, superconductors, and nanotechnology that, in turn, will make much better batteries, robust materials, and a system that could harness energy effectively (Fowler et al., 2012).

**Conclusion.** In summary, the next decade will be essential for developing quantum computing. Quantum computing is expected to have a significant impact on many sectors. However, it should not be seen as an incremental step but as a revolution in how many industries-from cryptography to health sciences will change. Hence, further research and investment in this field becomes mandatory if humanity wants to move towards the next generation of computing technology.

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# SMART BEEKEEPING: DIGITAL TECHNOLOGIESTRANSFORMING TRADITIONAL PRACTICES

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**Keywords:** smart beekeeping, digital devices, digitalization, innovation, agriculture.

**Introduction.** This study examines the digital transformation of beekeeping and the integration of innovative technologies within the industry. The significance of this research lies in addressing the critical need for modernizing traditional beekeeping practices to enhance production efficiency, improve bee health monitoring systems, and optimize apiary management processes in response to global challenges.

**Objectives.** The main tasks are to analyze modern technological solutions in the field of beekeeping, evaluate the effectiveness of the implementation of digital technologies in beekeeping, identify the main challenges and limitations in the implementation of innovative solutions, and investigate the international experience in the digitalization of beekeeping.

**Methods.** general scientific methods of scientific knowledge, induction, deduction, analysis, synthesis and systematization; graphic method – to present the results of the study.

**Results.** The modern development of technologies and equipment for beekeeping is primarily led by the United States and Germany, where advanced solutions for hive monitoring and product quality control are being engineered. Concurrently, China has established itself as a key player by mass-producing affordable equipment, while Israel is pioneering AI implementation and sophisticated bee health monitoring systems. An important contribution to the development of the industry is also made by Ukraine, known for its innovative hive designs and organic beekeeping practices; Australia, which introduced the groundbreaking automated honey collection system (Flow Hive), and Japan with its robotic beehive care systems.

Cooperation and exchange of experience between beekeepers actively takes place at the International Federation of Beekeepers' Associations, as well as at regional conferences. As an example, in July 2022, the winner of the European Bee Award 2022 in the nomination "Innovative and technological solutions" was the project "IT Beekeeping by AmoHive", developed with the participation of Ukrainian and Polish colleagues. AmoHive created a 3D model of a hive that monitors insect activity and sends the information to a server. The technology has already been implemented in Poland, Ukraine and Canada (Data Science in beekeeping – Smart Hives, Network and IoT Solutions, 2022).

By the way, at the ApiExpo-2023 international congress, Ukrainians once again distinguished themselves and received a bronze award for the industrial technology of obtaining bee bread (Rubryka, 2023).

Innovations in the beekeeping industry (Picture 1) are aimed at stabilizing food sources for bees and changing the way apiaries are managed. The main technologies include:

*Picture 1. Examples of digital devices in beekeeping: digital scales, anti-theft devices, temperature sensors, bee counters (Aspexit, 2022).*

ApisProtect. ApisProtect manufactures in-hive sensors that are placed under the roof of the hive and measure humidity, temperature, sounds and movement in the colony. The sensor sends data from the hive to ApisProtect's head office in Ireland, where it is analyzed and sent back to the beekeepers. The company currently works with 20 beekeepers in the US, Ireland, UK and South Africa, which together cover around 20 million bees.

Pollenity. Pollenity, founded in Bulgaria, is working on technologies to improve bee health. Her latest development is the Beebot, a smart sensor device that monitors the temperature, humidity level and buzzing frequency of bees. About 1,000 hives have already been equipped with this technology.

BeeWeb. BeeWeb is an online platform that uses an algorithm designed to optimize the placement of beehives to pollinate large areas. The main idea is to inform beekeepers where the most nutritious piles are located. This information allows them to set up hives nearby and provide a sustainable food source for their bees.

Varroa. Thermosolar Hive uses solar energy to heat the interior of the hive to 40°C for 150 minutes, killing any varroa mites in the hive without harming the bees. The treatment is repeated after 10 days.

To combat the varroa mite, beekeepers also use video systems with mirrors and special lighting that help detect parasites on the bees' bodies, and mobile applications and special gray underlays for the hive are being developed for counting mites on the frames.

Hornet-Sentry-Gun. Bees are also threatened by certain types of hornets (for example, the Asian hornet), which literally eat bees. Sound sensors that recognize the

required frequency of vibration, as well as laser systems for direct destruction are used to detect them (Ecrotek Beekeeping Supplies Australia, 2021).

Econect. The project offers a variety of educational games for bees: automated mazes where bees are marked with barcodes; passing tests using smell and visual stimuli. In addition, scientists use the developed devices to study the effect of pesticides, heavy metals and the quality of food on the cognitive abilities of insects.

GPS and tilt sensors. The simplest modern security system to protect against theft of beehives is GPS trackers, which warn the owner if the beehive moves far from the apiary, or tilt sensors, which signal a change in the position of the beehive.

The choice of technologies in beekeeping is really wide, but the economic model of introducing digital sensors causes a lot of debate. As some experts consider them too expensive to install on every hive, alternative approaches should be considered. A possible solution is to combine more expensive sensors with cheaper ones.

The digital beekeeping sector suffers from unnecessary discoveries and imperfect technological solutions. Many digital devices quickly disappear due to difficulties in production and implementation. Some companies end support for their products, leaving users unable to purchase or maintain equipment.

In response, many enthusiastic beekeepers create their own prototype devices. However, even the data obtained in this way are rarely useful. In most cases, the data collection time ranges from a few minutes to several days. Then, similar studies of the life of bees should include data for at least a whole year, because the behavior of the insect in winter and summer is radically different.

An important aspect of the introduction of digital technologies in beekeeping is their impact on the bees themselves. Most sensors are installed directly in the hive. Although bees are adapting to this intervention to some extent, the question of the impact of digital devices remains open (Aspexit, 2022).

**Conclusion.** Beekeeping is actively transforming in the era of digitalization, with the development and implementation of innovative technologies for monitoring hives, controlling bee health and optimizing honey production. Although digital technologies offer significant benefits to beekeeping, their implementation comes with challenges, including high cost, the need for long-term studies, and the need to assess the impact of these technologies on the bees themselves.

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## FUTURE TRENDS IN SCIENCE AND TECHNOLOGY: EVOLVING INNOVATIONS FOR THE NEXT DECADE

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**Keywords:** Artificial Intelligence, cybersecurity, urban planning, biotechnology.

**Introduction.** In an era of rapid technological progress, the coming decade promises profound changes across various fields – from artificial intelligence (AI) and biotechnology to automation and cybersecurity. These innovations hold the potential to transform industries, impact social structures, and challenge ethical norms. AI and data will become key drivers of this next phase of development, influencing decision-making processes and resource management. This progress requires a nuanced understanding of potential outcomes, both for economic growth and for social equity and ethical standards.

**Objectives.** To explore technological innovations and the anticipated impact of artificial intelligence, automation, and biotechnology on economic and labor structures. To analyze the role of data as a fundamental asset in innovation, focusing on issues of ownership and governance. To provide insights on integrating ethical considerations into technological development to ensure a sustainable and inclusive future.

**Methods.** The research uses an interdisciplinary approach, synthesizing insights from existing literature on future technological trends. The methodology includes qualitative content analysis to identify key themes related to the impact of technologies on economic and social structures. The analysis is based on historical data, projections from technology think tanks, and qualitative insights, creating an integrated view of possible future scenarios. Comparative analysis across fields, such as workforce automation and biotechnology in healthcare, provides a balanced examination of the opportunities and risks these technologies present.

**Results.** As we enter a new decade, the rapid advancement of technology promises to reshape industries and transform society in unprecedented ways. Innovations in AI, biotechnology, cybersecurity, and urban planning will bring significant changes to both economic structures and daily life (Brynjolfsson & McAfee, 2014).

Alec Ross (2016), in his book The Industries of the Future, predicts that AI will become a powerful tool capable of "freeing human labor for tasks that are more inherently human, such as creativity, empathy, and strategic decision-making" (p. 113). Integrating AI into everyday life, particularly through personal assistants and advanced customer service interfaces, will transform the labor market, allowing people to focus on more complex and sophisticated tasks. This aligns with Harari's (2018) warning in 21 Lessons for the 21st Century, where he cautions that "as soon as algorithms displace humans from the labor market, wealth and power could concentrate in the hands of a small elite" (p. 145). As AI increasingly assumes roles previously filled by humans, societies must be prepared for potential socioeconomic imbalances and address the fair distribution of the benefits that technology brings (Mazzucato, 2018).

Beyond labor market changes, the innovative use of data will play a defining role in the new economy. AI's ability to analyze vast amounts of data will enable personalized services in sectors like healthcare and retail, giving businesses the ability to offer customized experiences while providing consumers with data-driven recommendations. However, data ownership and ethical use demand careful oversight. As data becomes a source of both power and responsibility, transparent regulatory mechanisms are essential to ensure its potential is accessible and beneficial to society as a whole.

Alongside these AI-driven changes, urban spaces are also poised for technological transformation. So-called "smart cities" are one of the main trends enabling urban areas to become more efficient and sustainable through interconnected sensor networks, devices, and infrastructure. The smart city model, incorporating adaptive transportation systems and optimized waste management, will reduce environmental impact and enhance the quality of life for city dwellers.

Biotechnology and genetic engineering are other rapidly expanding fields, with scientific advancements allowing humans to "alter the fabric of our biology," as Ross describes it (Ross, 2016, p. 201). Technologies like bioprinting and gene editing open new horizons for addressing health issues, enabling personalized medicine and treating diseases at the genetic level. However, such levels of biological intervention raise deep ethical questions. As we redefine the nature of the human body, questions of identity, free will, and the sanctity of life must take center stage in biotechnology regulation.

The growth of society's digital interdependence introduces another significant area of concern: cybersecurity. With digital solutions playing a growing role in governments and corporations, issues of privacy, personal freedom, and control of technological corporations over digital security arise. Transparency, regulation, and a commitment to democratic values are key to ensuring cybersecurity protects rather than exploits the citizens it is meant to safeguard.

**Conclusion.** This research underscores the dual nature of technological progress: its immense potential for societal and economic growth alongside ethical and regulatory challenges. As the world embraces innovations in AI, automation,

biotechnology, and cybersecurity, it is crucial to prioritize human-centered values and effective regulation. Balancing these values with technological advancement will be key to building a future that benefits all participants.

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## TRENDS AND INNOVATIONS IN THE PRINTING INDUSTRY FOR 2024

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**Keywords:** printing industry, digital printing, sustainability, artificial intelligence, personalization, eCommerce integration, data analytics, 3D printing, smart factory technologies.

**Introduction.** The printing industry is undergoing a remarkable transformation in 2024, driven by rapid technological advancements, changing consumer preferences, and a growing emphasis on sustainability (GelatoConnect, 2024). Despite the challenges posed by the COVID-19 pandemic and the rise of digital media, the industry is experiencing steady growth as printers adapt to meet the evolving needs of consumers and businesses. Innovations such as print-on-demand, eco-friendly solutions, and comprehensive eCommerce integration are reshaping traditional practices, making it crucial for stakeholders to stay informed about these trends. Knowing about these changes is key for businesses that want to stay relevant and competitive in a market that's moving so quickly.

In addition, companies that adapt to these changes have a competitive advantage in working faster, more efficiently, and more environmentally friendly. These trends are shaping the future of the industry and pushing it towards more innovative and flexible solutions. As the industry continues to evolve, companies must stay ahead of the curve to meet the ever-growing demands of both consumers and the market.

**Objectives.** This research aims to identify and analyze the key trends and emerging technologies reshaping the printing industry in 2024, including:

1. To explore how print-on-demand meets customer needs for speed and customization.

2. Why eco-friendly printing is vital for environmentally conscious consumers.

3. To explore how artificial intelligence (AI) and machine learning (ML) are enhancing operational efficiencies and personalization in print production.

4. To analyze the impact of smart factory technologies and digital printing on production processes and market competitiveness.

5. To investigate tHow e-commerce integration and data analytics are helping businesses improve operations.

**Methods.** This study uses a combination of qualitative and quantitative data to provide a comprehensive overview of trends affecting the printing industry. Data was collected through literature reviews, industry reports, and interviews with key stakeholders, including business owners and technology providers in the printing sector. The study sampled a range of printing companies of varying sizes and specializations, allowing for a variety of perspectives on the adoption and impact of new technologies. Surveys, structured interviews, and data analysis were used to identify patterns and insights related to industry trends.

This approach ensured that the findings spanned different sectors of the printing industry. By incorporating input from both industry leaders and smaller companies, the study provides a more accurate and holistic view of the current and future state of the printing industry.

**Results.** The study reveals some interesting trends in the printing industry in 2024. First, print-on-demand services are gaining popularity due to their ability to provide fast turnaround times and a personalized approach. This attitude not only satisfies consumers' demand for speed, but also drives innovation and growth in the industry. To further strengthen this trend, companies are encouraged to implement AI-based tools that identify new preferences and adapt printing offerings, ensuring increased productivity.

Second, green printing is more than just a trend; it is a core part of business. It is becoming an essential aspect of business operations. Using green materials and methods is essential to reduce environmental impact and attract environmentally conscious customers. Innovative solutions such as the use of bio-inks and the search for alternative materials such as mushroom-based packaging materials can help print shops stand out in a crowded market. Working with suppliers to create a recycling system for printed materials can further increase the interest of environmentally conscious consumers.

Third, the integration of AI technologies can revolutionize print production. Automation streamlines workflows, while data-driven personalization improves customer engagement and brand loyalty. AI-powered quality optimization delivers superior print results, while predictive maintenance minimizes equipment downtime. Implementing AI-powered tools can help businesses optimize product management and reduce waste, which will also have an impact on the environmental footprint. This will lead to more efficient use of resources, less waste, and overall increased profitability.

Additionally, digital printing remains a core part of the industry, offering speed, cost-effectiveness, and the ability to create high-quality products tailored to

customer needs. To maximize the potential of digital printing, companies can invest in hybrid printing technologies that combine traditional and digital methods, providing greater flexibility and a wider range of applications. This combination allows companies to meet diverse customer needs while optimizing production processes. The adaptability of digital printing makes it an essential technological component for companies seeking to stay ahead in a competitive market.

Finally, an integrated approach helps companies to explore, expand their capabilities in different areas, help cover a larger market share, and improve customer interactions. Using different platforms can streamline the integration process, provide greater scalability, and make it easier to update product offerings. By analyzing data, companies can track performance indicators and market trends. This allows them to make more informed decisions and optimize processes and resources. As everything around us continues to evolve by the second, printing companies that want to stay relevant need to effectively integrate these technologies. This will allow them to be better able to meet the growing demand for fast, personalized, and high-quality printed products.

**Conclusion.** In summary, the printing industry is poised for significant growth in 2024 (GelatoConnect, 2024). It is evolving, driven by technological advancements and changing customer preferences. The trends I have identified include: personalized printing, interest in eco-innovation, integration of artificial intelligence, and data analytics. All of these factors are critical for companies looking to thrive in this dynamic industry. Understanding and following these trends will not only improve efficiency and productivity, but will also help companies become leaders in their field. By staying on top of current events, interested printing companies can seize the opportunities presented to grow and adapt in a rapidly evolving market.

As the industry continues to evolve, companies that adapt to these changes will be well-positioned to begin their growth and continue to grow successfully to become leaders in their industry (GelatoConnect, 2024) The future of the printing industry in 2024 is bright, with opportunities for those willing to adapt and stay ahead.

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# CRYPTOGRAPHIC E-VOTING PROTOCOLS. USING RSA FOR ENCRYPTION AND DIGITAL SIGNING. E-VOTING PROTOCOL WITH MIXING

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**Keywords:** e-voting, cryptographic protocol, RSA, encryption, decryption, digital signature.

**Introduction.** Cryptographic e-voting protocols, which is a branch of cryptography, is still actively developing but has already been tested in practice in many countries, such as the United Kingdom, the United States, Australia, Austria, Belgium, Canada, France, Spain, Estonia, and others.

**Objectives.** In this abstract we are going to overview the basis of this direction.

**Methods. Protocol** is a sequence of actions between two or more parties designed to solve specific tasks. The protocol is executed from start to finish in a particular order, with each action performed only after the previous one is completed. At least two people are required for its implementation, and the protocol's execution should conclude with specific results. Each participant in the protocol must know the sequence of actions and not disrupt the order. The protocol should be designed in such a way that it cannot be misunderstood and should account for all possible situations that may arise during its implementation.

**Cryptographic protocol** is a protocol that uses cryptography, incorporating a certain cryptographic algorithm. The participants of the protocol may want to share a secret with each other, jointly generate a random sequence of symbols, verify each other's authenticity, or sign a contract simultaneously. The purpose of using cryptography in protocols is to prevent or detect fraud or betrayal. The main rule of such protocols is that it is impossible to do or learn more than what is defined in the protocol (Benefits and risks of e-voting and on-line voting, 2020).

**Cryptographic e-voting protocols** are data exchange protocols designed to implement secure and secret electronic voting over the internet using computers. To ensure the correctness, reliability, and confidentiality of such elections, protocols with proven security are used, which rely on verified **cryptographic encryption systems** and **digital signatures (DS)** (Benefits and risks of e-voting and on-line voting, 2020).

Participants can securely exchange their messages only by **encrypting** them. To do this, participants must first select an **encryption system** and **choose keys**. Then, they **encrypt** their messages, send them to each other, and **decrypt** them upon receipt.

To verify the authenticity of a document or to agree to it, **DS** are used. They provide the following properties: the signature is authentic, the signature cannot be

forged, the signature cannot be reused, the signed document cannot be altered, and the signature cannot be repudiated.

An **ideal protoco**l should meet at least the following properties:

(1) Only those who have the right to vote can do so.
(2) Each person can vote no more than once.
(3) No one can find out who a specific voter voted for.
(4) No one can vote on behalf of someone else.
(5) No one can secretly alter someone's vote.
(6) Each voter can verify that their vote is counted in the final results.

**RSA** is a public-key cryptographic algorithm based on the difficulty of solving the factorization problem of large numbers. This algorithm can be used for both encryption and digital signatures (GeeksforGeeks, 2017). The **RSA** digital signature algorithm works as follows:

1. **Key Generation**
2. **Forming the Digital Signature:**

2.1. Form the message.
2.2. Hash the message.
2.3. Create the digital signature using the private key.
2.4. Send the message with the digital signature to the recipient.

3. **Verifying the Digital Signature:**

3.1. Hash the received message.
3.2. Extract the hash from the digital signature.
3.3. Compare the two hashes (they should match).

**Key Generation Procedure:**

– Choose prime numbers $p$ and $q$.
– Calculate their product: $n = p \cdot q$
– Calculate Euler's totient function: $\phi(n) = (p-1)(q-1)$
– Choose an odd number e, which must be coprime with $\phi(n)$and such that $0 < e < \phi(n)$
– Choose a number d such that $(e \cdot d) mod\ \phi(n) = 1$ (can be computed using the extended **Euclidean algorithm**).
– The numbers $e$ and $d$ are the RSA keys.
– The pair $(e, n)$ is the public key, and $(d, n)$ is the private key.

To form a digital signature, the private key $(d, n)$ and the hash of the message H is used (GeeksforGeeks, 2021). The formula for creating the digital signature S is:

$S = H^d mod\ n$

Where:

– S is the digital signature.
– H is the hash of the message.
– d is the private key exponent.

– n is the modulus derived from the key generation process.

To verify the digital signature, the public key $(e,n)$, the digital signature S, and the hash of the message H are used (GeeksforGeeks, 2021). The formula for obtaining the hash from the digital signature is:

$H_c = S^e mod\ n$

Where:

– H′ is the hash obtained from the digital signature.
– S is the digital signature.
– e is the public key exponent.
– n is the modulus derived from the key generation process.

To complete the verification process, you would compare H′ with the original hash H. If they match, the signature is valid.

**E-voting protocol with mixing**

The **E-voting protocol with mixing**, also known as voting without a central election commission, means that there is no election commission involved, and voters conduct the voting independently, ensuring adherence to the protocol and preventing fraud.

1. **Voter Registration**: Individuals wishing to vote compile a list of voters.
2. **Ballot Creation and Encryption**: Voters create their ballots and encrypt them according to established rules. The process begins with encrypting the ballot using keys in descending order. Before each encryption, a random string is added to the resulting ciphertext. The second stage is also encrypted using keys in descending order.
3. **Submission of Encrypted Ballots**: All voters send their encrypted ballots to the first voter on the list.
4. **Decryption and Verification by the First Voter**: The first voter decrypts all the ballots using their key and removes the random strings. They ensure their ballot is present, shuffle all the ballots, and send them to the next voter in ascending order. Each subsequent voter repeats this process until reaching the last voter. After that, all ballots are sent back to the first voter on the list.
5. **Final Decryption and Signing**: The first voter decrypts all received ballots, verifies the presence of their own ballot, signs all the ballots, and sends them to all participants of the electronic voting. Each following voter on the list verifies the validity of the digital signature of the previous voter and repeats the same actions with the ballots. The last voter sends the signed results to all voters.
6. **Verification of Digital Signatures**: All voters check the digital signatures to ensure their ballots are present.
7. **Result Calculation**: Random strings are removed from all ballots, and the results are counted.

**Results.** The new branch of cryptography – cryptographic e-voting protocols is the way we can make e-voting safe and trustworthy.

**Conclusion.** Cryptographic protocols play a vital role in ensuring the security and confidentiality of electronic voting systems. The integration of cryptographic

algorithms, such as **RSA**, provides robust mechanisms for protecting sensitive information, validating the authenticity of voters, and ensuring the integrity of the voting process.

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## PREDICTION OF INDICATORS OF PROBLEMATIC INTERNET USE IN CHILDREN BASED ON PHYSICAL INDICATORS

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**Keywords:** childhood addiction, predictive analysis, mental health, problematic Internet usage, physiological data, machine learning.

**Introduction.** The amount and time of use of gadgets by children, including the Internet, is growing every day. This fact is of concern to most inhabitants of our planet, as it can lead to negative consequences for both the mental health of children and their physiological health. Problematic use of the Internet by children causes behavioral and psychological deviations, such as increased stress levels, decreased academic performance, and even social isolation. That is why, in our time, forecasting indicators indicating problematic use of the Internet by children is a very important area.

Recent studies have shown that some of the main indicators for monitoring problematic Internet use in children are physiological parameters such as sleep patterns, daytime activity, heart rate, etc.

**Objectives.** The main goal of such research is to analyze and identify key physical indicators that can directly indicate problematic Internet use in children and to develop models for timely prediction of possible problems and deviations. This means that it is important to understand the correlations between physiological data and their impact on Internet use patterns. In addition, it is important to consider that the models should have maximum accuracy and reliability, which leads to the conclusion about the importance of trying different methods and algorithms.

**Methods.** In the context of forecasting tasks, the main ones are machine learning methods, as well as neural networks, which can predict indicators of problematic Internet use by children with high accuracy and a minimum number of errors. To determine the best algorithm, it is necessary to go through several different

approaches, such as decision trees, random forests, support vector machines. Also, a possible good solution may be neural networks, deep learning architectures in order to identify complex non-linear correlations in the data that conventional algorithms may miss.

An integral part is data preprocessing, which includes normalization, filling in missing values, and removing anomalies. To assess the accuracy of the results, performance metrics such as accuracy, precision, recall, and F1-score, as well as cross-validation, are used.

Thus, the result of this stage is a model for effective prediction and early detection of problematic Internet use in children.

**Results.** The end result of such a study is a software product capable of comprehensively and reliably predicting indicators of problematic Internet use in children based on physiological parameters. The product should have an easy-to-understand and visually pleasing interface, real-time indicator monitoring, and a signal alert for timely intervention. The software should be able to integrate with wearable devices and be configured to correctly read the child's physical indicators.

**Conclusion.** To summarize all of the above, it is worth noting that the creation of a forecasting model, as well as a software product for the early detection of negative consequences of children's use of the Internet, is of great importance for the field of digital well-being and healthcare, since our children are our future.

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# IMPULSE HARDENING OF EXCAVATOR BUCKET TEETH

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**Keywords.** wear resistance, excavator bucket teeth, explosive-thermal treatment, combined technologies, durability, structure.

**Introduction.** The mining and metallurgical complex of Ukraine (MMC) plays a key role in the national economy, contributing to approximately one-third of total industrial production and around 40% of foreign currency earnings from exports. One way to enhance the durability of mining equipment parts is through surface hardening methods that utilize concentrated energy flows (explosions).

Currently, in the mining industry, leading experts worldwide are actively working to improve equipment reliability and lifespan. Manufacturers are increasingly focusing on extending the lifespan of heavily worn components, such as excavator buckets, teeth, and crowns. Key priorities include reducing the costs of purchasing new parts and enhancing the operational reliability of main structural elements.

In this context, improving the wear resistance of mining equipment components is a highly relevant topic, as the costs of producing spare parts are comparable to those for manufacturing new equipment elements. To strengthen components like excavator bucket teeth, liners, crushers, rod mills, and other equipment, methods involving plastic deformation hardening using explosive energy are widely applied. An analysis of the current state and prospects for developing hardening technologies has shown that research in explosive hardening is actively conducted in leading countries such as the United Kingdom, the United States, Japan, and Ukraine (Drahobetskyi, Shapoval, Shchepetov et al., 2017).

**Objective** is to develop and investigate the methods to enhance the strength of parts by using bulk explosives and combined technologies with additional alloying.

**Research methods.** During the development of the detonation hardening method for parts, research methods, including theoretical analysis and experimental validation of the hypotheses and obtained results were employed. The foundation of the theoretical research comprised the fundamental principles of continuum mechanics, plasticity theory, explosion physics, the method of joint solution of equilibrium and plasticity equations, and an approximate method for solving the dynamic problem of elastic and plastic deformation with numerical implementation of the differential equations of motion of a metal workpiece during the hardening operation and local plastic deformation by explosion (Dragobetskii, Shapoval, Mospan, Trotsko, Lotous, 2015).

Modern measurement techniques, involving advanced equipment and processing of experimental data, as well as a method for determining stresses in the plastic region based on hardness distribution were used.

**Main Part.** The process of extracting mineral resources – iron-containing ores (Poltava Mining and Processing Plant) – involves such operating conditions where the durability of excavator buckets and their working elements, such as teeth, is insufficient for stable operation (Fig. 1).

*Fig. 1 – Worn buckets of quarry excavators (Drahobetskyi, Shapoval, Shchepetov et al., 2017)*

During the initial attempts at hardening bucket teeth using explosions, plastic explosives were widely used in the mining industry. However, due to the rising cost of plastic explosives, researchers had to seek new methods for hardening working surfaces (Dragobetskii, Shapoval, Mospan, Trotsko, Lotous, 2015).

The second method for surface hardening of parts and assemblies through explosions involved the use of bulk explosives, which are significantly cheaper than plastic ones. Taking into account the already high cost of EKG-10 excavator bucket teeth, explosive hardening was applied to already worn teeth (Fig. 2).

*Fig. 2. Explosive loading of worn excavator bucket teeth (Drahobetskyi, Shapoval, Shchepetov et al., 2017)*

The loading was performed using 200 grams of ammonite 6ZhV and a detonating cord that was wrapped around the working surface of the tooth. No fractures or damage to the teeth were observed under such loading.

Following a similar scheme, a test batch of five teeth was hardened (Fig. 3), each tooth was hardened with a new method.

On two of the teeth, explosive alloying with titanium and vanadium powders was performed (Fig. 4).

Schemes for hardening the teeth in a fan arrangement were also tested (Fig. 5). One tooth was hardened on both sides (the central one), while the two outer teeth

were hardened on one side only, implementing the self-sharpening principle. The teeth hardened on one side experienced additional bending deformation. The explosion was initiated with three strands of detonating cord (Fig. 6) (Dragobetskii, Shapoval, Mospan, Trotsko, Lotous, 2015).

*Fig. 3. Vertical scheme for tooth hardening (Drahobetskyi, Shapoval, Shchepetov et al., 2017)*

*Fig. 4. Tooth tip with Ti+V powder (titanium + vanadium) (Drahobetskyi, Shapoval, Shchepetov et al., 2017)*

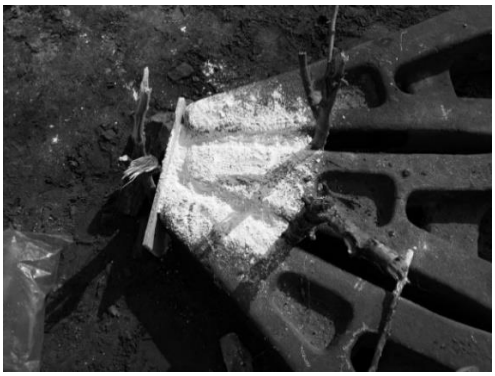

*Fig. 5. Hardening with teeth arranged in a fan (Drahobetskyi, Shapoval, Shchepetov et al., 2017)*

*Fig. 6. Hardening scheme with explosive wave (Drahobetskyi, Shapoval, Shchepetov et al., 2017)*

Two subsequent batches of teeth were hardened using the tested one-sided hardening schemes, which involved double explosive hardening. The teeth were positioned horizontally, and the surface to be hardened was coated with graphite lubricant for complete adhesion of the explosive. The explosive material, ammonite 6ZhV, was placed in a polyethylene bag and positioned on the hardening surface of the tooth. A detonating cord was then laid across the entire surface of the flat explosive material.

After the explosion, secondary hardening was performed using a running shock wave. The explosive used was welding ammonite AS-1 (50% ammonite 6ZhV + 50% ammonium nitrate) (Drahobetskyi, Shapoval, Shchepetov et al., 2017).

As in previous experiments, the explosion was initiated with three strands of detonating cord. After hardening, the teeth were installed on the EKG-10 excavator (Fig. 7). During the operation of the hardened teeth, changes in their shape were monitored (Fig. 8) depending on the amount of extracted ore (unoxidized iron

quartzites), and the amount of extracted ore was recorded. This amount was compared to average statistical data for the quarry's extraction complex (Kulinich, Shapoval, Drahobetskyi, Vorobiov, Shlyk, Pieieva, Arhat, Vorobiova, 2022).

*Fig. 7. Hardened teeth on the excavator bucket (Drahobetskyi, Shapoval, Shchepetov et al., 2017)*

*Fig. 8. Appearance of worn teeth (Drahobetskyi, Shapoval, Shchepetov et al., 2017)*

It is also worth noting the promising technologies for processing excavator bucket teeth and their potential applications.

One of the most promising and practically valuable areas of explosive processing is producing semi-finished products and parts from materials whose microstructure is refined to a level where grains have one or more linear dimensions in the range of hundreds or tens of nanometers. The implementation of explosive processing is carried out by applying a running shock wave and converging shock waves, ensuring intensive plastic deformation. The abnormally high strengthening of metals is associated with phase transitions at strong shock wave fronts (over 10 GPa). From the perspective of nanostructural changes in the alloy, the mechanism of abnormal strengthening is double lattice recrystallization, which results in additional distortion of structural defects – twins and dislocations (Dragobetskyi, Shapoval, Shchepetov, 2017).

Further improvement in the performance of 110G13L steel under impact-abrasive wear conditions can be achieved through additional alloying, which intensifies transformation, strengthens the solid solution, and produces fine carbide phases (Dragobetskii, Shapoval, Mospan, Trotsko, Lotous, 2015).

**Research results.** The analysis of existing methods for explosive hardening of mining equipment parts confirmed the feasibility of further development of this technology, which could eventually eliminate the possibility of brittle (fragmentary) failure of excavator bucket teeth material during one-sided hardening with bulk explosives (Dragobetskyi, Shapoval, Shchepetov, 2017).

A two-stage hardening method for excavator bucket teeth was developed, ensuring a 45–50% increase in wear resistance while maintaining existing productivity. This method has been implemented as a technological hardening scheme and is protected by Ukrainian Patent No. 88752 (Dragobetskyi, Shapoval, Shchepetov, 2017).

Methods for explosive hardening and alloying of excavator bucket teeth have been developed and tested, which involve additional loading with converging shock waves and titanium and vanadium particles (Dragobetskyi, Shapoval, Shchepetov, 2017).

**Conclusions.** Based on the conducted studies of explosive hardening of excavator working elements, it has been established that the use of a two-stage technology with bulk explosive materials is an effective method for enhancing the wear resistance of parts. This approach significantly improves the operational characteristics of bucket teeth, reducing the risk of failure and extending their service life by 2 to 2.5 times. Through the use of hardened bucket teeth, approximately 300,000 UAH was saved annually per unit of equipment.

The introduction of the new technological scheme for explosive hardening has been validated through numerous experimental studies and modelling processes, which correspond to mathematical calculations. This provides prospects for further development of hardening methods, enhancing the durability and efficiency of parts in the mining industry.

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## THE ROLE OF VERSION CONTROL IN MODERN SOFTWARE DEVELOPMENT: ENHANCING COLLABORATION AND CODE QUALITY

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**Keywords:** Version Control, Git, Software Development, Collaboration, Code Quality.

**Introduction.** Today, for any software developer in the project leads to achieve success, it is critical to maintain code quality and encourage efficient

collaboration among the developer. As team sizes grow, systems grow in complexity, and faster, more reliable releases are required by more people, version control systems (VCS) are an integral part of the development lifecycle. One of the most popular VCS is Git which adds a framework on distributed collaborative coding and allows developers to track, manage, and merge changes from many contributors. Using version control serves to improve collaboration, assure code quality, and sustain software practice at scale, answers this research.

Developers get them to revert changes, create extra branches, work in different branches simultaneously and see a clean trail of all the modifications applied to the code. The features allow for many of the benefits of a structured, accessible environment for team-oriented development, tracking and quality assurance. In this work we study how the use of VCS such as Git can give structured workflows, lower integration conflicts, and enhance code reviews to such an extent that version control is now as crucial in modern programming as it has been in producing proofs.

**Objectives.** In order to assess the effect of version control systems on collaborative development – specifically the ways in which VCS tools like Git assist teamwork, distributed and parallel development on the same codebase. We investigate how VCS plays a part in maintaining code quality – to study the effect of commit history, versioning, pull request process on improving code standards and avoiding errors. To investigate good practices of how to make the most of version control – finding out what approaches and workflows are best to use VCS at its best, including branch strategies, commit policies, and integration with continuous integration/continuous deployment (CI/CD) tools.

**Methods**. Based on a mixed methods approach, quantitative analysis and qualitative case studies and survey insights are used in this research. To collect the data, a sample of professional developers on different teams and projects that were experienced with Git or any other VCS was gathered. In these efforts, we focused on specific perceived benefits of VCS in real world projects in terms of the collaboration and code quality, and presented detailed case studies on how VCS, helped to achieve the project outcomes (Tsourakakis, & Gousios, 2018).

Moreover, essential Git features like branching, merging, and pull requests were also analyzed in terms of technical side. Compared were the various workflows such as Git Flow and GitHub flow to see the extent of increase it gives to project efficiency. VCS was assessed in terms of performance metrics of code integration times, number of merge conflicts, and bug detect rates in order to determine whether VCS improves productivity and code quality.

**Results.** The research revealed that version control greatly fosters team collaboration by facilitating the allowance of developers to conduct concurrent development on different branches. By isolating changes in this approach, and resolving conflicts by merging into the same codebase without direct interference, this branch-based approach minimizes conflicts and provides a seamless way for contributing to the same codebase. To bring Git to the example, Git's ability to branch and merge helps teams work on feature specific branches and then merge

those branches into main code base through pull requests. With frequent changes, this distributed model keeps bottlenecks at a minimum, so even with large teams on board, they can be efficient (Chacon, & Straub, 2014).

Besides, version control facilitates working on asynchronous workflows, which means that the members of the remote team can work each in their own time zone. GitHub and GitLab are VCS tools that give you an integrated environment for branch management, commits, pull requests and has a history which is well documented for all team members to access. The study uncovered those developers who had taken part in survey considered version control for the better because 85% agreed that it enhanced team communication and task division.

Our second big takeaway is that version control helps improve code quality by giving code reviewers structured processes and the ability to track changes. Structured code review – wherein each change is made via pull requests and then merged it in the main branch – can be implemented by VCS. By going through this process twice, we're making sure that all new code is to the team standards and that it's thoroughly vetted for errors before going live; fewer bugs and maintainable code are the results of this occurrence (Loeliger, & McCullough, 2012).

With version control's commit history, it creates an audit trail showing the developers what the progression of the codebase looks like and when specific changes were introduced (Rubin, 2012). According to the survey, 78% of developers said VCS enabled them to identify, and more effectively, resolve errors. On top of this, VCS allows easy rollbacks to past versions – you can simply go back to the previous version without affecting the stability of the main branch. This is particularly useful for large projects with multiple developers along with it allows for easy of debugging.

**Conclusion**. While involving lots of steps, the continuous delivery process becomes much faster with version control systems particularly Git that support team collaboration, improves code quality, and provides an organized and scalable workflow. Version control specifies for branching, merging and commit history tracking to minimize conflicts, hold accountable and maintain a production ready cleaned codebase for the developers. Working through best practices, such as structured workflows and integrating CI/CD, development teams can most fully enjoy the advantages of version control in small and large projects, returning reliable code and high quality. Version control will be a cornerstone for efficient, collaborative and of high-quality software development as software development progresses (Spinellis, 2012).

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## AI-DRIVEN SOLUTIONS FOR SMART CITY INFRASTRUCTURE: ENHANCING URBAN MOBILITY AND ENVIRONMENTAL SUSTAINABILITY

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**Keywords:** AI, smart cities, urban mobility, environmental sustainability, predictive analytics.

**Introduction.** As urban populations grow, cities face increasing challenges related to transportation efficiency, air quality, and resource management. AI-driven technologies can offer transformative solutions for developing smarter, more sustainable urban infrastructure. AI has the potential to significantly improve sustainability in urban infrastructure (Chang & Gupta, 2023; Nakamura & Zhou, 2022). However, these innovations must be approached with ethical consideration to ensure fairness and transparency in governance (Smith & Taylor, 2020). This study explores how predictive analytics and real-time data processing in AI systems can optimize urban mobility, reduce emissions, and improve resource allocation, ultimately enhancing residents' quality of life.

**Objectives.** Urban traffic congestion not only causes delays but also leads to increased emissions, energy consumption, and economic costs. This objective focuses on exploring how AI-driven predictive analytics, real-time data processing, and traffic pattern recognition can be utilized to create adaptive traffic management systems. Efficient public transportation is essential to reducing urban congestion and reliance on private vehicles. This objective explores how AI can enhance public transportation by improving operational efficiency, rider experience, and system reliability. Monitoring environmental conditions like air quality, noise levels, and greenhouse gas emissions is crucial for sustainable urban development. This objective examines how AI-driven environmental monitoring systems provide cities with real-time insights, enabling swift and effective responses to environmental issues. Given the sensitivity of data and the potential for unintended biases, implementing AI in public infrastructure must be done ethically and transparently. This objective outlines the development of a framework that ensures responsible AI practices, focusing on transparency, fairness, and community involvement.

**Methods.** This research employs a mixed-methods approach, combining quantitative analysis with qualitative case studies to comprehensively evaluate the impacts of AI on urban infrastructure. By integrating these methods, the study aims to gather both numerical insights and a contextual understanding of AI applications in smart cities. The quantitative component involves statistical analysis of datasets from urban traffic, public transportation, and environmental monitoring systems across various cities. The qualitative component includes in-depth case studies of selected smart cities that are currently implementing AI solutions for traffic management, public transportation, and environmental monitoring. These case studies provide a nuanced understanding of implementation challenges, ethical considerations, and public perceptions of AI in infrastructure.

The study analyzes data from a representative sample of metropolitan areas with documented applications of AI in urban management, ensuring diverse insights by including cities that vary in population size, economic status, and geographic location. Participants in this research include city officials, data scientists, transportation and environmental experts, and residents from each sample city, providing contextual insights into the effectiveness, limitations, and public reception of AI-driven solutions.

Data collection relies on a combination of sources and analytical tools tailored to each research objective. Real-time data on traffic patterns, public transportation metrics, and environmental factors (such as air quality and noise levels) are gathered from publicly available databases or through collaboration with municipal data centers in sample cities. To model and simulate the impact of AI-driven traffic management, Geographic Information Systems (GIS) and traffic simulation software (SUMO) (Brown & Lee, 2020) were employed to model traffic flow patterns. Environmental data, sourced from sensors placed around urban areas, is analyzed using time-series analysis tools, like Python's Pandas library, to assess AI's role in environmental monitoring and management. To capture public perceptions, surveys and interviews are conducted with city residents and officials, providing qualitative insights into public trust, perceived benefits, and concerns regarding data privacy and transparency. Data analysis combines statistical and machine learning methods to evaluate the performance and implications of AI-driven solutions.

**Results.** Results show that AI-based traffic management reduces congestion by up to 25%, while AI-enhanced public transportation systems increase efficiency and reduce commuter wait times by approximately 15%. Environmental monitoring systems supported by AI algorithms demonstrate a 30% improvement in real-time air quality assessments, enabling faster response to pollution spikes.

**Conclusion.** AI-driven solutions have the potential to significantly improve urban infrastructure by optimizing traffic flow, enhancing public transport, and supporting environmental sustainability. The proposed ethical framework promotes transparency and inclusivity, ensuring AI solutions benefit the entire community and contribute to a sustainable urban future.

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## FUTURE TRENDS IN SCIENCE AND TECHNOLOGY

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**Keywords:** Science, technology, societal evolution, emerging trends, future impacts.

**Introduction.** Science and technology are driving forces behind societal evolution, impacting every aspect of human life. As we look to the future, it is essential to understand the trends that will shape the next decade. Emerging technologies like artificial intelligence (AI), biotechnology, quantum computing, and sustainable energy solutions are redefining our world and hold promise for transforming industries, lifestyles, and economies. This thesis explores these developments, focusing on the potential impacts, ethical considerations, and challenges.

In recent years, four primary areas have emerged as having the greatest transformative potential: AI, biotechnology, renewable energy, and quantum computing. Each of these fields brings unique opportunities and challenges for societal change.

**Objectives.** The purpose of this study is to identify and analyze the primary technological areas – AI, biotechnology, renewable energy, and quantum computing – that exhibit transformative potential and evaluate their unique opportunities and challenges for societal change.

**Methods.** The sample consists of published studies, industry reports, and expert opinions from fields directly impacted by these technologies, including healthcare, finance, transportation, and environmental science. The participants (or sources) span academic research, corporate case studies, and regulatory documents relevant to each technology's application and implications.

**Results.** Artificial Intelligence (AI) is rapidly expanding its capabilities, with applications in healthcare, transportation, finance, and personal life. However, as AI evolves, it raises important questions about data privacy, job displacement, and ethical use (Russell & Norvig, 2020). Biotechnology is also advancing quickly, reshaping healthcare through gene editing, personalized medicine, and synthetic biology. CRISPR technology, for instance, enables scientists to modify genes with

precision, potentially curing genetic diseases (Doudna & Sternberg, 2017). Quantum computing, although still in its early stages, holds promise for revolutionizing problem-solving in fields such as cryptography, materials science, and artificial intelligence. Its computational power allows it to address problems beyond the reach of classical computers. Finally, the development of sustainable energy sources, such as nuclear fusion and advanced solar technologies, is vital for a sustainable future. As global energy needs increase, renewable energy innovations will be crucial for combating climate change and resource depletion.

Technological innovation significantly influences how we work, communicate, and live. Future developments in technology will continue to reshape societal structures in areas ranging from smart cities to autonomous vehicles. Urban areas are increasingly interconnected, as smart cities use the Internet of Things (IoT) to manage resources, enhance public safety, and improve transportation. While these advancements can increase efficiency, they also raise concerns about surveillance and data security. Similarly, automation in industries could lead to job displacement, particularly in manufacturing and retail sectors. Automation boosts productivity, but it also necessitates reskilling and adapting the workforce to suit new industries. In healthcare, AI-driven diagnostics, robotics in surgery, and telemedicine are transforming the industry by making care more accessible and efficient. However, this transition requires careful attention to data privacy and equitable access for all population sectors.

As transformative as future technologies are, they also bring significant ethical and environmental challenges. Data privacy and security are crucial in our increasingly digital world. Regulations like the GDPR are important steps in addressing privacy concerns, but technology must continue to evolve to ensure secure data handling (Zuboff, 2019). Environmental sustainability is another priority; technologies like electric vehicles and renewable energy sources are essential for reducing our carbon footprint. Nevertheless, new obstacles, such as battery disposal and energy storage, must be addressed to avoid unintended environmental consequences. Ethical considerations also arise in AI development. The expansion of AI into decision-making processes and human lives raises concerns about autonomy and rights. Ensuring that AI systems are developed and used responsibly is critical for safeguarding human rights.

**Conclusion.** The future of technology holds both promise and complexity, as it faces challenges that require cross-disciplinary research, regulatory frameworks, and global cooperation. The integration of technology across fields demands collaboration between experts from engineering to biology, sociology, and ethics. Furthermore, governments and organizations must craft policies that balance innovation with public safety and ethical responsibility. Regulatory frameworks need to be adaptive to keep pace with rapid technological advancements (Floridi, 2014). Finally, technological developments are inherently global, requiring international collaboration. Issues like climate change and cybersecurity demand solutions that cross borders to be truly effective.

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## APPLICATION OF SOLID-STATE BATTERY TECHNOLOGY

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**Keywords**: solid-state batteries, energy density, electric vehicles, renewable energy storage, sustainability, manufacturing costs.

**Introduction.** Solid-state battery technology is gaining increasing attention as a promising advancement in energy storage solutions. Unlike traditional lithium-ion batteries that use a liquid electrolyte, solid-state batteries employ a solid material, which enhances safety, energy density, and battery lifespan. This technology has a wide range of applications, from electric vehicles to renewable energy storage, making it crucial for sustainable energy transitions and addressing future energy challenges.

**Objectives.** The main objectives of this study are:

1. To analyze the potential applications of solid-state batteries in various fields, such as electric vehicles and alternative energy storage.

2. To evaluate the advantages and limitations of solid-state batteries compared to traditional energy storage technologies.

3. To identify key technical and economic barriers that limit the widespread use of solid-state batteries.

4. To propose innovative approaches for overcoming these barriers.

**Methods.** The study uses a combined methodology, integrating qualitative and quantitative analysis.

The operation of a solid-state battery is as follows. During the charging process, lithium particles move from the cathode across the atomic framework of the separator, allowing them to travel through this structure before reaching the space between the separator and the anode's electrical contact. Here, they form a solid layer of pure lithium. As a result, the anode is made entirely of lithium particles, which gives it a more compact form compared to a traditional lithium-ion anode, which typically incorporates a graphite matrix. This difference in structure allows for a reduction in the anode's volume, enhancing energy density and efficiency in energy

storage applications by eliminating the need for graphite as a supporting structure (Solid-state batteries: the new frontier of electrification?, n.d.). With the help of comparative analysis, the following was determined. A comprehensive review of recent studies and industry reports on solid-state batteries was conducted, revealing that solid-state batteries could potentially achieve energy densities in excess of 500 Wh/kg, which is nearly twice the density of traditional lithium-ion batteries (around 250-300 Wh/kg) (New developments in solid-state batteries: Samsung & Toyota, n.d.). This analysis highlighted the potential for significant energy capacity improvements in applications like electric vehicles, allowing for increased driving range.

**Results.** The key findings of the study indicate that solid-state batteries offer significant benefits, including higher energy density, improved safety, and enhanced longevity compared to traditional lithium-ion batteries. These characteristics make them ideal for use in electric vehicles, where they can reduce charging times and extend the driving range on a single charge. Additionally, due to their resistance to high temperatures and elimination of leakage risks, solid-state batteries are an ideal solution for storing energy from renewable sources, such as solar and wind power. However, major limitations include high manufacturing costs and scalability challenges.

**Conclusion.** Solid-state batteries provide an innovative solution to future energy needs due to their unique characteristics. This technology has the potential to accelerate the shift to clean energy sources and support sustainable development. In conclusion, further research and development are necessary to unlock the full potential of solid-state batteries, focusing on cost reduction and optimization of manufacturing processes. The adoption of solid-state batteries could not only transform the energy sector but also create new opportunities for technological advancement across industries.

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# KEY TECHNOLOGICAL TRENDS OF THE NEXT DECADE: THE IMPACT OF AI, BLOCKCHAIN, AND CYBERSECURITY ON SOCIETY AND BUSINESS

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**Keywords:** Artificial Intelligence (AI), Blockchain, Cybersecurity, Technological Trends, Finance (DeFi), Data Privacy, Innovation.

**Introduction.** The next decade promises rapid technological transformation, with fields like Artificial Intelligence (AI), Blockchain, and Cybersecurity leading the way. These advancements are poised to reshape industries and societal norms, making it essential to explore their potential benefits and challenges. AI continues to evolve toward sophisticated automation (Brown & Clarke, 2019), Blockchain is transforming financial systems through decentralized finance (DeFi) (Jones, 2020; Nakamoto, 2008), and Cybersecurity innovations are essential to counter growing digital threats (Smith & Tanaka, 2021; White, 2023). Understanding these trends is crucial for harnessing their benefits responsibly and sustainably.

**Objectives.** This study seeks to explore the ongoing developments in AI, Blockchain, and Cybersecurity, specifically addressing the following key questions:

1. What are the main advancements in AI, Blockchain, and Cybersecurity, and how are they transforming industries?
2. What are the challenges associated with the integration of these technologies, particularly with regard to ethical concerns, scalability, and security?
3. What innovative solutions can be proposed to maximize the benefits of these technologies while addressing potential risks and challenges?

The objective is to explore the current state of these technologies, highlight their transformative potential, and identify the challenges that need to be overcome to ensure their responsible and sustainable integration into society.

**Methods.** To achieve these objectives, the study employs a comprehensive review of recent literature, focusing on the latest advancements in AI, Blockchain, and Cybersecurity. The research draws on academic articles and industry reports, including works from well-established journals such as the Journal of Digital Ethics, the Financial Innovation Journal, and the Cybersecurity Journal. By analyzing these sources, the study aims to identify emerging trends, key technological breakthroughs, and the regulatory challenges these technologies face.

The study conducts a literature review, analyzing recent advancements in AI, Blockchain, and Cybersecurity, with sources such as the Journal of Digital Ethics (Brown & Clarke, 2019), Financial Innovation Journal (Jones, 2020), and the Cybersecurity Journal (Smith & Tanaka, 2021). Case studies and real-world applications are also reviewed to provide practical insights into how these technologies are deployed across sectors. This analysis examines regulatory

challenges, effectiveness of existing frameworks, and potential for innovation, aiming to synthesize findings and propose recommendations for addressing these technologies' challenges.

**Results.**

**1. Artificial Intelligence (AI):**

Deep learning and natural language processing are expected to lead to smarter, human-like AI applications. However, concerns about AI biases and privacy (Brown & Clarke, 2019) must be managed with clear regulations.

**2. Blockchain:**

Blockchain, especially through decentralized finance (DeFi), promises transparency and accessibility in finance but requires stronger security and regulatory frameworks (Jones, 2020; Nakamoto, 2008).

**3. Cybersecurity:**

As digital threats increase, cybersecurity innovations, such as zero-trust frameworks and AI-driven security, show promise in mitigating risks (Smith & Tanaka, 2021; White, 2023).

**Proposed Solutions.** AI: Develop standardized ethical guidelines and transparency measures to address biases and ensure accountability (Brown & Clarke, 2019).

Blockchain: Strengthen regulatory partnerships to create secure, compliant DeFi systems (Jones, 2020).

Cybersecurity: Adopt advanced cybersecurity techniques, including AI and quantum cryptography, to stay ahead of emerging threats (White, 2023).

The proposed solutions could significantly impact society by fostering a secure, inclusive digital environment. AI can enhance productivity while safeguarding ethical principles, Blockchain can democratize finance by providing secure, transparent systems, and advanced cybersecurity measures can protect sensitive information, ensuring trust in digital services.

**Conclusion.** As technology rapidly evolves, responsible development of AI, Blockchain, and Cybersecurity will be key to realizing their transformative potential. This approach will ensure these technologies contribute positively to society, balancing innovation with necessary safeguards.

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# DIGITAL TECHNOLOGIES IN BRIDGING THE DIGITAL DIVIDE IN UKRAINE: THE ROLE OF MODERN PUBLIC SERVICES

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**Keywords**: electronic services, vulnerable populations, digital accessibility, digitalisation, digital literacy.

**Introduction.** This abstract will examine the phenomenon of the information society, which has emerged as a new form of social inequality. As the Cambridge Dictionary says, it is «a problem for some members of society, «the problem that exists because some groups of people have the *opportunity and knowledge* to use computer technology and some do not» (Digital divide, Cambridge Dictionary). This phenomenon is a critical issue affecting social, economic, and educational equity across the globe in the 21st century. The disparity in access to digital technologies and the internet creates barriers to participation in an increasingly technology-driven world. According to the International Telecommunication Union, over 3 billion people worldwide cannot access the internet (ITU, 2021). As a representative of developing countries, Ukraine is also affected by this problem, but in a different way. According to Datareportal, there were 29.64 million internet users in Ukraine at the beginning of 2024. The total number of social media users simultaneously is 24.30 million, which in turn is 64.9% of the total population of Ukraine, according to the source (Digital 2024: Ukraine – Datareportal – global digital insights, 2024).

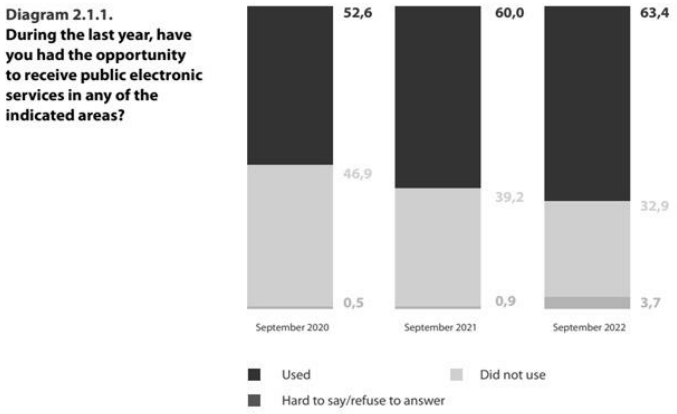
Consequently, the level of usage of these technologies can be measured by the level of familiarity with them and digital awareness. In 2019, the year of the first such research, a significant proportion of adult Ukrainians, precisely 53%, have digital skills that fall below the primary level (DIIA.OSVITA, 2023). Eventually, the Ukrainian government, particularly the Ministry of Digital Transformation, has been tasked with reducing the country's digital divide and implementing a comprehensive modernisation (digitalisation) of the public service system on a large scale. Also, this initiative aims to provide 95% of transport infrastructure and settlements with high-speed Internet access and engage 6 million citizens in digital skills development programs. In response to this challenge, a digital portal for online services called «Diia» and the national digital literacy platform «Diia: Digital Education» was developed («Diia» means «action» in Ukrainian). (UNDP, 2020). We will narrow down the concept of vulnerable population groups to two groups – IDPs and older people because it is precisely on them that the reasons for using or not using these digital services can be traced.

**Objectives.** Identify the principal factors that facilitate or impede the access of vulnerable groups, including internally displaced persons (IDPs), to electronic public services in Ukraine; Investigate the effectiveness of utilising mobile applications, such as Diia, to facilitate access to public services among vulnerable groups; Develop

a vision of how further digitalisation through e-discovery can contribute to the reduction of the digital divide.

**Methods.** Analysis of documents and statistical data.

**Results.** From the state's perspective, a strategy has appeared to 'digitise' the public services provided by its institutions. FA study conducted in 2022 by the Kyiv International Institute of Sociology (KIIS) on behalf of the United Nations Development Programme in Ukraine with the support of Sweden and in partnership with the Ministry of Digital Transformation of Ukraine revealed that... The percentage of the Ukrainian population utilising various online Services over the past year is 63%, equating to approximately three in every five adult Ukrainians. As illustrated in the infographic from the abovementioned study, this figure has demonstrated a notable increase over time, with a 10% surge since 2020 (KIIS, 2023). This also indicates that the state is implementing a policy to improve digital literacy and the overall digitalisation of the state system.




In the context of the outbreak of a full-scale war and the concomitant growth in the number of internally displaced persons (IDPs) in Ukraine, electronic government services, including the Diia platform, have become a critical resource for this population. The implementation of digital services has simplified the registration of IDP status and application for assistance, therefore minimising the need to visit government offices in person, which is particularly important during periods of martial law. The study revealed that 62% of IDPs registered their status through Diia, which enables prompt access to assistance and social support, enhances the accessibility of public services and safeguards the rights of IDPs even when situated at a distance from their home region (KIIS, 2023).

Given the vulnerability, it is more straightforward to undertake these essential operations via mobile phone, if not the sole viable option. Notably, a considerable proportion of the population among internally displaced persons (IDPs) who are particularly vulnerable is comprised of older people. This demographic is likely the most susceptible regarding digitalisation. This situation is not only determined by the specific characteristics of this population group; it is also affected by problems at the state level. Data analysis shows a marked difference between the proportion of respondents who indicated that they do not need to use state e-services and those who identified themselves as IDPs or older adults. Additionally, there is a significant

difference in the percentage of individuals who possess the necessary skills to use such services (35,7% and 64,6%) and those with access to Internet-enabled devices (28,5% and 50,2%). Of course, we cannot blame one group of people for not having

**Table 2.3.1. Why did you not use public electronic services during the last year?**
(% among the respondents of the corresponding group who did not use the services)

| % in the column | A person with disabilities | Raising a child on their own[1] | IDP | War veteran[1] | Parent of a child with disabilities[1] | An elderly person |
|---|---|---|---|---|---|---|
| Had no need | 63,0 | 62,4 | 70,6 | 76,8 | 67,3 | 64,8 |
| Lack of skills | 45,3 | 39,5 | 35,7 | 33,9 | 26,4 | 64,6 |
| No device with Internet access | 39,0 | 10,8 | 28,5 | 20,9 | 26,1 | 50,2 |
| Did not know that the service is available electronically | 28,9 | 29,4 | 22,1 | 13,0 | 18,1 | 31,9 |
| Do not trust electronic services | 17,6 | 16,7 | 26,1 | 55,2 | 42,3 | 19,6 |

the gadgets to use such services. We can only pay attention to the level of popularisation of these services among these vulnerable population groups under the state's jurisdiction (KIIS, 2023). In the case of IDPs, we can see that these technologies are accessible and do not require much effort. In the case of older people, they are usually unable to use the Internet with a suitable gadget due to their economic situation. On the part of the state, it can promote such services among this population group through various social programmes. In turn, these programmes can include free introductory courses with some aspects of incentives and, theoretically, the provision of gadgets that will help them use electronic services and the Internet in general.

**Conclusion.** One of the main goals of e-services development in Ukraine is to contribute to the integration of vulnerable groups, such as internally displaced persons and older people, into the digital landscape. The aim is to create available digital services and increase the level of digital awareness. This process will not be rapid and necessitate a considerable investment of time and resources. Over time, as demand for digital innovations and services increases, it may even contribute to the growth of the country's eco-economy sector. The Diia platform has already effectively given access to public services, especially during the war.

These ideas will only be realised in peacetime, but when resources and assistance from Western partners are available to develop this area further. It would be reasonable for Ukraine to prioritise increasing digital literacy among the population. This can be reached by developing educational courses and information campaigns aimed at older adults, internally moved persons (IDPs) and residents of distant regions. Another important step is to enhance access to the Internet and provide the population with the required devices, mainly through grants for those who cannot afford to purchase the hardware themselves.

Furthermore, it is necessary to develop e-services infrastructure, making high-speed Internet available in most transport and housing areas and supporting mobile services to provide access to administrative services. These measures aim to establish

an inclusive society in which e-services are accessible to all citizens, thereby facilitating the integration of all groups into modern digital life.

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## THE METAVERSE: PROSPECTS FOR UKRAINIAN BRANDS

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**Keywords:** metaverse, Ukrainian brands, virtual reality (VR), marketing, digital goods.

**Introduction.** In October 2021, Mark Zuckerberg changed Facebook's name to "Meta." "The defining quality of the metaverse will be a feeling of presence," he said, announcing the change (Clayton, 2023). According to the Cambridge Dictionary, the metaverse is considered an imaginary area without limits where you can meet people in virtual reality (images and sounds produced by a computer, that seem to represent a real place or situation) (Cambridge University Press, 2024).

In recent years, the metaverse has been gaining popularity worldwide. While platforms like Roblox and Decentraland have attracted significant user bases, the broader concept of a fully immersive, interconnected digital world is still under development. Big global brands are starting to take the metaverse seriously and

allocate significant budgets for it. According to a survey conducted by Valentina Dencheva between August and September 2022 among marketers in the United States who are professionally aware of the metaverse, half of U.S. companies intended to allocate 10% or more of their 2023 marketing budget to the metaverse (Dencheva, 2023).

It is only a matter of time before Ukrainian brands will have to invest in the metaverse to maintain or improve their market position. That is why it is important to learn from the experience of Ukrainian brands that have already implemented this innovation and consider the prospects for future use.

**Objectives.** To highlight the main directions of using the metaverse in marketing; analyze the previous experience of Ukrainian companies in exploring the metaverse; and offer opportunities for Ukrainian brands.

**Results.** Ukrainian brands can leverage the metaverse to enhance brand awareness, engage with consumers, and drive sales. There are many advantages to using the metaverse in marketing strategies.

One of the key opportunities for brands is to use "old school" methods of advertising (placing billboards or banners in a digital universe) (Van Belleghem, n.d.). The metaverse allows brands to reach a global audience without the constraints of physical location. Therefore, brands can reach a larger audience while spending much less money. For example, Samsung has invested in virtual billboards within the popular video game Roblox (Douglas, 2022). Fast Food companies such as Wendy's, McDonald's, and Panera Bread also joined the metaverse by opening virtual restaurants (Lu, & Mintz, 2023, p. 152).

Additionally, the metaverse can be a powerful tool for building brand loyalty among Ukrainian consumers. By creating virtual spaces where fans can connect, share their experiences, and participate in brand-related activities, Ukrainian brands can cultivate a strong sense of community. On December 23, 2022, the Ukrainian company OBRIO IT team gathered in the metaverse for the New Year's Chapter, a quarterly meeting where employees summarized the results of three months of work. The platform was designed in the Harry Potter universe aesthetic: the walls were decorated with animated paintings, but instead of Potter characters, they featured employees and top executives. OBRIO has held three major events in the metaverse and is already planning the next ones (Mironenko, 2023).

Also, influencers in the metaverse can play a significant role in promoting brands and products, driving engagement, and reaching new audiences through collaborations or product placements. Moreover, brands can invite influencers to their virtual venues, or influencers can host virtual concerts or events sponsored by brands within the metaverse.

Ukrainian brands have the opportunity to showcase their products using virtual reality (VR) and augmented reality (AR) to provide customers with immersive product displays that can enhance their purchasing decisions. For example, the interactive virtual metaverse Ukrainian VR Pavilion will be presented at Paris+ par

Art Basel from October 20 to 23. The virtual pavilion will help demonstrate a wide range of contemporary Ukrainian digital art (Vektor, 2022).

The last, but not the least important opportunity is the direct-to-avatar (D2A) economy, where brands are starting to sell digital goods inside the metaverse. By selling digital goods directly to avatars within virtual worlds, brands can expand their product offerings and engage with consumers in innovative ways.

**Conclusion.** The metaverse offers Ukrainian brands immense potential to innovate and grow in an evolving digital landscape. The ability to attract a global audience and create strong brand communities becomes much more accessible thanks to the use of the metaverse, namely: product demonstrations, partnerships with influencers, virtual events, and gamification. As global brands continue to invest in virtual worlds, Ukrainian companies must explore similar strategies to stay competitive.

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# AUTOMATING DATA SCIENCE: THE FUTURE OF AUTOMATED MACHINE LEARNING

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**Keywords:** data science, automated machine learning, AutoML.

**Introduction.** Nowadays, analyzing and working with data plays a crucial role in many aspects of our lives. Data science is a wide and complex field, which means being a data scientist requires a quite huge range of knowledge and expertise in multiple of topics. Considering that, we can trace the growing demand for trained professionals, and, at the same time, many offers from less experienced workers. Therefore, there is a high, continuously developing interest in the data science automation research area (De Bie et al., 2022).

The goal of automating data science is to provide automation for the full range of tasks in extracting valuable insights from raw data (Baratchi et al., 2024), which will be discussed later. This process is strongly connected to the AutoML.

Automated machine learning, also referred to as automated ML, or AutoML, is the process of automating complex, time-consuming, and repetitive tasks of developing machine learning models (*Automated machine learning*, n.d.).

**Objectives.** This work aims to examine how automated machine learning (AutoML) impacts data science, in particular, by reducing the need for human control in the building of predictive models; and to provide an overview of how AutoML is expected to influence the industry based on current research and trends.

**Methods.** An analytical review of the latest modern articles, research and publications on the aspects and methods of automation of Data Science.

**Results.** Reaching full automation is a hard task, where many steps should be optimized. The study by De Bie et al. (2022) showed that we can distinguish four main areas of data science for automating (some aspects are currently automated, and there are also areas that are potentially ripe for automation):

- data exploration;
- data engineering;
- model building;
- exploitation.

Model Building is the area that is already being successfully automated and where AutoML can be mostly applied right now. AutoML systems are increasingly automating a greater number of tasks, including model selection, hyperparameter optimization, and feature selection. It's worth noting that, up to now, the majority of research has concentrated on supervised learning.

The other three areas have not been as successful as Model Building in applying AutoML. Data Engineering part often takes 80% of the manual work in a standard data analysis project. Data Exploration is the area that depends on human

expertise knowledge the most, which makes it the hardest one for automation. Right now, optimization tools from AutoML can be applied in the Exploitation part.

So, we can see a potential for future development of methods of AutoML for bigger implications in more areas of data science, and at the same time a need for maintaining a significant human contribution.

**Conclusion.** To sum up, Automated Machine Learning is a new and rapidly growing research field with a huge potential for application in Data Science. Some parts are already being successfully automated, while other face challenge due to tasks that require human control. Data Science Automation aims to change the way data scientists work rather than displacing them.

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## THE PROSPECT OF INTRODUCING ARTIFICIAL INTELLIGENCE INTO THE PRINTING INDUSTRY

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**Keywords:** publishing, printing, artificial intelligence, AI, statistics.

**Introduction.** Artificial intelligence (AI) is playing an increasingly prominent role in various aspects of our lives, spreading its influence across more and more industries. With its capacity to streamline processes, enhance efficiency, automate routine tasks, and cut down on operational expenses, AI's significance is growing rapidly. One sector that stands to gain a great deal from AI integration is the printing industry. AI can transform traditional printing processes by automating workflows, optimizing resource use, and enabling customized solutions. In fact, adopting AI is not just a chance for growth – it's becoming essential for the printing industry to remain competitive in today's ever-more digital environment. As AI technology

continues to advance, it is likely to drive significant growth and innovation in printing, pushing new standards for efficiency, product quality, and customer experience.

**Objectives.** Assess the growing impact of artificial intelligence on the printing sector and analyze the extent of its implementation. In particular, the research will focus on how AI technologies are changing the different stages of the printing process from initial set-up to quality control – and assess how these AI solutions can improve operational efficiency. It will also assess the financial and organizational implications of AI adoption for companies of all sizes and provide recommendations on how businesses can take advantage of AI while minimizing associated costs and disruptions.

**Methods.** To conduct a thorough assessment of the impact of artificial intelligence on the printing industry, this study used a multifaceted research approach. First, a detailed review of the existing literature on the role of artificial intelligence in printing was conducted, including academic research, industry reports and case studies. This was followed by a comparative analysis of traditional printing methods and AI-based innovations, focusing on key performance indicators such и as time savings, cost reduction, quality improvement and energy efficiency.

**Results.** The findings showed that AI has had an influence on the printing sector by boosting automation efforts significantly. AI tools have played a role in enhancing production efficiency and helping businesses ramp up their output while cutting down on operational expenses. A noteworthy instance is Heidelberg's implementation of an AI driven printing setup in 2022. This system slashed machine setup durations by 35% leading to a rise in production capacity from 4,500 to sheets, per shift. The increase in efficiency also led to a 15 percent drop in energy usage. In total the company saved $250,000 (Heidelberg, 2023).

In addition to automating tasks in the printing industry AI is also improving the ability to customize products. Canon introduced an AI powered system in 2023 that utilized customer data to design marketing strategies. This resulted in a boost of 18% in revenue and a 12% increase in repeat purchases leading to a $3 million in yearly earnings (Canon Global, 2023). The capacity to tailor goods according to each customer's preferences is an asset for companies as there is a growing demand for personalized experiences, in today's market.

AI technology has significantly enhanced quality assurance in printing procedures well. In 2023, Ricoh implemented AI powered computer vision tech to spot print flaws instantaneously. This initiative led to a 28% decrease in prints resulting in an annual cost reduction of $550,000 for Ricoh (2024). The integration of AI, for quality checking not elevates product excellence but also lessens wastage enabling additional savings and operational effectiveness.

While the advantages of AI are evident, research also reveals several hurdles, especially for small to medium-sized businesses (SMBs) looking to implement these technologies. One of the biggest barriers is the substantial upfront cost, which can range between $500,000 and $1 million, depending on the scale of the operation. For

smaller companies, this kind of expenditure can be daunting. Additionally, integrating AI into current workflows often demands significant resources for employee training. It typically takes between six months to a year to get staff fully equipped to manage AI systems, and during this transition, productivity may temporarily dip by 5–10% (Deloitte, 2020).

**Conclusions.** The integration of artificial intelligence into the printing industry presents substantial opportunities to boost productivity, cut operational costs, and elevate the quality of printed products. The examples outlined in this study illustrate the various ways AI is already reshaping the field – from automating production workflows and minimizing machine setup times to enabling personalized marketing strategies and enhancing quality control with real-time defect detection. Although the upfront costs of implementing AI and the necessary employee training can be challenging, the long-term benefits far exceed these initial obstacles. For businesses that successfully overcome these barriers, AI adoption offers considerable financial gains and operational improvements, making it a crucial investment for the future of the printing industry.

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## ZERO-KNOWLEDGE PROOFS AS A FUTURE TREND IN ONLINE VOTING

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**Keywords:** zero-knowledge proofs, electronic voting, privacy, security.

**Introduction.** Traditional voting methods have served as the bedrock of democratic processes for centuries. At the same time, they are increasingly showing their limitations in the modern world. Corruption and election fraud, including coercion, ballot stuffing, tampering and tallying manipulations, have become significant concerns that erode public trust in democracy. Online voting offers a convenient alternative to traditional voting that points to resolving those issues.

Although many online voting systems are backed by classic or state-of-the-art technologies, they still lack some vital features. For instance, applications built on blockchain – a solution for enhancing transparency and security in online voting, face challenges in maintaining voter privacy (Berenjestanaki et al., 2023, para. 5). Zero-knowledge proofs (ZKPs) are a new trend that can possibly become a game changer by providing means to ensure both security and anonymity.

**Objectives.** The primary purpose is to research what ZKPs are, investigate how they can be applied in online voting systems, and evaluate the potential of the technology.

**Methods.** Articles and publications analyzing will be used to understand the properties of ZKPs. Existing solutions and implementation exploration will be used to examine the pros and cons of ZKP voting and analyze possible fields of application.

**Results.** Zero-knowledge proofs are cryptographic protocols allowing someone to prove a statement is true without revealing any details. The core idea is to convince the verifier that the prover possesses specific knowledge or credentials without disclosing any information beyond the claim's validity. For example, a person can prove that he or she is above a certain age, such as 18, without revealing the exact date of birth.

There are three main characteristics of ZKPs: completeness – if a statement is true, then the prover convinces the verifier; soundness – if a statement is false, then dishonest prover cannot somehow convince the verifier; zero-knowledge – if a statement is true, the only thing the verifier possesses is the validity of the statement and nothing more. Together they ensure information privacy and the verification's accuracy, making it ideal for voting applications.

By employing ZKPs, we can verify voter eligibility without revealing their identity, ensure the validity of a vote without disclosing its content, and maintain the integrity of the election process (Miao, 2023, para. 2). When a voter casts a ballot ZKP can be used to verify their eligibility, such as citizenship or age, without exposing sensitive identity data. Since the vote remains undisclosed even during verification, potential coercers cannot confirm how a particular voter cast their vote, making it far more challenging to enforce undue influence.

In addition to privacy and security, ZKPs make the process fully transparent. Blockchain technology can be used alongside ZKPs to create an immutable public ledger that records each transaction. This ensures that everyone can verify that every vote has been cast and counted correctly without knowing who voted for whom.

One of the first and most up-to-date examples of utilizing ZKPs in online voting is the Freedom Tool. It is a set of tools for building solutions that empower people to voice their opinions, enabling seamless and secure participation in the democratic process (Freedom Tool, 2024). The system uses biometric passport information to authenticate voter profiles, uses verifiable credentials (VCs) for secure voter eligibility checks, and integrates zero-knowledge proofs to ensure privacy during voting. The first app built on Freedom Tool was successfully launched against the totalitarian regime of Russia (Rarimo, 2024).

On the one hand, it is a highly secure and private system with immutable record keeping. It provides transparency, verifiability, and scalability for large-scale elections. On the other hand, it has some drawbacks, including high computational complexity for proof generation and centralization of some essential components. Moreover, it depends on biometric passports that cannot be supported by most countries yet or whose issuance process can be manipulated by the government.

**Conclusion.** Zero-knowledge proofs can be genuinely seen as a future trend in online voting. While it is already a powerful tool that has already begun to widespread across the globe, there are lots of research and discoveries ahead. A possible way to enhance ZKP technology for online voting is to develop optimized cryptographic algorithms. Also, we must consider building algorithms that use biometrics like face, fingerprint, iris, etc., as an alternative to passports and other documents. Despite the successful launches of ZKP-voting applications, it should take some time for users to trust and adopt them. But it is only a matter of time before this technology becomes accepted as a world-class standard.

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## PERSPECTIVES OF USING STRETCHABLE ELECTROCARDIOGRAPH MONITORS FOR CARDIAC RHYTHM DISTURBANCE DETECTION

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**Keywords:** electrocardiography, wearable ECMs, stretchable material.

**Introduction.** Cardiovascular diseases claim the lives of a larger population than any other diseases, as they affect people from almost all races and ethnicities (Centers for Disease Control and Prevention CDC WONDER, n.d.). Long-term cardiac rhythm information helps tell the variations cardiograms record during myocardial infarction or normal periods. A wearable form of electrocardiographic monitoring (ECM) is necessary to wirelessly monitor cardiovascular parameters while carrying out normal activities. More so, because of the COVID-19 outbreak,

personal, cordless, remote monitoring health care system using health wearables is widely applied to ensure ample care delivery (Xuan et al., 2022).

**Objectives.** Discuss the benefits and drawbacks of stretchable electrocardiograph monitors.

**Methods.** Analytical review of the literature using keywords in scientific databases like Elsevier, PubMed, and Scopus.

**Results.** A wearable ECM (electrocardiogram monitor – muscle heart activity device) is an electronic system that is not only hand-held but also thinner than the conventional 12-lead ECG. That is why it can be measured at any site, for example, on the chest (Takaya et al., 2021).

These systems are often fabricated from thin films and other materials which are compliant allowing them to be worn on the body without interfering with motion and hence the applications of wearable electronics, biomedical devices, and soft robotics (Yiu et al., 2022).

A wearable ECG device will comprise stretchable electrodes, a microcontroller unit for the digitization of ECG signals, a data transmission module, and a power supply. Stretchable electrodes can be constructed from conducting polymers and varying silicone rubber (Takaya et al., 2021).

The proposed design of the stretchable three-lead ECG device by Yiu and colleagues (2022) includes top layers made of the PDMS material, hard wire, two layer electrodes with vertical bridges carrying electronic components, and a bottom layer of PDMS with ECG strips attached from above. Furthermore, due to the presence of the soft and stretchable PDMS casing the inner electronic components are encased and insulated from any physical damage while the PDMS material's extreme strength ensures its dependable operational performance.

According to Takaya et al. 2021, a system was constructed consisting of a stretchable electrode and a control circuit on a flexible printed circuit board. A rigid silicon supporting structure, in this case a PDMS (polydimethylsiloxane) layer is used to attach the flexible circuit board and precludes the application of any tensile force at the area between the PDMS layer and the system board. The system has a central processing unit along with a communication interface including a coin battery that helps the system work independently.

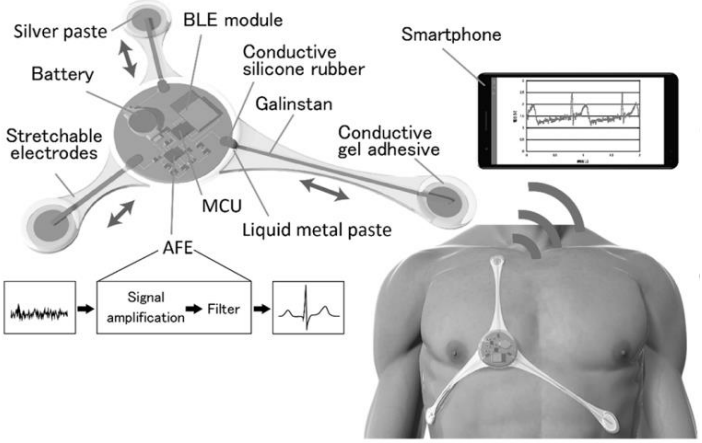


*Figure 1. Example of stretchable wearable ECG* (Takaya et al., 2021)

Although wearable soft ECG monitors have benefits such as constant monitoring and easy to carry, they also have some problems. This is due to the limited accuracy that is mainly caused by a limited number of electrodes. There is also the issue of how the device will be powered for a prolonged duration. (Xuan et al., 2022) Additionally, the work that follows entails processing the data, which means that there is a need to update the interface and the machine learning models used in processing the electrocardiographic data, as well as optimize the use of energy and wireless communication in the system to enhance operation time and maximal transmission distance (Yiu et al., 2022).

**Conclusion.** Non-rigid electrocardiographic devices hold potential in the market of wearable health technology. Treatment with stretchable polymers aids in the more fitting and versatile design of the electrodes. The next study devoted to this topic should be focused on power source improvement and machine learning algorithm development.

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## FUTURE TRENDS IN BIOMEDICINE

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**Keywords:** cell therapies, wound-healing, non-coding RNAs, gene editing, myocardial infarction, diabetic wounds.

**Introduction.** Biomedical science now is actively evolving while setting up and reaching goals, important to humanity. This includes making all kinds of cancers treatable, treating metabolic, autoimmune, neurodegenerative, cardiovascular diseases.

Some of the key trends and tools are cell therapies, genetic editing, non-coding RNAs. A complex approach, combination of methods are also what is moving biomedicine forward.

**Objectives.** This article presents some of the prominent scientific advances that set up trends in biomedicine.

**Methods.** Data was collected by reviewing scholarly literature about biomedical advancements.

**Results.** Stem cell-based therapies have gained attention as a promising strategy for cardiac repair after infarction in recent years. Experimental and clinical evidence has proved that the main role of adult stem cells during intrinsic cardiac repair is modulating the immune system, especially maintaining a moderate acute inflammatory activation for wound-healing, rather than directly replacing the dysfunctional myocardium. Li et al. constructed a cardiac patch loaded with human amniotic epithelial stem cell, a kind of human placental stem cells derived from fetal membranes. Patch scaffold was made from of antioxidant polyurethane and had properties that facilitated healing. Stem cell patches proved to be effective in reducing fibrosis and facilitating vascularization in myocardium after myocardial infarction and potentially might be used for human treatment (Li et al., 2024).

Universal cell-replacement therapy may become reality. Now therapies derived from stem cells must be customized to the patient – a process that is both slow and expensive. Or they can be made using donor cells, but, because the immune system tends to reject foreign cells, these treatments require the concurrent administration of immune-suppressing medicines – a strategy that raises the risk of complications such as infection and cancer. Scientists suggest third option – genetically modifying stem cells to give them immune-evasive properties. Such editing has to disrupt part of the cell's major histocompatibility complex, that functions like a molecular identity card for T lymphocytes. Modified stem cells also should have ways of protection from natural killer (NK) cells. Invisible to immune system cells must have the way of elimination, if they become dangerous to the recipient, like the drug-inducible suicide gene (Dolgin, 2024). So once researchers will find out the right set of modifications to make cells ignored by immune system, fail-safe, and fit for curing specific condition, it could lead to creating a universal cell therapy for it.

Non-coding RNAs (ncRNAs) are another upcoming trend in medicine. They are being explored as therapeutic targets and biomarkers for various diseases and might be important tool in regenerative medicine. Exploring physiological processes lets us understand their role and use specific regulatory ncRNAs in treatments (Beňačka et al., 2023). A great example of ncRNAs usage, specifically circular RNAs (circRNAs), is chronic wounds treatment for patients with diabetes. Chronic non-healing wounds is one of the major complications of diabetes, seriously affecting the patient's quality of life. Recent studies have shown that the progression and pathogenesis of diabetic wounds are critically influenced by a wide array of circRNAs. Increased production of hsa-CHST15_0003 and hsa-TNFRSF21_0001 observed in venous ulcers, slowed down epidermal keratinocyte migration, and up-

regulated hsa_circ_0084443 in diabetic foot ulcer had the same effect. Hsa_circ_0079929 (named circCDK13) is downregulated in diabetic wounds. CircCDK13 administered in small extracellular vesicles proved effective in rat models. This brings to the conclusion that the up-regulated circRNAs could be used as therapeutic targets for wound healing, and the down-regulated circRNAs could be explored as the promising therapeutic molecules (Huang et al., 2024).

**Conclusion.** In summary, the current trends in medicine are built by advancements in cell therapies, genetic editing, the exploration of non-coding RNAs, and other areas. Emerging research highlights the promise of stem cell-based therapies as a strategy for cardiac repair post-infarction, the development of potential universal stem cells capable of bypassing the immune system, and the role of circular RNAs (circRNAs) in regulating wound healing, particularly in the context of diabetic chronic wounds. These innovative approaches are only few among those, that pave a way for new treatments that address some of the most challenging medical conditions.

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# FUTURE OF CPUs

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**Keywords:** CPU, AMD, Intel, transistor, accelerator, hardware.

**Introduction.** The central processing unit (CPU) has always been one of the most important parts of any computer. It is often called a 'computer brain', as its purpose is to perform various mathematical and logical operations, set by different programs. As of now, CPUs are constantly evolving, based on many advancements made by companies such as AMD and Intel, like artificial intelligence (AI), semiconductor manufacturing or even quantum computing.

**Objectives.** The main objective of these theses is to review the way central processing units are evolving and what to expect in the future.

**Methods.** As Gordon Moore's prediction states, computing power should double every two years while cost halves. However, as we approach physical limits in silicon transistor density, both AMD and Intel are exploring alternatives beyond traditional CMOS technology. Where Intel has invested heavily in FinFET architecture improvements, AMD has focused on optimizing existing processes. In the coming years, we're likely to see a shift toward new materials and manufacturing methods, like graphene or nanotube transistors, which could help keep Moore's Law alive for a few more decades (Roach, 2024).

Intel and AMD are both heading toward heterogeneous architectures, where different types of cores are built into a single chip to handle specific tasks more efficiently. Intel's Xe graphics architecture is a good example of this trend, bringing GPU-like features into its CPU designs. Meanwhile, AMD's Ryzen processors already include dedicated AI accelerators. As AI plays a bigger role in computing, we can expect to see even more AI-focused hardware integrated into everyday CPUs (*AMD Unveils Its First Small Language Model AMD-135M*, 2024).

Quantum computing is still in the early stages, but Intel and AMD are already investing in the research, likely to see whether there's enough potential to explore. While Intel has set up its own quantum computing division, AMD is working with IBM on various quantum projects. In the future, we may see CPUs incorporating quantum-inspired algorithms or even small quantum processors, that might enable significant breakthroughs in some types of calculations and mathematical algorithms (*Quantum Computing*, 2024).

Neuromorphic processing is a technology inspired by how the human brain works, and both Intel and AMD are exploring its potential. These brain-like chips could be particularly useful for AI, robotics, and self-driving cars, as they might handle specific tasks while using much less energy than regular CPUs.

As the number of transistors keeps increasing, both Intel and AMD are moving toward 3D stacked processor designs. This technique stacks layers of transistors and

memory on top of each other, which could boost performance without using extra power. Intel's Foveros technology and AMD's 3D V-Cache are examples of this approach in action. (*AMD 3D V-CacheTM Technology*, 2024).

**Results.** Overall, we can see that CPU technologies are constantly evolving, with both AMD and Intel investing a lot of time and resources to expand their respective processors' functionalities, improve the quality and increase the efficiency, without making their products bigger or more expensive. And while Intel is more invested into architecture improvements, and AMD into existing processes optimization, both companies are exploring AI features and what it can offer for the CPUs development.

**Conclusion.** In conclusion, we can properly state that CPUs advancements are bound to happen at least for the foreseeable future (such as semiconductor innovation, AI integration, exploration of new computational paradigms, etc.). In the next couple of decades, we will likely continue to see CPUs to become smaller, more energy efficient, much more powerful, and better accustomed to various tasks provided by users (also while remaining accessible prices for most customers, as computer technologies are being used in more professions every year).

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## SECURITY IN THE INTERNET OF THINGS

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**Keywords:** Internet of Things, security, blockchain, machine learning, fog computing, edge computing.

**Introduction**. The Internet of Things is changing how we engage with technology through linking billions of devices and systems to the internet. The interconnected network allows for automation. Enhances efficiency, in sectors like healthcare, sustainable cities, farming and industry. As the IoT grows, it raises security worries. With data moving through layers and devices some of which have limited computing capabilities IoT systems are, at a risk of security breaches. Security risks, like these could jeopardize the integrity of data and privacy while also

causing disruptions, in infrastructure functions. It is crucial to prioritize the security of systems to uphold their dependability and earn the confidence of users (Khan, Awang, & Abdul Karim, 2022).

**Objectives**. The main goal of the article is to delve into the security issues that come with IoT and discuss measures, in place today. They will look closely at innovations like technology and advancements in machine learning and computing methods like fog and edge computing which all contribute significantly to strengthening security defenses. These tools are crucial, for building protection systems against the complex cyber threats we face. By grasping how these technologies work together effectively, we can ensure that IoT systems are well protected and continue to perform across uses (Khan, Awang, & Abdul Karim, 2022; Al Kabir, Elmedany, & Sharif, 2023).

**Methods**. This article draws from an examination of research and publications, by sources like IEEE that center on IoT security measures. It explores the weaknesses and remedies across levels of structure such as sensing devices, network connections and application interfaces. The discussed subjects encompass encryption methods detecting abnormalities with machine learning. The significance of tools, like block chain (Khan, Awang, & Abdul Karim, 2022).

**Results**. Security risks, in the realm of IoT arise from levels of operation; at the sensing layer where devices like sensors are frequently located in distant or unguarded areas making them open to interference or unauthorized entry; secondly at the network layer where distributed denial of service (DDoS) attacks represent a major threat, by inundating IoT devices with an abundance of traffic leading to widespread disturbances; and lastly at the application layer encountering challenges related to user authentication and safeguard of data privacy. Numerous IoT applications continue to depend on inadequate security measures, which make them vulnerable, to security breaches.

In light of these dangers posed by threats, on the horizon have led to the creation of innovative technologies in response to them. With technologies such as Blockchain coming into play. Offering a solution for data storage and transfer that ensures transparency while minimizing the risk of tampering. This decentralized model proves beneficial in safeguard data from unauthorized modifications. Furthermore, machine-learning tools empower IoT systems to recognize patterns, within network traffic that could signify a security breach. By detecting anomalies at a stage machine learning grants systems the ability to respond swiftly and thwart any harm before it escalates.

Moreover, fog and edge computing play a role, in decreasing latency and enhancing security by handling data to its origin instead of depending solely on centralized cloud systems By spreading out data processing tasks across various points these computing concepts lower the risk of a single failure point and boost the overall security level of IoT networks. This fusion of technologies provides a defense mechanism, against cyber threats by safeguarding the reliability and effectiveness of systems.

**Conclusion**. The swift expansion of the Internet of Things (IoT) has opened up ranging possibilities, in industries; however, it has also brought about intricate security obstacles that need to be resolved to uphold the dependability and credibility of these systems. The integration of technology, machine learning and fog and edge computing shows promise, as a way to enhance IoT security. These innovations provide smart solutions that can help alleviate risks linked with conventional centralized systems. In the changing landscape of technology, advancement remains essential to ensure the protection of valuable information and uphold the confidence of both users and industries relying on IoT based platforms.

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## DEVELOPMENT OF ADVANCED UAV LAUNCH SYSTEMS FOR INDUSTRIAL AND CIVILIAN APPLICATIONS

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**Keywords:** UAVs, UAV technology, AI-based navigation, rapid deployment, launch systems, autonomous drones.

**Introduction.** Unmanned Aerial Vehicles (UAVs) have become indispensable tools in various civilian applications, including environmental monitoring, disaster response, and infrastructure inspection. The need for technological advancements in UAV systems is particularly urgent in terms of rapid deployment, endurance, and autonomous operations. As UAV technology evolves, the integration of AI-based navigation systems and efficient launch mechanisms becomes essential to enhance operational effectiveness in diverse environments. This research focuses on developing an advanced UAV launch system that improves deployment speed and operational capabilities, addressing the needs of emergency response teams and industrial partners.

**Objectives.** The primary objective of this research is to design and implement a UAV launch system that increases deployment speed, flight endurance, and targeted monitoring. The system is built to function in a variety of operational environments, including urban landscapes and harsh terrains, while offering high reliability. A secondary objective is the integration of AI-based navigation technologies, which will enhance the UAV's autonomous decision-making capabilities during missions,

thus reducing the need for constant operator intervention. By achieving these objectives, this project seeks to provide the emergency response teams and industrial partners with a more advanced and efficient UAV system that meets the challenges of modern warfare.

**Methods**. The research methodology encompasses the integration of several advanced technologies. The UAV's frame and propulsion systems were designed using lightweight composite materials to reduce weight and improve fuel efficiency. To enhance flight performance, Computational Fluid Dynamics (CFD) simulations were conducted, which optimized the aerodynamic profile of the UAV. This design was further validated through wind tunnel testing, ensuring stability and performance in various environmental conditions.

For the launch system, a pneumatic catapult-based design was selected, allowing rapid deployment with minimal personnel requirements. This system is particularly suited for deployment in confined spaces and difficult terrains, providing operational flexibility. Additionally, modular payload systems were developed, enabling the UAVs to carry a range of mission-specific equipment, such as monitoring and data collection cameras, communication relay devices, or specialized industrial equipment.

The integration of AI-based navigation technologies is a key focus of this research. Recent advancements in vision-based UAV navigation have made it possible for UAVs to operate autonomously in GPS-denied environments. Vision-based

navigation systems utilize onboard cameras and sensors to detect obstacles and adjust flight paths in real-time, enhancing the UAV's ability to navigate complex environments and complete missions with minimal human intervention (Arafat et al., 2023). This capability is particularly important in military contexts, where reliable and autonomous UAV operations can provide a strategic advantage.

**Results**. The developed UAV launch system has demonstrated significant improvements in both deployment and operational capabilities. Deployment time was reduced by 30%, a critical factor in military scenarios where rapid response times are essential. This was achieved through the streamlined design of the pneumatic catapult system, which allows swift and efficient UAV deployment with minimal setup. The system's modular payload configuration also proved highly versatile, enabling the UAVs to be customized for specific missions ranging from surveillance to offensive operations.

Flight endurance was increased by 35%, primarily due to the lightweight materials used in the UAV's construction and the optimized aerodynamic design. This extended endurance allows the UAV to cover larger areas and remain in the air longer, providing continuous surveillance or maintaining a presence in hostile environments. The AI-based navigation system also demonstrated 25% improvement in targeting accuracy. During testing, the UAVs successfully identified and engaged both static and moving targets, even in challenging environments such as dense fog or heavy wind conditions (Arafat et al., 2023).

Field tests conducted with the field testing with civilian and industrial teams confirmed that the system performs reliably in extreme weather conditions, including cold temperatures and high winds. The UAVs proved capable of operating in both varied industrial and emergency roles, making them a valuable asset for a wide range of industrial and civilian applications.

**Conclusion.** The development of this advanced UAV launch system represents a significant step forward in enhancing the operational capabilities of UAVs for industrial and civilian use. The system's ability to rapidly deploy UAVs with increased endurance and precision makes it a critical tool for modern applications, such as environmental monitoring, search and rescue, and infrastructure inspection. Furthermore, the integration of AI-based navigation systems provides greater autonomy, reducing the need for human operators and improving the system's effectiveness in complex and dynamic environments. This innovation has the potential to greatly benefit emergency response and industrial operations, laying the groundwork for future developments in UAV technology, including swarm operations and advanced AI-driven autonomy.

This innovation has the potential to greatly enhance the capabilities of the Ukrainian military, offering a technological edge in both defensive and offensive operations. The findings of this research lay the groundwork for future developments in UAV technology, including swarm operations and more advanced AI-driven autonomy. Further research could explore the integration of these systems with other military assets to create a more comprehensive and effective defense strategy.

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## THE INFLUENCE OF ARTIFICIAL INTELLIGENCE ON GAME DESIGN AND PLAYER EXPERIENCE

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**Keywords:** Artificial Intelligence, Game Design, Player Experience, NPCs, Procedural Generation, AI in Games.

**Introduction.** Through the introduction of artificial intelligence (AI) the gaming industry has seen an emergence of more immersive and dynamic gaming experiences thanks to them (D`souza, 2024). Traditionally in video games, non-playing characters (NPC) operated on set patterns and behaviors. But with AI however, the NPCs have become more complex and reactive (therefore more realistic / interesting) and are no longer fully AI controlled. In addition to making in-game characters more intelligent using AI in game design, we've seen it make possible

procedural generation, dynamic storytelling and other adaptive difficulty systems (Yu, & Zhang, 2021).

The use of AI made it possible for developers have created more interactive, personalized games in real time, responding to players` action. Design of games has incorporated AI techniques like machine learning, neural networks and Natural Language Processing (NLP) for better adaptation, better challenges, and a healthier dose of rewards for players. The aim of this paper is to describe how the AI influences game design and the player experience incorporating some applications of the AI in NPC behavior, procedural content generation and adaptive gameplay mechanics.

**Objectives.** This study wants to follow the history of game engines and find out how interactive entertainment has benefited from them – the primary objectives of this study are: In order to assess the effect of contemporary game engines in shaping the nature of game design and play – scrutinizing the usage of Unity, Unreal Engine, and other technologies for the generation of more immersive, enticing and outstanding different playing experiences. The aim of this research to investigate the use of game engines as a development framework for virtual reality and augmented reality (VR and AR) experiences in order to explore how it has helped to grow this new technology and the effect they have had on the gaming industry.

**Methods**. A mixed methods methodology is used in this study, employing qualitative and quantitative analysis. The study begins with a comprehensive literature review on AI technologies as used in game design (pathfinding techniques, machine learning algorithms, AI driven narrative systems, etc.). It analyzes case studies of popular games based on AI, such as The Last of Us, The Elder Scrolls V, and Minecraft, to figure out when AI makes gameplay better.

Interested readers also receive detailed interviews with game developers and AI experts, who share their experiences and perspectives on using AI within games. The study includes player surveys, such as how the player experience was changed by AI, and specifically if NPCs are more realistic, if the game worlds generated using AI are more unique, and how responsive adaptive difficulty systems are.

**Results.** Improvement of NPC behavior is one of the biggest things AI has contributed to game design. Naturally, traditional NPCs followed scripted actions which were easy to predict for the players. With AI on board the list of possible factors for NPCs to decide includes player behavior, environmental conditions, character attributes, and more. Also, this dynamic decision making makes NPCs more responsive, making them more lifelike and because of that more immersive (Laird, 2019).

As such, the ideas brought in from the real world (and coined for individual game titles as playgrounds) such as flanking, taking cover, coordinating attacks with other enemies based on a player's actions are all real and can be found quite easily in The Last of Us, where AI powered enemy NPCs do so and do so much better. The AI companion NPCs supporting you in the game also block out moves, thinking as AI, giving advice, and reacting to your choices. Different from the usual, players felt

more emotionally engaged to NPCs if their behaviors were more intelligent and responded appropriately to the situation, as described by Dahl and Goetz (2020).

Complex and real NPCs are created with such behavior trees and finite state machines algorithms. But what these AI algorithms make them can evaluate what their environment is, detect the player, and then interact in a way that they try to behave human that can impact the game. The NPC conversation is so complicated at this level that it makes gameplay more engaging and unpredictable, and leaves players hanging on edge in a challenge mode.

In game design, AI has also made itself increasingly important in procedural content generation (PCG). Instead of building out game worlds one tile, level and quest at a time, algorithms that are abstracted through PCG, allow developers to pave the way for expansive and unique worlds. PCG made more dynamic, realistic and coherent by AI.

Adaptive gameplay experiences that react to the player's behaviour and play skill are also created by the presence of AI. Adaptive difficulty makes the game get more difficult and less frustrating based on how you've been playing. This is a technique known as dynamic difficulty adjustment (DDA), and used sparingly in games such as Resident Evil 4 and Left 4 Dead. For example, in Resident Evil 4, it changes within Resident Evil 4 the frequency at which the enemy appears, how much health it has and how much ammunition the player has.

The more resources the player has the fewer enemies, and the less skilled player the more enemies the player has to face and less rewards. Adaptive difficulty driven by AI keeps players engaged while the experience remains balanced enough you don't just grind out everything. In addition, AI can facilitate personalization of the player's experience – and game narrative, quests, or interactions can be adjusted to the individual player's choices. Games like The Elder Scrolls V: Skyrim and Mass Effect both use AI to adjust the story and NPC interaction for the player, related to the player's previously chosen and engaged in solutions.

**Conclusion**. Game design and the player experience have all been greatly transformed by artificial intelligence. AI involves learning the attributes of the player, so game developers have come up with ways to make games more realistic, more immersive, more dynamic, with more interactive experience based on player behavior. NPC behavior has seen a boost from AI, making it now much more knowledgeable and likely choosing a more intelligent and realistic decision; the advances of AI have pushed the creation of procedurally generated worlds that can offer players infinite possibilities and made it possible to create adaptive difficulty systems capable of adjusting to the player's skill level.

There is so much more that can be done with AI technologies as they grow. What's more likely is that, in the future, gaming will become even more engaging and personalized by integrating ever more advanced machine learning, natural language processing, and behavioral AI. And they are not the same ones making these future games: for developers and players, AI is creating a future for interactive entertainment that is both exciting and transformative.

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## PRECISION OF LLM-GENERATED NUMBERS IN COMPUTATIONAL TASKS WITH AND WITHOUT SELF-EVALUATION

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**Keywords:** GPT, Llama, precision, self-evaluation.

**Introduction.** This study aims to evaluate the numerical precision of responses generated by several large language models (LLMs), as well as their capability for self-evaluation.

**Objectives.** For each model, we test three main hypotheses:

Hypothesis 1: $H_0$: There is no significant correlation between the model's self-predicted errors and the actual observed errors in their numerical responses.

Hypothesis 2: $H_0$: The likelihood of an error for each digit in a numeric response follows a uniform distribution, demonstrating monotonic characteristics.

Hypothesis 3: $H_0$: The presence of self-evaluation prompts does not affect the precision of the numerical answers.

Regardless of whether we reject these hypotheses, we expect this research to yield valuable insights into the numerical reliability and limitations of current LLMs, helping to identify scenarios where their numeric outputs may be more dependable.

**Methods.** The study evaluated four LLMs – GPT-4o-mini, GPT-3.5-turbo, Meta-Llama-3.1-70B-Instruct, and Meta-Llama-3.1-8B-Instruct – chosen for their distinct capacities (Peng et al., 2023; Touvron et al., 2023). Each model was assigned numerical tasks under two conditions: with and without self-evaluation. For the self-evaluation condition, models returned their absolute error and a probability (0 to 1) indicating their confidence in the response's precision; they were also instructed to avoid rounding. The primary task was floating-point addition, though the highest-performing model was further tested on averaging 10 or 20 numbers and counting specific digits in 100-digit numbers. Floating-point values were generated from a normal distribution (mean = 100,000, SD = 1,000) to control for scale effects.

Responses were analyzed for accurac and error distribution. Statistical analyses included correlation tests to assess the relationship between self-evaluation and actual

errors, Chi-square tests for error distribution patterns, and one-way ANOVA to determine the impact of self-evaluation prompts on accuracy.

**Results.** Over 3500 requests were made. Only one outlier was removed. Identifying outliers proved challenging, as errors followed an exponential distribution (at least for some tasks) with a mean exceeding that of actual deviations and a median, as a better estimator (Leys et al., 2013), slightly below the actual deviation mean.

For **Hypothesis 1**, the correlation between self-evaluation scores and actual errors showed no statistically significant relationship ($|r| < 0.15$, p-value $> 0.3$). The observed randomness of errors led to further exploration of the subsequent hypotheses.

For **Hypothesis 2**, simple addition tasks involving floating-point numbers were used to gather reliable data from less precise models. It was observed that all models tend to truncate numbers quickly, so we focused on a precision of 5 digits after the decimal point as well as 6 digits before it. Detailed findings are summarized in Table 1 below.

Table 1: Results for Floating-Point Addition Tests

| Metric | GPT-4o-mini | GPT-3.5-turbo | Meta-Llama-3.1-70B-Instruct | Meta-Llama-3.1-8B-Instruct |
|---|---|---|---|---|
| With Self-Evaluation | | | | |
| Answer Validity (%) | 97.5 | 99.0 | 61.3 | 54.5 |
| Mean Relative Error (%) | 3.1 | 1.3 | 9.1 | 9.4 |
| Digit Correctness Mean (%) | 96.4 | 91.6 | 87.0 | 89.2 |
| Truncated (limited to fewer than 5 decimal places) (%) | 0.0 | 9.0 | 2.2 | 1.5 |
| Chi-sq. Test for $H_0$ (p-value) | 0.990** | 0.211 | 0.957* | 0.900 |
| Without Self-Evaluation | | | | |
| Answer Validity (%) | 100.0 | 100.0 | 90.1 | 87.2 |
| Mean Relative Error (%) | 0.8 | 0.2 | 9.6 | 8.6 |
| Digit Correctness Mean (%) | 90.6 | 90.8 | 80.7 | 87.3 |
| Truncated (limited to fewer than 5 decimal places) (%) | 0.8 | 0.3 | 1.2 | 0.0 |
| Chi-sq. Test for $H_0$ (p-value) | 0.011 | 0.005 | 0.446 | 0.528 |

* $p > 0.95$; ** $p > 0.99$, indicating a likely uniform distribution

In general, all models demonstrated similar abilities to produce correct digits. The uniformity tests were met in only two of eight comparisons ($p > 0.95$). Close analysis suggests this was largely due to answer truncation. Notably, "GPT-3.5-turbo" tends to round response numbers even when self-evaluation was requested.

For **Hypothesis 3**, we conducted a series of one-way ANOVA tests to further investigate the effect of self-evaluation on answer precision. No significant differences were found across models, except for "GPT-4o-mini." Here, responses with self-evaluation consistently showed larger errors than responses without self-evaluation across all four tasks ($p < 0.05$), suggesting that self-assessment prompts may affect the precision of numerical outputs in this model.

**Conclusion.** The study examined the numerical precision and self-assessment abilities of four advanced large language models. Our findings reveal that these models may provide consistently accurate numerical answers for simple computational tasks, while their self-evaluation scores are often too random and prone to outliers to be reliable indicators of accuracy. Notably, "GPT-4o-mini" produced more consistent results when self-evaluation was not included, suggesting that the act of self-assessment may detract from precision, which aligns with other studies (Wu et al., 2023; Xu et al., 2023). It is recommended to exclude it from the same prompt. This research provides clearer insights into when these models can be reliably trusted with numeric outputs.

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# CYBER SPACE AND CYBER SECURITY IN INTERNATIONAL RELATIONS

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**Keywords:** cyberspace, cybersecurity, digital infrastructure, international relations, cyberattacks, cyber threats.

**Introduction.** The rapid advancement of digital technology has transformed cyberspace into a central component of modern international relations. Cyberspace, once a space for communication and commerce, has evolved into a crucial arena for political power, security, and economic influence. As nations increasingly depend on digital infrastructure, the growing prevalence of cyber threats – such as cyberattacks, espionage, and information warfare – poses significant risks to both national and global security. The significance of this topic lies in the fact that cybersecurity has become a priority issue in international relations, with the potential to shape the political and economic future of countries around the world.

**Problem Statement.** As cyberspace becomes a more contested geopolitical domain, the challenge of ensuring cybersecurity in this space grows. The lack of clear, universally agreed-upon rules and norms complicates the process of defining and responding to cyber threats. States, private companies, and other actors in cyberspace are often left to navigate an evolving landscape with limited guidance on acceptable behaviors. This situation leads to tensions and conflicts over issues such as cyberespionage, cyberattacks, and digital manipulation, which threaten national security and undermine global stability (PwC, n.d.).

**Research and Findings.** Recent studies show that cyberspace has emerged as a new domain for power struggles between states. Nations are increasingly investing in cyber capabilities, not only to defend their own infrastructure but also to gain an advantage over adversaries. Cyberattacks, including data breaches, infrastructure disruptions, and disinformation campaigns, have already had serious consequences for political stability and economic growth (Political Violence at a Glance). Initiatives like the Paris Call for Trust and Security in Cyberspace (2018) highlight the growing need for international cooperation in addressing cyber threats. Additionally, organizations such as ICANN play a critical role in maintaining the global stability of cyberspace by managing domain names and internet identifiers (Paris Call, n.d.)

**Proposed Solutions/Innovations.** To address the challenges posed by cybersecurity in international relations, several key solutions can be proposed. First, the creation of internationally recognized legal frameworks and norms is essential to establish clear rules of engagement in cyberspace. These frameworks would help define cyberattacks, set boundaries for state behavior, and provide guidelines for mitigating cyber risks. Second, enhanced international collaboration through

information-sharing agreements can strengthen collective cybersecurity efforts. Nations should commit to sharing intelligence on emerging cyber threats, vulnerabilities, and attack strategies (United Nations Office on Drugs and Crime). Lastly, joint cybersecurity exercises and operations between countries would improve coordination in responding to cross-border cyber incidents, fostering greater trust and collaboration.

**Impact.** The implementation of these solutions could have a profound impact on the global digital landscape. By establishing universal cybersecurity norms, states could reduce the risks of misunderstandings and miscalculations that often arise in cyberspace. Economic consequences from cyberattacks could be minimized, and critical infrastructure could be better protected. Furthermore, greater cooperation in cybersecurity would foster international trust, making it easier for states to collaborate on other global challenges. Ultimately, a more secure cyberspace would contribute to overall global stability, promoting peace and cooperation in the international system (Council on Foreign Relations).

**Conclusion.** In conclusion, the growing importance of cyberspace in international relations demands increased attention to cybersecurity. By establishing international norms, enhancing information-sharing, and promoting joint cybersecurity operations, states can work together to safeguard cyberspace and minimize the risks associated with cyber threats. The proposed solutions offer a path toward a more secure and stable digital environment, which is critical for maintaining global peace and fostering stronger international cooperation in the digital age.

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# TECHNOLOGIES OF THE NEXT DECADES FOR TYPE I CIVILIZATION

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**Keywords:** modern science and technology, Type I civilization, renewable energy sources, intelligent power grids.

**Introduction.** Modern science and technology is continuously changing many areas of energy generation at speeds unprecedented in human history, indicating an all-important phase transition to another civilizational scale (Prasad et al., 2022). From the viewpoint of the Kardashev scale, Type I civilization requires a radical change in the way we produce, store and consume energy since it has to harness all the energy resources the whole planet can provide. Innovations in the next 10 years are believed to drive the highest use of renewables possible, modernize infrastructure, improve energy efficiency, and develop hydrogen technologies. This will also enable humanity to build a greener and cleaner future through enhanced scientific research and environmental programs, together with better regulation programs (Chernetska & Zamulko, 2020).

**Objective.** Efforts are made to reach a point where we have a sustainable energy transition to reliable, clean and efficient energy utilization while we are on our way towards Type I civilization time. This encompasses full-range integration of renewables, infrastructure upgrade, efficiency enhancement, and deployment of new technologies, such as hydrogen and modular nuclear reactors, to limit environmental damage and dependency on fossil fuel sources.

**Methods.** The first step of Type I civilization is to raise the proportion of renewable energy, above all solar, wind, hydro, and geothermal. The expansion of solar and wind plants has to be more efficient and less expensive. The renewable plant operation must also be tailored to the location features, e.g. thermal energy is available in volcanic areas, and hydropower in mountainous parts of the country. Nuclear energy is still essential as a low-carbon transition technology, and new investments will be directed towards safer and modular reactors for stable energy generation (Danylyshyn & Koval, 2022).

With future energy demand requirements, the existing power grid falls short. Smart grids are expected to better integrate renewable sources while decreasing overloads and failures, due to digital tech that tracks and balances electricity in real time (Chernetska & Zamulko 2020). In addition, batteries, hydrogen tanks and pumped storage can all help lessen peak demands or fluctuation in renewables requiring backup. These technological advancements will make energy supply and demand more stable.

One more component of Type I civilization is enhancing energy efficiency. This means scaling up energy conservation techniques from construction, transport and production. Consolidate industrial energy-saving initiatives (for instance, waste-

to-energy applications) and strengthen high-voltage direct current (HVDC) lines are designed to minimize distance transmission losses. Electric vehicles along with their corresponding infrastructure provide essential service to lessen the reliance of the transport sector on fossil fuels.

Another option for stable, long-term energy storage is hydrogen, which can be produced by excess renewable energy via electrolysis. Where electricity cannot be used (e.g. in heavy industry and transportation), hydrogen can fill the gap. According to Danylyshyn & Koval (2022), hydrogen infrastructure development will protect a strong and sustainable supply chain in these segments.

**Results**. In fact, much research and innovation is necessary to accelerate the energy transition, and that will require considerable investment. Fusion energy could provide power in the future, and innovation in energy storage, solar efficiency improvements, and green battery designs will originate from start-ups and research institutions. Also, cybersecurity will be essential to safeguard this growing energy infrastructure.

The decrease of adverse effects on the ecosystem must always be combined with energy generation. The move towards cleaner energy can be supported through environmental taxes, emission quotas, and subsidies for renewables. Modernization of old plants, along with government programmers to promote distributed energy systems, will reduce carbon footprint.

Thus, Type I civilization has attained a planetary standard of economics. This civilization would either be a regional microstate or a community of states, helping each other with the energy transition projects they are crafting. Making our ecosystem more collaborative with technology will bring quicker adoption of renewable energy and less fossil fuel dependency (Prasad et al., 2022).

Milestone international agreements like the Paris Agreement create a foundation for global collective action to reduce greenhouse gas emissions and mitigate climate change. These agreements allow for shared effort and pooling of resources to combat the environmental problems.

**Conclusion.** It is very reasonable for most scientists to believe that the next 10 years present a challenge for the modernization of the energy sector. Energy sources include an area of change to Type I civilization on the Kardashian scale. Solar power, smart grids, energy storage, and innovative development will enhance the efficiency of cleaning and using available resources, while ensuring sustainable conditions for the development and improvements of the quality of life around the world.

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## MODERN FRONTEND DEVELOPMENT: TOOLS, TECHNIQUES, AND CHALLENGES IN THE 21ST CENTURY

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**Keywords:** Frontend Development, JavaScript Frameworks, Web Design, User Experience, Responsive Design, Web Performance.

**Introduction.** The frontend is more sophisticated and necessary than ever in the fast-changing world of web development. Creating the front-end parts of a website and application is frontend development and it has to be visually appealing, responsive and performant throughout various devices is what frontend development is about. New technologies, frameworks, and methods of design have caused the field to shift rapidly over the past decade, enabling web interfaces to be built and optimized on entirely new terms. The aim of this research is to highlight how modern frontend development tools and techniques are achieving their objective through trendy solutions like responsive design and using JavaScript frameworks to deliver faster, more efficient websites.

**Objectives.** For the investigation of the evolution of frontend development tools and frameworks. One is to study how modern design techniques like responsive design and component-based architecture is helping to improve user experience. In short, I want to explore how frontend developers are tackling the performance optimization problem and browser compatibility issues. So, we can talk about how frontend development trends will change web applications in the future.

**Methods**. Research consisted of studying existing literature on modern frontend technologies starting from the Journal of Web Development Technologies to key industry reports such as of known platforms such as GitHub and Stack Overflow. We evaluated tools and frameworks such as React, Angular, Vue.js and how these can impact frontend development workflow, as well as the growth of CSS preprocessors such as SASS and LESS. The study also considers industry case studies of the leading tech companies who demonstrated how responsive design and performance improvements had enhanced the usability of their website and application. To have a quantitative evaluation, we measured some of the performance metrics, like page load time, time to interactive, rendering performance, using tools such as Google Lighthouse and Webpage Test across different devices. We used these metrics to analyze comparisons of traditional websites to modern frontend frameworks websites.

**Results.** It's been over a decade since modern frontend development evolved into its own niche, fueled more by the rise of JavaScript frameworks and libraries that let developers build more interactive and dynamic web apps. For example, React, which now powers over 40% of developers across the globe, becomes possible thanks to the component-based architecture that allows to create reusable UI components and significantly streamline the development (GitHub, 2023).

In the same vein as everything else, another major shift in frontend development has been the adoption of responsive design. Responsive web design has become the standard, to ensure websites work well across all devices with different sizes. There are many frameworks like Bootstrap and CSS Grid that have become easier to write layouts for which the resolution will automatically change fluidly for different screen resolutions and thus provide better user experience on mobile devices (Feldman & Wilcox, 2022). That is, though, until the advent of JavaScript-heavy applications which have raised new performance challenges.

Heavy client-side rendering websites can cause slower load times which degrades user engagement and search engine optimization (SEO). To resolve these problems, new techniques like code splitting, lazy loading and server-side rendering have been introduced, to reduce the amount of JavaScript that needs to be passed away by the client side. But case studies with e-commerce platforms such as Shopify show how adopting these optimizations can result in a 20 to 30% improvement in load times (Wang et al. 2021). The other issue is browser compatibility.

In spite of a great deal of effort currently ongoing to standardize browser behavior, browsers can sometimes have different interpretations of CSS and JavaScript and there may still be issues to be worked out. However, this renders portable the majority of the functionality that developers rely on, as often developers use polyfills, and build tools such as Webpack and Babel, to ensure consistency between browsers and devices.

**Conclusion**. Recently, the frontend development has become very dynamic; there has been significant need to create more dynamic, responsive, more performant web applications as well as a strong demand. Responsive design and JavaScript frameworks like React and Vue.js have completely changed the way developers build a user interface, while websites continue to be effectively accessible and functional on all types of devices due to the rise of responsive design techniques. But front-end development has become more and more complex with growing performance optimization and cross browser together challenges. With the evolution of web applications from simple to more sophisticated, web frontend development trends in the future will probably mostly take the path of performance and accessibility enhancement, especially taking into consideration the reduction of web technologies bloat. Future developers will have to consistently position innovation in balance with the ordinary demands of the users, so that websites don't just look good, but also load fast and work flawlessly in every platform.

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## TEACHING SPANISH THROUGH VIDEO GAMES: THE CASE OF "A TRIP TO VALENCIA"

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**Keywords:** Serious games in ELE, ELE teaching, gamification, Chinese-speaking students.

**Introduction.** With the rapid growth of the video game industry, scholars in the field of education are gradually turning their attention to this industry, contributing ideas to bridge the seemingly opposing domains of video games and education.

Andreu Andrés and García Casas (2001) highlight that the relationship between learning and play is not antagonistic, but rather a natural one. Similarly, Mora (2014) suggests that play serves as a guise for learning. Currently, there are already many relevant studies in this area, with the most common being research on gamification, which refers to applying the characteristics of video games in real classrooms to enhance student motivation. However, there is relatively little research focused on the direct use of video games in teaching and learning, and most of the video games used for educational purposes are not serious games specifically designed for educational objectives.

According to Pérez Tamayo (2022), the current educational model in China remains traditional and mechanical, and the same applies to the teaching of Spanish as a Foreign Language in China. Manzanares Triquet (2020: 274) notes that this situation has persisted since ancient times, with a long-standing history. However, despite the difficulty of changing such a deeply rooted tradition, efforts to do so are worthwhile. This research aims to provide new ideas for ELE teaching methods.

**Objectives.** The objective of the study is to explore the effect of applying video games in the teaching of Spanish as a Foreign Language (ELE), to understand the students' level of acceptance of this teaching method, and at the same time, to investigate the feasibility of video games as a teaching tool for Spanish. This study begins with a theoretical review of key concepts such as gaming, gamification, and

motivation in language learning, and it continues with our experiment before the conclusions are reached.

**Methods.** The methodology of this research consists of a preliminary questionnaire, which serves as a tool for analyzing the needs of 52 university students at the B1 level and understanding their prior experiences with gaming. Based on their preferences, a serious video game focused on teaching Spanish as a Foreign Language (ELE) was then designed, with content centered on two grammatical topics: the use of the simple conditional and the future imperfect. Finally, a second questionnaire was administered to gather students' impressions and assess the results.

**Results.** In this type of research, the level of student motivation plays a crucial role. "Flow," a concept defined by Csikszentmihalyi (1992) and cited by Fernández (2015), explains the relationship between motivation and challenge. When a student's ability matches the difficulty of the challenge they face, their motivation reaches its peak; otherwise, feelings of anxiety or boredom may arise. The game designed in this study matched the language level of most participants, as reflected in the second questionnaire, facilitating the success of the research. Additionally, student involvement in the game's development was highly significant, with activities such as voice acting for game content and becoming characters in the game, which further enhanced their motivation to engage with the game. Finally, the use of simple game development software, such as the RPG MAKER series, made the creation of this type of game highly accessible. It does not require mastery of complex computer languages, and the games are easy for students to operate, allowing them to focus on the content.

**Conclusion.** In summary, the results of this research demonstrate that the application of video games in the teaching of Spanish as a Foreign Language can be an effective educational method. Both students and teachers exhibited a positive attitude toward this approach to learning Spanish, particularly highlighting the interactivity and the alignment of content with their language proficiency level. Although the study was conducted with a specific sample of Chinese students and faced certain methodological limitations, the findings suggest that video games hold great potential for integration into ELE teaching programs.

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## WIRELESS CHARGING OF ELECTRIC VEHICLES AS AN INNOVATION FOR A SUSTAINABLE FUTURE OF TRANSPORT. WITRICITY TECHNOLOGY

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**Keywords:** electric vehicles, wireless charging, WiTricity, magnetic resonance, energy efficiency, dynamic charging, infrastructure, sustainable development.

**Introduction.** In today's world, where environmental issues and sustainable development are becoming increasingly important, electric vehicles are becoming a key trend in the transport industry. However, several technical challenges need to be addressed to ensure the convenient and widespread introduction of electric vehicles, with the creation of an efficient charging infrastructure being a top priority. According to a recent survey, 96% of users expressed interest in wireless charging, and 70% said that the availability of such technology would encourage them to buy an electric car (WiTricity wireless EV charging. Power up, cable-free, n.d.). This underscores the importance of WiTricity technology, which enables wireless charging of electric vehicles by transferring energy without physical contact, making the charging process more convenient and attractive to users.

**Objectives.** The rapid development of wireless charging technologies for electric vehicles, such as WiTricity, is taking the industry to a new level of quality, increasing the efficiency of energy transfer and reducing the need for large charging batteries. The introduction of such technologies expands the applications of electric vehicles, providing continuous charging while driving and helping to reduce dependence on fossil fuels, which can reduce global $CO_2$ emissions by tens of millions of tons annually.

**Methods.** The thesis presents a quantitative and comparative analysis.

WiTricity is a pioneer in the development of wireless charging for electric vehicles, aiming to make the charging process as easy and efficient as a conventional plug-in. The WiTricity charging system uses the principle of magnetic resonance to transfer electricity over a distance without the need for physical connections such as cables. As a result, electric vehicle owners can charge their cars by simply parking them over a charging panel.

The system consists of a power source and a receiver that operate at the same resonant frequency. The alternating current (AC) electricity passes through the charging station coil, generating an oscillating electromagnetic field that the resonator picks up and transmits to another coil. A rectifier then converts the received energy into direct current (DC) to power the battery. This technology delivers energy transfer efficiency of over 90%, similar to a conventional cable connection. It works through a variety of materials, such as asphalt, cement, snow or ice, and provides parking flexibility with XY positioning to support charging vehicles of all heights (WiTricity. Wireless EV Charging, n.d.).

The WiTricity technology supports power outputs of up to 10W for mobile devices, 6kW for cars and 25kW for fleets and buses, and is scalable to reach hundreds of kilowatts for heavy vehicles. WiTricity electric vehicles can be charged at speeds ranging from 3.6 to 11 kW and support bi-directional power transfer, which allows the batteries to be used to stabilise the grid or power a home (WiTricity, n.d.).

In addition, WiTricity is developing wireless charging for public transport, enabling buses and trams to be charged at bus stops or even in motion, contributing to clean and continuous transport in cities.

**Results.** The results show that WiTricity technology can achieve energy transfer efficiency of up to 90%, which is competitive with wired charging stations. The introduction of stationary wireless stations in car parks and dynamic charging zones on major highways allows for a hybrid system that meets different user needs. Stationary stations provide charging during stops, while dynamic charging zones allow cars to be charged on the move, reducing the need for large batteries and reducing range anxiety. This can help to facilitate a faster spread of electric vehicles among the population.

**Conclusion.** WiTricity technology offers an innovative approach to charging electric vehicles that overcomes the limitations of existing infrastructure and makes the charging process easier and more attractive to users. The proposed hybrid model, which combines stationary wireless stations and dynamic charging zones, has significant potential to reduce carbon emissions, cut infrastructure costs, and reduce negative environmental impact. The introduction of wireless charging will not only improve the convenience of using electric vehicles, but also contribute to the development of sustainable transport, which is in line with global climate protection and sustainable development goals.

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## THE FUTURE OF ARTIFICIAL INTELLIGENCE IN MEDICINE: CHALLENGES AND OPPORTUNITIES

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**Keywords:** artificial intelligence, medicine, healthcare, machine learning, diagnostic tools, personalized treatment.

**Introduction.** Artificial Intelligence (AI) has been growing exponentially in the 21st century, and ushering into various industries from healthcare (Cabitza, Rasoini, & Gensini, 2017). And yet AI technologies are being woven into diagnostic tools, treatment protocols and even surgical procedures, all in the hopes of transforming medical practice, and patient care, in dramatic ways. This abstract is an introduction into what AI has, can, and may pose as a threat to the medical sector. With the rapidly growing complexity of diseases and the need for personalized treatment, AI brings innovation with it that can change modern medicine. While the integration of AI into healthcare has advantages, the same technology also poses ethical, regulatory and technical challenges which must be tackled for its full potential to be realized (Rajpurkar et al., 2018).

**Objectives.** The purpose of this research is to summarize the state of the art of AI in medicine, identify the major benefits, challenges, and prospects. Specifically, the study aims to answer the following questions:

1) What can AI bring to reducing the diagnostic accuracy and efficiency in healthcare?
2) Where are we currently with integrating AI in clinical practice and what are the limitations and risk?
3) Where society currently stands on AI in medicine, and what are the ethical issues surrounding AI in practice involving patient privacy and data security?
4) In what ways can we expect AI technology to evolve and change over the decades in healthcare?

**Methods**. A mixed methods approach, adopting literature review as well as case study analysis on the role of AI applications in existing healthcare, is taken in this research. The theoretical framework is grounded in a comprehensive review of the peer-reviewed journal articles, conference proceedings and reports of reputable institutions. It also looks at some real-life use case studies of AI in diagnostic tools like IBM Watson Health and Google's DeepMind to see how effective they are in actual world clinical settings. In thematic analysis, data analysis is adopted to find patterns and insights about the advantage and challenge of AI in healthcare.

**Results.** There are a number of key areas where AI is changing medicine, the research finds. Second, AI has shown promise to outperform traditional diagnostic methods in identifying diseases like cancer, cardiovascular conditions, and neurological disorders, based on data from AI driven diagnostic tools including machine learning based algorithms. Let's take an example of how AI models have been extraordinarily successful in analyzing medical images like MRI and CT scans to detect anomalies which our human physicians are not able detect (Topol, 2019).

Moreover, AI is advancing by means of personalized treatment plans based on analyzing large masses of patient information, by means of patient histories, genes and real time health metrics. This way, AI can suggest more accurate and customized treatment options to the patients on a one-to-one basis, which may lead to better results and reduce treatment process. Even some AI-driven platforms have been able to predict the success rates of certain treatments so that doctors can make better, informed choices. However, the study also exposed a number of important less than ideal constraints. However, like many things AI, the implementation of AI in medicine is still in its infancy and adoption is hindered by issues ranging from lack of standardized data sets to biases in algorithms to high cost of implementation. In addition, patient privacy and data security are of increasing concern due to the fact that AI systems routinely need to access sensitive personal health information in order to function properly (Obermeyer et al., 2019).

Such risk exists without proper safeguards, which introduces a high likelihood of data breaches, misuse, etc. Concerning ethics, AI is raising questions about what role the physician should have in a world that more and more, is automated. Although AI will help in making a decision, but it is not assisted with human aspects of empathy and moral judgment that are fundamental for patient care (Ardila et al., 2019). Furthermore, there is the problem of accountability: if an AI system makes a mistaken diagnosis or a mistaken treatment, who does it hold accountable?

**Conclusion**. With its potential to enhance diagnostic accuracy, personalization of care and reduce the burden on healthcare professionals, AI has huge potential to remake health care. But, to make AI useable in medicine it has to face several challenges. Some of the them are – creating a more standardized as well as diverse datasets to train AI models, ensuring enhanced protection to AI models, and facilitating the work between the developers of the AI models and the medical professionals, so that these AI models are made both safe and efficient. To move forward, policymakers, medical practitioners, and AI experts need to work together to address ethical, legal and technical challenges of integrating AI into healthcare. AI when used to set up an environment of cooperation and innovation can help create an efficient and effective and equitable healthcare system for all.

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## POSSIBLE DEVELOPMENT OF NEW PROGRAMMING LANGUAGES OR IMPROVEMENT OF EXISTED IN THE NEXT 10 YEARS

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**Keywords:** Programming Language Trends, Error Handling Mechanisms, Concurrency and Multithreading, Language Evolution and Community Impact.

**Introduction.** Today's world is fast-changing and we are seeing significant changes in programming, especially in programming languages. We are observing shifts in preferred programming paradigms and changes within the languages themselves. It is important to maintain long-standing challenges like multithreading, data and package management, syntax sugar, and the balance between simplicity and versatility in a language.

In this study, trends in new programming languages have been analyzed. They were created in the last 10 years to understand what they bring to the programming landscape, identify the biggest challenges in language development, and discover the main trends to understand where both new and established programmers should focus their attention.

**Objectives.** The potential future of new programming languages has been explored over the next 10 years. This will help programmers direct their focus towards relevant paradigms and problems that can be addressed by emerging languages. By better understanding the future of programming languages, developers can make better decisions about which languages to learn, enhancing their career path or avoiding languages with limited popularity. This approach aims to create specialists in the fields of these programming languages.

This study can also inspire and guide people connected to programming language development, inspiring them to create new languages. By researching trends in programming languages, it can cultivate a deeper understanding and enthusiasm for language creation.

**Methods.** The main methods used in this study are case studies of Zig, Rust, Go, and Elixir to provide real-world examples. This method aims to create an understanding of the current landscape and future direction of programming languages.

**Results.** Firstly, case studies like Zig, Rust, Go, and Elixir are taken. Something common has been found among all four of these languages. Firstly, there is error handling. None of these languages use try-catch as the usual error-handling mechanism. This feature is probably common because error handling is something people are very likely to forget to do.

Zig has special syntax sugar and error unions for error handling, so errors are in the type (Zig Software Foundation, n.d.). Rust has Result and Option, where errors are also in the type (The Rust Project Developers, n.d.). We can use explicit error returns in Go, so we also have an error value in returns (Go Team, n.d.). Elixir error handling uses tuples, and despite the try-catch-rescue mechanism for handling exceptions, this is not the same imperative try-catch. This is because Elixir has a philosophy and functionality for the 'let it crash' paradigm. So, errors are caught later in the process, not just by try-catch (Elixir Team, 2024).

The second theme is multi-threading. Only Zig has a library without added features. Rust has a set of multi-thread parameters and atomic operations with locks. But the main feature is ownership, which helps us avoid race conditions in threads. Go is built with concurrency in mind and uses coroutines and lightweight threads managed by the Go runtime. Coroutines allow easy multitasking without worrying about thread management. Elixir uses the Erlang virtual machine to support threads, with each process isolated in the VM, which creates efficient multi-threading that is also optimized.

The next thing is null handling. We can find the word null or nil in Zig, Go, and Elixir. However, none except Go treat it as a typical null value. In Elixir, it is similar to null but operates in a functional style so many methods are adapted to this behavior. Zig and Rust handled this with option types, ensuring we do not forget to check whether the value is null or valid.

Marketing is something in common among these four languages. Every language emphasizes that they are highly optimized, highly productive, and created with a focus on productivity. Even with the increasing power of our computers and technology, we reached a point where everyone, even with significant computational resources, wanted an optimized language because of inefficient modeling or costly abstractions. Also now we have better tools for language creation, it is not as difficult as it was even 20 years ago to create a highly productive language. Zig, for instance, was created by one person plus a community around it.

With the emergence of new languages, we often overlook older, established ones. Popular languages like JavaScript, Python, and Java have dominated for around 20 years (Samarth Tambad et al., 2020). JavaScript, crucial for web development, owes its popularity more to necessity than to its simplicity or innovative features. Similarly, Java remains widely used due to the many legacy projects that require

maintenance. Also, part of the problems with the popularity of new programming languages is often the fault of working with a community of these languages, as bad quality of support or documentation (Partha Chakraborty et al., 2021). For new developers, learning JavaScript seems like a rational choice. However, even though newer languages may not be as popular or rank in the top 10, they significantly influence the programming landscape. For example, they have inspired changes in Java, such as the introduction of streams and more functional programming features, Python has adopted more typing options. Due to these influences, even C# has incorporated LINQ, a significant feature. These changes prove impactful, showing that even less popular languages can drive evolution in the field.

**Conclusion.** In this study's conclusion, we observed that new programming languages often tackle the same challenges and try to address similar issues, like multithreading, performance, and memory management, each in its own way. For instance, null handling is a tough topic, and new languages aim to introduce fresh approaches to it. Many of these innovations are inspired by mathematical concepts, like monads for results and options, which attempt to eliminate issues using functional programming techniques. An exception to this trend is Zig, which uses explicit error handling and panics to make it difficult to introduce errors unknowingly while also supporting optional types.

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# HOLOGRAPHIC PROTECTION TECHNOLOGIES AS A METHOD OF DECORATION OF PRINTED PRODUCTS

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**Keywords:** hologram, holographic images, protection, book decoration, printing products.

**Introduction**. In the global market, mankind is modernizing and inventing original methods of designing printed products every day. In an effort to attract the interest of ordinary consumers, engineers and designers are trying to use all the possibilities available to them, from finishing with traditional methods such as embossing, varnishing, and cutting out certain elements of the product to using modern technologies such as augmented reality (AR).

One of the possible ways to protect printed materials is holography. In recent years, holograms have become widely used to protect securities, documents, and goods in the form of holographic security elements (HSEs). However, we will consider the option of using it as a decor for printed materials and look at the technology of its use.

**Objectives**. The main goal of this article was to analyze the theoretical basis for creating a holographic image on printed materials and the rationality of its use as a method of decoration.

**Methods**. The main research method is the analysis of scientific works in the field of holographic elements over the past few years. The studied theoretical framework makes it possible to develop a possible variant of book production decoration.

**Results**. Initially, in combination with the concept of printing, holography is associated with the creation of security features to protect securities, documents, and goods. There are quite complex in execution, and therefore difficult to fake it.

A hologram itself is a physical structure that uses light diffraction to create a three-dimensional image. The main difference between a hologram and a photo is that a hologram is a record of a light field, not an image formed by a lens. This process is made possible by two properties of light waves: diffraction and interference. In the process of visualizing a hologram at a certain point in space, two waves (reference and object waves) are superimposed, which is formed as a result of the laser beam splitting. The reference wave is formed directly by the light source, and the object wave is reflected from the object. A photographic plate is placed at the intersection of both beamlines, where dark stripes are "imprinted" depending on the distribution of electromagnetic energy (interference) (KNDISE, 2022).

Today, the most commonly used hologram is a rainbow hologram created by combining optics, computer systems and material science technologies, such as Dot-

matrix and E-beam technologies (methods of recording basic holograms using special laser and electronic installations and generating images using computer programs).

Before working on an image, you need to agree with the customer on all the requirements for this type of product. It is important to approve the dimensions of individual elements, the nature of image dynamics, fonts, hidden images, microtexts, nanotexts, and other protective elements. This provides the basis for preparing information for a computer hologram generation system or making photo templates that correspond to different spatial layers or multi-colored elements. (Havenko et al., 2018).

Every year, more and more publishers are trying to interest readers with more and more interesting book designs. For example, in the summer of 2024, Vintage Publishing released The City and Its Uncertain Walls by Haruki Murakami, where the cover was created from a hologram. Buyers were surprised by the unusual concept, which added interest to contemporary prose (Murakami, 2024).

Namely, after having already studied the technology of creating a holographic image, we can modernize it into a more simplified version in order to interest future buyers in interesting products. However, in the realities of modern Ukraine, this is not possible, as the technology needs to be seriously simplified so that it can be used in products of lower cost. Currently, this method of decoration is very expensive.

**Conclusion**. To sum up, as a result of the study, the peculiarities of the technology for creating a holographic image were presented and the possibility of using it as a way to decorate book products with it was considered. Today, this technology has only an approved form for creating GES, and therefore it requires a more economical and simplified version for the production of printed products.

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## THE FUTURE OF BIONIC LIMBS

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**Keywords**: bionic limbs, prosthetics, osseointegration, neural interfaces, artificial intelligence (AI), sensory feedback, virtual reality (VR), amputees, human augmentation.

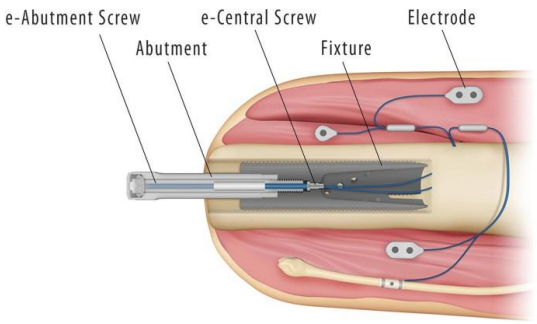
**Introduction.** The challenge of providing amputees with prosthetic limbs that offer both functionality and comfort remains significant, as traditional prosthetic solutions often fall short of replicating the natural experience of movement and sensation. Conventional designs, while offering basic utility, frequently lack the intuitive control and sensory feedback necessary for restoring limb function. Addressing these limitations, recent advancements in bionic limb technology offer a promising solution by combining biological interfaces with advanced electronics.

**Objectives.** To evaluate advancements in bionic limb technology, particularly osseointegration, neural interfaces, AI, and VR training, in enhancing prosthetic functionality and user experience.

**Methods.** A literature review, case study analysis, and expert interviews have been used.

**Results.**The future of bionic limbs represents a transformative integration of biological and technological advances, aiming to restore lost functions and enhance sensory feedback in prosthetic devices. Central to this progress is the work of Dr. Ortiz Catalan's team in Ukraine, which is pioneering prosthetic systems that blend biological interfaces with sophisticated electronics, allowing amputees to experience nuanced sensations in their artificial limbs. This development signifies a substantial shift from traditional prosthetics that relied primarily on mechanical or aesthetic functionality.

A significant advancement in this technology is the use of osseointegration, where a titanium implant is directly integrated into the residual bone of the amputated limb. This creates a stable foundation for the prosthesis, eliminating the discomfort of traditional sockets that press against the skin. Over time, bone cells develop around the titanium, forming a durable bond. This process, first developed for dental implants, has been adapted to prosthetics, offering a more permanent and comfortable solution for limb replacement (Ortiz-Catalan et al., 2014).

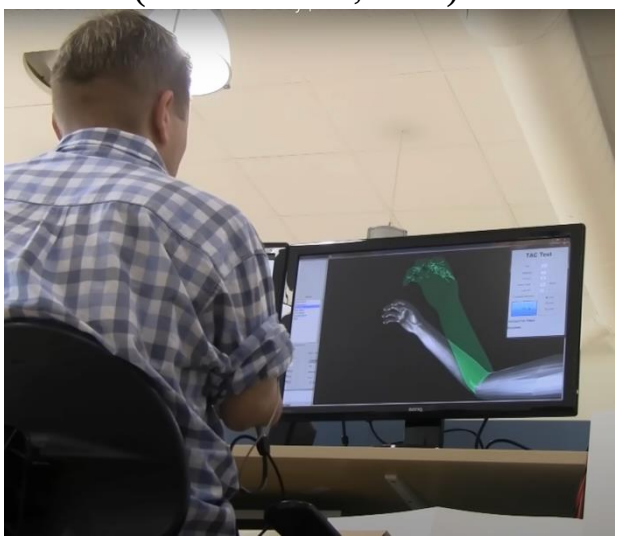



One of the most remarkable features of Dr. Catalan's bionic arm is its ability to be controlled through implanted electrodes. Unlike conventional prosthetics, which rely on external electrodes that are susceptible to interference from movement or electrical signals from nearby devices, these electrodes are surgically implanted within the nerves and muscles. This not only makes the prosthetic more responsive but also ensures its stability during everyday movements. The electrodes capture neural signals directly from the muscles, allowing the prosthesis to respond more naturally to the user's intentions.

In cases of above-elbow amputations, where fewer muscle and nerve pathways remain, the team has developed innovative methods to 'rewire' the body's original biological system. By transferring nerves from the hand to the biceps, they can allow patients to control their bionic hands with the same ease as they would a biological

limb. Additionally, the team uses a free muscle graft from the leg to provide further control, ensuring that even the most complex amputations can be addressed.

These neural signals are then amplified by the prosthetic's onboard computer, which translates them into actions that control the movement of the robotic fingers. However, the technology goes a step further by incorporating artificial intelligence (AI) into the system. The prosthetic's CPU must be trained to interpret these neural signals, a process that involves the patient performing specific movements while the system records the corresponding brain signals. This training is essential to ensure that the bionic hand functions precisely as the user intends, whether opening or closing the fingers or performing more complex tasks (Zbinden et al., 2024).



Virtual reality plays a vital role in this training process, providing aplatform for patients to practice controlling their bionic limbs in a safe, controlled environment before they are fitted with the physical prosthetic. This training helps fine-tune the AI and plays a crucial role in managing phantom limb pain (Keesom et al., 2024), a common issue amputees face. Through VR and other technologies, the brain's neural resources can be re-engaged, reducing discomfort and helping the patient adapt to their new limb (Researchfeatures, 2023).

Once the patient is comfortable with the virtual training, the final step involves fitting the physical prosthesis and testing it through everyday activities, such as picking up objects or packing a suitcase. The prosthesis is equipped with sensors in the fingertips, allowing users to feel objects in their grasp. Although tactile feedback is not as refined as a biological hand, it provides valuable sensory information, such as the pressure exerted on an object or the sensation of it slipping away.

The prosthetics are powered by rechargeable batteries, which can last a full day, eliminating the need for cumbersome external power sources. This marks a stark contrast to the bulky systems of the past, where patients had to carry heavy backpacks of computers and batteries. Despite the current cost of over $10,000 for these advanced prosthetics, there is hope that with broader adoption, the price will decrease, making this life-changing technology accessible to more people in need.

**Conclusion.** Looking ahead, bionic limbs could go beyond simple restoration to human augmentation. While we are not yet at the stage where prosthetics can exceed the dexterity or power of a biological limb, there is potential to develop prosthetics that enhance human abilities, such as increasing strength or speed. However, the primary focus remains on improving the quality of life for amputees by offering them more natural, responsive, and functional limbs that integrate seamlessly with their body's biological systems. With ongoing advancements in AI, virtual

reality, and neural interfaces, the future of bionic limbs is promising, offering new hope to millions worldwide.

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## ARTIFICIAL INTELLIGENCE IN DRUG DISCOVERY: A NEW ERA OF PREDICTING CHEMICAL SAFETY

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**Keywords:** artificial intelligence (AI), drug discovery, mutagenicity, genotoxicity, machine learning (ML).

**Introduction.** The 21st century has witnessed a paradigm shift in scientific research through the integration of artificial intelligence (AI) and machine learning (ML). In the pharmaceutical industry, these technologies are emerging as key drivers of innovation, particularly in the fields of drug discovery and safety evaluation. Detecting mutagenic and genotoxic effects of chemical compounds early in drug development is crucial to minimize risks and enhance the efficacy of new treatments. AI and ML offer efficient alternatives to traditional experimental methods, capable of handling vast datasets and accelerating the prediction process. However, these advancements also bring unique challenges, such as the need for robust model validation and interpretability.

**Objectives.** The objectives of this review are to summarize current AI and ML approaches for predicting mutagenicity and genotoxicity, discuss the strengths, limitations, and future potential of these methods, and highlight key insights into how AI can be integrated into drug discovery pipelines to improve safety assessments.

**Methods.** This study reviews AI and ML techniques used in drug discovery, focusing on mutagenicity and genotoxicity prediction.

**Results.** Evaluating chemical toxicity for drugs, consumer products, and environmental agents is essential for safeguarding human health. Traditional animal-based testing methods, although widely used, are costly, labor-intensive, and frequently ineffective at predicting toxic responses in humans due to interspecies differences. In this context, computational toxicology emerges as a promising and efficient alternative, leveraging machine learning (ML) and deep learning (DL) algorithms to assess the toxic potential of various chemical compounds. These advanced techniques have the potential to transform toxicity screening by providing rapid, cost-effective, and more human-relevant predictions (Jia et al., 2023).

Computational methods for toxicity prediction play a crucial role in the early stages of drug development by identifying compounds that may not succeed in clinical trials, allowing for their exclusion. AI has also transformed drug discovery and optimization, enabling the design of novel compounds with enhanced pharmacological properties (Cavasotto & Scardino, 2022). Through machine learning algorithms and virtual screening techniques, large libraries of compounds can be analyzed quickly to identify promising drug candidates with strong binding affinity for target proteins. Additionally, AI-driven de novo drug design facilitates the generation of diverse compounds, optimizing their binding properties, pharmacokinetics, and overall drug-like characteristics, further accelerating the development of more effective and safer therapeutic agents (Chen et al., 2023).

One notable AI model is DeepTox, an ensemble prediction tool for chemical toxicity. Its core architecture is built on a three-layer deep neural network (DNN). After data cleaning and quality control, chemicals are encoded using molecular descriptors ranging from 0D to 3D, which serve as inputs to the DNN. The DeepTox pipeline is optimized by fine-tuning hyperparameters like the number of hidden units, learning rate, and dropout rate. Results on the Tox21 dataset show that DeepTox outperforms other models in accurately predicting toxicity, showing an accuracy of around 85% (Mayr et al., 2016).

AI has become a powerful tool in drug discovery. However, several challenges limit its potential.

The main problem is the lack of high-quality data. Despite growing biological and chemical data, poor quality and class imbalances hinder model performance. Improved data curation and collaboration, alongside techniques like oversampling and undersampling, are necessary to address this.

Another challenge is the lack of model interpretability. AI models often can't explain their predictions, making it hard for scientists to trust them. Post hoc methods, such as visualizations and attention mechanisms, can improve transparency (Chen et al., 2023)

In the next decade, AI-driven drug discovery and computational toxicology will see significant growth, fueled by improved data quality and advanced algorithms. Enhanced machine learning techniques will lead to more accurate and interpretable

toxicity predictions, increasing trust in AI models (Yadav et al., 2024). AI will play a larger role in designing novel compounds with optimized properties, while collaborations between academia, industry, and regulators will establish standardized guidelines for AI tools in drug safety. These advancements will make drug discovery faster, more cost-effective, and safer for human health.

**Conclusion.** AI and ML have the potential to revolutionize mutagenicity and genotoxicity prediction, making drug discovery faster, cheaper, and more efficient. As these technologies evolve, collaboration between computational scientists, chemists, and regulatory bodies will be crucial to ensure reliable and transparent risk assessment methods. Despite current limitations, the integration of AI in toxicological assessments is a pivotal step toward more innovative and safer pharmaceutical development.

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## USE OF AUTOMATED DRONE SWARMS CONTROLLED BY ARTIFICIAL INTELLIGENCE

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**Keywords:** artificial intelligence, drone swarms, automation, industry.

**Introduction.** This subject is highly relevant in today's context, given the rapid progress in the field of unmanned aerial vehicles (UAVs) and the increasing need to develop efficient swarm control systems for various industries and societal needs. As new technologies enabling the autonomy and coordination of multiple drones emerge, creating reliable and effective solutions for swarm management

becomes a top priority. Swarm drones are increasingly used in agriculture, logistics, environmental monitoring, defense, and search-and-rescue operations. As the complexity of tasks performed by drone swarms grows, so does the demand for automated control systems that ensure high efficiency, reliability, and safety.

**Objectives.** The main objective is to research ways in which the development and implementation of new and improved methods for AI-based automated swarm management can be used.

**Methods.** A review of modern publications on drones, drone swarms, swarm robotics (Hamann, 2018), drone automation, autonomous navigation, artificial intelligence, AI-assisted algorithm development, object detection (Cybulski & Zieli´nski, 2021), and the impact of implementing drone technology.

Research of current implementations of automation (Leder & Menges, 2023), drones, and swarms across different industries and their impact on the efficiency, safety, and capabilities of affected establishments.

**Results.** Research shows that new AI-driven swarm management methods can provide high efficiency, reliability, and adaptability in various operational scenarios and provide significant benefits for many industries.

In agriculture, for instance, swarm drones can significantly enhance precision farming techniques, enabling farmers to monitor crops, assess field conditions, and even apply fertilizers or pesticides with unparalleled accuracy. In logistics, drone swarms hold the potential to revolutionize the transportation of goods by improving delivery times and reducing costs, especially in remote or hard-to-reach areas. Environmental monitoring is another field where swarm drones are proving invaluable, as they can be used to track wildlife populations, measure pollution levels, and survey large geographical areas in real-time. The defense sector is perhaps one of the most well-known areas for drone swarm deployment, with militaries around the world investing in drone swarms to perform tasks such as surveillance, reconnaissance, and even offensive operations in highly dynamic combat environments.

However, as the complexity of tasks performed by drone swarms grows, the demand for advanced, automated control systems also rises. These systems must ensure high levels of efficiency, reliability, and safety while simultaneously coordinating multiple drones' movements and actions. The challenge lies in developing AI-driven algorithms capable of autonomously managing the swarm, making real-time decisions, and adapting to changing conditions or unforeseen obstacles. Traditional control systems are often ill-suited for this level of complexity, as they require constant human input and are not equipped to handle the dynamic interactions between drones in a swarm.

By integrating artificial intelligence into swarm control systems, researchers and engineers are striving to create more robust solutions that allow drones to operate autonomously with minimal human oversight. AI can be used to optimize flight paths, ensure collision avoidance, and enable real-time communication between drones to complete tasks more effectively. Machine learning algorithms can also

enhance the swarm's ability to adapt to new tasks, learn from previous operations, and continuously improve its overall performance.

Furthermore, the application of swarm intelligence, a concept inspired by the collective behavior of social organisms such as bees, ants, and birds, plays a key role in shaping the future of swarm drone technology. This decentralized approach allows individual drones to make local decisions while contributing to the global objectives of the swarm, leading to greater flexibility and scalability in various operational contexts.

As new technologies enabling the autonomy and coordination of multiple drones emerge, the development of reliable and effective solutions for swarm management becomes a top priority. The integration of AI and machine learning into these systems holds the promise of revolutionizing how industries and governments approach tasks that involve large-scale aerial operations, making them more efficient, cost-effective, and scalable than ever before. Additionally, ensuring the safety and reliability of these systems is crucial, especially when they are deployed in critical sectors such as defense or emergency response.

**Conclusion.** The use of AI assistance will offer innovative methods for safe and efficient swarm drone management, enhancing their autonomy and capability to perform complex tasks under uncertain and changing conditions. These solutions will unlock new possibilities for drone applications across industries, including defense, logistics, agriculture, and environmental monitoring.

In conclusion, the continuous development of automated swarm drone control systems, powered by artificial intelligence, represents a major step forward in the evolution of UAV technology. As the capabilities of drone swarms expand, the ability to manage and control these swarms effectively will become increasingly vital, opening up new opportunities for innovation across a wide range of industries.

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# FUTURE TRENDS IN COMPUTER GAME DEVELOPMENT TECHNOLOGIES

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**Keywords:** computer game development, artificial intelligence (AI), large language models (LLM), virtual reality (VR), non-player character (NPC), procedural content generation (PSG), role-playing video games (RPG).

**Introduction.**The computer game development technologies are a fast-growing and promising field of activity which does not chase modern trends in technology, but rather is chased by them. This is a huge and profitable business. Microsoft, Sony, Amazon, Twitch, SteelSeries are all just a part of the big-name influencers that support the growth of computer games and the development technologies they require. In recent years, computer game developers are actively harnessing artificial intelligence (AI), large language models (LLMs) andvirtual reality (VR) to improve game experience for the gamers worldwide.

**Objectives.** With this in mind, the main purpose of our research is to examine the main trends in computer game development, with the specific focus on the integration of AI for providing auto-generated game level design, the role of LLMs in enhancing non-player character (NPC)-player interactions, the impact of cross-platform gaming on the industry, and the ongoing evolution of VR from a novelty to a mainstream experience.

**Methods.** In order to achieve the set goals, we analysed the relevant scientific sources, and industry reports.

**Results.** Based on the conducted analysis, we have identified several key trends in computer game development technologies. The first trend deals with *AI and Procedural Content Generation (PCG) employment*. PCG is the process of producing game content algorithmically with minimal or indirect users' input. Essentially, it involves software that can autonomously generate game elements, either independently or collaboratively with one or more designers or players. PCG methods have the potential to enable the development of absolutely new types of games. By integrating PCG with player modelling such as analysing and utilizing neural networks to predict players' reactions to specific game elements, game developers can design adaptive games that aim to maximize the enjoyment players get from the games. The classical example of PCG use in gaming is the1980s dungeon-crawler Rogue, where each new game features randomly generated levels. In contrast to creating engaging experiences, automatic content generation often lacks visual sophistication (e.g. Dead Cells, The Binding of Isaac or Valheim (See figure 1))(Georgios, Togelius, & Togelius, 2018).

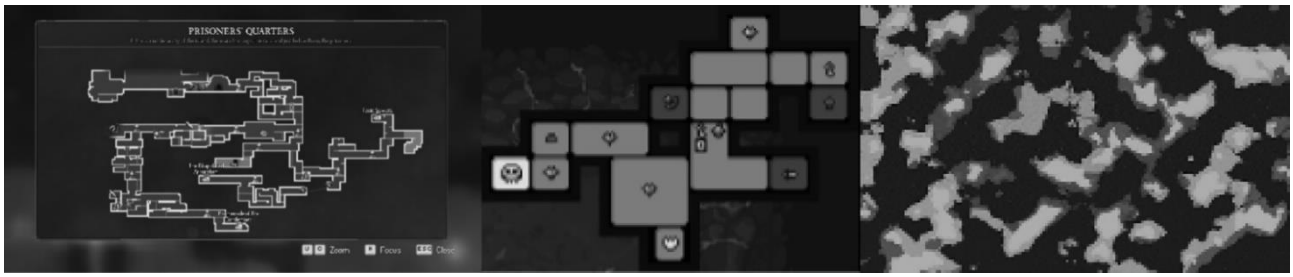


*Figure 1. Screenshotsofminimapsfromgames Dead Cells, The BindingofIsaacandValheim*

The second trend is *a growing role of LLMs* in enhancing NPC-player interactions. In recent years, role-playing video games (RPGs) have become extremely popular mainly due to the immersive gameplay and deep storytelling. A key factor that attracts gamers i is the interaction with NPCs. ChatGPT, an LLM created by OpenAI, has transformed not only the field of natural language processing, but contributed to the development of video games. Ai Dungeon is a bright example of an LLM-based game, where the gamer can create their own story of a dark elf mage who wants to become a god (Csepregi, 2023; Reed, 2023).

The last but not least is the continuous evolution of VR. Its main features include accessibility, versatility, and a profound impact on our interaction with digital environments. Due to its ability to provide immersive and interactive experiences, VR technology appears to be extremely promising in terms of game technology development.

The VR features can be found in such games as Beat Saber, Half-Life: Alyx and Phasmophobia. However, VR technology is still not affordable and accessible enough (Brodowicz, 2024).

**Conclusion.** Computer game development industry is rapidly evolving. AI-based generation procedures are gaining a momentum enhancing the speed of project development and reducing the game product costs. LLM contributes to interactivity with game characters and atmosphere. The behaviour of NPCs gets closer to the reality. VR transfers game development to another level of functioning. The synergy of all these technologies will result in the games able to adjust better to players' needs and contexts. It opens unlimited perspectives to creativity and innovation.

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# ARTIFICIAL INTELLIGENCE IN CLIMATE CHANGE MITIGATION: A NEW FRONTIER FOR ENVIRONMENTAL SUSTAINABILITY

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**Keywords:** artificial intelligence, climate change, sustainability, machine learning, renewable energy, carbon emission reduction.

**Introduction.** With such urgent need for innovative solutions to reduce greenhouse gas emissions, enhance climate resilience, and make a more sustainable future, the world is struggling against tackling climate change. However, Artificial Intelligence (AI) has been able to address these complex challenges with its power. AI is solving problems associated with the climate through the analysis of huge volumes of environmental data and optimizing systems to make them energy efficient and to manage resources. In this abstract, AI application for climate change mitigation is explored, showing the benefits, challenges and future directions of the field.

**Objectives.** Article explores how AI can help reduce carbon emissions, improve energy efficiency. This thesis investigates the possibilities of AI as a tool for managing renewable energy systems. It aims to identify the risks and challenges in bringing AI to climate change solutions, as well as describe future trends and innovations in AI technologies that can help deliver even better climate resilience, while at the same time enhancing the efforts for environmental sustainability.

**Methods.** A literature review was made, covering works of peer reviewed journal articles, environmental organizations' reports and studies on AI development over climate related fields. Scientific publications from Nature Climate Change, Journal of Environmental Management, as well as International Journal of Sustainable Energy, were data sources. In addition, by analyzing rare case studies of AI inspired climate models, ranging from Google's DeepMind efforts to rework the energy usage in data centers to IBM's Green Horizon project, we make sense of the practical effect of AI on climate change mitigation. To evaluate the effectiveness of these technologies on the basis of energy savings, emission reductions and overall sustainability impact we carried out qualitative analysis.

**Results.** AI has shown remarkable promise in optimizing energy systems and reducing emissions across various sectors. For instance, Google's DeepMind AI has successfully reduced energy consumption in their data centers by up to 40%, demonstrating the potential of machine learning algorithms to optimize energy efficiency in large-scale infrastructures (Evans & Gao, 2016). Similarly, AI is being used to predict and manage renewable energy sources more efficiently, such as by forecasting wind and solar power generation, which allows for better integration of renewable energy into the grid (Baker et al., 2018).

AI driven climate models also deliver supercharged predictive power of extreme weather events and climate trends, giving governments and organizations the ability to better plan and respond to climate disaster. For example, IBM's Green Horizon project works to forecast air pollution levels and how to decrease emissions in real time (Nguyen et al., 2019). In particular, this model seems to have most extensively been applied to urban areas, where air quality control is vital to maintain public health and environmental sustainability.

AI for climate change mitigation has shown promise irrespective of these challenges. Even ones that use data centers and computational resources are concerned about the energy consumption of such AI systems. It is critical that developing more energy efficient AI models helps avoid offsetting environmental benefits of AI with AI's own carbon footprint (Strubell et al., 2019).

**Conclusion.** Climate change mitigation has a transformative opportunity through Artificial Intelligence, which promises to change how we operate energy systems, reduce emissions and adapt to the effects of global warming. AI is already contributing to sustainability in major ways, by optimizing energy use, improving the efficiency of renewable energy sources, and improving the accuracy with which climate predictions are made. Yet, with challenges of energy requirement of AI system and the requirement of the transparency and ethical use of AI technology, full potential of AI technologies cannot be realized.

Future research needs should develop energy efficient AI and collaborate between AI developers, policymakers, and environmental scientists in the way they work with AI technologies to use it responsibly and effectively in the war against climate change. The environmental challenges of the next millennium could be addressed by one of the most powerful tools on AI's horizon.

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# BACKEND DEVELOPMENT IN THE 21ST CENTURY

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**Keywords:** backend development, microservices, cloud computing, APIs, databases, scalability.

**Introduction.** Backend development is an indispensable part of the contemporary Web and mobile application that provides data management, business logic implementation, and communication with the server. Backend development in the 21st century has been equally defined by improvements in microservices architecture cloud computing and; scalable APIs. These technologies have helped developers to develop more robust, flexible dependable applications. These abstract aims to identify and outline today backend development by the means of the tools, frameworks and methodologies available, as well as the issues affecting backend development to guarantee high performance and security and scalability.

**Objectives.** The objectives of this research are:

1. To analyze the evolution of backend development frameworks and architectures.
2. To examine the role of microservices, containerization, and cloud platforms in modern backend infrastructures.
3. To identify the key challenges faced by backend developers, particularly regarding performance, security, and scalability.
4. To explore future trends in backend development, including serverless computing and the rise of edge computing.

**Methods**. In order to do that, I reviewed literature of current state of Backend development tools and approach namely Node.js, Django and Spring Boot. We study the architectural shift toward microservices and its effect on scalability and maintenance of systems. The case studies looked at companies like Netflix and Uber who have implemented microservices and cloud computing to scale to large user bases for complex workflows. Performance benchmarks from recently published industry reports were reviewed to quantify the benefits of these modern practices.

**Results.** To know how they deal with application deployment and scaling, tools like Docker and Kubernetes were analyzed for this task because they are extensively used for Kubernetes and containerization respectively. Finally, the study compares different database solutions (such as relational databases, e.g., PostgreSQL, and NoSQL databases, e.g., MongoDB) under different workloads for performance evaluation.

The transition from monolithic to microservices has been one of the biggest changes in everything behind the scenes. Where all-application components are tightly coupled (monolithic) these systems can be difficult to maintain and scale as the application grows. These and differ with micro services being able to deploy

independently but can be scaled to specific parts of an application and can be more fault tolerant (Newman, 2022). Tools such as Docker and Kubernetes have enabled this shift to microservices by making it possible to containerize as well as orchestrate. This means that Docker allows developers to put their applications, including all their dependencies, into a container, making developers work across different environments consistent. Containers are already orchestrated by Kubernetes, which performs automatic scaling, load balancing, and self-healing (Burns et al, 2021). Thanks to these technologies, managing large scale applications was neither an easy nor simple task but that has significantly reduced the complexity of scaling applications to hundreds of thousands of transactions per second on distributed systems. And these cloud platforms like amazon web services (AWS), google cloud platform (GCP) and Microsoft Azure have also transformed backend development by providing scalable infrastructure on demand.

Behind the scenes, these platforms allow backend services to scale with user base automatically without developers having to lift a finger (Rozek, 2020). As well, cloud computing has also given rise to the new paradigms, which consist serverless architecture, which allows developers to write and deploy code, and not to deal with servers. This has further streamlined development workflows as well as operational overhead.

While it feels much improved, there are still many challenges that face backend developers. Nevertheless, performance optimization continues to be a top consideration for applications which serve millions of users. Caching via tools such as Redis and Memcached can help relieve some of the load on the database, leading to better response times, but keeping things consistent when caching strategies are implemented across systems becomes complicated (Lopez et al., 2022). On top of that, security is still a big challenge, which means, especially for developers, the solution has to add secure authentication and encryption so the data remains safe. This also raises a scalability issue (particularly in high traffic applications). Traditional relational databases may stand little hope of scaling horizontally, whereas MongoDB can alleviate this problem by allowing horizontal scaling to multiple nodes. But in the end, with respect to the application's requirements (Stonebraker, 2018), you want a tradeoff between consistency, availability, and partition tolerance (CAP theorem).

**Conclusion**. In the last decade, backend development has made a huge change as microservices, cloud platforms, and container technologies have been widely applied. They have made it easier to build systems that are scalable, maintainable, and simpler to manage the infrastructure – so less complex. Backend developers, however, still struggle to achieve performance, security and scalability targets, as applications grow in organization. The future of backend development is probably going to be influenced by trends such as serverless computing and edge computing, and looking ahead, it seems to be clear of what belongs to the future. Serverless architectures will remain popular because they're simple and cheap, and edge computing will enable processing closer to the user to cut latency and improve

performance for real time apps. The good news is that developers will need to stay competitive in this space and constantly work to optimize their systems for both performance and security to stay ahead of these trends.

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## THE INTERNET OF THINGS (IOT): CONNECTED DEVICES FOR A SMARTER WORLD

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**Keywords:** Internet of Things, IoT, Connectivity, Smart Devices, 5G, Automation, Smart Cities.

**Introduction.** The Internet of Things (IoT) represents a technological revolution, connecting devices to create smarter, interconnected systems. IoT comprises a network of "things" – physical objects embedded with sensors, software, and other technologies that enable data exchange with other devices and systems via the internet. This integration promises to reshape industries and enhance daily life through improved connectivity, automation, and data-driven insights (Russell & Norvig, 2020). From smart homes to healthcare and urban infrastructure, IoT applications demonstrate significant potential in modern society (Murphy, 2019).

**Objectives.** This paper aims to explore the evolution of IoT, its essential components, applications across various sectors, and its future prospects. Additionally, we will consider the role of 5G in advancing IoT connectivity, as well as the potential challenges and opportunities in a world increasingly reliant on connected devices (Goodfellow, Bengio, & Courville, 2016).

**Methods.** The study draws from a comprehensive literature review on the history, development, and current applications of IoT technology. Case studies on IoT use in healthcare, agriculture, and urban planning provide insights into its impact.

Data on the integration of IoT with 5G networks and its influence on real-time control, security, and data processing in high-density areas were also reviewed (Russell & Norvig, 2020; Murphy, 2019).

**Results.** IoT's integration has introduced transformative changes across multiple domains:

– Smart Homes: IoT enhances energy efficiency, security, and convenience in home environments through connected devices such as thermostats, security cameras, and lighting systems (Murphy, 2019). These systems allow remote control and automation, optimizing household resource use.

– Healthcare: IoT is revolutionizing healthcare with innovations like remote patient monitoring, telemedicine, and asset tracking. Devices can monitor patient vitals in real-time, provide timely healthcare interventions, and support remote diagnostics, improving patient outcomes and expanding healthcare accessibility (Goodfellow, Bengio, & Courville, 2016).

– Smart Cities: IoT contributes to urban efficiency and sustainability by supporting smart city initiatives. It enables infrastructure monitoring, waste management, and energy use optimization, improving the quality of life for urban residents. IoT applications in transportation enhance traffic flow, reduce congestion, and support environmental monitoring (Russell & Norvig, 2020).

– Industrial Automation: In manufacturing, IoT allows for real-time equipment monitoring, predictive maintenance, and enhanced automation. It minimizes downtime, optimizes production processes, and ensures safety in industrial settings.

– Agriculture: IoT enables precision agriculture through tools for crop monitoring, soil analysis, and automated irrigation. These innovations lead to increased yields, reduced water use, and improved sustainability in farming practices (Murphy, 2019).

– 5G Integration: The integration of 5G networks accelerates IoT potential, offering faster speeds, reduced latency, and massive connectivity for high-density environments (Goodfellow, Bengio, & Courville, 2016). This connectivity is crucial for real-time control in IoT applications, particularly in smart cities and industrial automation, where speed and reliability are essential.

– Data Privacy and Security: The increase in connected devices poses security risks, as cyber-attacks and data breaches become more prevalent. Ensuring data privacy and implementing robust security protocols are paramount (Russell & Norvig, 2020).

– Infrastructure Costs: The high cost of implementing IoT infrastructure can be prohibitive, especially for small businesses and developing regions, potentially exacerbating the digital divide.

– Regulatory and Ethical Issues: As IoT expands, regulatory bodies must address issues related to data governance, safety standards, and ethical considerations, particularly in healthcare and security applications (Murphy, 2019).

**Conclusion.** The Internet of Things is at the forefront of technological innovation, offering solutions that improve efficiency, sustainability, and quality of life across various sectors. By enabling interconnected devices to communicate and respond in real-time, IoT has the potential to transform industries ranging from healthcare and agriculture to urban infrastructure and industrial automation. Its applications are reshaping the way we interact with technology, fostering a future where systems are smarter, more responsive, and capable of providing data-driven insights that support decision-making at every level (Russell & Norvig, 2020; Murphy, 2019). Looking to the future, the integration of IoT with emerging technologies such as 5G and AI promises even greater advancements. The low latency and high-speed connectivity offered by 5G will support real-time IoT applications in high-density environments, making possible smart cities and autonomous transportation networks on a large scale. AI will further enhance IoT by providing sophisticated data analysis and decision-making capabilities, enabling predictive maintenance, dynamic response systems, and personalized user experiences. Additionally, IoT is expected to play a vital role in environmental monitoring and climate action, allowing for comprehensive tracking of emissions, pollution levels, and natural resources (Russell & Norvig, 2020).

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## IOT TECHNOLOGIES AND THEIR ROLE IN THE MODERN WORLD

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**Keywords:** IoT ecosystem, automated system, information security.

**Introduction.** Automation and digitalization of various technological and applied spheres of human activity are among the leading development directions in the modern information world. Internet of Things technologies are already a promising and widely used solution for increasing the productivity of control and decision-making systems, power supply, and energy efficiency. An expansive list of scientific works investigating and justifying the necessity and advantages of using Internet of Things systems confirms the importance of creating new and modernizing existing solutions. Such systems make it possible to develop software and physical products that perform various tasks and increase the productivity of individual

businesses, enterprises, and entire industries. This is an essential step in creating today's highly efficient industrial world.

**Objectives.** The main task is to describe the general concepts of the Internet of Things, its current state and directions of development in the modern world of information technologies, to characterize the advantages of application, to identify existing security risks and potential obstacles to further improvement and integration of Internet of Things systems.

**Methods.** The primary goal of the Internet of Things system is to create a particular IoT ecosystem that unites various intelligent devices and autonomously controls them based on processed data. The formation of the system of devices occurs with the help of wired and wireless communication technologies between devices and sensors, such as Ethernet, Bluetooth, and Wi-Fi. Various software allows you to design such systems in a virtual environment and estimate potential resource costs. For the physical implementation of such a system, combining the appropriate control software components with physical components is necessary. The primary levels of the architecture of such a system are:

– Level of sensation/perception – the main elements are a set of sensors and actuators.

– Network/communication layer – various connections, internet gateways, and data collection systems.

– Data processing level – specialized data processing software, including cloud services.

– Application-level – implements direct interaction with the user using the interface.

We will note some modern solutions for the application of IoT systems: the creation of smart city systems that control public transport and communal services, the restructuring of product supply chains, and their organization in warehouses. Improvement and management of energy systems, optimization of production lines and processes at enterprises, and monitoring of patient health indicators are common areas of use of such systems (Nancholas, 2024).

The main benefits of using Internet of Things systems include increasing the efficiency of data collection and analysis, forming an automated system, improving decision-making algorithms, and creating and managing effective components in business and production. These solutions, in turn, increase the productivity of systems and optimize the use of time and resources to perform various tasks.

Considering the results of numerous studies, it can be noted that the use of Internet of Things technologies and systems is accompanied by several interrelated risks and obstacles, namely the risk of information security, the scaling of the system of many devices and data, the reduction of system energy consumption (Vicci, 2024). Solving these problems is possible by using specialized data transmission protocols, creating a flexible architecture of components and devices, and periodic system modernization. Still, these steps significantly increase the cost of implementing such systems in various industrial and domestic spheres of human activity.

**Results.** Considering the above information, Internet of Things systems play an essential role in the modern world of information technology. However, implementing such systems into existing solutions is complex and challenging, with several security, scalability, and component interoperability issues. The necessary steps are conducting research and creating more flexible and cost-effective patterns for implementing systems in various areas of human activity.

**Conclusion.** Despite the significant advantages of using Internet of Things systems to optimize, automate, and improve the productivity of various tasks in many areas of human activity, an important step is to solve the urgent issues of developing and systematizing a wide range of devices and sensors to achieve the necessary level of compatibility and data synchronization between them. Privacy and information security of data are among the main areas of continuous improvement and modification of IoT ecosystems. This technology is one of the drivers of the economic and industrial development of the world market of goods and technologies, so it is necessary to train and form a layer of qualified workers who can accelerate the automation of processes in their homes, cities, and factories.

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## FUTURE TRENDS IN SCIENCE AND TECHNOLOGY