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CONTENTS

RESHAPING THE FUTURE OF WORK: NAVIGATING THE IMPACTS OF LIFELONG LEARNING AND DIGITAL COMPETENCES IN THE ERA OF 5.0 INDUSTRY
Ana Nešić Tomašević......1-6

AN ETHICS CRISIS IN VIRTUAL MEDIA SPACE
Aleksandra Penjlšević, Branislav Sančanin, Margarita Bogdanova......7-13

APPLIED INFORMATION TECHNOLOGIES IN AGRICULTURE
Branimir M. Bajac, Momčilo B. Bajac, Lazar. V. Stošić......15-20

ERP SYSTEMS AND THE CHALLENGES OF LEGAL PROTECTION OF PERSONAL DATA
Lazar. V. Stošić, Aleksandra V. Janković, Igor Ristić, Momčilo B. Bajac......21-26

NANOINFORMATICS, COMPUTER APPLICATIONS FOR NANOMEDICINE
Aleksandar Đorđević......27-32

IMPROVING CONSTRUCTION PROJECTS AND REDUCING RISK BY USING ARTIFICIAL INTELLIGENCE
Milena Senjak Pejić, Mirjana Terzić, Dragana Stanojević, Igor Peško, Vladimir Mučenski......33-40

INTEGER SINGLE-ERROR-CORRECTING CODES AS AN ALTERNATIVE TO THE INTERNET CHECKSUM
Aleksandar Radonjic, Igor Ristic, Ivan Scepnovic......41-44

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RESHAPING THE FUTURE OF WORK: NAVIGATING THE IMPACTS OF LIFELONG LEARNING AND DIGITAL COMPETENCES IN THE ERA OF 5.0 INDUSTRY

Ana Nešić Tomašević[1]

[1]Faculty of Technical Sciences, University of Novi Sad, Serbia,
e-mail: ana.nesic@uns.ac.rs

Abstract: Technological advancements and changes in the labor market require workers to continuously enhance their skills. Lifelong learning becomes a necessity in reality, and proposals in developed countries for returning to college after graduation open up new opportunities for acquiring new knowledge. Digital literacy, communication skills with both humans and robots, and understanding complex problems may become key skills for the 21st century. Jobs in the fields of medicine and technological innovation are expected to be in high demand. Furthermore, the digitization of society requires an increase in digital competences. These competences encompass not only computer literacy but also readiness for collaboration, quick problem-solving, and understanding of social relationships in a digital context. The paper "Lifelong Learning and Digital Competences in the Era of Industry 5.0: Keys to Success in the Future of Work" highlights the importance of continuous education and the development of skills necessary in the modern work environment, which is increasingly shifting towards Industry 5.0 and digital transformation.

Keywords: Industry 5.0, work, technology, lifelong learning.

Introduction

The COVID-19 pandemic has had a strong impact on changes in the labor market, and it is questionable whether work and employment will continue in the future in the same way as before the pandemic. However, it is important to note that the pandemic is not the only factor shaping the future of work. Automation and artificial intelligence also play a crucial role in reshaping the mix of occupations, required skills, and transitions that workers face. While the pandemic has brought significant changes in the way we work, it is certain that some of these changes will persist in the post-COVID global society. Flexible work models, such as remote work or hybrid work arrangements, have become increasingly popular and may continue to evolve and be applied in the future. Many organizations have recognized the benefits of these models, such as greater work flexibility, reduced space costs, and increased employee satisfaction.

Automation and artificial intelligence are becoming commonplace in work processes and have a profound impact on the labor market. These technological advancements are changing the way we perform certain jobs and require workers to develop new skills and adapt to changing market demands. While some traditional occupations may be replaced by automation, new occupations will simultaneously emerge that will require understanding and management of this technology. In order for workers to successfully adapt to these changes, continuous learning and acquisition of new skills become vital. Educational institutions, employers, as well as governmental institutions (national governments) must collaborate to ensure access to relevant education and training that will enable workers to adapt to the new demands of the labor market. In addition to technical skills, it is also important to develop skills such as critical thinking, problem-solving, and teamwork, which are necessary for success in the modern work environment. Although the pandemic has created challenges, it has also accelerated some positive changes in the labor market. Organizations have become aware of the need for greater digitization and modernization. New business conditions establish new work rules, but also new approaches to viewing and interpreting business reality. First of all, it refers to a multidisciplinary approach that is based on a

*Corresponding author: ana.nesic@uns.ac.rs

unified view of several scientific disciplines such as sociology and psychology of work, economic sociology, economic anthropology, behavioral economics, sociology of politics...

Materials and methods

When considering the future of work in Europe, it is important to keep in mind that the old continent is a complex mix of highly diverse local labor markets, which have historically witnessed increasing geographic concentration of employment growth. However, there is a pronounced polarization between dynamic cities and declining regions, creating inequalities in access to job opportunities and economic prospects.

Forty-eight dynamic cities, such as Amsterdam, Copenhagen, London, Madrid, Munich and Paris, where approximately 20% of the European population resides, play a crucial role in generating economic growth. They have been the epicenters of European GDP growth, job creation, and population attraction over the past decade. However, simultaneously, 438 declining regions, mostly located in Eastern and Southern Europe, face challenges such as labor shortages, aging populations, and lower levels of education. This situation further exacerbates regional inequalities and poses new challenges for labor market management.

Unfortunately, the COVID-19 pandemic marked the end of years of strong employment growth and increased social mobility in Europe. The crisis has endangered up to 59 million jobs, which is approximately 26% of the total number of employed people in Europe. This situation has resulted in reduced working hours, wage reductions, temporary layoffs, and permanent job losses. The employment rate has sharply declined, interrupting the growth trend that characterized 85% of European countries before the crisis. This crisis has particularly affected vulnerable groups of workers and regions that were already facing structural issues.

Prior to the pandemic, social mobility was on the rise in Europe. Most migrations occurred within countries, but a significant number of Europeans worked in other European countries. From 2003 to 2018, the number of people who moved to work in another European country doubled, reaching a figure of 16 million. Eastern European countries experienced a significant loss of population as people moved westward in search of better work conditions.

In Europe, after economic recovery, there is expected to be a shortage of skilled workers despite the growing wave of automation. This shortage is primarily due to a decreasing labor force, as Europe's working-age population is expected to decrease by 13.5 million (or 4%) by 2030 due to the aging process. Additionally, the trend of shortened workweeks could further reduce the labor supply by an additional 2%.

Various studies and theories on the pace of automation adoption indicate that by 2030, up to 22% of current job activities could be automated, equivalent to 53 million jobs. However, it is important to note that not all of these jobs will be permanently lost, as new jobs are expected to be created in areas such as technology, tourism, and healthcare. These sectors have the potential for growth and opening up new employment opportunities to compensate for some or even all of the job losses due to automation.

The future of work cannot be discussed without mentioning Industry 5.0, which represents the next step in the evolution of industry. While Industry 4.0 focused on smart technology and automation in manufacturing, Industry 5.0 emphasizes the importance of human involvement in generating ideas and driving change (Teixeira & Tavares-Lehmann, 2023). Its goal is the "rehumanization" of automation and bringing the human factor back into focus.

The concept of Industry 5.0 was first introduced in an article titled "INDUSTRY 5.0 - from virtual to physical," published in 2015, where the author recognized the need for such an approach following the implementation of Industry 4.0. The article highlighted concerns that complete automation would lead to the redundancy of human labor and the dehumanization of work processes (Rada, 2015).

Industry 5.0 advocates for synergy between humans and technology. Instead of being a replaced factor, humans are seen as a critical component in innovation and solving complex problems. Technology is used to support human capabilities rather than replace them. Interaction and collaboration between workers and advanced technologies such as artificial intelligence, automation, and robotics become the foundation for productivity and creativity. Industry 5.0 refers to the collaboration between humans and robots in the work environment, aiming for robots to assist humans in working faster by utilizing advanced technologies like big data analytics (Javaid et al., 2020; Martos et al., 2021).

Technological advancements in automation can lead to changing skill requirements in the labor market. As a result, workers will need to adapt to new skills and areas of work to remain competitive. It is important for educational institutions and employers to recognize these changes and provide educational programs and upskilling opportunities that enable workers to adapt to the new demands of the labor maket.

Additionally, demographic changes and population aging trends require adjustments to labor policies and social protection systems to ensure long-term sustainability and inclusiveness of the labor market. Efforts need to be made to promote active aging, requalification, and transition to new occupations in order to maintain productivity levels and social security in society. Managing these changes in the labor market requires collaboration between government authorities, employers, trade unions, and educational institutions. It is important to establish policies that encourage innovation, entrepreneurship, and adaptation to ensure a secure and prosperous future of work in Europe.

Even with a 4% decline in the total number of jobs by 2030, there would still be a noticeable labor shortage to fill vacant positions. This situation is particularly evident in the mentioned dynamic growth cities. Unless the work-from-home trend, resulting from the COVID pandemic, alters patterns of urbanization, these 48 cities could encompass over 50% of potential job opportunities in Europe in the next decade, intensifying geographical concentration and centralization, trends we have already witnessed in previous decades. In such a scenario, the most likely outcome would be attracting workers from other areas to fill over 2.5 million job vacancies.

When it comes to Serbia, according to the data from the Statistical Office, by 2030, more than half of the population will be 45 years old or older, which presents a specific challenge for economic development and contributes to slower growth. Population aging can have serious consequences for the workforce, productivity, and the sustainability of the economy. In such circumstances, it is crucial to focus on developing policies that stimulate retraining, training, and support for older workers to remain active in the labor market. Additionally, it is important to establish cooperation between educational institutions and employers to ensure a continuous influx of qualified workforce.

To overcome the labor shortage, it is important to invest in the education and training of young people, as well as promote innovation and entrepreneurship. Encouraging links between the academic sector and the business sector, as well as creating a stimulating environment for the development of new technologies and industries, can contribute to attracting and retaining young talents. Furthermore, promoting inclusivity, diversity, and equal opportunities in the workplace is crucial for ensuring a productive and prosperous labor market in the future.

More than half of the workforce in Europe is facing significant changes, in addition to the mentioned labor shortage. Automation will require all workers to acquire new skills to adapt to market changes. Around 94 million workers may not need to change their occupations but will require retraining as technology takes over about 20% of their current activities. While some workers in declining sectors may be able to find similar jobs, it is expected that around 21 million workers will need to change their occupations by 2030.

It is particularly noteworthy that the majority of workers who will require retraining have a medium level of vocational education. This fact is of special significance when considering the educational structure of the population in the Republic of Serbia, as according to the latest population census from 2011, the majority of the population (41.1%) has precisely this level of education. This situation requires taking appropriate measures to properly prepare workers for changes in the labor market. The educational system needs to be adjusted to the needs of the future labor market, and workers should have access to retraining and upskilling programs that enable them to acquire new skills and adapt to new demands.

Moreover, it is important to establish cooperation between educational institutions, employers, and relevant institutions to identify future trends regarding labor market needs and provide support to workers in their transition to new occupations. These changes in skill requirements also present an opportunity for the development of new sectors and industries, and the authorities and the business sector need to work together to promote innovation and support entrepreneurship to create new employment opportunities and foster economic growth.

Social capital will play a crucial role in the future of work, alongside intellectual and human capital. According to the theory of Pierre Bourdieu, social capital is defined as a set of real or imagined resources that are interconnected through institutional or non-institutional relationships and connections. The foundation of social capital lies in the relationships among people, which are based on various motives, with these relationships varying in intensity, quality, and the shared goals or achievements they realize.

In the future, workplaces will increasingly focus on newly acquired skills that are already in demand today. This means that workers will be expected to possess more sophisticated skills to meet the requirements of emerging jobs. In addition to expertise in specific technical areas, workers will need to develop social skills as part of their social capital.

Social skills, such as teamwork, communication, leadership, and adaptability to different situations, are becoming increasingly important in the work environment. Quality relationships with colleagues, superiors, clients, and other relevant stakeholders become a key factor in workplace success. Creating and maintaining positive and productive work relationships help in developing efficient teams and facilitating the achievement of organizational goals.

Furthermore, social capital can foster innovation and creativity as it creates opportunities for exchanging ideas, collaboration, and joint problem-solving. Openness to different perspectives, the ability to build networks, and support for mutual learning can be crucial factors for success in a dynamic and changing business environment.

In light of these changes, educational institutions and organizations need to recognize the importance of social capital and enhance educational programs to foster the development of social skills among their students and employees. It is also important for individuals to recognize the value of social capital and actively cultivate it through the creation and maintenance of quality interpersonal relationships.

In summary, social capital will be a key factor for success in future work patterns.

The key challenge for the future of work will be addressing labor market mismatches worldwide, with potentially different solutions for each individual community and society. Regarding our country and Europe as a whole, four significant imperatives stand out:

1. Resolving the skills gap (and upskilling): Addressing the shortage of skills and promoting continuous learning and skill development.

2. Improving access to jobs in dynamic growth centers, potentially through increased remote work: Enhancing opportunities for employment in areas experiencing dynamic growth and exploring the potential of remote work.

3. Revitalizing and supporting shrinking labor markets: Providing support and resources to regions where job opportunities are expected to decline, as 40% of Europeans are projected to live in such regions over the next decade.

4. Increasing labor force participation: Encouraging higher workforce participation rates and reducing barriers to employment.

Employers will need to make strategic decisions regarding their workforce, skills, and social responsibility. Their choices should reflect the skills, occupational mix, and geographic footprint of their workforce. Assisting individuals in connecting with new opportunities and preparing for the jobs of tomorrow is a shared task for every region across Europe and likely the world (Nešić Tomašević, 2021).

Industry 5.0 represents a revolution in which humans and machines work together to improve production efficiency (Imoize et al., 2021). Ocicka, Rogowski and Turek suggest that Industry 5.0 is the result of synergy between different industrial technologies, philosophies, and other factors that focus on human factors and technologies in production systems (Ocicka et al., 2022). Also, Industry 5.0 is considered the pinnacle of the smart factory, where communication between robots and humans is achieved. Social networks are used for communication between people and electronic components (Carayannis et al., 2022).

Industry 5.0 introduces concepts focused on human-centric, sustainability, and resilience into the industrial revolution. It will revolutionize production systems worldwide by reducing repetitive tasks performed by humans. Intelligent robots will penetrate production chains and workflows at unprecedented levels (Ietto et al., 2022).

Industry 5.0 aims to promote flexibility, adaptability, and personalization in manufacturing. Through the use of advanced technologies such as 3D printing and the Internet of Things, it is possible to create customized products and services according to individual user needs. This new era of industry also opens doors for the development of new jobs that require interdisciplinary knowledge and skills.

The revolution of Industry 5.0 is primarily about the collaboration between humans and machines to improve industrial production efficiency. Human workers and universal robots enhance productivity in manufacturing industries (Majumdar et al., 2020). The executive teams of manufacturing companies are tasked with defining the production line, monitoring key performance indicators, and ensuring smooth process operations. The future of Industry 5.0 is oriented towards the production of robots and industrial robots. Advances in artificial intelligence and cognitive computing technologies accelerate the manufacturing world and increase operational efficiency. Besides its benefits in manufacturing, Industry 5.0 also contributes to sustainability as it aims to develop a sustainable system that utilizes renewable energy.

Discussions

To embrace Industry 5.0, companies require proper interaction between machines and operators. Knowledge in robotics and artificial intelligence is essential (Zhang & Chen, 2020; Chowdhury, 2020). The role of business organizations lies in decision-making regarding advanced factors. Training employees through virtual education is necessary to reduce costs for companies, as production does not need to be halted for employee training. This type of training provides a safe environment that prevents workers from being exposed to unnecessary risks during the training process. Communication and employee motivation are enhanced through interactive knowledge acquisition environments (Longo et al., 2020; Angelopoulos et al., 2020). Job positions are connected with communication with robot systems and artificial intelligence.

Collaborative robots are designed for intuitive interaction with humans. The development of digital twins is a necessary technology in Industry 5.0. Visual models of products, processes, and generations will enable better understanding and testing. The Nexus Integra platform is the software required to drive the transformation of industrial operations in Industry 5.0 (Nahavandi, 2019). It is an integrated system for managing industrial assets on a large scale, enabling companies to take a step towards digital transformation. Previous generations have adapted to what machines can do (Wang et al., 2020; Deepa et al., 2021). However, Industry 5.0 differs from all previous solutions as humans now have a central role in the manufacturing processes. This new era of industry emphasizes the importance of collaboration between humans and machines, with a focus on efficiency, sustainability, and the development of new technological solutions.

While Industry 5.0 is still in its early stages of development, its potential to transform work and production methods is already being recognized. While technology plays a crucial role, the human factor remains essential for innovation, creativity, and solving complex problems. The rehumanization of work processes through Industry 5.0 opens up new opportunities for workers to engage at a deeper level and realize their full potential. Industry 5.0 is about reintegrating humans and human influence into production and increasing collaboration and connectivity between humans and smart systems for long-term success. It is not against automation but emphasizes the intelligent use of automation, enhancing the roles of both humans and machines. Industry 5.0 states that the future lies in creating a harmonious relationship between humans and machines, enabling them to work better together to build more successful businesses in the long run.

Critics of the Industry 5.0 thesis argue that it is not a technical or developmental continuation of Industry 4.0, let alone a new fifth industrial revolution. Instead, they see it as a practical and relatively inexpensive solution to labor issues in manufacturing, primarily targeting areas where introducing a higher degree of automation is not cost-effective. It helps address product personalization, which is always individual and often requires human creativity and skill. In this context, critics believe that introducing the term Industry 5.0 was overly ambitious, suggesting a new leap forward in society or a continuation of Industry 4.0 (Nikolić, 2018).

Conclusions

At this moment, artificial intelligence has made a huge leap that is actually a new industrial revolution. The consequences of this discovery will certainly be long-lasting and multi-faceted. Dealing with them will not be possible without understanding the social reality. The most important role in the new development belongs to the increase and sharing of knowledge, as well as the personal development of all participants in the work processes.

Lifelong learning has become a necessity in today's world. In some developed countries, there is even consideration of providing vouchers to university graduates after 10 to 15 years, allowing them to return to college and acquire new knowledge. The 21st century brings about the need for new skills that encompass digital literacy, the ability to communicate with both humans and robots through various platforms and technologies, as well as an understanding of multidimensional real-world problems in work processes to analyze risks and ensure safety. For example, jobs as digital mentors require a combination of knowledge about people, society, and technologies.

According to research from the U.S. Bureau of Labor Statistics, the most in-demand jobs in the next 10 to 20 years will be in the fields of medicine and technological innovation. Recently, approaches to economics and business that involve neuroeconomics, neuromarketing, and bioethical scientific advancements are gaining more prominence. The digitalization of society, which reduces personal contact but simultaneously diminishes personal influence, requires an increase in digital competencies. Digital competencies involve responsible and secure use of digital technologies both in the workplace and leisure time.

However, digital competencies are not solely about computer literacy. They primarily refer to the readiness to collaborate, openness to new things, speed and problem-solving skills, as well as an understanding of the social relations that exist in relation to digital technologies. This new era demands that individuals adapt to changes and actively work on developing their digital skills to be successful and competitive in a world increasingly reliant on technology.

Conflict of interests

The authors declare no conflict of interest.

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AN ETHICS CRISIS IN VIRTUAL MEDIA SPACE

Aleksandra Penjlšević[1], Branislav Sančanin[1], Margarita Bogdanova[2]*

[1]Faculty of Management, Sremski Karlovci; Union – Nikola Tesla University, Belgrade, Serbia;
e-mail: aleksandra.penjisevic@famns.edu.rs; branislav.sancanin@famns.edu.rs
[2]Faculty of Management and Marketing, Tsenov Academy of Economics - Svishtov, Bulgaria;
e-mail: m.bogdanova@uni-svishtov.bg

Abstract: This paper will address basic ethical issues in virtual space determined by global multidirectional networking through different space and time. Numerous ethical issues will be stressed which, as a result of the complex reflections of ubiquitous media convergence, determine each individual topic, from issues of personal data protection and information security, to strengthening credibility and building trust in the virtual community. In relation to the objectives and established development guidelines, different ethical dimensions, in their complexity and multi-layeredness in a digitally empowered future, should not be viewed in isolation but exclusively through their complementarity and a quality foundation for further in-depth research.

Keywords: virtual space, media, social networks, ethics.

Introduction

In response to market challenges, the media constantly strives to raise the professional ladder, while the existential imperative is visualized through the need to be the first, constantly present and different from others. In such an environment, media workers have less and less time to confirm the veracity of information which, along with the emergence of user-generated content within the online sphere, has contributed to the accelerated erosion of journalism. In a virtual space that knows no time and space boundaries, each individual has the opportunity to create his own vision of reality and distribute his own truth about phenomena, events and personalities. Given insufficient statutory regulations, but also the absence of an effective control mechanism, the global network is a space for a plethora of subjectively colored, incomplete, and often inaccurate information.

Despite its modest credibility, online media has been experiencing a multi-year upward trend that may be explained by the fact that the audience in media hyperproduction is less and less oriented towards a search for information, and has been increasingly exhibiting the expectation that media products should find them.

Multimedia platforms do not have passive information recipients but active users who autonomously create and market new content, and have unlimited opportunities to redistribute existing information. The communication dynamics offered by web 2, to members of the virtual community, transformed the static observer into an individual who, thanks to interactivity, actively participates through unlimited space and time.

The veracity and credibility of information, in an unregulated virtual space, makes online media the weakest link on the media market, where professional standards are consciously suppressed by favoring sensationalist titles and forms. The speed of information transmission has become its key quality, leading the media to a state that can be diagnosed as an autoimmune disease that sacrifices professionalism and destroys reputation.

Media discourse should be significantly strengthened with ethically sensitized topics. It cannot simply rely on the sporadic steps of individuals who, through ethically sensitized topics content, reflect on the future of not only the profession but society as a whole.

*Corresponding author: aleksandra.penjisevic@famns.edu.rs

Virtual space between rights and obligations

“On the Internet, nobody knows you’re a dog”, the now iconic cartoon by Peter Steiner was published in the American newspaper The New Yorker on July 5, 1993, and shows two dogs, one is seated at a computer as he utters this phrase to his companion seated on the floor. The symbolism in the phrase, which indicates the ability of the user to receive and send messages clouded by privacy and anonymity, did not receive much public attention at the beginning, but later interest grew so much that it is still being talked about as the most reproduced cartoon of The New Yorker.

Image 1. “On the Internet, nobody knows you’re a dog”
Source: Steiner, 1993.

Over the past few decades, the digital landscape has changed beyond recognition. The first phase in the evolution of digitally driven technology was characterized by the process of convergence, where “Internet 1.0” basically dominated, with numerous information, entertainment and communication technologies for printing, publishing, broadcasting and telecommunications. The economic, editorial, creative, and consumer consequences arising from the Internet have been profoundly transformative for society, enabling, for the first time, the potential connectivity of individuals and groups.

The second phase of digital evolution, which we recognize as “Internet 2.0”, is characterized by user-generated content and the emergence of social media. It is social media that has become dominant in our digital landscape with a variety of descriptive clichés for connection and expression such as Facebook, YouTube, Twitter, Tik-Tok, etc.

“Internet 3.0” refers to artificial intelligence and includes technologies such as blockchain. In many ways, Internet 3.0 is already strongly present in all fields (Williams, 2022).

Ethics in the media implies a healthy media environment: functional legislation, a high education level of journalists, their economic stability and independence, as well as the financial stability and autonomy of their media houses (Skrozza, 2013).

In order to preserve its reputation, the Reuters Agency established standards that represent a guide for understanding overall media activities, and made the features of journalistic work transparent (Reuters News Agency):

- Adhere to the principle of trust in all news activities;
- Keep punctuality sacred;
- Look for an honest comment;
- Correct errors transparently;
- Strive for balance and freedom from bias;
- Disclose potential or actual conflicts of interest to the manager;
- Avoid injecting unattributed opinion into a media story;
- Do not invent or plagiarize;
- Do not modify still images or video footage, except by methods normally used to prepare content for editorial use;
- Do not pay for information, accept bribes or trade inside information.

Afzal (2012) notes that a large number of virtual space interactions depend on the right information, and that it is the abundance of information that has led to the need for evaluation: there should be services that can help the user find out about the nature of available information, that is, about its authenticity, scope and quality.

Fragmentation and new mergers will be accelerated within many media components, and will be accompanied by outcome unpredictability. However, as Williams (2022) points out, with so few barriers to entry into the digital world, the cost of failure has never been lower as the cost of innovation continues to decline. This is of crucial importance as it represents a big change, especially for existing companies, as the previous protection erodes from that position.

If we agree that digital media ethics targets a wide range of ethical issues, practices and online media norms, we will recognize numerous dilemmas that require quick answers, primarily about how global and multimedia professional journalism can use online information and photos, created as user-generated content. Therefore, differentiation takes place at the level of two extremes: one extreme is professional journalism based on truth, integrity and impartiality of the so-called “gatekeepers”, while on the other, the online side, we have an insistence on speed, subjectivity, directness and rectifications after content publishing.

Davidović (2022) points to the personal aspect, verification and ethics in the use, transfer and dissemination of information, considering that these are relevant determinants of information literacy, which clearly emphasize that the consequences of information (il)literacy is of concern to everyone. Focusing on citizens - media consumers, the author emphasizes the necessity of establishing a critical attitude towards the content, while at the same time understanding the information and media functioning.

Establishing standards for informed consent for the acquisition, retention and sharing of personal data is an elementary prerequisite for all other ethical issues, i.e., issues of concern for the digital user. The intersection between the Internet and privacy begins with the realization that applications and devices are collecting vast amounts of data, which can in turn be analyzed, shared, and used. Trust is essential for this complex network of systems to achieve the desired outcome, yet it often disappears off the radar (Allhoff, & Henschke, 2018).

The forced mass transfer of communication processes into the digital space of social networks, online services, discussion platforms and blogs, caused by the COVID-19 pandemic, exposed the need to establish common rules of communication within a virtual space. Some authors unequivocally indicate that it became obvious that anonymity, and as a result, the permissibility of speech behavior against the background of general social tension, has caused a sharp increase in the use of indecent language, insults aimed at individuals, certain social groups and societies as a whole, and has also contributed to the spread of false and slanderous information (Krasnova et al, 2022).

Despite the fact that there are numerous examples of how virtual reality, by inspiring social change, can be used to improve the quality of life, Fiona McEvoy (2017) lists 10 ethical concerns:

Vulnerability. In order to create a hyper-realistic environment, reality is often masked in order to create an overall immersive experience. Limited access to sensory data makes users vulnerable to accidents and can lead to a complete disruption in functioning.

Social isolation. The entire experience takes place in one user’s field of vision, which consequently excludes all others from physically participating. Despite the fact that certain social networks provide the possibility of interaction between users, the issue of their neglect of social connections and the real “face to face” world remains.

Desensitization. A well-known threat is that immersion in a virtual reality environment can cause some users to become desensitized to the real world, i.e., inability to empathize with acts of violence.

Overestimation of ability. The problem has been detected that users overestimate their abilities in the real world, basing those abilities on experiences gained in virtual space.

Psychiatric effects. There is a concern that virtual reality could reveal the psychiatric vulnerability of individuals much faster, i.e., cause some users to experience psychotic episodes.

Distasteful fantasies. In themselves, tasteless fantasies are not problematic until they become impressive. For example, to what extent is it acceptable to make a game out of the events of 9/11?

Virtual crime. In order to clarify at what point virtual behavior constitutes an impermissible act in the real world, there is a need to appreciate and understand the pain, harm, violence and trauma inflicted by other users in a virtual environment.

Manipulation. Attempts at corporate manipulation with the help of flashy advertising gimmicks are not new, but so far they have been two-dimensional.

Appropriate roaming and responsiveness. One of the most exciting selling points of virtual space is that it can allow us to roam the earth from the comfort of our homes, a good experience for those who cannot travel. However, this is probably where one must think about where it is appropriate to have a virtual experience.

Privacy and data. The more we "connect" in the virtual world, the more we will have to give of ourselves. That could mean growing privacy concerns.

The author Nikolić (2010) notes that the ethical responsibility of the media is enormous, perhaps many times greater than that of other public institutions, given that their reach is direct and truly global, and emphasizes that the media perceive reality and present it, while the most common question may be to what extent they deconstruct the same reality, and then represent the realized image in a way and in accordance with one's expectations.

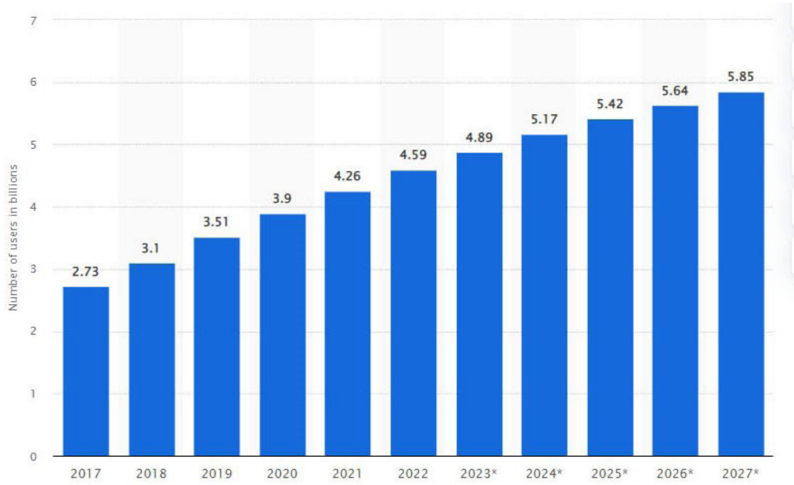
Perrsonal and business use of social networks

Social networking is a phenomenon that strongly influences the work of media organizations and the daily interaction between individuals. Social multidirectional connections result in a vast production of user-generated content, transmission and dissemination of information.

The reasons for the use of social media, especially social networks, should be sought in their continuous availability, economy and interest, as well as in the fact that the media product can be seen as a semi-finished product which has not been ultimately defined, and which gives the possibility of so-called feedback links, thus visualizing the increasingly thin border between producers and consumers of media content (Sančanin, & Ratković Njegovan, 2020).

Authenticity, transparency, and genuine intent are critical to building trusting personal and professional relationships, and as such, the ethical use of social media is paramount for both individuals and organizations. Ethics, by definition, is the concept of what is good, bad, right and wrong. In social media, a correct ethic equals a correct perspective and correct thinking about how to use social media appropriately and how to engage people in the right way. More precisely, ethics is a code of conduct within the context of our society (Socially Savvy, 2022).

One of the most popular online activities is the use of social media: there were 4.26 billion global users during 2021, while it has been predicted that this number will reach almost six billion by 2027 (Graph 1). The penetration of social networks has been increasing across all regions, and has been linked to the development of infrastructure as well as the availability of mobile devices. On average, users spend 144 minutes a day on social networks and messaging applications, which is an increase of more than half an hour compared to 2015 (Dixon, 2022a).



Graph 1. Number of social network users from 2018 until 2027
Source: Dixon, 2022a

A number of companies have realized the potential of the online environment and the opportunities provided by the exploitation of social networking sites. Each social network has unique characteristics or a specific purpose, and organizations strive to exponentially increase their visibility by recognizing that shared content lasts as long as its users redistribute and/or recreate it (Sančanin, & Čerović, 2021).

The use of social networks in a way that encourages innovative teamwork, co-creation of user value, cooperation with external partners and interactive communication between leaders and employees, represents an important driving force for business and individual change, which contributes to increased work productivity (Burrus, 2010).

Regardless of whether we use social networks for private or business purposes, in order to increase the number of followers and achieve the desired credibility, it is necessary to create a stable "Step By Step" activity schedule:

- Define the goals to be achieved through the use of social networks;
- Identify the target group;
- Choose keywords for more effective identification of the target group;
- Key messages must be unique, clear and easily accessible;
- Arouse the attention and move the target public to action;
- Consider previous user experiences;
- Ensure continuous control and adaptation to new circumstances.

With about 2.93 billion monthly active users in the second quarter of 2022, Facebook is the most used social network in the world. The platform surpassed two billion active users in the second quarter of 2017, and it took a little over 13 years to reach this milestone. For comparison purposes, it took Instagram 11.2 years and YouTube 14 years to reach this landmark. The leading audience base of the Facebook social network is in India, with close to 330 million users, while the United States takes second place with 179 million users. The platform has experienced exceptional popularity in Indonesia and Brazil as well (Dixon, 2022b).

Although numerous studies point to a wide variety of misinformation on social media, Americans still rely heavily on platforms like Facebook and Twitter for their news. As many as 50% of American adults get their news from social media at least sometimes, making it their key source of information. Facebook and YouTube are the most frequently used news sources, with one in four US users regularly receiving news via both of these platforms. It is interesting to note that, during the last two years, Facebook, Twitter and other "established" social networks have seen a decline in the share of users who receive their news in this manner, probably as a result of revelations about systematic disinformation (Richter, 2022).

Research by the American non-profit organization Ethics Resource Center (Clancy, 2012) , dedicated to the relationship between ethics and social networks, showed that users of social networks show more tolerance for activities that are considered unethical. As many as 42% of active users said they consider it acceptable to blog or tweet about their company in a negative connotation, and that they consider it acceptable to take a copy of work software home and use it on their personal computer.

The survey conducted in the USA from July 18 to August 21, 2022, showed that in many cases there are demographic differences between those who are regularly informed on social networks. On some social networks, young people under the age of 30 make up the largest share: the 18-29 age group has the largest share on Snapchat (67%), TikTok (52%) and Reddit (50%). Women make up a larger share of regular news users on Facebook, while the opposite is true for sites like Twitter and Reddit (Pew Research Center, 2022).

The main issue with ethical behavior, regarding information technology in a business environment, is how it can be used to violate personal privacy, how someone can use sensitive information for personal gain, and whether or not it is within different degrees of what is considered ethical behavior (Farah, 2013).

Sančanin (2022) indicates that social networks enable direct communication and interactive contact with the target group, that is, they provide enviable breadth and profitability. Nevertheless, this kind of communication does not provide sufficient security, especially compared to control in traditional media, which is a visible deficiency but not so significant that it will represent a dam to future, frequent use of social networks. In this context, Krasnova et al., (2022) states that solving the perceived problems of digital ethics, requires a series of solutions that will enable the construction of a certain infrastructure aimed at limiting the destructive consequences of the growth of digital communication, as well as changes in the area of legislative and moral regulation. Understanding the increasing impact of digitization on individuals and society, as well as its consequences, presupposes an ethical reflection of digital processes on society and the development of a system of moral regulations.

The increasingly unethical practice of social networks is visible through information filtering, which, in this way, is not only unavailable to all users but consequently produces fragmentation and polarization of the virtual community. The process of globalization and increasingly intensive networking, as noted by Radović Marković, Salamzadeh and Vujičić (2019), imposes new economic and business patterns, which will reflect on the optimal use of resources and the provision of advantages to the most developed countries in the world. In this context, we should expect an even greater number and variety of ethical issues based on values such as expertise, excellence, autonomy, productivity and impartiality.

Conclusion

The creation of a unified code of ethics based on cultural values, and followed by its rapid and complete implementation, represents a rational and expected approach to solving a series of ethical dilemmas within the sphere of the culture of behavior within a virtual space. A special responsibility lies with the academic community, which is expected to, within the framework of digitalization inclusiveness, sensitize the professional and general public on topics of key ethical categories. Reducing the threshold of tolerance between the offline and online spheres is a process that should primarily provide users with the most complete informative and educational function, taking into account that virtual reality on social networks is both private and public, at the same time. Today, users of virtual media space give less faith to traditional authorities and increasingly more trust to online friends, but also to communities made up of unknown individuals. In an interaction thus created, with modest or no control mechanisms for entering the virtual space, the only constant will be uncertainty and change. The future nomination of such topics should further stimulate and encourage the continuous critical thinking of researchers, practitioners and educators about the dynamic and changing virtual space in order to constitute an applicable ethical code of conduct.

Conflict of interests
We have no known conflictof interest to disclose

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APPLIED INFORMATION TECHNOLOGIES IN AGRICULTURE

Branimir M. Bajac[1*], Momčilo B. Bajac[2], Lazar. V. Stošić[2,3]
[1]Biosens Institute Novi Sad, Serbia, Senior Researcher (Center for Sensor Technologies)
e-mail: branimir.bajac@biosense.rs
[2]Faculty of Management, Sremski Karlovci, University UNION Nikola Tesla, Belgrade, Serbia;
e-mail: momcilo.bajac@famns.edu.rs; lazar.stosic@famns.edu.rs
[3]Don State Technical University, Rostov-on-Don, Russian Federation

Abstract: This paper examines the possibility of transitioning towards sustainable food production, considering the accelerated growth of the world population and increased demand for food on one hand, and the consequences that the previous approach has had on the biosphere and sociosphere at a global level on the other hand. The first part of the paper presents alarming and precise data and facts that require an ultimate paradigm shift, this time based on the most powerful technological and scientific methods and practices to date. The second part establishes the relationships between the concepts of Agricultural Social Network (ASN), Agricultural Value Chain (AVC), new digital technologies and approaches, with the need for transition towards Society 5.0, where a balance between economic progress and a society tailored to human needs is established. In the third part, the technologies on which the new concept of "precision agriculture - PA" relies are identified, and a case study of the Agrosens digital platform is provided as a good practice example to support agricultural producers. Finally, the last part demonstrates, through the concrete example of Project Provenance Ltd., how the application of new technologies can connect processes and actors in Supply Chain Management (SCM) to establish transparency, efficiency, traceability, and other performance measures necessary for effective and responsible SCM. This enables the implementation of corrective actions and measures to promote responsible production, distribution, and consumption of food or other widely used products.

Keywords: food production, agricultural value chain, blockchain, supply chain management, Society 5.0.

Introduction

There is no doubt that today's agriculture cannot feed the population of tomorrow. Predictions suggest that the world's population will increase by 2 billion by 2050, resulting in approximately 9.7 billion people to feed. The increasing demand for food, along with the exploitation of natural resources, changing dietary habits, climate change, biodiversity loss, inadequate management, and competing agricultural systems, are all driving the need for agriculture to find new ways to improve efficiency. In simple terms, agriculture must be sustainable in the face of population growth, social development, industrialization and climate change adaptation. Consequently, new solutions must be sought to optimize and enhance the efficiency of the agricultural and food chain. On the ground, a chain reaction is initiated due to the rising demand for agricultural production. Expanding arable and agricultural land indefinitely to increase yields is not a sensible approach; instead, the focus should be on optimizing efficiency within existing areas. Agricultural practices aimed at boosting yields are often carried out, but they frequently have negative effects. An all-too-common mistake is the excessive or inadequately controlled use of pesticides, herbicides, and other chemical compounds. These substances can directly impact soil quality and the health of consumers through the consumption of contaminated products or polluted water. The consequences extend beyond humans, affecting the entire ecosystem by introducing excess micro and macronutrients that can harm flora and fauna in rivers and lakes. Heavy metal contamination, resulting from pesticides in water from deep wells and industrial sources, poses a significant threat as well. Additionally, agricultural practices also endanger the air. Animal farms contribute substantial amounts of CO2 and methane, two of the three main greenhouse gases, while nitrogen oxides indirectly result from emissions from agricultural land and crop cultivation. Many of these negative environmental impacts can be mitigated through timely information and farmer education. To address these challenges, it is crucial to bridge the gap between science and agriculture by integrating new digital technologies. This integration should aim not only to increase productivity but also to optimize production outcomes, protect the environment, and achieve social justice

*Corresponding author: branimir.bajac@biosense.rs

through fair food distribution (Fróna, D., Szenderák, J., Harangi-Rákos, M. 2019). Implementing digital technologies can significantly improve the complex and efficient management of agricultural processes.

Materials and methods

Agriculture plays a crucial role in the global economy as it provides food, raw materials, and employment opportunities. The increasing demand for food, climate change, and the necessity for sustainable agricultural practices involve an ever-growing number of stakeholders, forming a complex Agricultural Social Network (ASN), especially in the wake of the global COVID-19 crisis (Tombe, R.; Smuts, H., 2023). Traditional agricultural production is not economically or ecologically sustainable. Climate change and extreme weather conditions are significant contributors to global hunger and food insecurity. The high volatility of food prices, market manipulation, counterfeiting, and fraud have become prevalent in the liberalized agricultural market over the past decade. Inadequate food supply can lead to riots and social unrest, which not only have economic and social impacts but also raise ethical and political concerns (Fróna, D., Szenderák, J., Harangi-Rákos, M. 2019).

The utilization of advanced digital technologies such as the Internet of Things (IoT), big data, data mining and analytics, systems integration, smart sensors, robotics, ubiquitous connectivity, augmented reality, machine learning, blockchain, and artificial intelligence is revolutionizing the management of food production systems and supply chains in agriculture. This digital transformation enables the seamless flow of information throughout the agricultural value chains (AVC), encompassing farmers-producers, processors, advisory and regulatory services, traders, and consumers (Tombe, R.; Smuts, H., 2023). Digitizing the agricultural value chain (AVC) is crucial in addressing the various challenges associated with managing food systems, from the initial stages of production in the field to the final consumption at the fork.

Due to the factors mentioned above, the management of the agricultural value chain (AVC) faces significant challenges, as does supply chain management (SCM). SCM needs to establish a robust control and management system capable of dealing with supply and demand fluctuations, perishable products, logistical complexities, food fraud (counterfeiting and fraud), and stringent food safety standards. The digitization of AVC can introduce innovative digital systems to enhance productivity, food security, supply chain management, knowledge sharing, and the income of indigenous communities collaborating through different agricultural social networks (ASNs).

The concept of Society 5.0 merges digital technologies with social innovation to foster a human-centered society. Society 5.0 comprises technology, systems, and people, and emphasizes the interactions among these elements to promote the digital economy in the agricultural sector. Society 5.0 envisions a harmonious integration of cyberspace and physical space, aiming to balance economic progress with addressing social issues (Tombe, R.; Smuts, H., 2023) Consequently, to ensure inclusivity and empower individuals and communities through the integration of digital technologies, stakeholders must collaborate and create digital economy solutions that drive sustainable development within the agricultural value chain (AVC).

Digitalization practices and challenges in agriculture

The term commonly used to describe the application of information technologies in agriculture is “precision agriculture” (PA). According to various factors drive or hinder the adoption of digitalization practices in agriculture. These include competitive and contingent factors, socio-demographic factors, and financial resources. Research has shown that key parameters influencing the adoption of digital tools in agriculture are the size of agricultural land and the education level of farmers (Perpaoli et al. 2013). Farmers’ education is often linked to their age and their willingness to adopt and trust computerized tools. In practice, the United States of America stands as the global leader in this field, mainly due to significant investments in applied innovation, research, and development at academic and scientific levels. The US has made notable progress, particularly in the concept of carbon farming. This involves implementing well-organized systems that provide subsidies to farmers for employing various techniques to capture CO2 from the air and store it in the soil. This approach is more advanced compared to the rest of the world. The European Union also has a strategy to reduce greenhouse gas emissions through the Carbon Agriculture Initiative, implemented as part of the European Green Deal, alongside its Farm-to-Fork and Biodiversity strategies[1]. On the European continent, the Dutch agricultural system stands out as a prime

[1] European Comission, Technical Guidance Handbook: Setting up and implementing results-based carbon farming mechanisms in the EU (2021), Brussel, 2021.

example of efficient modern agriculture.

Education on digital practices in agriculture is not only relevant to the well-being of plants, animals, and the environment but also extends to the operation and maintenance of machinery used in farming, such as combine harvesters. These high-capacity and multifunctional machines significantly enhance efficiency, but their operation requires specialized knowledge and skills. However, due to the high cost involved, such advanced machinery is not commonly found in underdeveloped countries. In animal husbandry, automation has been widely embraced, primarily through the implementation of various sensors. Mature solutions in livestock farming include automated milking and feeding systems, climate and atmosphere control, animal identification and tracking, calving detection, and manure removal, among others. These advancements in automation have brought notable improvements to the efficiency and management of livestock farming.

Proximal monitoring tools, which are placed directly in the field and provide real-time data on crop conditions, have a higher likelihood of adoption by farmers. On the other hand, satellite imaging technologies are globally used but are still in the early stages of development and are primarily applied in developed countries due to their significant financial requirements. This represents a novel approach to collecting large amounts of data and applying various data processing methods to enhance monitoring capabilities. However, satellite imagery is rarely utilized to evaluate the impact of agricultural practices on crop yield and well-being. Unlike sensor readings, satellite image processing is not a direct service to farmers. In practice, satellite images usually need to be processed by powerful computers and made accessible to end-users through a platform or server (Kubitza at al. 2020).

An exemplary case of good practice in this regard is Argosense, a platform developed by the Biosense Institute from Novi Sad, Serbia. It is designed not only as a source of plant health indices and environmental data but also as a space for farmers to socialize, exchange best practices, and facilitate communication among various stakeholders, including farmers, the food industry, agronomists, retailers, insurance companies, and policy makers. Agrosense is a digital platform empowered by cutting-edge technologies such as sensors, yield monitors, drones, soil sampling probes, the Internet of Things (IoT), big data analytics, and artificial intelligence. It provides farmers and agricultural companies with the means to monitor crop conditions and plan agricultural activities[2]. Available as a web or Android application, Agrosense enables easy and swift data entry into the system, granting agricultural producers instant access to various field data. This includes location-specific weather forecasts, satellite crop indices that describe plant growth and photosynthetic intensity, water and nutrient availability, soil analysis summaries, crop photos, and the latest information on the occurrence of diseases and pests in the vicinity of the field.

Agricultural data is inherently diverse, encompassing various formats, types, intentions, data collection methods, and protocol devices. This necessitates the seamless integration of data, processes, and systems. Thus, effective platforms are needed to facilitate communication and information exchange among farmers and other stakeholders within Agricultural Social Networks (ASN). These platforms aim to support appropriate activities that enhance agricultural practices, increase productivity and profitability, ensure food quality and safety, and ultimately meet consumer needs. In addition to blockchain technologies, which provide transparency, traceability, and data security on a decentralized network, especially in supply chain management (SCM), the Internet of Things (IoT) and smart sensors play a crucial role in connecting the physical and virtual realms. Furthermore, the combination of Edge and Cloud Computing enables the analysis of big data using artificial intelligence techniques. These technological advancements contribute to the efficient processing and utilization of agricultural data, fostering improved decision-making and sustainable practices in the agricultural sector (Tombe, R.; Smuts, H., 2023).

Similar to other sectors that have embraced digitalization, the digital transformation of agriculture necessitates the interoperability of digital systems and technologies. This entails the operationalization of standardized data formats within an established ethical and legal framework. Only through this approach can all stakeholders within the Agricultural Social Network (ASN) collaborate effectively, exchanging data and information pertaining to agricultural practices, markets, pricing, and distribution channels. Interoperability, when combined with the utilization of decentralized blockchain platforms like Ethereum, opens up new opportunities for smart agriculture. These possibilities encompass enhanced financial accessibility through decentralized finance (DeFi), novel organizational structures and management through Decentralized Autonomous Organizations (DAOs) and smart contracts, as well as the inclusion of agricultural populations previously excluded from ASN. It also enables them to access broader digital markets at regional and global levels.

[2] https://agrosens.rs/#/app-h/about

Blockchain and Supply Chain Management

It's surprising how little the average consumer knows about most of the products they use every day. Before reaching the final consumer, goods traverse a wide and predominantly unseen network involving sellers, distributors, transporters, warehouse facilities, and suppliers who participate in the design, production, delivery, and sale of these goods. However, the production, exchange, and utilization of material products carry numerous potential negative consequences, including environmental damage, child labor exploitation, unsafe working conditions, fraud, counterfeiting, and substantial waste of valuable materials at the end of a product's life cycle.

The establishment of comprehensive "chains of custody," which verify the origin of each product or material, remains fragmented and susceptible to fraud and errors, even among certified companies. Blockchain-based applications have the potential to enhance supply chains by providing infrastructure for registering, certifying, and tracking goods transferred between remote parties within the supply chain who may lack mutual trust.

Through blockchain technology, supply chain participants can ensure transparency, traceability, and accountability. This enables the verification of product origins, ethical sourcing, fair trade practices, and compliance with safety and quality standards. By leveraging blockchain, the supply chain ecosystem can be strengthened, fostering increased trust and efficiency while mitigating the negative consequences associated with the production and distribution of goods.

Without delving into the intricate details of blockchain technology, we can say that "blockchain" is an immutable irreversible linear chain of cryptographically hashed "blocks" on which transactions are recorded. This linear history of time-stamped events is verified and stored in a decentralized DLT-based manner, and network nodes "witness" transactions and reach consent on which transactions are considered regular through a consensus e.g "Proof of Work" algorithm (Bjelajac, Ž., Bajac, M. 2022). Each transaction's data recorded and validated on the blockchain is immutable and irrevocable, accessible for inspection by anyone or authorized auditors.

In the realm of food production and processing, a precise and up-to-date blockchain-based register is expected to aid in identifying various aspects of a product, including information regarding the origin and composition of raw materials, processing facilities, storage conditions, transportation, manufacturing and expiration dates, and more. Consequently, during situations such as outbreaks of infections, adulteration, or fraud, details can be obtained regarding how and where the food was grown and who inspected it.

By creating a "digital passport" or "digital avatar" of physical products, blockchain not only provides reliable information but also ensures transparency regarding a company's business footprint. Through its design, blockchain enforces the transparency, security, authenticity, and auditability necessary for establishing traceability of the chain of custody and product attributes. This, in turn, empowers customers to access high-quality information, enabling them to make more informed choices.

As a result of implementing blockchain technology in the supply chain, a multi-layered system of supply chain validators emerges, and the choices made in the market determine which business practices thrive and survive, and which ones fade away. This new system, serving as a source of interconnected, secure, and unalterable information, enables smarter and more informed purchasing decisions in supply chains and among end consumers. It also ensures the sustainability and viability of economic activities on both the biosphere and sociosphere.

The information architecture for the certification and chain of custody system on the blockchain takes takes into account the following stakeholders[3]:

1. Raw material producers (e.g. cattle breeders).
2. Producers of the final product (e.g. manufacturers of processed food)
3. Registrars, organizations that provide credentials and unique identities to stakeholders (e.g. accreditation services, Agency for Business Registers).
4. Standardization organizations, which define specific rules and standards (e.g. Fairtrade, ISO).
5. Certifiers and auditors, typically separate entities responsible for incpecting raw material producers and final product manufacturers to verify compliance with certain standards).
6. Buyers of product throught the supply chain, including end consumers.

Transactions involving supply chains often deal with multiple actors who transact based on concealed information or with a lack of knowledge regarding the product's origin. Corporations can use the Blockchain to identify these multiple layers that are often linked to human and natural resource exploitations, environmental footprints, and waste productions and gain a more transparent supply chain as a result (Ly, P. 2018). Project Provenance Ltd has developed a decentralized blockchain-based dApp that collects and verifies a product's provenance and other attributes in real-time, providing it with a "digital

[3] https://www.provenance.org/whitepaper

passport" that can be tracked along the entire supply chain until it reaches its destination.

This architecture consists of a series of modular programs distributed on the blockchain and independently controlled. However, because they operate within the same blockchain system, they can seamlessly communicate with each other. These programs include[4]:

1. Registration, standardization, and certification modules: These programs handle the of participants, establish standards, and certify compliance with those standards.

2. Production module: This module specifies the input goods and tracks their transformation through the production process, from sources such as bull farms to the final packaged meat found on supermarket shelves.

3. Labeling module: This module establishes a link between the digital and physical worlds through unique cryptographic QR codes or NFC tags. These tags connect the origin of the material, ingredient, or product to its physical counterpart.

4. Linking module: Physical goods and materials are identified and linked to their digital representation on the blockchain using serial numbers, barcodes, digital tags like RFID and NFC, or genetic tags. These tags uniquely identify a physical asset and its digital counterpart.

By utilizing smartphone applications, customers can aggregate and access reliable real-time information, enabling them to make informed purchasing decisions. This technology can be implemented through discreet and removable labels easily verified via QR codes read on smartphones, holograms, or RFID tags embedded in brand labels. These features allow product owners to prove the authenticity of their products at any time by accessing blockchain data via tokens[5].

All these systems rely on tracking the attributes of material things not only during their creation but also during their use. This comprehensive record of a product's life cycle can significantly impact the afterlife of goods and contribute to broader initiatives such as the circular economy.

One specific aspect, particularly relevant in more developed countries, is food waste management. It is estimated that approximately one-third of all food produced is wasted, with a significant portion being discarded directly from consumers' plates. In response, the EU has implemented a strategy to reduce food waste, which includes measures such as identifying and prioritizing target groups, improving the food management chain, implementing food donation strategies, and enhancing food labeling to prevent waste. Some of these actions legally obligate stakeholders to reduce food waste.

Educating society on how to effectively manage food waste is a crucial part of these efforts. This includes activities such as sorting, selecting, and recycling food waste, which have proven effective in reducing waste across many EU countries. Many strategies also promote food waste education in schools to foster an understanding of food quality assessment, raise awareness of the impact of food waste on climate change, and encourage individuals to adopt responsible behaviors towards food.

Conclusion

Technological development has always been the primary catalyst for paradigm shifts. During Third Industrial Revolution, which introduced the Internet and propelled the world into the Information Age, it was anticipated that the inherent connectivity of this technological innovation would bring people closer together and diminish alienation. However, a paradoxical situation unfolded – people became more interconnected than ever before, and communication became increasingly effortless, yet the process of alienation between individuals persisted and intensified (Filipović A., Bajac, M., & Spaić, I., 2022). Despite numerous strategies and agendas that were implemented, it became evident that the biosphere and sociosphere were unable to withstand the impact of the existing neoliberal paradigm. The economic model, driven by the pursuit of maximizing utility from technical, human, and natural resources, prioritized capital accumulation rather than meeting human needs. The technologies associated with the Fourth Industrial Revolution, such as quantum computers and artificial intelligence, have the potential to offer new prospects for improving the overall quality of life for citizens. However, they also raise concerns about the potential emergence of a totalitarian dystopia with uncertain consequences. One of the most prominent figures associated with the World Economic Forum (WEF), Yuval Noah Harari, emphasized in his speech that the automation of jobs through the implementation of AI systems often results in job losses and the emergence of a cohort of "unemployable and useless" individuals. He argued that while people in the past feared exploitation, in the 21st century, the fear will shift towards a sense of uselessness. Being considered useless is perceived as far worse than being exploited.

[4] https://www.provenance.org/whitepaper

[5] https://www.provenance.org/whitepaper

Precision agriculture (PA), in conjunction with the concept of smart cities, plays a pivotal role in the transition from an information society to the notion of Society 5.0. This transition involves an unprecedented connection between cyberspace and physical space. Establishing sustainable production, ensuring equitable distribution, and shaping consumer behavior are critical factors for the success of this concept. Therefore, further research necessitates an interdisciplinary approach with a greater emphasis on social and human sciences such as social psychology, anthropology, and philosophy. This approach aims to ensure that the implementation of cutting-edge technologies genuinely leads to a social organization in which every individual can live an active and fulfilling life.

Conflict of interests

We have no known conflictof interest to disclose

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ERP SYSTEMS AND THE CHALLENGES OF LEGAL PROTECTION OF PERSONAL DATA

Lazar. V. Stošić[1,2*], Aleksandra V. Janković[3], Igor Ristić[1], Momčilo B. Bajac[1]
[1]Faculty of Management, Sremski Karlovci, University UNION Nikola Tesla, Belgrade;
e-mail: lazar.stosic@famns.edu.rs; risticig@famns.edu.rs; momcilo.bajac@famns.edu.rs
[2]Don State Technical University, Rostov-on-Don, Russian Federation
[3]Academy of Professional studies South Serbia – Leskovac, Department of Preschool Teacher Training School Bujanovac,
e-mail: aleksandra.j78@gmail.com

Abstract: Due to the increasingly rapid development and implementation of information technologies, the amount of information obtained via the Internet, the business environment, and increasing competition in the market, companies have a need for services and information systems that will fully support their businesses and at the same time enable development goals. On the scene come ERP systems that represent a wide range of business software for business management, ranging from financial management to operations management. In this whole process, the challenges of legal protection of personal data also arise.

Keywords: ERP systems, information technologies, legal protection, production processes, data processing, and legal data protection.

Introduction

With the development and application of information technologies came the development of the first applications that automated the production process and data processing itself. This refers primarily to the input-output of goods, invoicing, bookkeeping... The adoption of information technologies in organizations has led to changes in basic business procedures. Ever since the early 1950s, companies have begun to apply information technology to business applications. In the beginning, companies used stand-alone mainframes. These were mainframe computers stored in offices where the main computer was in one room and could only be accessed by MIS (Management Information System) staff. This phase was followed by the use of mainframes and dumb terminals. Going to a separate computer was time-consuming, and the process itself was inefficient. It was resorted to setting up the so-called stupid terminals, which consisted of placing "weaker computers" through which users could enter data into the main computer. At the end of the 1970s, the first personal computers appeared, and at that time, almost every user had a personal computer to work on. With the increase in the number of personal computers, there was a need to introduce a local network (local area networks; client/server computing). Data entered into personal computers was now easily transferable to the main computer, and the term client/server computing was born. Already at the beginning of the 1990s, with the development of the Internet, companies began to use TCP/IP network protocols, and the process itself was significantly accelerated. That phase is labeled enterprise computing. Since the development and application of the Internet, the process itself has proceeded at an incredible speed, and the need for fast transmission, storage, and security of data has arisen. A new phase has emerged: cloud computing and mobile computing. All data is located on the so-called server. Cloud storage can be accessed by everyone.

ERP (Enterprise Resource Planning)

The application of information technologies led to the development of production itself, from classic production to the system of the entire company, primarily in logistics. The concept of applying information technologies to logistics is known as ERP (Enterprise Resource Planning) systems. ERP systems are

*Corresponding author: lazar.stosic@famns.edu.rs

software programs that assist companies in managing their resources and operations. The ability of organizations to automate many of their activities is one of the major advantages of ERP systems. These systems try to integrate all the functions of the different departments of society into one computer system that can be used by all departments. The software can be used to perform a variety of tasks, including supply chain management, configuration, pricing, financial data accuracy, employee life cycle, business needs assessment, payroll and human resource management, accounting, standardization of critical business procedures, streamlining, and better project planning.

ERP systems are made to give managers a thorough understanding of business operations so they can make wise decisions. They offer real-time information on a variety of business variables, including inventory levels, sales results, and manufacturing schedules. This information can be utilized to streamline operations, cut costs, and boost productivity. The ability of managers to make better, quicker decisions is considerably improved by this knowledge. ERP systems also offer a central database that all staff members can access. Because of this, collaboration and communication within the company can be enhanced as everyone has access to the same information.

Due to the great expansion of the development of information technologies, there was also a sudden development of the ERP system. ERP systems were primarily intended for the integration of business processes in the company. With the help of the ERP system, information from numerous market sources is integrated with corporate data and the specifications of the suppliers themselves. It remains an open question whether the application of information technologies causes the centralization or decentralization of decision-making in the organization. The application of modern information technologies reduces the costs of communicating information and improves and speeds up the quality and speed of information processing, as well as management decision-making, which leads to more centralized management. On the other hand, their application reduces the costs of the agency through the improvement of monitoring capabilities, which leads to the decentralization of decision-making. Be that as it may, the application of information technologies, primarily software, has had the effect of disrupting or improving the work of companies in the search engine industry.

Despite these difficulties, many companies have discovered that investing in an ERP system has been worthwhile. ERP systems have helped firms increase their bottom line and stay competitive in today's fast-paced business environment by streamlining their processes and offering real-time data.

Enterprise Resource Planning Systems - Enterprise resource planning systems

The background of the systems itself has a common database with which it functions and through which all data can be updated. By updating and controlling data through a single database, it is easier and faster to implement planning, management, and the use of all company resources.

The main goals of ERP systems are to enable the smooth flow of information through them. This means that changes in one area are immediately reflected in all other relevant functional areas. Regardless of the difficulty of implementing ERP systems, most companies have successfully implemented and introduced them. The purpose of ERP systems was initially to facilitate business processes, later to evaluate the same, and today they include administrative, sales, marketing, and human resources.

Advantages and disadvantages of ERP systems

A key advantage of ERP systems is enhanced productivity. Organizations can automate jobs, cut down on duplication, and streamline their operations by connecting different business processes. Cost reductions and increased productivity may result from this. Additionally, ERP systems improve the visibility of business operations, enabling firms to base choices on current data.

The main advantages of the ERP system are:

- organizational flexibility and agility
- decision support
- quality and efficiency

The quality of production, distribution, and customer service can all be significantly improved by integrating and optimizing an organization's business processes with ERP systems.

Disadvantages of the ERP System:

- The best practices created by the ERP vendor are frequently used to pre-define business processes in ERP software.
- Implementing an ERP might give you the chance to revamp obsolete, inefficient, or inefficient

processes, or even improve them. Even though vendor best practices are, by definition, suitable for the majority of enterprises, they might not be the "best."

• The failure or improper operation of key corporate processes and information systems resulted in significant losses in revenue, profit, and market share.

• Orders and shipments are often lost, inventory changes are not properly recorded...

In order for the preparation for the new ERP system to be successful, planning and timely planning, as well as the development and training of personnel, are necessary.

The main causes of ERP implementation failure include:

• Lack of training and unpreparedness of workers for the new work requirements required by the ERP system

• Desire to implement ERP systems as soon as possible

• Employee participation in the planning and development stages of change management processes is delayed...

ERP implementation strategy in 8 steps (https://www.erpdb.info/erp-implementation-strategy/):

1. Define the requirements
2. Check the specifications to see if your company can meet them
3. Document user procedures
4. ERP installation tactics include a Big Bang, phased, hybrid, and parallel adoption approach
5. Carefully consider adaptation alternatives
6. Choose the right project leader
7. Don't forget mobile users
8. Provide training with enough time and resources.

ERP systems are effective tools that can boost an organization's productivity, teamwork, and decision-making. Organizations can streamline their operations and improve visibility into their business operations by integrating diverse business processes into a single platform. Scalability, usability, and support services are critical considerations when selecting an ERP system.

ERP II Systems

ERP II (ERP/2) systems are new concept systems that provide the latest extensions to ERP systems (Classe, 2001). The first version of the ERP system did not cover sales and marketing, did not include the ability to manage relationships with clients, so these were clearly missing and incomplete. Nowadays, it is unthinkable to use any system without exchanging data via the Internet, and the original systems did not provide user support on the Web. ERP systems currently incorporate administrative, sales, marketing, and human resource functions as a result of their evolution over time. The Web may now be used by businesses to link all components of the value chain, including inventory and manufacturing, with their clients, suppliers, distributors, and other key players.

Differences between ERP and ERP II

ERP	ERP II
It is developed in 1990s.	It is developed in 2000s.
ERP was concerned with optimizing an enterprise-Internal Optimization.	These systems are about optimizing the supply chain through collaboration with trading partners.
Focuses on manufacturing and distribution.	Focuses on all sectors and segments of business.
It's process is internal and hidden.	It's process is externally connected.
Data is internally generated and consumed.	Data is internally and externally published and subscribed.
It is web-aware, closed and monolithic.	It is web-based, open and componentized.

Source: https://www.geeksforgeeks.org/difference-between-erp-and-erp-ii/

Major ERP trends

Mobile ERP - employees and managers have direct access to information regardless of where they are. Any company involved in an ERP evaluation and planning to implement a mobile ERP must consider the role of mobile applications in its overall business solution (Hossein, 2004).

ERP in the cloud is a newer type of service, i.e. upgrade, implementation of the old ERP solution on the selected cloud platform. By using the cloud, companies are relieved of the costs and complexity of physical infrastructure. This becomes important for small and medium-sized enterprises with a limited budget. "Software as a service uses a cloud, which provides the computing power to run the solution but is not a cloud itself" (Lenart, 2011).

ERP in the cloud offers specific services according to the needs of the company and provides numerous benefits. Some of the leading public cloud platforms: Microsoft Azure, Amazon Web Services, and Google Cloud.

Advantages of using ERP in the cloud:

• Lower cost of ownership – costs of owning physical and software components are reduced due to the use of cloud services. There is no need to invest in IT resources to maintain infrastructure and hardware.

• Better availability of the solution - the existence of the ERP system on the cloud enables constant support and correctness of the system because a special service takes care of its use.

• Solid integration – great service around the integration of ERP solutions and offers of various business applications.

• Personalized cloud model - the possibility of choosing between a public or private cloud model gives you the opportunity to choose the optimal solution for the company and adapt it to your requirements by choosing a personalized cloud model.

• Agility and scalability at the level of application and exploitation of IT resources...

Steps to the introduction and use of ERP in the cloud:
1. Analysis of software requirements and business processes
2. Installation of selected ERP software
3. Setting up cloud hosting and managing services that support ERP
4. Use of ERP services with expert support

Utilizing an ERP system that is cloud-based has three key benefits:

• The system can be accessed from any location that offers Internet connectivity.

• Organizations employing cloud-based ERP are able to avoid the hardware and software implementation costs that are typical of on-premises solutions.

• Because cloud-based ERP solutions are scalable, it is possible to add new ERP modules and expand ERP functionality to include new business partners (such as suppliers) and business processes.

The company must carefully consider the disadvantages of using cloud-based ERP systems as well. The following are the top three disadvantages of using a cloud-based ERP system:

• It's unclear whether cloud-based ERP solutions are safer than systems installed on-site.

• Organizations that use ERP systems hosted in the cloud give up control of an important IT asset.

• The third disadvantage is a direct result of the inability to manage IT resources.

Social ERP - deals with social media and its importance. With the development of various social media services, primarily Facebook, Twitter, and LinkedIn, communication, marketing, and data exchange are a much faster, more efficient, and more entertaining level. Social media is gaining momentum in the implementation of the ERP system itself. Using an existing ERP system, social ERP capabilities can help employees and partners collaborate and communicate. People may be rapidly and easily connected, enabling them to work together to proactively address business challenges.

Six basic benefits of social functionality research for ERP systems (http://www.strategic.com/blog/social-erp-the-next-step-in-collaboration-and-customer-engagement/):
1. Facilitates cooperation and communication in the company
2. Monitor conversations, projects and processes
3. Improves business processes
4. Document business processes to support lean initiatives
5. Increases customer engagement

6. Builds and maintains your knowledge base

Two-tier ERP - an organized way to run essentially two different ERP systems at the same time: ERP for the corporate level, while the other is at the subsidiary level.

The challenges of legal protection of personal data

“In addition to the advantages that the Internet brings us, such as a large source of useful information and literature, electronic banking, shopping from home, doing work from home, the Internet can also be a tool for committing criminal acts and violence” (Janković and Stošić, 2022, p. 98). The rapid progress of digital technologies and their application in all areas of society also requires the harmonization of legal regulations that would regulate their safe application and provide protection against possible violations of some rights during their application. One of the results of the digital economy is the increasingly pronounced collection of data on natural persons both by private companies, as well as by state bodies and public institutions on an ever-increasing scale for the needs of their businesses, and at the same time, the challenges we face in the field of personal data protection (European Parliament and EU Council, 2016). The implementation of the ERP system in the economy is introduced with the aim of enabling more efficient operations through a unique record of finances and human resources within a company. The collection, processing, and deletion of data on natural persons is present on an ever-increasing scale, along with possible abuses. “It is logical that, in parallel with the growth of collected data on each individual, the danger of misuse of this data, both by individuals and by companies and state institutions, has also increased drastically” (Andonović, Prlja, 2020, p. 7).

The protection of natural persons in relation to data processing is provided for both by international documents (Article 8, paragraph 1, of the Charter of Fundamental Rights of the European Union) and by domestic regulations (Article 42 of the Constitution of the Republic of Serbia). Globalization in the field of the digital economy also required that the issue of personal data protection be regulated in a uniform manner in a wider area, and accordingly, the European Parliament and the EU Council adopted the General Data Protection Regulation. On the international level, the International Convention of the Council of Europe on the Protection of Persons in Relation to the Automatic Processing of Personal Data was adopted (2005), and ratified by the Republic of Serbia (2006). In accordance with the obligation to harmonize domestic legislation with EU regulations, the Republic of Serbia has adopted a series of regulations that adequately provide protection to natural persons in relation to data processing, namely: the Personal Data Protection Strategy, Personal Data Protection Act. As part of the obligation to create an institutional apparatus in the Republic of Serbia, the institution of the Commissioner for Information of Public Importance and Protection of Personal Data was introduced.

The process of data collection and the creation of a database requires compliance with certain principles that are stipulated in both international documents and domestic regulations (Personal Data Protection Strategy, Article 5 of the Personal Data Protection Act). These are: (1) The principle of legality, which provides for the observance of certain rules concerning the existence of the written consent of the person whose data is collected and the authority to collect the data; (2) The principle of limitation of purpose, which stipulates the obligation to specify the purpose for which the data is collected before the start of data collection, which cannot be changed or expanded later; (3) The principle of proportionality stipulates that data that are needed for the purpose for which they are collected, and not data that have nothing to do with the purpose for which the data is collected; (4) The principle of transparency of processing, which stipulates that the person about whom the data is collected is informed about the actions of data processing and about the purpose for which the data is collected; (5) The principle of accuracy of the data collected; (6) The principle of time limitation in which data is processed and stored, which in the case of companies and employees would be the period during which they are employed, and after the termination of the employment relationship there is no legal basis for storing and processing data and there is an obligation to delete data; (7) The principle of non-discrimination, which foresees the obligation to respect the right to data protection for everyone, regardless of race, gender, or religion (Krivokapić et al., 2016).

Violation of the rules prescribed by law on the collection, processing, and storage of personal data entails misdemeanors, and in some cases, criminal liability. The Personal Data Protection Act provides for misdemeanor liability and fines for legal entities and responsible persons in cases of violation of the Personal Data Protection Act. The criminal law provides for criminal liability in cases of unauthorized collection of data (Article 146), unauthorized deletion and alteration of data (Article 298), and entry of incorrect data (Article 301). “Along with the development of technology, one of the characteristics of modern society is the appearance of criminal acts precisely by using the same technology to commit criminal acts" (Stošić and Janković, 2022, p. 84).

Conflict of interests
We have no known conflictof interest to disclose

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NANOINFORMATICS, COMPUTER APPLICATIONS FOR NANOMEDICINE

Aleksandar Đorđević[1*]
[1]Department of Chemistry, Biochemistry and Environmental Protection, Faculty of Sciences, University of Novi Sad, Serbia,
e-mail: aleksandar.djordjevic@dh.uns.ac.rs

Abstract: Nanoinformatics emerged in the early 21st century as a response to the need for computer applications at the nano level. While nanomaterials offer the potential for developing new devices in various industrial and scientific fields, they also provide revolutionary perspectives in disease prevention, diagnosis, and treatment in humans. This review paper analyzes different aspects of nanoinformatics with a special focus on nanomedicine. Another important aspect is the use of informatics in further advancing the biological and clinical applications of basic research in nanoscience and nanotechnology. Nanoinformatics can accelerate the development of the emerging field of nanomedicine, similar to what happened with the Human Genome and other -omics projects, through the exchange of modeling and simulation methods and tools, linking toxicity information with clinical and personal databases, or developing new approaches for scientific studies.
Keywords: Nanoinformatics, nanomedicine, nanocarriers, nanodrug, fullerenol.

Introduction

Over the past five decades, numerous computational methods and applications have been developed in the context of biomedicine, leading to interdisciplinary fields such as medical informatics, bioinformatics, and other related areas (Kulikowski, 2002). New informatics disciplines related to biomedicine encompass a wide range of scientific and technological approaches for addressing complex problems, including, among others, data and knowledge integration methods, biomedical ontologies and vocabularies, data and text mining, DNA and RNA sequencing, decision support in medicine, prediction of gene mutations and disease associations, development of data representation and exchange standards, as well as the development of informatics methods and tools for integrating multiple levels of data and creating simulations of biomedical systems. Mathematical and technical knowledge have successfully contributed to these research areas, leading to the complete realization of major global projects such as the Human Genome Project, computerization of clinical practice, or the creation of computer systems for decision suppor (Maojo, & Kulikowski, 2003). Numerous pioneering studies have been conducted, and after several decades, new scientific fields in nanomedicine have been discovered, holding promise for scientific and technological breakthroughs that can transform conventional medicine (Kim, Rutka, & Chan, 2010). Research in this field is often associated with nanotechnology, and there are many areas where computational methods themselves are crucial for advancing research and providing practical support (Maojo et al., 2010). These areas can be divided into fundamental groups.

Characterization of nanoparticles
Modeling and simulation
Imaging techniques
Terminologies, ontologies, and standards
Data integration and exchange
System interoperability
Data and text mining for nanomedicine research
Linking nano-information with computerized medical records
Basic and translational research
Networks of international researchers, projects, and laboratories
Education in nanoinformatics
Ethical considerations

[*]Corresponding author: aleksandar.djordjevic@dh.uns.ac.rs

Nanoinformatics primarily deals with these issues, with the support of major organizations such as the U.S. National Science Foundation, the National Cancer Institute, and the European Commission. In this new context, nanoinformatics employs information techniques for the analysis and processing of information regarding the structure, physicochemical characteristics of nanoparticles and nanomaterials, their interaction with the environment, and their applications in nanomedicine (Maojo et al., 2011). These new applications emerge at a time when genomics and personalized medicine are gaining recognition and promising additional perspectives for biomedicine. The term "nanoinformatics" or "biomedical nanoinformatics" or "nanomedical informatics" can also be associated with other nanotechnology applications, but this work will only focus on the biomedical applications of nanodrugs in clinical oncology. According to the opinions of many scientists, nanomedicine is considered a new branch of medicine operating at a different, nano level, which entails significant physical and chemical differences. This poses great challenges for research, medical practice, and economic implications due to the novel toxicotherapeutic relationships at the nanoscale (Thomas, Pappu, & Baker, 2011). In that sense, we can recall what happened around 1995-2001 when bioinformatics contributed to the rapid completion of the Human Genome Project, and we can assume that informatics will also be crucial for progress in the development of nanomedicine. Nanomedicine encompasses a wide range of significant topics with practical and scientific implications, such as early disease detection, including cancer, the ability to achieve highly specific targeted therapies, new molecular imaging methods based on the optical properties of nanoparticles, drug delivery control methods in very small doses, nanorobots for diagnosis and therapy, hyperthermia treatments, and new approaches to overcoming solubility limitations of new or existing drugs (Kim, Rutka, & Chan, 2010; Thomas, 2023; Thapa, & Kim, 2023). In addition to human applications, nanoinformatics is also being developed in various branches of agriculture (Thakur, Kumari, & Dev, 2021; Borišev et al., 2016; Kojić et al., 2020). Researchers at the Polytechnic University of Madrid have developed a computer application based on text mining techniques, called "nanotoxicity searcher," which automatically searches for toxic information in scientific literature. In the searches conducted for paclitaxel, information on nanotoxicity was found, combined with appropriate ontologies such as the nanoparticle ontology (Thomas, Pappu, & Baker, 2011). This research and other efforts (de la Iglesia et al., 2011) have raised questions related to the management of information about nanotechnology, particularly:

1. The lack of appropriate standard classifications for nanomaterials.
2. The rapid development of knowledge about numerous complex biological, chemical, and physical processes occurring at the nanoscale.
3. The heterogeneity of information and structure in many scientific papers across various disciplines and sub-disciplines of nanotechnology.

All these issues increase the challenges of applying standard information retrieval methods in the literature without additional knowledge of the specificities within the presented scientific fields and subfields. New computer-based approaches are needed to effectively and efficiently connect information from nanomedicine, while considering the different levels of complexity encompassed in research, development, and application in nanotechnology. In this context, researchers proposed a direction for this field in the first decade of the 21st century (National Science Foundation, 2010).

Perspective for the applications of nanoinformatics

The contemporary approach to information retrieval involves comparing nanoinformatics with computational applications in biomedicine from six different perspectives."The Workshop on Nanoinformatics Strategies" was the first of its kind, held in Virginia in 2007 (Workshop on Nanoinformatics Strategies, 2007), followed by various professional conferences in the field. This workshop focused on practical engineering perspectives, without incorporating the existing computational infrastructure. Given the rapid development of nanoinformatics and the fact that nanotechnology deals with issues beyond medical and biological domains, it is expected that the use of nanomaterials will have an impact on human health. From a fundamental standpoint of quantum physics, very characteristic quantum effects and phenomena associated with nanoparticle size occur at the nanoscale, which do not manifest in bulk materials. This knowledge raises many questions about the use of new models and tools for predicting interactions between nanoparticles and biomolecules, as well as comparing the results of these models with in vitro and in vivo experimental measurements. Structuring information in nanomedicine is crucial for research development. New concepts have been introduced into the vocabulary, such as "nanoparticles" (National Library of Medicine. National Institutes of Health). New taxonomies and ontologies have been developed, such as the nanomedicine ontology (Gordon, Sagman, & Alliance, 2003) and ontologies for nanotechnology indexes, along with the adoption of applications like BiomedGT for mapping across different ontologies (Baker et al., 2009).

Tools supporting the selection of nanomaterials for medical diagnostics, therapy, or theranostics should be based on several key criteria for nanoparticles, including size, shape, charge, chemical composition, topology, pharmacokinetics, biological activities or toxicity, and others.

In the late twentieth century, numerous initiatives were launched, such as the National Centers for Biomedical Informatics (USA) and the Virtual Physiological Human (VPH) program (Europe) (Viceconti, Clapworthy, & Van Sint Jan, 2008), to support biomedical research. A large number of projects are focused on modeling and simulating various systems, organs, tissues, and cells, as well as their relevance to applications in clinical practice. In addition to fundamental research in fields such as chemistry, physics, molecular biology, biochemistry, histology, and physiology, some engineering disciplines play a significant role in signal and image processing, modeling, and simulations, which can easily be adapted to nanoinformatics projects.

Among the most important information expected from such simulations are characterizations and simulations of the behavior of nanoparticles in biological models, the formation of interactions with target molecules in living systems, or the development of new imaging techniques using quantum dots (Network for Computational Nanotechnology, National Science Foundation, 2009; CaNanoLab). Researchers at the University of Talca in Chile, in collaboration with members of the National Cancer Institute-Frederick's Center for Advanced Biomedical Computing, have developed a database of nanostructure called the Collaboratory for Structural Nanobiology (Collaboratory for Structural Nanobiology).

Education in nanomedicine and nanoinformatics introduces new content from various scientific disciplines, such as the fundamentals of quantum physics and chemistry, new imaging modalities, modeling, and other areas. Experts with knowledge and skills in the application of nanoinformatics will play an important role in facilitating communication between different medical fields in the near future. The first step is undoubtedly the establishment of nanoinformatics infrastructure and the collection, cataloging, annotation, organization, and archiving of available data. The development and expansion of databases, software tools, and nanoparticles, including their physical and chemical properties, 3D structures, toxicity, and biomedical applications, are crucial.

Semantic interoperability of heterogeneous information systems containing nano and other data will be a key issue in nanoinformatics (Munteanu, 2011). Adapting the structure of scientific papers for ease of search and classification of nanoparticles is essential for establishing new hierarchies/taxonomies based on physical, chemical, clinical, and toxicological characteristics (Gerstein, Seringhaus, & Fields, 2007). 3D representations and visualization of molecular structures (O'donoghue, et al., 2010) can be adapted for visualizing nanoparticles. Adding information to understand changes in genotype caused by interactions with nanomaterials could provide new foundations and explanations for phenotypic traits. Hypothetically, a "nanotype" could include a large catalog of nanoparticles and biological interactions.

Modern nanomedicine requires new insights beyond current information technology, which is typically focused on collecting, displaying, and connecting heterogeneous information. In this broad multidisciplinary field, several fundamental questions have been recognized that need to be addressed, and one of them is the nanoparticle database. Other issues include diagnostic and therapeutic methods based on new nanomaterials, new models of electronic health records for personalized therapies, databases on the toxic and secondary effects of nanoparticles, and more. As an example, the collection of information on the application of nanoparticles as carriers for the antineoplastic agent doxorubicin (DOX) can be considered. Doxorubicin is an anthracycline antibiotic approved for clinical use as early as 1972. A major problem with the clinical application of this drug is its numerous adverse effects, with cardiotoxicity being the main concern. Over decades of research on this still indispensable chemotherapy drug, various approaches have been developed to reduce cardiotoxicity. One of them is the chemical synthesis of newer derivatives of doxorubicin. Several derivatives of doxorubicin have been developed to improve its pharmacological efficacy or reduce adverse effects. Some of these derivatives include daunorubicin, epirubicin, and idarubicin. However, this approach has not yielded the desired results in clinical practice. Another approach involves the use of cardioprotective agents such as Dexrazoxane, vitamin C, phenolic natural products, organic chelators, and others. In modern clinical practice, a combination of doxorubicin with other antineoplastic agents has been applied for a long time. The approaches mentioned above to address the fundamental problem of high cardiotoxicity have yielded minimal progress. A new strategy in the application of this drug is the synthesis of novel doxorubicin nanoformulations. Table 1 presents different groups of nanoparticles as carriers for doxorubicin.

Table 1. Groups of nanoparticles as carriers for doxorubicin

Various nanocarriers of doxorubicin	References
Gold nanoparticles	26
Polymeric nanoparticles	27
pH-responsive nanocarriers	28
Lipid nanocarriers	29
Magnetic nanocarriers	30
Carbon-based nanocarriers Fullerenes Carbonnanotubes Graphens	31,32
Other nanocarriares	33

Water-soluble polyhydroxylated derivatives of C60 fullerene, such as C60(OH)24 fullereneol, are nanoparticulate molecules capable of self-assembly in biological media, forming stable polyanionic nanoparticles ranging in size from 5 to 90 nm with a charge ranging from -20 to -55 mV, depending on the conditions (Djordjevic et al., 2015; Vraneš et al., 2017). Fullerene-based nanoparticle (FNP) has shown low cytotoxicity in in vitro studies and low acute, subacute, and chronic toxicity in in vivo models using mice and rats (Dragojevic-Simic et al., 2011). FNP exhibits high antioxidant properties in both chemical and biological models (Mirkov et al., 2004; Bogdanović et al., 2004; Trajković et al., 2007; Bogdanović et al., 2008; Milic et al., 2009; Stankov et al., 2013 Vesna et al., 2016 Kojić et al., 2020). FNP also possesses chelating properties, which were the basis for its cardioprotective potential in DOX applications (Đorđević et al., 2009). Moreover, FNP, in the presence of DOX, forms stable nanoparticles that have demonstrated significant cytotoxic effects on various malignant cell lines (Jović et al., 2016; Seke et al., 2016) while causing considerably fewer negative effects on vital organs in in vivo models (Injac et al., 2009a; Injac et al., 2009b; Torres et al., 2010; Milic Djordjevic et al., 2006; Injac et al., 2008a; Injac et al., 2008b; Injac et al., 2008c Borović et al., 2014; Srdjenovic et al., 2010; Vapa et al., 2012; Jacevic et al., 2017; Petrovic et al.,2018).

Conclusion

Computer engineering and the speed of information flow are developing rapidly. We are witnessing that quantum computers will be the leading technology in the near future. Nanotechnology began to be understood only from the middle of the last century, and in the past few decades, many scientific fields and applications based on nanomaterials have been developed. One of these fields is nanomedicine, which is increasingly being applied in clinical practice. A large number of scientific publications, fundamental and clinical studies, patents, numerous presentations at scientific conferences, and other sources provide information in the field of nanomedicine. A major challenge for the scientific community is how to classify and process all this information. Software programs have been developed that can recognize keywords in the field and classify information for both fundamental and applied research in biomedicine and clinical studies. By developing databases in the nano field and related software for simulating the interactions of nanoparticles in living systems, among other things, research time will be shortened, new mechanisms of action will be recommended, and overall resources will be saved. This approach has introduced a new, complex strategy for biomedical applications.

Conflict of interests

We have no known conflictof interest to disclose

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IMPROVING CONSTRUCTION PROJECTS AND REDUCING RISK BY USING ARTIFICIAL INTELLIGENCE

Milena Senjak Pejić[1*], Mirjana Terzić[1], Dragana Stanojević[1], Igor Peško[1], Vladimir Mučenski[1]
[1]University of Novi Sad, Faculty of Technical Sciences, Department of Civil Engineering and Geodesy, Novi Sad, Serbia
e-mail: senjakm@uns.ac.rs; terzic.mirjana@uns.ac.rs; dragana.stanojevic@uns.ac.rs; igorbp@uns.ac.rs; mucenskiv@un.ac.rs

Abstract: Architectural, engineering and construction (AEC) industry has large amounts of data, the analysis of which can predict risks such as project delays, project budget overruns, low resource use efficiency, environmental damage, reduced safety, and the like. Research has shown that 98% of construction projects are realized with the contracted budget and deadline exceeded. This paper aims to show the significant potential and possibilities of applying artificial intelligence (AI) in the AEC industry, pointing out the benefits and obstacles faced by the AEC industry during the implementation of AI. The benefits of applying AI in the AEC industry relate to increasing efficiency, reducing costs, increasing productivity, increasing safety, better planning and providing timely and accurate information. The key obstacles that hinder the implementation of AI in practice are high implementation costs, incomplete data, job loss due to automation, mistrust of AI technology, cyber vulnerability, and lack of understanding field of AI.

Keywords: AEC industry, artificial intelligence, construction technology, AI opportunities.

Introduction

The Architecture, Engineering and Construction industry (AEC) is one of the industries that is slowest to use and adopt the capabilities of modern analytical methods of artificial intelligence to predict factors that could have a negative impact on the project (Egwin et al., 2021).

Artificial intelligence (AI) has significant potential to contribute to the AEC industry throughout the project's lifecycle from various aspects such as project safety, cost, timeline and resource management. A key benefit of applying artificial intelligence in construction is automating human processes, making processes more efficient while reducing potential human errors. The benefits of applying AI in the AEC industry relate to solving or reducing problems that are almost inevitable in a project, from various aspects of a construction project.

The problem of schedule and budget overruns in the construction industry is a global problem (Sambasivan et al., 2007), and almost 98% of construction projects are overscheduled and over budget (McKinsey, 2015). The reasons that cause these overruns are inadequate project planning and management, lack of communication between project participants, ineffective material management, equipment failure, project solution variations, ineffective resource management, and the use of outdated tools and technologies (Tariq, 2023).

With the development of artificial intelligence, it is necessary to pay more attention to the protection of data and the application of controls to protect against cyber attacks. Cyber attacks are increasingly common in the construction industry, containing large amounts of confidential data about projects and employees (Beckage and Parziale, 2021). Cyberattacks are often carried out for profit, as in the case of the Canadian company Bird Construction in 2019 and the French company Bouygues in 2020 (Haynes, 2023). In both cases, the cyber attackers demanded a ransom by locking and encrypt-ing confidential data from the project. This affected the delays in the projects of these companies. Cyber attacks often cause a chain reaction, triggering a series of risks in the company.

A review of the existing literature found that the application of AI is possible in almost all phases of a construction project and significantly affects the improvement of the overall quality and delivery of the project.

[*]Corresponding author: senjakm@uns.ac.rs

Application of Artificial Intelligence in the AEC Industry

By applying artificial intelligence in construction projects and processes, it is possible to reduce the risk in different phases of the construction project. The risks that are most often realized during the project are exceeding the estimated budget and the deadline for the project implementation, violation of safety and health at work, and excessive consumption of resources during the construction and maintenance of facilities. The authors developed models and algorithms based on AI, and the results positively impacted the projects.

Cost

Artificial intelligence can improve the accuracy of project cost estimates and thus reduce economic risks. As traditional cost estimation is subject to human error, AI-based models automatically analyze large amounts of data and thus provide more accurate project cost estimates. Elfahham, 2019 evaluated the construction cost index (CCI) with the help of predictive models based on artificial intelligence. This index is helpful when predicting costs on future projects and reducing the risk associated with the inflation rate.

Integrating drones and artificial intelligence for construction inspection and data processing significantly reduces costs by eliminating the need for inspection vehicles, platforms and cranes for inspection at height and hiring more trained operators. Also, by regularly and reliably inspecting the structure, maintenance costs are reduced if the damage is detected in time (Nwaogu et al., 2023).

Kim et al., 2004 performed a comparison of three models for estimating total project costs based on multiple regression analysis (MRA), artificial neural networks (ANN) and case-based reasoning (CBR). The database consisted of 530 projects of built residential buildings. A model based on neural networks gave the most accurate cost estimate, whose average absolute error was 2.97%. The average absolute estimation error of the MLR model was 6.95%, and that of the CBR model was 4.81%.

Deadline

Extending the deadline for project implementation is one of the most frequent challenges faced by the construction industry. Egwim et al., 2021 developed a multi-layer Ensemble Machine Learning Algorithm (EMLA) to improve the predictive power compared to applying only one algorithm when predicting the extension of deadlines in construction projects. Twenty-four input data were used, such as project scope, equipment failure, inflation or sudden increase in the price of raw materials, the effectiveness of communications, weather conditions, design solution of construction, decision making, cash flow during the project, procurement of materials, political influences, quality of project control and the second.

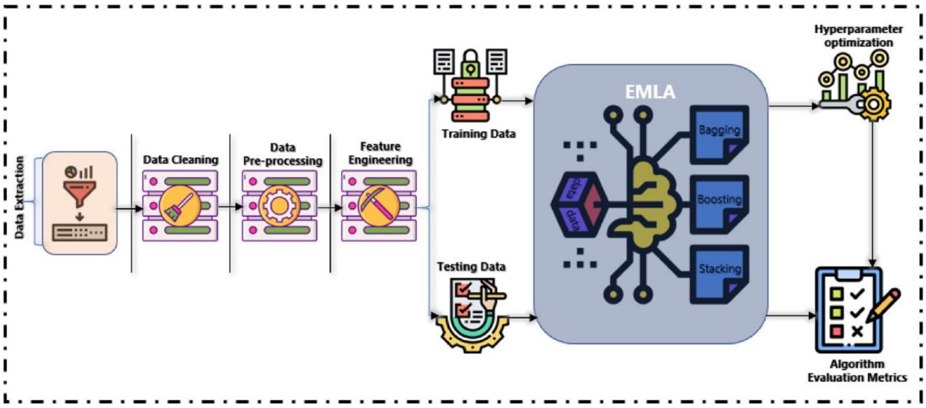

Figure 1. Methodological Approach to the Development of the EMLA assessment model (Egwim et al., 2021)

Figure 1. shows the methodological approach to developing the EMLA prediction model. This approach involves collecting, processing and preparing data for model development, then model development. Model development refers to training and testing models based on machine learning, setting hyperparameters and evaluation, i.e. measuring model accuracy. The analysis showed that EMLA algorithms provide better results than using only one machine learning algorithm.

Quality of communication

Project results, productivity and efficiency of activities depend on the level of communication quality. Rahimain et al., 2022 developed a model based on artificial neural networks to predict the quality of mutual communication among project employees. The predictive model connects interpersonal skills with communication, which can indicate conflicts before they escalate, and at the same time, direct construction managers to form interpersonal skills training. The database based on which the prediction of the quality of communication was made consisted of 180 responses from experts from the construction industry. The survey was formed so that experts formed opinions about the level of communication quality based on leadership style, listening, team building and clarifying expectations. The achieved accuracy of model prediction is up to 80%.

Safety and Health at Work

Safety and health at work are necessary conditions for the realization of a construction project. Baker et al., 2020 developed predictive models based on machine learning to estimate incident type, injury type, body part injured and injury severity. Over 80 attributes were defined with the help of the Natural Language Processing NLP method from injury reports, which include means and methods of construction as well as environmental conditions. Prediction models based on the following algorithms were compared: CART, Random Forest, KSGBoost, and Linear SVM. The SVM model proved to be the best predictive model.

Project planning and monitoring

Lin and Golparvar-Fard, 2017 proposed a project management system that aims to compare the visual data of the current state of the construction site by advanced mapping in 4D with the BIM model representing the planned facility. The authors use predictive analytics and real-time information from the construction site to predict construction progress, highlight potential site-specific issues, and support collaborative decision-making that eliminates the causes of loss.

Generative design, projecting

Algorithms for generating project solutions are a great help to designers because, in a short time, they generate a large number of project solutions and can compare from different aspects. Zhang et al., 2021 developed a parametric generative algorithm that combines artificial intelligence and green building design principles to optimize the performance of residential buildings in the early stages. The generative algorithm was formed using Rhino/Grasshopper and Python tools. Alsakka et al., 2023 developed an approach based on generative design concepts, generic algorithms and the Lagrangian Multiplier Method to design reinforced concrete elements with an optimized shape to achieve material savings and reduce CO2 emissions. Figure 2 shows the difference between a classically designed cantilever beam and one optimized from the aspect of material installation.

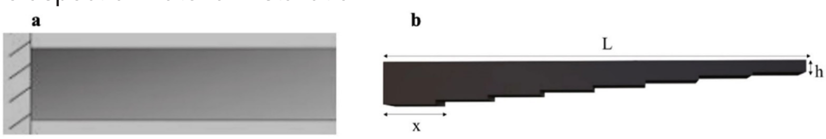

Figure 2. Traditionally designed beam (a) and optimized (b) (Alsakka et al., 2023)

Optimization of building maintenance

By processing the data collected from smart buildings with the help of artificial intelligence, it is possible to optimize building maintenance from energy efficiency. By managing the temperature, lighting and CO2 concentration in the building, energy consumption and the comfort of the living space are optimized. Visual systems and sensors can improve the safety of residents in buildings, especially during fire detection Baduge et al., 2022.

Improvement in construction

Digital Twin Construction represents a comprehensive construction method that provides the possibility of closing control loops where management decisions are made based on reliable, accurate, complete and timely information. Information is obtained through continuous monitoring of construction site status and data analytics to assess possible outcomes of alternative projects and planned decisions Sacks et al., 2020.

Nwaogu et al., 2023 investigated the integrated application of drones and artificial intelligence. Drones greatly facilitate the visual inspection of construction and access to inaccessible places, while the application of artificial intelligence facilitates the collection and processing of data.

Kumar et al., 2016 considered how the construction work's automation and robotisation affect the project. The construction activities covered in the study are preparing reinforcing mesh, finishing works on the interior and floors, quality inspection, using drones to transfer cargo and sensors to detect proximity. The study results show that with automation and the use of robots, it is possible to shorten the time of performing activities by up to 57.85% and reduce total costs by 51.67% while increasing quality. Costs caused by rework and waste are reduced by 66.76%.

Advantages and limitations of the application of subfields of artificial intelligence

As AI is widely used in the construction industry and almost all phases of the construction project, it is necessary to investigate the level of resistance and the benefits of its application. It is very important to explore further strategies to overcome the barriers and justify the investment of monetary resources and efforts to apply AI in AEC. Table 1 shows the advantages and obstacles when implementing the subfield of artificial intelligence in different construction project phases.

Table 1. Advantages and limitations of the application AI in AEC (Abioye et al., 2021)

The field of artificial intelligence	**Application advantages**	**Limitations of application**
Machine learning	Relevant predictive and prescriptive insights	Incomplete data
	Increasing efficiency	Learning from streaming data
	Reduction of costs	Working with high-dimensional data
	Improving security	Model adaptability
	More efficient use of resources	Distributed computing
	Reduction of project errors and omissions	
Computer Vision	Faster checks and monitoring	A complete understanding of the entire scene
	Higher precision, reliability and transparency	Recognition of equipment or work activity
	Higher cost efficiency	Improvement of tracking accuracy and effective visualization of tracking results
	Increased productivity	
	Increased security	
Automated Planning and Scheduling	Cost reduction through process improvement, better logistics	High cost of implementation
	Increasing productivity	It can be complex
	Reduction of planning effort	Representing knowledge necessary for models, monitoring issues, integration, etc.
	Simplification of monitoring and control	
	Optimal plans and schedule	
Robotics	Increased security	High initial investment
	Increased productivity	Potential job loss during automation
	Improved quality	Unstructured work environment
	Better reliability and accuracy	
	Faster and more consistent than humans	
Knowledge-based systems	Easy access to relevant information	Intellectual property protection and security issues
	Simple data update	Problems of acquiring knowledge
	Ability to explain the reason for the adopted solution	Problems with knowledge validation
	Consistency and availability	
	Ability to work with incomplete information	
	Pure logic	
Natural language processing	Increased productivity	Adequate representation of fragmented, extended and erroneous language
	Cost efficiency	Speech recognition issues include construction site noise, homonyms, accent variability, etc.
	Time efficiency	Privacy and data security issues
	Improved communication between stakeholders	
Optimization	Increased productivity through process optimization	It requires significant computing power
	Increased efficiency	A question of scalability
	Cost and time savings	

Distrust as an obstacle to the application of AI in AEC

The application of artificial intelligence in the AEC industry is growing, but research into the relia-bility of this technology is important. In their work, Emaminejad and Akhavian, 2022 analyze the relia-bility and safety of the application of artificial intelligence and robotics in the AEC industry by analyzing 584 scientific papers published in the last two decades. It was found that simpler systems that are ex-plainable and transparent have more reliable results and that AI systems must be protected from un-authorized actions to avoid accidents due to the operation of heavy construction robots. As people have certain expectations regarding the performance of AI applications, autonomous systems must show timely failures or errors in processes to maintain trust in such systems.

An et al., 2021 argue that the lack of a comprehensive understanding of the factors that lead to insufficient reliability, uncertainty, and the application of artificial intelligence in the AEC industry limits the effectiveness of the application. Reasons that lead to insufficient reliability are limited data sets, generalization, subjectivity in initial assumptions, and subjectivity in algorithm structures. The author has generated a framework for which he proposes steps to improve the application of artificial intelligence in the AEC industry. The framework includes three basic elements: ITC (Information and Communication Technology) infrastructure for data digitization, RIBA (Royal Institute of British Architects) work plan that defines the required data sets, and AI algorithms' application to defined data sets. After that, the model's performance is evaluated based on the obtained results. If the results are satisfactory, the process ends. Otherwise, the previously mentioned reasons that lead to insufficient reliability are analyzed, and guidelines are proposed for reducing uncertainty. The model's performance is re-evaluated, and this process is repeated until satisfactory results are obtained. Figure 3. shows the framework for improving the application of artificial intelligence in the construction industry.

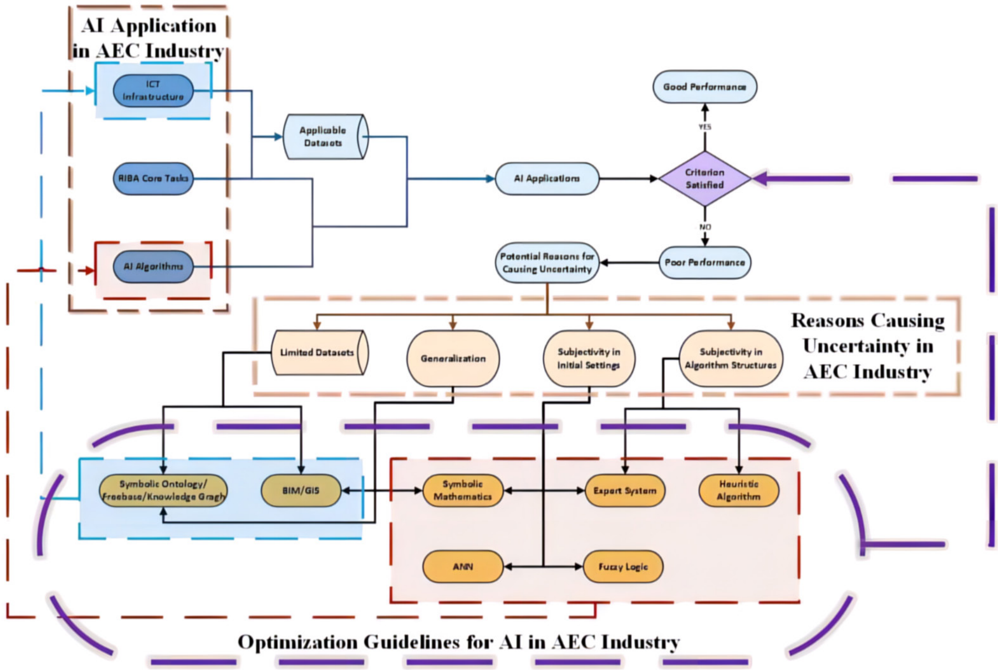

Figure 3. Framework for advancing the application of AI in the AEC industry (An et al., 2021)

Revolutionary solutions provided by artificial intelligence must be adopted cautiously due to cybersecurity issues. Garcia de Soto et al, 2022 conducted a survey to understand AEC industry experts' awareness of cybersecurity issues. The results were analyzed to identify shortcomings and make suggestions for improving cyber security in practice. Cyber attacks to achieve profit or other goals can lead to the disruption of processes and changes in information that can cause material damage or loss of human life. Survey results show that 84% of respondents are concerned about cyber security. However, only 39% said their company has a cyber security plan, indicating that cyber security is not a top priority for companies. A better understanding of threats and vulnerabilities is necessary to create and follow adequate guidelines for defence against cyberattacks. There is a lack of cybersecurity frameworks specific to the construction industry to help develop strategy, adjust budgets, and make cybersecurity a higher priority. Governments have no cybersecurity requirements for contractors to ensure a safer work environment.

Conclusions

The application of different sub-fields of artificial intelligence in the field of the AEC industry can significantly improve the performance of the entire project through different phases. By analyzing the changing market and economic factors that affect costs, it is possible to obtain information that could predict economic instability. With the help of artificial intelligence, it is possible to understand the scope of the project better and identify missing information, as well as identify conflicts on the project, thereby ensuring the possibility of determining more precise offers for the entire project, deadlines for implementation, as well as the risk of injuries. Implementing AI in the planning and monitoring phases of building construction ensures an increase in safety at work and an increase in the quality of communication between collaborators on projects. Generative algorithms optimize the use of resources throughout the entire life cycle of the building. Some of the obstacles that significantly slow down and make it difficult to realize the full potential of AI application in AEC are related to mistrust due to a lack of understanding of the field of AI, fear of job loss due to process automation, limited data sets that lead to wrong generalization as well as higher initial financial investments. Applying AI in construction can improve various parameters such as time, cost and quality.

Acknowledgements

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Conflict of interests
We have no known conflictof interest to disclose

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INTEGER SINGLE-ERROR-CORRECTING CODES AS AN ALTERNATIVE TO THE INTERNET CHECKSUM

Aleksandar Radonjić[1*], Igor Ristić[2], Ivan Šćepnović[2]

[1]Institute of Technical Sciences of the Serbian Academy of Sciences and Arts, e-mail: aleksandar.radonjic@itn.sanu.ac.rs
[2]Faculty of Management Sremski Karlovci, e-mail: risticig@famns.edu.rs; scepanovic@famns.edu.rs

Abstract: The paper considers the possibility of using integer single-error-correcting (SEC) codes instead of the Internet checksum (IC). It is shown that such a replacement can be easily carried out, since the integer SEC codes are a generalization of the IC.

Keywords: Integer codes, single error correction, multimedia data, Internet checksum.

Introduction

The Internet has become one of the most important means of communication. It is used not only for broadcasting television and radio programs, but also for mutual communication. The most known example is the Skype application, which allows people not only to make phone calls, but also to see their interlocutors.

Generally speaking, the Internet is a global computer network that is based on four layer networking model. The first layer is the data layer, which defines how the communication through packets delivery works between two network nodes (computer, firewall, switch or router). Above the data layer is the network layer, which deals with the routing of packets from one network node to another. The third layer is the transport layer, which is responsible for the delivery of the application data, while the last (application) layer provides an interface between the applications and the underlying network (Figure 1).

For the purpose of reliable multimedia communication, the most important layer is the transport one. At this layer, the multimedia data are delivered using User Datagram Protocol (UDP) (Aracil and Callegati, 2009). This protocol is designed for fast and simple data transmission without ensuring delivery. More precisely, by using the Internet checksum (IC), the receiver only checks whether the data was received in error. If they are received without error, the packet will be delivered to the application. Otherwise, it will be discarded, which can negatively affect the quality of multimedia content playback.

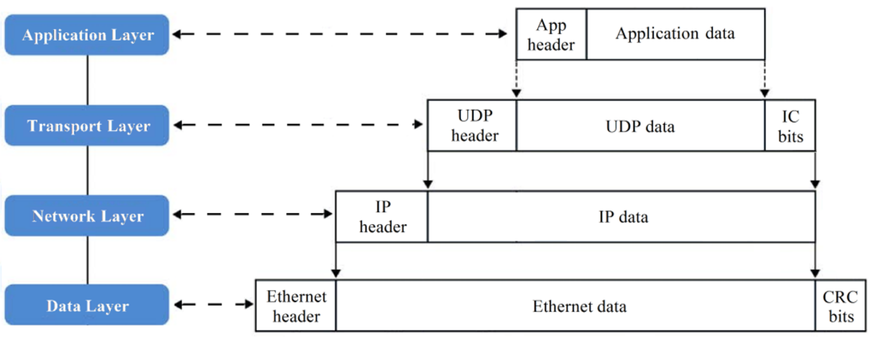

Figure 1. Encapsulation of multimedia data for transmission over the Internet.

In this paper, we will show that the problem of packet dropping can be significantly mitigated if integer single-error-correcting (SEC) codes are used instead of the IC. In addition, it is important to note the receiver would not undergo any hardware changes, since the integer SEC codes are a generalization of the IC.

[*]Corresponding author: aleksandar.radonjic@itn.sanu.ac.rs

Codes Construction

The construction principle of integer SEC codes is explained in detail in (Radonjic, 2018). Here we will list only the most important results.

Definition 1. *Let* = {0, 1,…, $2^b - 2$} *be the ring of integers modulo* $2^b - 1$ *and let* $B_i = \sum_{n=0}^{b-1} a_n \cdot 2^n$ *be the integer representation of a b-bit byte, where* $a_n \in \{0, 1\}$ *and* $1 \le i \le k$. *Then, the code C*(*b, k, c*)*, defined as*

$$C(b,k,c) = \left\{ (B_1, B_2, ..., B_k, B_{k+1}) \in Z_{2^b-1}^{k+1} : \sum_{i=1}^{k} C_i \cdot B_i \equiv B_{k+1} \pmod{2^b - 1} \right\} \quad (1)$$

is an (*kb* + *b, kb*) *integer code, where c* = (*C*1, *C*2, ..., *Ck*, 1) $\in Z_{2^b-1}^{k+1}$ *is the coefficient vector and* $B_{k+1} \in Z_{2^b-1}$ *is an integer*.

Definition 2. *Let x* = ($B_1, B_2, \dots, B_k, B_{k+1}$) $\in Z_{2^b-1}^{k+1}$, *y* = ($\underline{B}_1, \underline{B}_2, \dots, \underline{B}_k, \underline{B}_{k+1}$) $\in Z_{2^b-1}^{k+1}$ *and e* = ($\underline{B}_1 - B_1, \underline{B}_2 - B_2, \dots, \underline{B}_k - B_k, B_{k+1} - \underline{B}_{k+1}$) = ($e_1, e_2, \dots, e_k, e_{k+1}$) $\in Z_{2^b-1}^{k+1}$ be the sent codeword, the received codeword and the error vector respectively. *Then, the syndrome S of the received codeword is defined as*

$$S = \sum_{i=1}^{k} C_i \cdot \underline{B}_i - \underline{B}_{k+1} \pmod{2^b - 1} = \sum_{i=1}^{k+1} e_i \cdot C_i \pmod{2^b - 1} \quad (2)$$

Definition 3. *The set of syndromes corresponding to single errors is defined as*

$$\xi_{b,k} = \left\{ \pm 2^r \cdot C_i \pmod{2^b - 1} : 0 \le r \le b-1, 1 \le i \le k+1 \right\} \quad (3)$$

Theorem 1. *The codes defined by (2) can correct all single errors if there exists k different coefficients* $C_i \in Z_{2^b-1} \setminus \{0,1\}$ *such that* $\left|\xi_{b,k}\right| = 2 \cdot b \cdot (k+1)$, *where* $\left|\xi_{b,k}\right|$ *denotes the cardinality of* $\xi_{b,k}$.

Proof. The theorem is proved in (Radonjic, 2018).

In order for the data to be correctly encoded/decoded, it is necessary (with the help of a computer) to find the coefficients Ci. For the purposes of this paper, we are interested only in the values of the Ci's when b = 16. Out of a total of 2031 found coefficients, Table 1 shows 690 of them.

Comparison with the Internet Checksum

The IC, in essence, is a special case of 16-bit integer SEC codes. This can be seen from the fact that it can be defined as

$$IC(k) = \left\{ x \in Z_{2^{16}-1}^{k+1} : \sum_{i=1}^{k} B_i \equiv B_{k+1} \pmod{2^{16} - 1} \right\} \quad (4)$$

where *x* = ($B_1, B_2, \dots, B_k, B_{k+1}$) $\in Z_{2^{16}-1}^{k+1}$ and $k \ge 1$. On the other hand, the 16-bit integer SEC codes are defined as

$$C(16,k,c) = \left\{ x \in Z_{2^{16}-1}^{k+1} : \sum_{i=1}^{k} C_i \cdot B_i \equiv B_{k+1} \pmod{2^{16} - 1} \right\} \quad (5)$$

where *x* = ($B_1, B_2, \dots, B_k, B_{k+1}$) $\in Z_{2^{16}-1}^{k+1}$, *c* = ($C_1, C_2, \dots, C_k$, 1) $\in Z_{2^{16}-1}^{k+1}$ and $1 \le k \le 690$ (Table 1).

Although the construction differences between the mentioned algorithms are minimal, they have a great.

Table 1. First 690 coefficients for 16-bit integer SEC codes.

3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33
35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65
67	69	71	73	75	77	79	81	83	85	87	89	91	93	95	97
99	101	103	105	107	109	111	113	115	117	119	121	123	125	127	129
131	133	135	137	139	141	143	145	147	149	151	153	155	157	159	161
163	165	167	169	171	173	175	177	179	181	183	185	187	189	191	193
195	197	199	201	203	205	207	209	211	213	215	217	219	221	223	225
227	229	231	233	235	237	239	241	243	245	247	249	251	253	259	261
263	265	267	269	271	273	275	277	279	281	283	285	287	289	291	293
295	297	299	301	303	305	307	309	311	313	315	317	319	321	323	325
327	329	331	333	335	337	339	341	343	345	347	349	351	353	355	357
359	361	363	365	367	369	371	373	375	377	379	381	383	385	387	389
391	393	395	397	399	401	403	405	407	409	411	413	415	417	419	421
423	425	427	429	431	433	435	437	439	441	443	445	447	449	451	453
455	457	459	461	463	465	467	469	471	473	475	477	479	481	483	485
487	489	491	493	495	497	499	501	503	505	507	517	519	521	523	525
527	529	531	533	535	537	539	541	543	545	547	549	551	553	555	557
559	561	563	565	567	569	571	573	575	577	579	581	583	585	587	589
591	593	595	597	599	601	603	605	607	609	611	613	615	617	619	621
623	625	627	629	631	633	635	637	643	645	647	649	651	653	655	657
659	661	663	665	667	669	671	673	675	677	679	681	683	685	687	689
691	693	695	697	699	701	703	705	707	709	711	713	715	717	719	721
723	725	727	729	731	733	735	737	739	741	743	745	747	749	751	753
755	757	759	761	763	773	775	777	779	781	783	785	787	789	791	793
795	797	799	801	803	805	807	809	811	813	815	817	819	821	823	825
827	829	831	833	835	837	839	841	843	845	847	849	851	853	855	857
859	861	863	865	867	869	871	873	875	877	881	883	885	887	889	891
893	899	901	903	905	907	909	911	913	915	917	919	921	923	925	927
929	931	933	935	937	939	941	943	945	947	949	951	953	955	957	959
961	963	965	967	969	971	973	975	977	979	981	983	985	987	989	991
993	995	997	999	1001	1003	1005	1007	1041	1043	1045	1047	1049	1051	1053	1055
1057	1059	1061	1063	1065	1067	1069	1071	1073	1075	1077	1079	1081	1083	1085	1091
1093	1095	1097	1099	1101	1103	1105	1107	1109	1111	1113	1115	1117	1119	1121	1123
1125	1127	1129	1131	1133	1135	1137	1139	1141	1143	1145	1147	1149	1155	1157	1159
1161	1163	1165	1167	1169	1171	1173	1175	1177	1179	1181	1183	1185	1187	1189	1191
1193	1195	1197	1199	1201	1203	1205	1207	1209	1211	1213	1219	1221	1223	1225	1227
1229	1231	1235	1237	1239	1241	1243	1245	1247	1249	1251	1253	1255	1257	1259	1261
1263	1265	1267	1269	1271	1273	1287	1289	1291	1293	1295	1297	1299	1301	1303	1305
1307	1309	1311	1313	1315	1317	1319	1321	1323	1325	1327	1329	1331	1333	1335	1337
1339	1341	1347	1349	1351	1353	1355	1357	1359	1361	1363	1365	1367	1369	1371	1371
1375	1377	1379	1381	1383	1385	1387	1389	1391	1393	1395	1397	1399	1401	1403	1405
1411	1413	1415	1417	1419	1421	1423	1425	1427	1429	1431	1433	1435	1437	1439	1441
1443	1445	1447	1449	1451	1453	1455	1457	1459	1461	1463	1465	1467	1469	1475	1477
1479	1481														

Although the construction differences between the mentioned algorithms are minimal, they have a great impact on their performance: the IC can detect burst errors of length up to 15 bits, while 16-bit integer SEC codes can correct all single errors within an N-bit codeword ($N \leq 32512$). In other words, if error control were to be performed using the IC, the receiver would discard all corrupted packets, which could degrade the quality of service perceived by the user. However, if error control were to be performed using integer SEC codes, the receiver could repair the vast majority of the corrupted packets, especially if they are transmitted over optical links [according to (Stone and Partridge, 2000; James, 2005; Yao et al. 2016), 90% of all channel errors are single errors].

Apart from this, it should be noted that using 16-bit integer SEC codes (instead of the IC) has no negative effect on the packet size. From (Aracil and Callegati, 2009) we know that the packet size depends on the version of the Internet protocol (IP) used. In particular, if voice data (VoIP packets) are delivered over IP version 4 (IPv4) network, the IC protects between 60 and 280 bytes (Figure 2). On the other hand, if the transmission is carried out over IP version 6 (IPv6) network, the IC will protect 84 to 304 bytes. As for delivering television content (IPTV packets), the IC covers at least 228 bytes in the case of transmission over an IPv4 network, i.e. at least 252 bytes if an IPv6 network is used. All these facts point to the conclusion that 16-bit integer SEC codes can protect all multimedia packets.

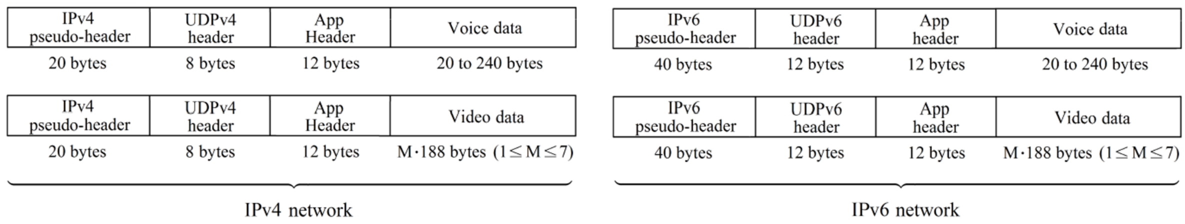

Figure 2. The packet fields covered by the IC

However, for the integer SEC decoder to be able to correct single errors, it is necessary to reserve $|\xi_{b,k}| \times |2 \cdot b + log_2\lceil k+1 \rceil| \leq |22112| \times |32 + log_2\lceil 691 \rceil| \leq \approx$ 0.116 MB of memory (for storing the syndrome table). This, of course, is not a problem for today's processors that have several MB of the cache (Table 2).

Conclusions

The transmission of multimedia data over the Internet suffers from the problem of dropping corrupted packets. The reason for this lies in the inability of the IC to correct channel errors. In this paper, we have presented one solution that can improve the transmission of multimedia data over the Internet. The proposed solution is based on replacing the IC with integer codes that can correct single errors.

Conflict of interests

The authors declare no conflict of interest.

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