DOI: 10.21857/94kl4cld6m

Pregledni članak / Review paper
Prihvaćeno / Accepted: 13. listopada 2022.

ARTIFICIAL INTELLIGENCE AND ROBOTICS AS THE DRIVING POWER OF MODERN SOCIETY

Bojan Jerbić, Marko Švaco

Summary

In synergy with other technologies, the AI significantly accelerates the scientific and technological development of human society. New possibilities of the application of technological achievements are constantly opening up – in industry, healthcare and everyday life. AI-based robotics is the main driver of the present industrial revolution. Robots have already played an important role in production and changed the production economy over the past decade. New generations of smart robots, or smart technical systems in general, are turning to new applications, especially in service industries, medicine and home use. In the future, autonomous and mobile robots will be able to assist the elderly and immobile, help with household chores, act as caregivers and perform repetitive, tedious or dangerous jobs in nursing homes, hospitals, military environments, disaster sites and schools. The potential benefits are great, but they pose significant ethical challenges too. Our autonomy may be compromised and social interaction obstructed. Expanded use of robots can lead to reduced contact among people and possible restrictions on personal freedoms. Machines of these kinds shape the new world radically, leading to significant economic and cultural changes, creating both winners and losers on a global scale.

Keywords: robotics; artificial intelligence.

1. INTRODUCTION

Over the last ten years, we have made remarkable progress in digital technology and related fields. The most exciting breakthrough can be seen in robotics and artificial intelligence (AI), because the scientific and technological revolution we are witnessing is primarily characterized by the transformation of digital technology from virtual to physical. Therefore, we are surrounded by more and more smart things that can store and process data. When such things are networked with other things, systems and people, we call them the Internet of Things (IoT). The best example of this digital transformation is a robot, since it can be understood as a computer with hands, which converts information and/or knowledge into (physical) action. Robot is what we can interpret as a "cyber physical system", or the physical expansion of digital technology. Due to the complexity of the interaction of robotic mechanics with the surrounding world or with humans, the application of control methods that rely on elements of intelligence is inevitable. Artificial intelligence is therefore a commonly used term referring to the field of science that has the ambition to enable machines (robots) to perform advanced functions such as perception, learning, planning, problem solving, and decision making. This is why robotics and artificial intelligence are inextricably intertwined and often imply each other, Figure 1.

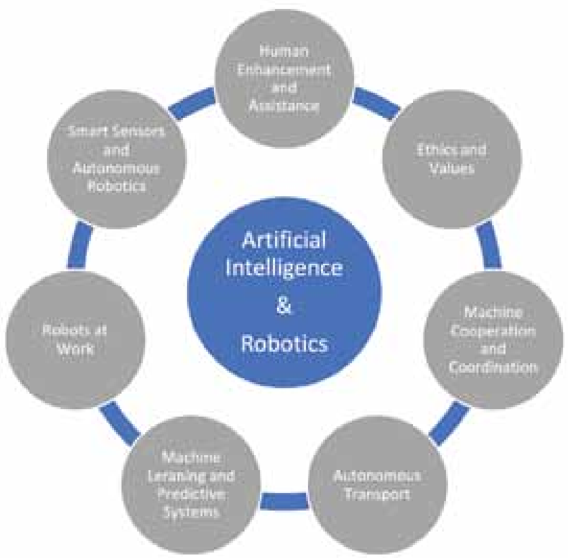

Figure 1. Artificial intelligence and robotics synergy (Source: World Economic Forum)
Slika 1. Sinergija umjetne inteligencije i robotike (Izvor: World Economic Forum)

The AI simply denotes technical system that can sense, gather information, reason, learn, and act in terms of programmed goals. In synergy with other technologies, the AI significantly accelerates the scientific and technological development and progress of human society. New possibilities of the application of technological achievements are constantly opening up – in industry, healthcare and everyday life.

The EU is aware of the strategic importance of a comprehensive digital transformation of the society as a whole, with robotics and the AI being the main drivers of impending changes. In accordance with the Coordinated Plan of the European Commission on Artificial Intelligence 2021 [1] (Review of 2018 Communication Coordinated Plan on Artificial Intelligence, [2]) the EU ought to (quote) *seize opportunities of AI technologies and to facilitate the European approach to AI, that is human-centric, trustworthy, secure, sustainable and inclusive AI, in full respect of our core European values, this review of the Coordinated Plan puts forward four key sets of proposals for the European Union and the Member States:*

- Set enabling conditions for AI development and uptake in the EU
  - Acquire, pool and share policy insights
  - Tap into the potential of data
  - Foster critical computing capacity
- Make the EU the place where excellence thrives from the lab to the market
  - Collaborate with stakeholders through, e.g. the European Partnership on AI, Data and Robotics and expert groups
  - Build and mobilize research capacities
  - Provide an environment for developers to test and experiment (TEFs), and for SMEs and public administrations to take up AI (EDIH)
  - Support the funding and scaling of innovative AI ideas and solutions
- Ensure that the AI works for people and is a force for good in society
  - Nurture talent and improve the supply of skills necessary to enable a thriving AI eco-system
  - Develop a policy framework to ensure trust in AI systems
  - Promote the EU vision on sustainable and trustworthy AI in the world
- Build strategic leadership in high-impact sectors
  - Bring AI into play for climate and environment
  - Use the next generation of AI to improve health
  - Maintain Europe's lead: Strategy for Robotics in the world of AI
  - Make the public sector a trailblazer for using AI
  - Apply AI to law enforcement, migration and asylum
  - Make mobility safer and less polluting through AI
  - Support AI for sustainable agriculture (end quote).

Figure 2. Coordinated Plan of the European Commission on Artificial Intelligence 2021 [1]
Slika 2. Koordinirani plan Europske komisije o umjetnoj inteligenciji 2021 [1]

2. CHALLENGES AND SOCIOECONOMIC IMPACT

Artificial intelligence was officially recognized as an academic field during the Dartmouth conference in 1956 [3]. Five years later, George Devol patented the first industrial robot named *Unimate* [4]. The term artificial intelligence had been closely related to the field of "symbolic AI," which was widespread until the late 1980s [5]. To overcome some of the limitations of symbolic artificial intelligence, subsymbolic (or non-symbolic) methodologies [6] such as neural networks, fuzzy systems, evolutionary computing, and other brain-like computational models began to gain popularity, leading to the emergence of the term "computer intelligence" as part of the AI.

Real and complete AI does not yet exist. At this level, the AI will mimic human cognition to the point that it will give machines the ability to dream, think, feel emotions, and shape their own intentions and behaviors [7]. Although there is still no evidence that this type of true artificial intelligence could exist before 2050, the principles of computer science that drive artificial intelligence are advancing rapidly and it is important to assess its impact, not only from a technological, but also a social, including ethical and legal perspective.

The AI100 Committee [8], led by Stanford University, has identified 18 topics relevant to artificial intelligence:

Technical trends and surprises: Understanding the future, not only in the technical sense, but also in philosophical connotation, as well as how it is going to evolve and change our society and economy appears crucial. Trends and impacts need to be monitored to facilitate the AI in specific applications [9]. If artificial intelligence and robotics are technologies with a history of 60 years ago, one might wonder why this field is growing faster than ever before, Figure 3.

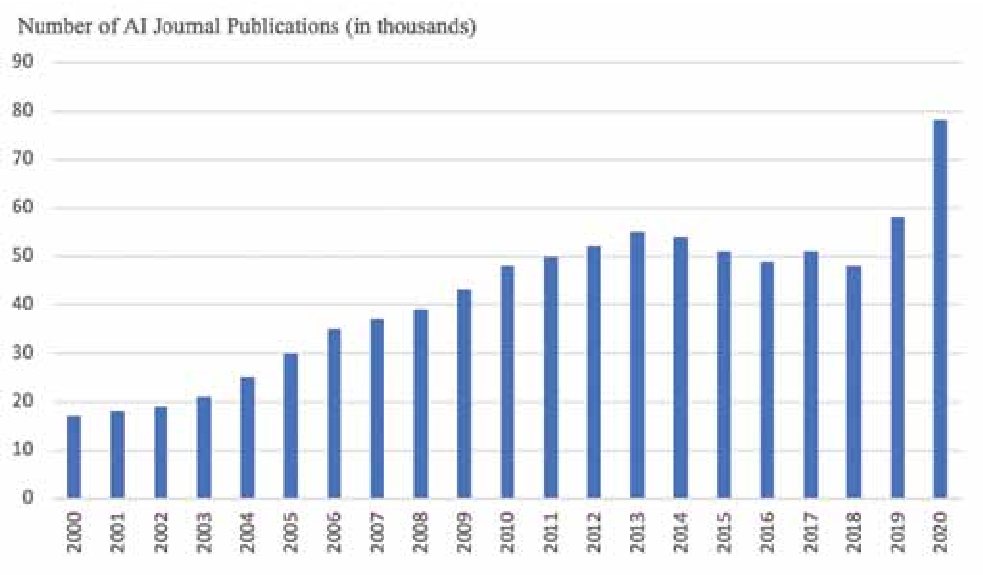

Figure 3. Number of the AI journal publications, 2000 – 2020 (Source: Microsoft Academic Graph, 2020 / Chart: 2021 AI Index Report)
Slika 3. Broj publikacija AI časopisa, 2000 – 2020 (Izvor: Microsoft Academic Graph, 2020 / Chart: 2021 AI Index Report)

Research in the field of artificial intelligence is intensifying: more than 120,000 peer-reviewed AI papers were published in 2019. There had been a significant increase in the AI papers from 2000 to 2019. In 2000, the share of the AI works was 0.8%, whilst in 2019, this percentage rose to 3.8% [9] - [11]. Consequently, Global corporate investment in the AI boosted nearly $68 billion in 2020, an increase of 40 percent in relation to the year before, Figure 4.

Data from the professional social network LinkedIn show that Brazil, India, Canada, Singapore and South Africa had the highest growth in the AI employment from 2016 to 2020 (Figure 5). The absolute number of the AI jobs is highest in the United States and China. Furthermore, the COVID pandemic did not slow down the employment trend in the AI sector during 2020. Considering that LinkedIn has a smaller share of profiles in India and China, it is possible that data from these countries are not entirely representative.

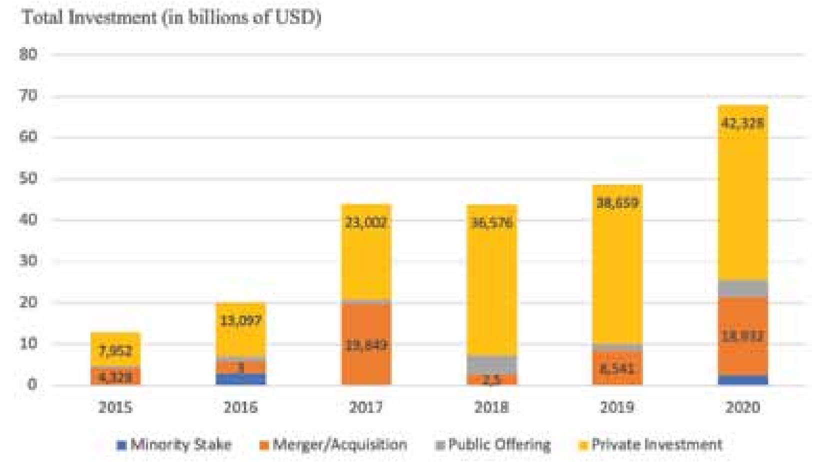

Figure 4. Global corporate investment in the AI, 2015 – 2020 (Source: CapIQ, Crunchbase, and Netbase Quid 2020)

Slika 4. Globalna korporativna ulaganja u AI, 2015 – 2020 (Izvor: CapIQ, Crunchbase, and Netbase Quid 2020)

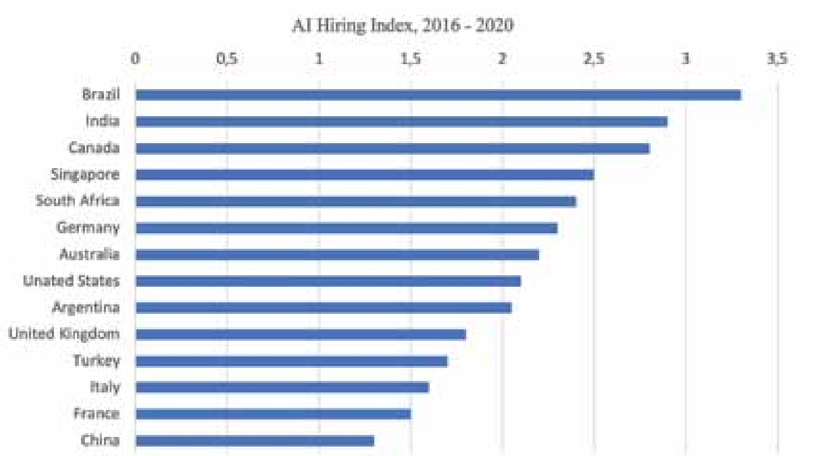

Figure 5. The AI hiring index by country, 2016-2020 (Source: LinkedIn, 2020 / Chart: 2021 AI Index Report)

Slika 5. Indeks zapošljavanja u AI sektoru po zemlji, 2016-2020 (Izvor: LinkedIn, 2020 / Chart: 2021 AI Index Report)

Robotics and the AI increase and enhance human resources, increase productivity and range from simple inference to human cognitive abilities, Figure 1. To understand the impact of artificial intelligence, it is important to learn from past successes and failures, as well as to anticipate its future directions and potential legal, ethical, and socioeconomic implications.

With the increased capabilities and sophistication of the artificial intelligence system, applications will open up in a variety of sectors, including finance, health, energy, manufacturing, education, transport and public services. The next phase of the AI is the era of extended intelligence, which seamlessly connects man and machine.

Key opportunities for the AI: How advances in artificial intelligence can help transform the quality of our life, including healthcare, education, science and administration, targeting not only economic benefits, but also social benefits and impacts. According to BusinessWire, the global smart robot industry is expected to reach US$ 14.3 billion by 2023, nearly tripled from its US$ 4.9 billion in 2018, growing at a CAGR[1]of 23.7% over this five-year period. The IFR predicts the growth of the global robotics market, which in addition to industrial robots includes personal service robots, military and professional service robots, as shown in Figure 6.

Figure 6. Global robotics market (Source: International Federation of Robotics; Japan Ministry of Economy; Trade & Industry; euRobotics; company fillings; BCG analisys)

Slika 6. Globalno tržište robotike (Izvor: International Federation of Robotics; Japan Ministry of Economy; Trade & Industry; euRobotics; company fillings; BCG analisys)

1 The compound annual growth rate (CAGR)

Large international companies that are able to design, manufacture or improve robots and / or artificial intelligence at low cost, and can generate revenue from direct and indirect sales currently dominate the competitive space in this area.

Some of the primary markets targeted by the AI and robotics companies are:

- Autonomous systems
- Software
- Electronic equipment
- Industrial machines
- Medical devices and applications
- Production
- Biotechnology
- Defense
- Car industry

The insufficiently known application of artificial intelligence in the analysis of the Internet sources or unstructured data should be pointed out. Thanks to global networking, the availability of data in all segments of human interest is growing, and artificial intelligence allows us to turn unstructured and unprocessed data into something efficient and useful. Analytical tools that use machine learning will be increasingly important in the future to understand new meanings, identify hidden problems and create new solutions. It ought to be emphasized that at the same time, legal regulations and technologies for preventing various forms of misuse of personal data, which we unfortunately often witness, will become increasingly important.

A very important trend is the development of robotic motor intelligence. It is a kind of intelligence that we are often unaware of; it allows us to control our body and move in simple everyday situations. For instance, washing a glass or storing a shirt in a closet is an almost automatic action for us, but if we try to implement the same on a robot, we encounter a number of extremely complex functions that are very difficult to implement. With the development of motor intelligence, we will enable robots to integrate into a complex human environment, and apply them in conducting completely new tasks.

Computer vision is already better than human in many applications today, and in addition to an increased surveillance of public spaces, it will be increasingly used to support various types of services. Privacy issues will therefore become increasingly important. Robots, in synergy with advanced computer vision, will significantly improve their performance in a dynamic and changing environment. Computer vision will have a special impact on the improvement of mobile robots and autonomous vehicles.

Until recently, computer speech comprehension had been unsuccessful, but thanks to the development of deep learning methods [12] - [16] and probabilistic models [17] - [19], it is now possible to communicate with a computer without difficulty. It is often difficult to distinguish whether we are talking to a computer or a human. In the future, such applications will, for ethical reasons, need to clearly warn the user to communicate with the computer.

Delays in translating the AI progress into real values: Substantial measures need to be taken to encourage the application of artificial intelligence achievements that can improve our civilization. There is an urgent requirement to better understand how we can more efficiently translate valuable AI potentials into real-world practice. The adoption of artificial intelligence greatly contributes to economic growth, especially in slow-growing developed economies, Figure 7. Driving mechanisms depend on a broader understanding of social phenomena, as well as the level of technical knowledge [8]. It is necessary to transform educational frameworks and communication with all stakeholders of society that will change the notion of technology as an imposed post-humanistic future. Technology is a product of human culture. It should therefore be understood that robotics and artificial intelligence are an equal part of our culture, for which we are personally responsible.

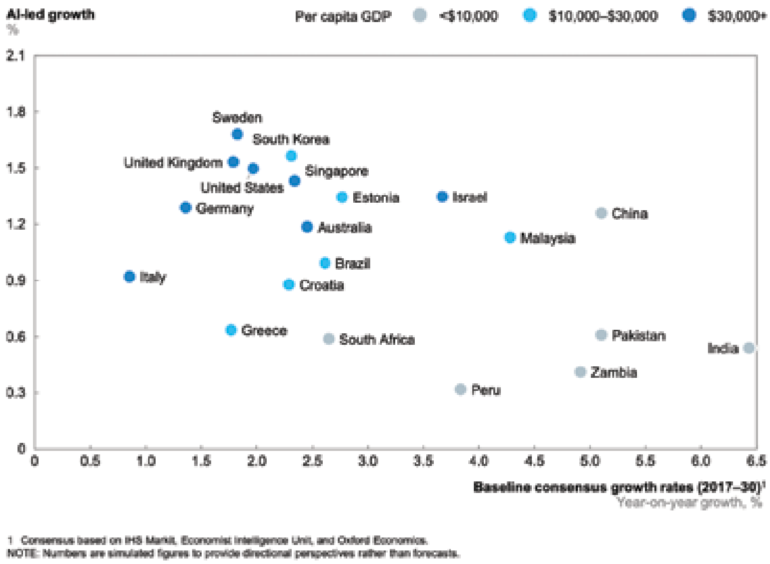

Figure 7. The adoption of artificial intelligence contributes to economic growth (Source: HIS Markit; Economist Intelligence Unit; Oxford Economics; McKinsey global institute analysis)
Slika 7. Usvajanje umjetne inteligencije pridonosi ekonomskom rastu (Izvor: HIS Markit; Economist Intelligence Unit; Oxford Economics; McKinsey global institute analysis)

Privacy and machine intelligence: If we want the AI to act as our close associate, it is imperative to provide smart systems with access to our personal data, including biometrics, personal medical data, what we love, what we read, what we buy, what music we listen to, and so on. Is it a potential challenge to our privacy? Should we allow the sharing of our data to make the AI better and more efficient? How can intelligent machines compromise our personal comfort? These are all questions to which we ought to have answers that are important to anticipate and prepare appropriate regulatory, legal and policy frameworks.

Democracy and freedom: The mass digitalization of human society increases the possible impact of artificial intelligence on our perception of social, ethical and cultural values through numerous applications we communicate with. Any kind of misjudgment resulting from the imperfection of the AI methods can contribute to some kind of disinformation of the public. Misinformation in the global digital space poses a serious threat to democracy or society as a whole, as it effectively alters the sense of objective truth, thus manipulating public opinion. Therefore, any misuse of artificial intelligence that may adversely affect democracy or in any way restrict human freedoms ought to be prevented.

Law: Autonomous systems, i.e. intelligent robots and computer applications are expanding their application in industry, service activities, education, healthcare and medicine, entertainment industry, transportation and military applications. The potential benefits are numerous, but such systems will in the future expand their competencies in terms of independent decision-making or automated reasoning. It is therefore necessary to identify legal actions to be taken to ensure the implementation of the law on the use of artificial intelligence and smart machines [20].

Ethics: In the future, we expect an increase in the complexity of interaction with robots, autonomous machines and intelligent computer applications. At the same time, accelerated development of bionic systems will intensify the integration of people and technologies, primarily through a variety of prosthetic devices and active implants. This raises issues of cyborgization, that is to say, where our biological foundation ends and technology begins, and vice versa. This undoubtedly provokes significant ethical challenges [21].

The so-called “Roboethics” [22], [23], [24] emphasizes two basic positions: the relation of people to machines, and the relation of machines to people.

The relationship of people to machines/robots (material goods) has always involved a kind of respect for something of value, and has been socially regulated (destruction of material goods is not allowed). Today, it is highlighted by the humanization of technology and the implementation of artificial intelligence (anthropomatic robotics, smart computer interfaces, biomimetic systems, etc.). As a result thereof, we can notice a kind of emotional relationship of people toward things that includes different aspects:

- *Simplified relationship* – no surprises, no disappointments, the relationship is unilateral, so that the human has *no moral obligation to machine/robot* as a person, only as a thing.
- *Complex relationship* – includes ”socio-technical” dimension that disturbs the existing social relationships. A robot or smart device appears as an intruder, an interactive social machine that is often placed among us, producing emotional interference. Although our *choice of "preservation"* between man and robot seems unquestionable, everything else becomes questionable.
- *Robot as an "electronic person"?* – such robots should have a certain kind of technical awareness and emotions. Then it would be necessary to grant them the moral rights (and obligations too).

The relationship of machines/robots to people becomes more significant nowadays, and it will be especially important in the future, thanks to the development of robotics and intelligent and autonomous systems. Due to the progress of artificial intelligence, the intensity and complexity of machine interaction with humans increases, emphasizing the following issues:

- *Moral duties of robot* are mainly coming from the control program made by man in accordance with the purpose the robot is intended for. Therefore, it appears that the *responsibility for the moral behavior of the robot is on the human side*, or we could say that in this case, roboethic issues are exaggerated (”AMAs[2] are designed by humans and cannot alter their own architectures” [23].).
- Autonomous systems based on the evolutionary and probabilistic methods enable the creation of a *behavior that is based only on expectations*. Can such robots undermine ethical principles despite the Asimov laws of robotics? *The complex interactive relationships can lead to morally questionable decisions.*
- *Can intelligent robots develop their own ethical standards?* If they could develop a certain kind of awareness and emotions, this would be possible.

Having in mind the current level of scientific and technological development, robots are not moral agents, but they might become so in the future [25] - [28]:

- *Moral behavior is learned behavior developed from the local culture*. It is therefore equally instinctive and rational ("… in order to be morally responsible, however, and act needs a participant, who is characterized by personality or subjectivity." [25]).

2 Ask Me Anything

- *Moral responsibility means understanding the context of one's own behavior.* Can a robot understand the culture? E.g. if the moral principle is violated, moral responsibility causes shame. Shame is obviously the emotional category. … can we "mathematize" moral beliefs and then ethical principles?

The SIENNA project proposes six classes of methods for the realization of ethical artificial intelligence and robotics [29]:

1. Methods for incorporating ethics into the research and development of the AI & robotics – including research ethics and Ethics by Design.
2. Methods for incorporating ethics into the deployment and use of the AI & robotics – aimed at organizations that deploy and use the AI & robotics technology.
3. Corporate responsibility policies and cultures that support the ethical development and use of the AI & robotics – aimed at developers, deployers / users and support organizations.
4. National and international guidelines, standards and certification for ethical AI & robotics – aimed at governance and standards organizations.
5. Policy and regulation to support ethical practices in the AI & robotics – aimed at governance and standards organizations.
6. Education, training and awareness raising for the ethical and social aspects of the AI & robotics – aimed at educators and the media.

According to the previous discussion, we will need to be able to define what to expect in terms of morale from intelligent and autonomous systems, and what the mutual responsibilities are, especially in terms of creating a *new bio-technological society* with an appropriate ethical codex.

Economics: Artificial intelligence and robotics unquestionably change economic relations and rules. They affect the change of the labor market and value categories. The fourth industrial revolution, unlike the previous ones, is based on the established digital economy and driven by the rapid advancement of artificial intelligence, which in combination with robotics, biotechnology and nanotechnology results in the rapid development of innovation. Today, highly educated workers are equally exposed to new technologies as the less educated workers engaged in the production of material goods. The AI already contributes to the production of intellectual goods, expands cognitive and creative abilities, or replaces highly educated staff in most routine jobs. According to the Nobel laureate Paul Krugman: "Education, then, is no longer the answer to growing inequality, if it ever was (which I doubt)". Artificial intelligence must help create a sustainable economy as opposed to a profitable and consumer economy.

The AI and Warfare: Advanced weapons supported by artificial intelligence have been around for twenty years. For now, however, people have partial control over the AI weapons. Smart missiles typically involve computer pairing of radar, the GPS information, and computer vision with a database of targets (aircraft, buildings, tanks, etc.). By applying the AI methods, the missiles manage their movement, identify the object of interest, and suggest actions. Ultimately, the human operator is required to decide whether the weapon will work against a computer-identified target. Unlike remote-controlled platforms such as drones, autonomous artificial intelligence-driven weapon systems independently control most of their critical functions. Autonomous weapons process data from built-in sensors, use algorithms for global and local navigation, and search, identify, track and attack targets without human intervention. In addition to the need to point out that this upcoming technology takes over life and death decisions without any human intervention, it should be emphasized that human control in general in the face of the AI is becoming increasingly threatened, and such a way of application is completely unacceptable. Human intelligence includes many complex aspects such as emotions, culture and morals. Artificial intelligence has neither empathy nor culture. Therefore, the AI is not capable of making decisions with social implications. It is this fact that underscores the inevitable asymmetry of warfare using the AI creating physical, emotional, and cognitive distance. Physical and emotional distance completely disrupts the moral symmetry of dangerous risk in combat, and thus a kind of morality of warfare, if we can accept it at all. Furthermore, cognitive distance compromises the human ability to assess the AI. People who use artificial intelligence-driven systems encounter a computer interface that necessarily “filters” a certain amount of data. It is a feature of all artificial intelligence algorithms that take only part of the picture of reality, so that they can make decisions in an acceptable time. The lack of alternative information that would allow people to estimate the AI makes it increasingly difficult to work with machines. It is clear that the use of artificial intelligence ought to be prevented in the war against humans. In the same way as the application of nuclear technology is regulated, it is necessary to regulate the use of the AI for military purposes. It is completely unacceptable to allow machines to kill people. However, the pronounced asymmetry in terms of technological progress among countries can further deepen disparities and disrupt international relations.

The criminal use of the AI: The use of the AI in the development of malware makes it extremely sophisticated, so the chances of gaining access to personal data or taking control over the machines and devices are increasing. We should all be aware of the existence of the “criminal AI” and the risks of “cyber security” issues. The international legal system ought to follow the development of science just as modern technology must prevent its malicious use.

Collaborations with machines: Collaborative robotic systems are becoming a new concept of robotization [30]. Thanks to artificial intelligence, it is possible to program robots so that they can sense human presence and understand human intentions. Intelligent robots can improve our physical and cognitive abilities. Combining the best of each, we get a complementary synergy of two worlds, human and robotic. It is an extremely complex task, having in mind how to carry out this cooperation in a safe way. As a result thereof, a completely new research domain called HRI – Human Robot Interaction has emerged. Some relevant research disciplines related to this are sensory informatics and human-computer or human-robot interfaces. This involves developing methods that give the control system the skill to explain its thinking in an understandable way for people, and at the same time understand people's behavior and the connotation of the work environment.

The AI and human cognition: The human creative potentials are mostly limited by our education, emotions, resources and culture. Our ability to break through the acquired boundaries represents an innovation power. To solve the urgent problems of our time, innovation ought to be speeded up by at least a factor of 10 [31]. We are facing a serious drop in research productivity for decades [32].

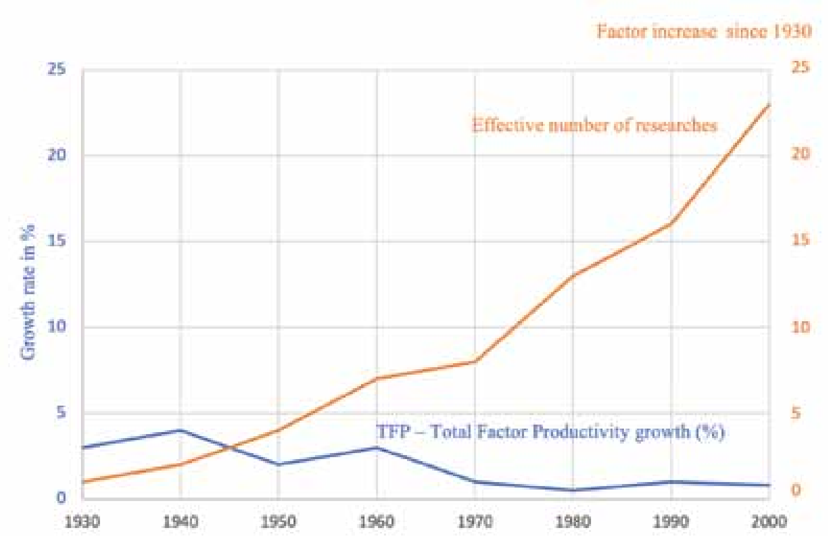

Figure 8. Aggregate data on growth and research effort [32]
Slika 8. Zbirni podaci o rastu i istraživačkim naporima [32]

It comes from the rising complexity of the technology we have ambitions to deal with. Some scientists claim that the times of the so-called "Low-hanging fruit" in terms of inventions are over. Therefore, today we need to make far more efforts to reach new scientific horizons, Figure 8. Artificial intelligence has no culture, no emotions and no aesthetics. The AI can create solutions without prejudice or limits, only on the basis of objective information. The better the data we provide, the better the results we get. Thus, the AI can help us open new yet undiscovered domains of possible solutions, and expand the horizons of creative thinking. According to David Rotman [33]: „The biggest impact of artificial intelligence will be to help humans make discoveries we couldn't make on our own". This is a huge potential for accelerating the innovative development of modern society [34].

Security and autonomy: The expectations from the AI are huge, sometimes even too large. Today, people uncritically believe in computer algorithms. Between man and machine, people usually estimate that the machine is less biased. However, when you consider that most AI applications are based on statistical and classification methods, it is a legitimate question to what extent a smart system has managed to adopt objective knowledge or wisdom about the problem domain based on an always limited set of data. It has been proven that many AI applications suffer from some kind of bias. Therefore, automated decision-making can lead to erroneous estimates that replicate and reinforce existing biases. Ignoring this fact about the AI can have dangerous implications in cases such as medical diagnosis, machine control (e.g. robotic vehicles, collaborative or surgical robots) or those that have some kind of social impact. Consequently, it is necessary to have formal tools in place to check and assess the safe operation of autonomous systems. Validation can focus on the process of reasoning and validating the knowledge base of an intelligent system, and ensure that the formulation of intelligent behavior stays within safety limits.

The loss of control over artificial intelligence systems: We should have in mind that many autonomous systems acquire their intelligence through unsupervised learning or use non-symbolic AI methods that are difficult to explain, i.e. whose knowledge is not transparent or readable enough to be verified. Autonomous systems do not behave exactly according to our expectations, but only in line with them. Therefore, the AI independence and consequently a certain unpredictability or some kind of disobedience represent major concern *("... how to stop the system, where is the switch?")*. The fear of such uncontrolled machine intelligence raises various questions, especially in terms of the AI "singularity". The AI singularity implies a turning point after which technological development becomes uncontrollable and irreversible, that is to say, when intelligent systems reach a state of self-awareness that develops independently beyond our control. Therefore, new legal frameworks with regard to the development and application of robotics and artificial intelligence are being intensively studied at the international level today. Related research should be encouraged in order to solve this problem from a technological point of view and ensure the responsible development of the AI.

The psychology of people and smart machines: The greatest danger of technological development lies in the potentially negative impact of machines on human psychology. We still do not know enough about how the coexistence of humans and intelligent machines will develop. What are the psychological implications of artificial intelligence on our own social and emotional development? For example, how will our self-perception, our sense of who we are, change with the rise of machines with human qualities and competencies? In the near future, it is to be expected that intelligent machines will surpass human intelligence, or at least complex skills, in the majority of the population. Will it then produce massive discomfort or fear in relation to smart machines. Therefore, the development of smart machines ought to be based on interdisciplinary approaches that take into account human psychology as a starting point to which machines need to be adapted, and not the other way around.

Communication, understanding and reach: In the near future, intelligent robots will increasingly become an integral part of ordinary people's lives. Their tasks can range from fun or play to helping people with difficult or tedious tasks. In such applications, the robot will work closely with people in their everyday environment (houses, offices, factories, hospitals). This means that it is necessary to create models for natural and intuitive communication between humans and robots. In general, we must be prepared to accept that robots will never fully have perceptual abilities like humans, and therefore may not be able to detect environmental features that humans want to deal with during communication. Multimodal interfaces should be useful due to their potentially high redundancy, higher sensitivity, increased accuracy, and possible synergistic effects of different individual modes of communication, if taken together.

On the other hand, the social acceptance of intelligent machines and the AI in general depends heavily on public communication and educational concepts that shape public opinion. These concepts ought to be formulated in ways that are understandable and acceptable to all regardless of education. For example, a robot is a physical incarnation of artificial intelligence; its appearance can be extremely important in achieving quality communication. If a robot has a humanoid appearance and exhibits human behavior, people can communicate with it in a more natural way. We must not forget the so-called non-verbal communication that people use intensively and often unconsciously in everyday communication. Even people who are not interested in or who do not accept robot technology can easily understand the behavior of an anthropomorphic or humanoid robot. The humanoid size and shape of the robot are important for integration into the human environment and sharing space with humans.

Therefore, an interdisciplinary effort is needed to address the integration of social informatics, human factors, cognitive sciences, and usability concepts in the design and programming of robotic technology and the AI interfaces.

Neuroscience and the AI: Perhaps the greatest importance of artificial intelligence lies in its impact on expanding our knowledge about ourselves, especially in the fields of cognitive sciences and neurosciences. Neuroscience and the AI can thus develop together. Despite this, we have little real knowledge of how the human brain really works. We have surprisingly little understanding of the neural system and the computational methods it uses. Neuroscience plays an important role in the development of artificial intelligence. New computer technologies enable the study of the brain through computer models and simulations, contributing to the discovery of new theories of cognitive processes.

The AI and the philosophy of mind: Fundamental philosophical questions address the categories of consciousness, culture, and morality, the miracle of dreams, intuition, and emotion. All these categories are difficult to define, and even more difficult to mathematize, i.e. turn into computer programs. We are constantly wondering if the robots we build can one day be aware of and experience inner or subjective worlds similar to those experienced by humans. Probably not, but we will certainly be able to develop some forms of technical awareness and artificial emotions that could resemble the human ones. However, we ought to be aware that such robotic incarnation of humanity will probably never be literally comparable to human characters. We will have to accept the AI robots as a separate species, a kind of artificial life. Then we will have to understand the inner world of machine psychology and their subjectivity.

3. OPPORTUNITIES

In industrialized countries, and especially those with high labor costs, automation and robotization have long since replaced human workforce in the production of material goods. This process began with the 3rd Industrial Revolution as early as in the 1970s. While the cost of one hour of production in the EU is 20 to 50 euros (*source:* Eurostat), the use of robots costs between 5 and 8 euros per hour. The industrial robot is therefore cheaper than workers in countries with traditionally low wages. Furthermore, the robot cannot get sick, does not get tired or strike and does not go to vacation. In addition to significant savings, robotics has contributed to increasing product quality.

The current 4th Industrial Revolution [35], unlike the previous ones, is based on the established digital economy and on the rapid advancement of artificial intelligence, which in synergy with robotics, biotechnology and nanotechnology results in the rapid development of new technological capabilities and economic growth [36]. Today, the term 5th Industrial Revolution is already coming into focus, as a kind of advanced 4IR, which emphasizes the personalization of technologies, encouraging innovation and the development of robotic consciousness [36] - [39]. The main difference between the 4th and 5th industrial revolutions is that Industry 5.0 attempts to achieve balance among artificial intelligence, robots and humans. The benefits are enormous, ranging from increasing productivity and product quality to improving human decisions and increasing human intelligence and creativity. The AI brings benefits that are not yet predictable or difficult to imagine. Therefore, we can freely say that we are living not only a new industrial revolution, but also a new scientific and technological revolution, in which artificial intelligence is expected to have the deepest overall impact on society, permeating all human activities.

According to [40] and [41], the prediction based on the average simulation shows that around 70 percent of companies might have adopted at least one type of AI technology by 2030, Figure 9. The AI can significantly improve realization as shown by sector (Source: McKinsy Global Institute analysis)9.

It is estimated that analytic AI techniques alone have an economic potential between US$ 9.5 and US$ 15.4 trillion in value annually [42]. The AI is becoming a kind of “electricity” of the modern age. Therefore, we can say that artificial intelligence is probably the most important technology in history. It is a technology that enters into our anthropological nature. Human kind has never in history come so close to developing artifacts that can compete with our cognitive dominance. The development of artificial intelligence is fundamentally changing our culture, in which humans traditionally have the position of being responsible for decision-making and action. Now, with the arrival of intelligent and autonomous robots, machines will gradually take responsibility for decision-making, problem-solving and job execution.

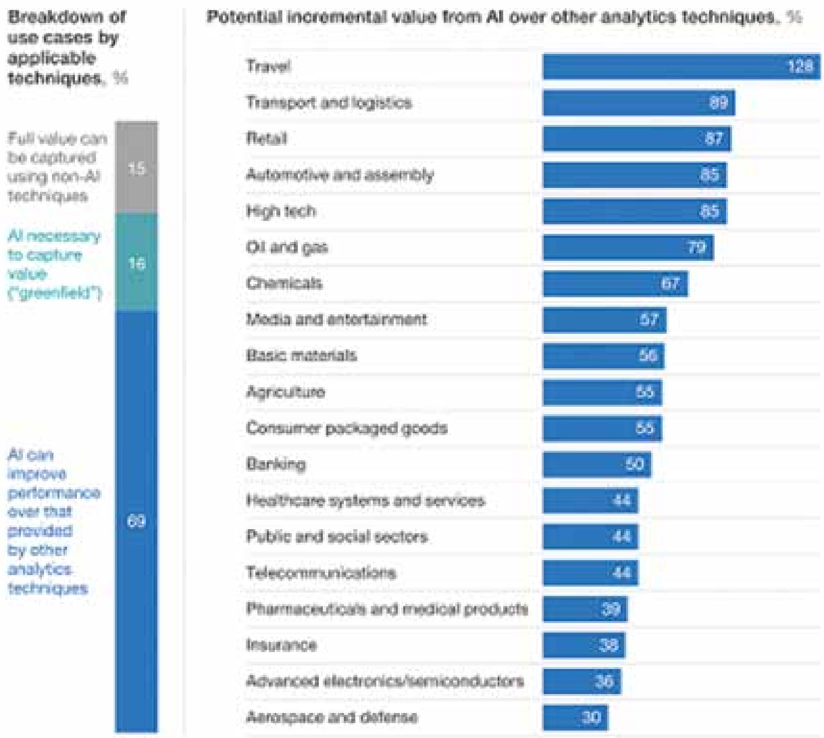

Figure 9. The AI can significantly improve realization as shown by sector (Source: McKinsy Global Institute analysis)
Slika 9. AI može značajno poboljšati realizaciju kao što je prikazano po sektorima (Izvor: McKinsy Global Institute analysis)

The main technological aspects of the modern age can be summarized in two main trends: Smart Systems – make all intelligent (CPS – Cyber Physical Systems and Smart Everything) and Networking – connect them all (Internet of Everything, Big Data to Smart Data). However, it is necessary to emphasize that modern advanced technologies are highly dependent on the following technological drivers:

- *Computing power*: parallel processing and quantum computing [43], in the future are important prerequisites for the AI algorithms hungry for processing power.
- *Open Data*: structured (in databases and spreadsheets) and/or unstructured (text, audio, video and images) data with trillions of sensors and cameras docu-

ment our lives and improve understanding of the world and the discovery of new patterns and theories.

- *Global networking*: accelerating the dissemination of information on all levels and encouraging the exchange of knowledge, leads to the emergence of "collective intelligence".
- *Open Source*: improved open-source AI algorithms and software increase return on investment through, for example, increasing the personalization of consumer products or using intelligent automation to increase their productivity; democratizing the use of the AI (TensorFlow, Caffe2, PyTorch and Parl.ai) accelerates development of innovation.
- *New theories*: such as Deep Learning, designed in a way inspired by the human brain, actually brain concepts of learning and data processing; then new field of research called "deep reinforcement learning – deep RL", in which the AI agent learns with little or no initial knowledge, through trial and error, optimizing the reward function to find a solution; as well as: brain-like robot control models (BLRC), evolutionary algorithms, semantic models, probabilistic methods, multilayer and hierarchical neural networks, "Creative AI", Cognitive OS, etc.

The convergence of these factors has transformed the AI from the "in vitro" into the "in vivo" technology. The result of this development is primarily reflected in the form of autonomous systems, and secondly in the intelligence integrated in things and increased human cognitive abilities.

An autonomous technical system – intelligent robotic system – does not depend on external factors, which means that it works reliably and constantly 24 hours a day, and can work in hazardous areas. Generally, its actions are reliable and cannot be obstructed by emotional influence or fatigue or other external influences. Performance can be standardized and synchronized to a greater extent, contributing to improved efficiency and better performance control. In the decision-making process, autonomous systems can be guided by objective criteria, so decisions can be made solely on the basis of facts.

The greatest impacts of autonomous systems are expected in the following areas:

Transportation: One of the most important characteristics of the human species is mobility, i.e. our need to move, to travel. It is therefore clear that transport plays an important role in today's globalized society and related economy, and has a major impact on employment. The transport industry directly employs about 10 million people and accounts for about 5% of gross domestic product (GDP). In the European economy, transport and storage cost 10-15% of the price of the finished product [44]. This is why competitiveness on the world market depends significantly on transport. Therefore, the mass use of autonomous vehicles will strongly transform the transportation industry, and consequently have impact on the global economy.

Despite the rapid development of driver-assistance technology and vehicle automation, fully autonomous vehicles will not be available in the next ten years. The term autonomous vehicle is considered to be automation level 4 or 5 according to the Society of Automotive Engineers (SAE) classification [45]. The SAE defines six levels of driving automation, ranging from 0 (fully manual) to 5 (fully autonomous), as shown in Figure 10.

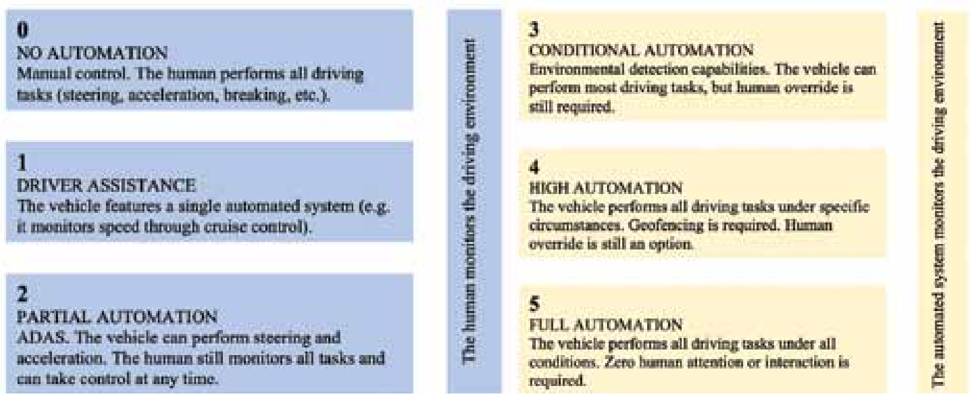

Figure 10. Six levels of driving automation according to the Society of Automotive Engineers (SAE)
Slika 10. Šest razina automatizacije vožnje prema Society of Automotive Engineers (SAE)

The problems of autonomous vehicle development can be roughly divided into hardware and software.

The hardware mainly relates to the processing power of the control computers, sensors (cameras, radars, etc.), and communication technology (general positioning devices and global/local communication systems). In order to provide reliable information about the vehicle environment, more and more information is generally expected from sensors, which in turn affects the increasing demands on processing power. Hardware development trends show that upcoming innovations will provide the necessary computing power, and it seems that prices (especially sensors) will continue to fall.

On the other hand, software development will remain a critical aspect. Fully autonomous cars have to make thousands of decisions per second. In doing so, they face issues such as perception, localization, mapping, decision-making, learning, and safety [46] - [49]. The most of the related decisions or solutions ought to be reached in real-time. For example, analyzing objects, recognizing them and understanding what they represent, are critical for autonomous vehicles, so that the right steering decision can be made on time. Decision-making algorithms ought therefore to be robust and fast. In order to deal with complex problems, these algorithms use artificial intelligence engines and learning methods [50]. We need to be aware of the fact that autonomous vehicles do not need to drive a vehicle completely imitating human drivers. The human driver controls the vehicle entirely by processing available data about the situation around him. The autonomous vehicle, on the other hand, has far more information at its disposal that can come from the traffic network or cloud or from other vehicles in the surrounding traffic. A human driver can only guess what other vehicles in traffic will do according to the prescribed rules. In case of autonomous vehicles, they can share their intentions, speed data and planned direction so that they can negotiate with each other and take harmonized action. They can furthermore combine information on global traffic and coordinate their behavior accordingly. While it is obvious that the use of the AI in the development of autonomous vehicles is an extremely difficult task that requires significant development, testing and validation, it is reasonable to expect that autonomous vehicles will be by far safer than human drivers, and will significantly improve the transportation segment with huge impact on the global economy and even lifestyle.

Autonomous vehicles infiltrate all stages of transport or the supply chain. It means autonomous mobile robots for inner transport in factories, hospitals and warehouses. Sales of autonomous mobile robots are expanding rapidly (Figure 11), and estimated to double to $27 billion by 2025, Figure 11.

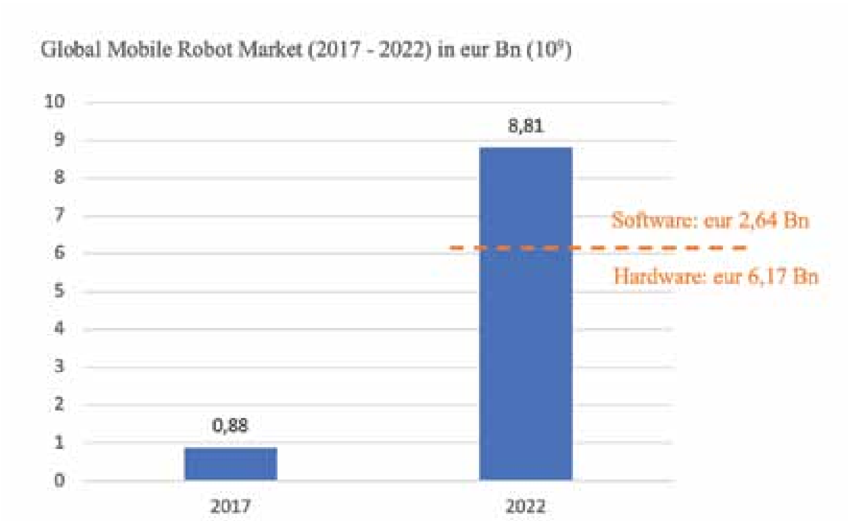

Figure 11. Global mobile robot market (2017–2022) (Source: Interact Analysis)
Slika 11. Globalno tržište mobilnih robota (2017. – 2022.)) (Izvor: Interact Analysis)

In addition to warehousing, delivery robots, also known as personal delivery devices (PPDs), are in trend. In the USA, 12 states have already legalized autonomous delivery robots. Amazon unveiled its first robots in San Francisco in 2017, and is constantly expanding its service. In the UK, the grocery retailer Co-Op unveiled its first delivery robots in 2017 too, and plans to have as many as 300 delivery robots in use by the end of 2021.

Manufacturing: With the integration of artificial intelligence, IoT devices, and other technological improvements, robotics promises significantly improved performance and pricing in the coming decade. Autonomous robots that incorporate artificial intelligence can communicate with each other and with workers, as well as learn from observation or from robotic clouds. Instead of robots replacing humans, autonomous robots are evolving as assistants that can drastically improve and enrich manufacturing jobs. Such collaborative robots that work alongside workers are called “cobots” [51] - [54]. They are easy-to-program, dexterous, and relatively affordable. In the recent years, collaborative robots have become increasingly accepted in industrial practice. The main reason is that the manufacturing industry is beginning to realize that the use of collaborative robots can significantly improve working conditions and production quality, which is crucial for maintaining competitiveness.

The demand for industrial robots and intelligent systems will continue to increase. Today, the number of industrial robots in the Asia-Pacific region is the largest in the world, especially in China, Japan, South Korea and Taiwan. In 2020, the Asia-Pacific region accounts for about 70% of the global industrial robot market, with a market size of US$ 44.6 billion, Figure 12. Annual installations of industrial robots by region (Source: IFR)12. The global industrial robot market is expected to reach US$ 73 billion by 2025, with an overall annual growth rate of 10.36%.

Within Industry 4.0, the application of intelligent robots is being expanded or intensified. Today, the manufacturing industry can better understand that the robotization, artificial intelligence and digitalization of production create an opportunity for development. The advantages of better productivity and guaranteed production quality provided by the use of advanced robotic systems are already to some extent a guarantee of competitiveness. Connecting the virtual and physical worlds through cyber-physical systems represents a new industrial age based on the concept of the “smart factory”. “Smart factory” is a flexible production systems that can react in real time conditions to allow radical optimization of the internal production process.

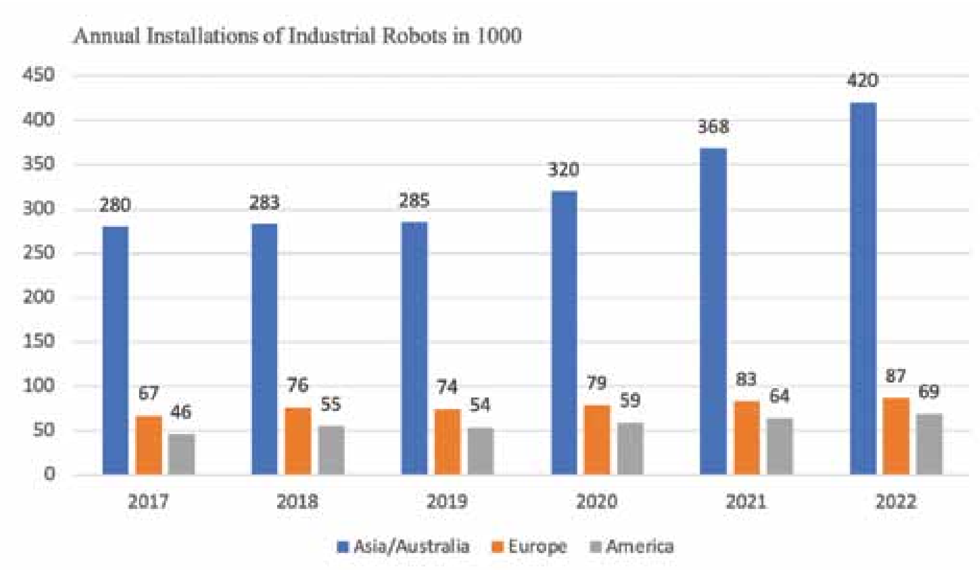

Figure 12. Annual installations of industrial robots by region (Source: IFR)
Slika 12. Godišnji broj instalacija industrijskih robota po regijama (Izvor: IFR)

Customer service: The AI-enabled robots are programmed to work alongside humans, interact with customers, and manage in human environment. The introduction of robots into our everyday life, outside the deterministic industrial environment, opens up completely new possibilities for application, especially in service jobs. Intelligent robots can play an important role in improving the quality of human life, as well as in improving various customer services [55]. Current generations of robots are difficult to implement in jobs that require intuition, judgment, empathy, and motor intelligence in particular. The development of service robots is an extremely complex task, because it is based on interdisciplinary science, not just robotic technology [56], [57]. It requires new and innovative thinking of the relationships among different entities [58]. Service robots represent the convergence/application of many technologies, including electronics, computers, mechanics, sensorics, navigation, applied psychology, sociology, language processing, and biology [57]. Due to direct interaction with humans, service robotics involves the sophisticated application of intelligence [59], assuming:

- sensory capability (verbal, visual, physical, kinesics, and paralanguage);
- cognitive capacity (autonomy, interactivity);
- affective experience (emotion).

In general, users respond positively to service robots, even in providing emotional interaction. However, it turns out that social interaction skills need to be improved [60]. Therefore, the application of service robots has expanded to a wide range of jobs [59]. Service robots can be classified in two main categories:

- *Professional* robots mainly perform tasks in the field of professional information and logistics services, increasing efficiency (reducing costs and downtime) and improving productivity [61] in a professional environment.
- *Personal service robots* are mainly designed to provide services to people [62] in the home environment. They are a kind of home assistants [63]. Given the sensitivity of the direct human-machine interaction and the many safety and ethical issues that may arise, the relationship between technology and humans may need to be reconsidered.

In case of professional service robots, the most common character of the use can be represented by the following practices [64]:

Chatbots and information assistants – it is one of the most common uses of artificial intelligence in customer service. It is about providing information services, mainly to address routine issues such as service information, account balance, ordering and the like. Chatbots can provide such services to a large number of people without fatigue and emotion, while reducing operating costs.

Google is developing an intelligent digital assistant that can fluently communicate with people and perform various secretarial tasks, such as arranging meetings or contracting services. Google's Intelligent Contact Center is now widely available, and claims to have more than a million developers working with it. Other IT giants like the IBM, Amazon and Microsoft offer the AI as a service platform too.

Today, users are increasingly encountering robots when calling customer support. Robots or intelligent digital assistants can provide a 24-hour availability without waiting. However, one should consider the fact that contact centers are the main employment sector in the UK, with more than 760,000 jobs. The UK companies receive almost two billion requests each year, whether by mail, phone or other channels (website, email, etc.) [65].

Robotic process automation (RPA) – can automate many simple tasks in different sectors. This primarily refers to repetitive service and logistics transactions that require no human labor. This application of service robots can significantly improve customer support and contribute to large savings of millions of euros each year.

Sentiment and advanced analytics – computer analysis of customer feelings and emotional state is becoming a common customer support service. Sentimental analysis can significantly improve the interaction of service robots and humans. Such systems are able to call on a person for help when they are not able to solve a problem.

The market share of professional service robots by application in professional sector is shown in Figure 13.

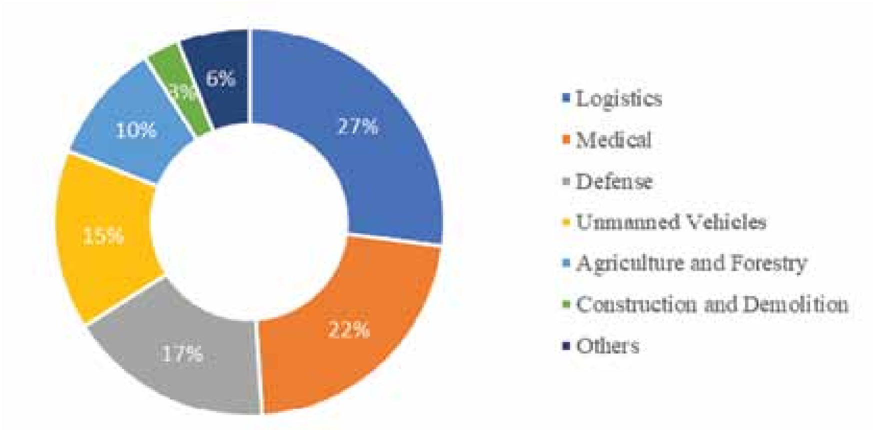

Figure 13. Global service robotics market share, 2019 (Source: www.fortunebusinessinsights.com)
Slika 13. Globalni tržišni udio uslužne robotike, 2019. (Izvor: www.fortunebusinessinsights.com)

The global professional service robots market size was estimated at US$ 12.3 billion in 2019, and is expected to reach the value of US$ 109.9 billion by 2027 at a revenue-based Compound Annual Growth Rate (CAGR) of 24,5% (some analyses predict even 41.0% [66]) from 2020 to 2027, Figure 14, [67].

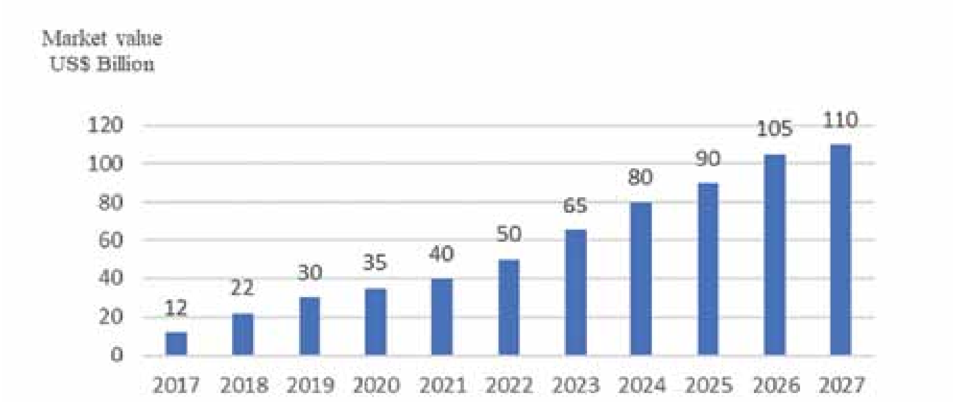

Figure 14. The global professional service robots market value prediction (Source: Coherent Market Insights)
Slika 14. Predviđanje globalne tržišne vrijednosti uslužnih robota (Izvor: Coherent Market Insights)

The personal service robots present, at least for now, a much smaller revenue domain. According to the IFR, projected sales for home robots alone, including applications such as vacuuming, lawn mowing and window cleaning, are estimated at approximately US$ 11 billion (2018–2020). The global personal robot market reached US$ 21.5 billion in 2019, and the CAGR is expected to grow by 7.8% over the forecast period (2020–2030). In 2030, the market is expected to reach US$ 51.5 billion. High acceptance of home cleaning robots and security robots, increasing demand for home automation, and growing consumer awareness of different types of such available robots are some of the important drivers for the personal robot market. This category furthermore includes companion robots, toy and hobby robots, multimedia / remote presence robots for education and entertainment, elderly and disabled assistance robots, and robotic wheelchairs.

However, it should be borne in mind that, although with low revenue, personal service robots achieve high sales volumes. As shown in Figure 15, 97% of all the robots sold in the world in 2019 relate to personal service robots. This sector is expected to grow rapidly in the long-term, possibly eclipsing the industrial and professional sectors. The 5G technology and the AI chips as growth drivers are also likely to have a strong impact on personal service robots. The development of usable motor intelligence and high cognitive skills that allows robots to fully integrate into the human environment will be a game changer.

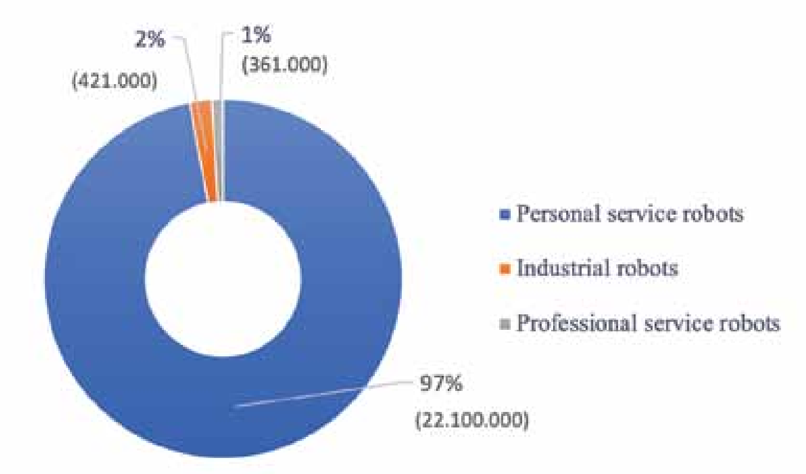

Figure 15. Annual robot unit sales by sector, 2019 (Source: Delotte Insights, IFR press conference presentation, Shanghai, September 18, 2019)
Slika 15. Godišnja prodaja robotskih jedinica po sektorima, 2019. (Izvor: Delotte Insights, IFR press coference, Šangaj, 18. rujna 2019.)

The main reason for integrating autonomous, automated technologies into the service sector is 24x7 customer availability. Until recently, customer-focused roles and departments depended heavily on human intervention, causing several challenges in logistics, convenience, and revenue. The introduction of robotic technology can help streamline processes and uniformity in the quality of the service offered.

Healthcare: With the integration of artificial intelligence, IoT devices, and related technological improvements, as a special segment of customer service, robotics have a huge potential in healthcare. The idea of robotics used for medical application is not new. Although the first papers on this subject emerged more than 50 years ago, the actual use began in the late 1980s with ROBODOC (Integrated Surgical Systems, working closely with the IBM), the orthopedic image-guided system for use in prosthetic hip replacement [66] - [71]. Soon after that, a urologic robot was developed for prostate surgery [72]. Furthermore, there were a number of computer-assisted systems used in (stereotactic) neurosurgery and otolaryngology. During the 1990s, telepresence robotic surgery appeared as a possible solution by removing distance as a factor in providing immediate and intensive treatment [73] - [76]. The turning point came with the introduction of the daVinci remote-controlled robot developed by the company named "Intuitive" [77]. The first commercial use of the daVinci was at the Leipzig Heart Center in Germany in late 1998; within a year, the sales expanded to 10 units throughout Europe. However, the real success of this robotic technology began in 2000, when the daVinci received an FDA approval for the American market. The "Intuitive" had high hopes that daVinci would be placed on the market for cardiovascular surgery, but its current success and more than 6,500 installations in the world by 2021 are mostly due to its use in urological procedures. A three-dimensional magnification screen on the daVinci robotic surgical system allows the surgeon to view the operating area with high-resolution clarity. Precise movements of the robotic arm without tremor ensure the performance of minimally invasive complex surgical microprocedures without making large incisions. Surgical procedures can be physically demanding, but robots are able to work without fatigue. Robots can also maintain position for as long as necessary, and provide access where traditional instruments cannot. Robots can significantly compensate for the loss of motor skills that experienced surgeons may lose during their careers. Today's abdominal surgical robots can move laparoscopic camera by means of an eye-tracking control. The robot provides haptic feedback, so that the surgeon can sense the forces encountered by the robot's arms, which significantly improves the robot's application.

Over the years, as motion control technologies have advanced, surgical-assistance robots have become more capable. From the path control level applied with guided robots, such as the daVinci, to the task level control, in which the AI-enabled robots, with computer vision, along with advanced sensors and data analytics, may even be able to perform tasks autonomously, allowing surgeons to monitor procedures and concentrate on clinical problems instead of demanding dexterity, Figure 16.

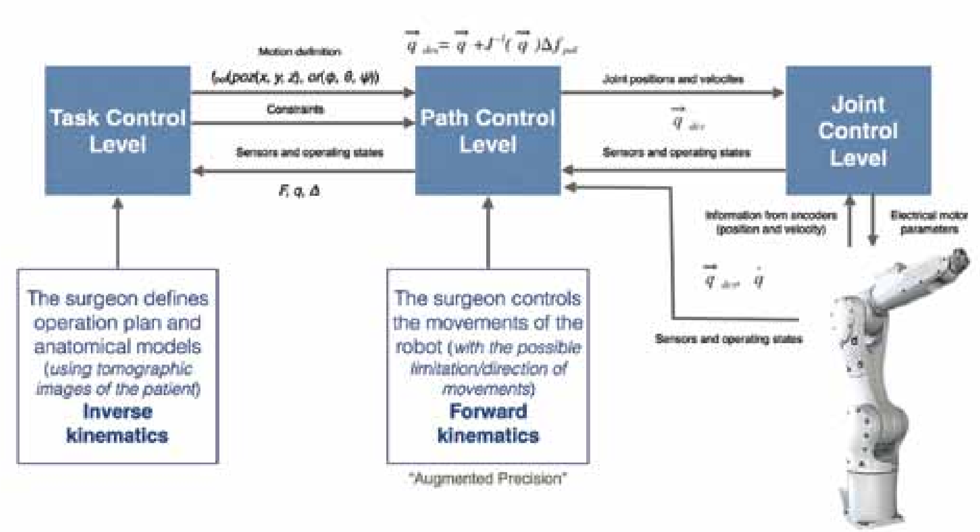

Figure 16. Robot control levels
Slika 16. Robotske upravljačke razine

Robotic surgeries are gaining in strength due to the increased efficiency and effectiveness they provide, along with the "minimally invasive" nature of the procedure. Intelligent computer vision enables surgical robots to differentiate between types of tissue within their field of view. They now have the ability to help surgeons avoid blood vessels or nerves during procedure. Figure 17. Global AI-based surgical robots market share, by application, 2020 (Source: www.grandviewresearch.com)17 shows the wide range of the AI-based surgical robots application share.

Even the neurology segment seems the smallest, the highest CAGR is expected during the forecast period. The exceptional performance and efficiency of robots in various neurological procedures compared to traditional methods are some of the crucial factors responsible for the growth of the segment. Furthermore, the increasing use and adoption of technologically advanced robots for surgeries is driving the growth of the market for surgical robots based on artificial intelligence [78]. Such initiatives and the rising acceptance of robots for various neurological surgeries are expected to push market growth over the forecast period.

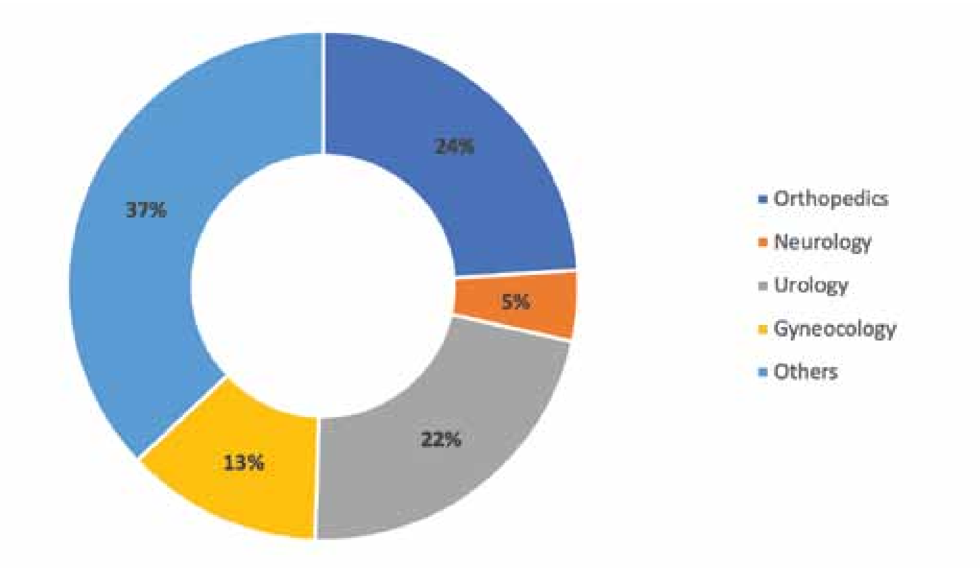

Figure 17. Global AI-based surgical robots market share, by application, 2020 (Source: www.grandviewresearch.com)
Slika 17. Globalni tržišni udio kirurških robota temeljenih na umjetnoj inteligenciji, prema primjeni, 2020 (Izvor: www.grandviewresearch.com)

Thanks to the task level control, the surgical robot can autonomously create and perform procedures according to surgical intentions. For example, the neurosurgical robot RONNA, developed at the Faculty of Mechanical Engineering and Naval Architecture of the University of Zagreb, with Clinical Hospital Dubrava as partner, uses tomographic images of the patient to analyze anatomical features and find bone markers to register the digital and physical space of the patient [79] - [86]. Figure 18 describes the application of the RONNA neurosurgical robotic system throughout the surgical procedure.

Apart from RONNA, many other manufacturers see the need to use deep learning data to teach robots without programming. Deep machine learning data is collected by observing the surgeon's performance or from any type of surgical example using machine vision to analyze scans and detect anomalies. Thanks to this data and to sophisticated algorithms, artificial intelligence can create patterns within surgical procedures in order to improve the best practices and enhance the accuracy of surgical robot operations within submillimeter precision.

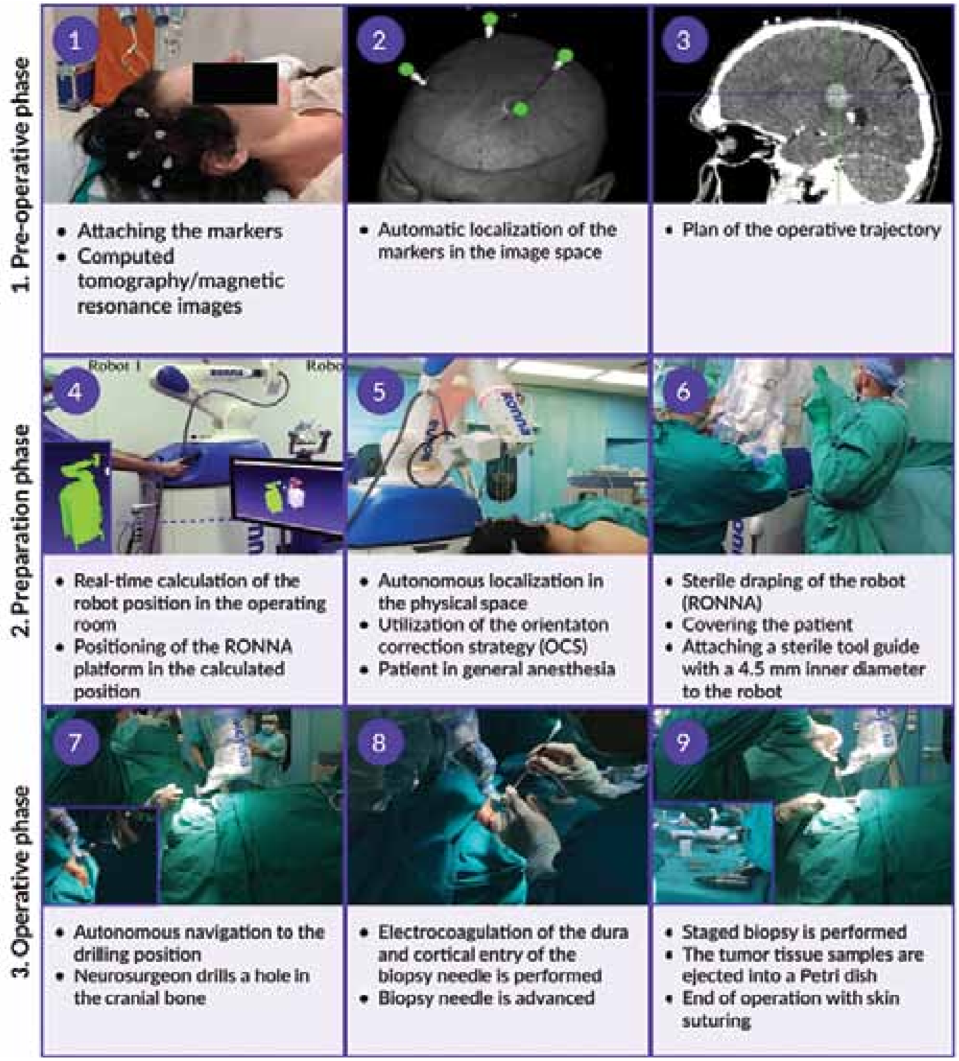

Figure 18. The application of the RONNA neurosurgical robotic system
Slika 18. Primjena neurokirurškog robotskog sustava RONNA

The penetration of artificial intelligence, advanced sensors and other advanced technologies in the field of robotic surgery has stimulated significant market growth. The size of the global market for surgical robots based on artificial intelligence is estimated at US$ 5.0 billion in 2020, and is expected to grow at a common annual rate (CAGR) of 17.2% from 2021 to 2028, Figure 19.

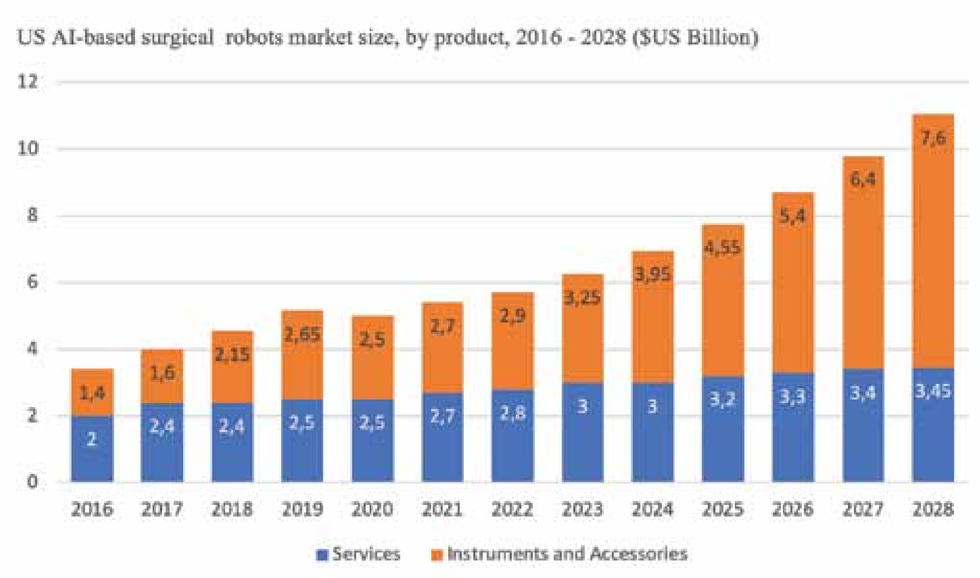

Figure 19. The US AI-based surgical robots market size (Source: www.grandviewresearch.com)
Slika 19. Veličina tržišta kirurških robota temeljenih na umjetnoj inteligenciji u SAD-u (Izvor: www.grandviewresearch.com)

During the COVID-19 pandemic, hospitals noticed that using robots in a wide range of tasks might reduce hospital staff exposure to pathogens. It has become clear that medical robotics offers values in many areas of healthcare. Robotics ecosystem in healthcare can be classified in three main segments:

- Medical robots:
  - Surgical robots
  - Diagnostic systems
- Healthcare service robots:
  - Medication delivery and dispensing
  - Cleaning and disinfecting
  - Telepresence and remote monitoring
  - Autonomous vehicles/auxiliary robots
- Care robots:
  - Companion robots/personal assistants
  - Assistive robots (elderly or immobile patients assistance and carriers, rehabilitation robots)
  - Prosthetics and exoskeletons

In addition to surgery, the AI and robotics are already performing tasks such as genetic testing, cancer research, diagnostics and much more. The ubiquitous growth of these two related technologies has the potential to transform many aspects of healthcare. From providing personal care to patients to automating the drug production process, the AI and robotics can provide shorter time cycles of introducing new drugs and personalizing treatment. For example, robots can clean and prepare patient rooms, limiting person-to-person contact in infectious disease wards. Autonomous robots will enable doctors, nurses and other health professionals to provide more empathy in patient care. The application of artificial intelligence methods in healthcare might create more time for substantive physician-patient interaction, and make the patient a place of care (POC) using portable diagnostic devices (built into smartphones, watches, T-shirts or patches), replacing awkward and bulky hospital devices and empowering patients to take responsibility for their own health. The application of service robots in hospitals simplifies routine tasks and reduces physical demands on human workers. Mobile robots for cleaning and disinfection enable fast disinfection of hospital rooms and preparation for incoming patients. Service robots may help maintain the safety of healthcare workers by transporting supplies and bedding to hospitals where exposure to pathogens is at risk.

The AI and robotics are revolutionizing the healthcare sector by providing advanced treatment solutions and becoming an important part of the healthcare ecosystem.

Education: The AI and robotics will change modern education, altering what learning is like, the role of teachers and researchers, and how universities work as institutions. Higher education will be most affected [87], [88]. According to [89], the AI education market is projected to have a market value of $20 billion by 2027. With the help of artificial intelligence, textbooks are digitized, virtual mentors help teachers, and facial analysis measures students’ emotions in order to adapt the knowledge presentation to their individual needs [90].

However, the application of the AI and robotics in education requires a broader understanding of the context that includes a range of pedagogical, practical, ethical, and social challenges [91]. In addition, it is commonly believed that new technologies cannot replace classical approaches in education. At the same time, technology stands out as a source of dehumanization of the learning experience. Despite initial skepticism, it is clear that modern technologies can significantly improve the ways in which knowledge is acquired, most often through complementary approaches. It is possible to divide approaches into virtual and physical.

Virtual approaches involve the application of various AI-assisted computer tools that help students master the courses [92] - [96], creating a personalized approach to improving different aspects of learning. The application of artificial intelligence in education may be summarized through the following methodologies:

- The AI designed to support teachers, not replace them.
- Automatic writing evaluation (evaluation assistant) [97] - [99].
- Conversational applications that encourage collaboration skills [100].
- Personalization of learning experiences through adaptability [101].
- Continuous performance supervising [102].
- Monitoring of haptic data in order to adapt the teaching material to the emotional and physical condition of students in real time.
- Virtual and augmented reality that contributes to the creation of an immersive learning experience.

Physical approaches involve the use of educational robots in the same space as the student, types of social robots designed to replace or support teachers. Such robots have intelligence that can help learning tasks interact with it through appropriate semiotic systems [103]. There is evidence that the learning process is better when the student interacts with the physical entity or physical incarnation of the teacher rather than with the invisible virtual agent [104].

The World Economic Forum estimates that, by 2025, a large proportion of companies will have adopted technologies such as the AI, intelligent robotics and smart systems [105]. They strongly encourage governments and educational institutions to focus on fast-growing STEM and non-cognitive soft skills, linked to artificial intelligence and autonomous systems, to meet the upcoming needs of the labor market. New technologies will produce major changes in the labor market. Various forms of digital transformation and automation might replace up to 50 percent of existing jobs in the USA alone. It is believed that students will have to master two aspects of this new world by the time they graduate:

- Know how to utilize ever-changing technology, such as the AI, to their advantage.
- Understand how to work with other people in a team to deal with complex multidisciplinary problems effectively.

Preparing students for life with artificial intelligence ought to begin at an early stage of education. Since many children are familiar with digital technology before they start school, it is important to teach them to understand new digital technology in a way that will allow them to thrive in the coming new digital world. Education must always be oriented to the future [106]. Increasing the amount of interdisciplinary knowledge needed to deal with new technologies requires radical changes in the education system, where artificial intelligence and robotics can significantly contribute to a faster acceptance of new knowledge, as well as increase the quality of the learning experience.

4. GLOBAL PHENOMENON

As trends in automation and digitization continue to evolve in developed countries, the question arises as to what extent developing countries can keep pace with development trends. According to a 2016 study by the World Economic Forum [107], technically highly equipped countries like Singapore, Finland, Sweden, Norway or the United States are well prepared for the new industrial revolution and the upcoming digital transformations. For example, the Netherlands are the first country to have had a national Internet of Things since 2016, allowing more intelligent technical devices to be connected than the country's population. Besides, Digital Riser Report 2021 by the European Center for Digital Competitiveness [108] defines a country's digital competitiveness in two main dimensions: its ecosystem and its mindset. For both dimensions, the Digital Riser Report includes five items from the Global Competitiveness Report. For the ecosystem and mindset dimensions, respectively, these items are:

Ecosystem

- Venture capital availability
- Cost to start a business
- Time to start a business
- Ease of hiring foreign labor
- Skillset of graduates

Mindset

- Digital skills among active population
- Attitudes towards entrepreneurial risk
- Diversity of workforce
- Mobile-broadband subscriptions
- Companies embracing disruptive ideas

The picture is more than exciting, Figure 20. The global leader in the G20 far ahead of all other countries is China, with a cumulative score of 211, meaning that in the last three years, China has increased its rankings by an average of 21 in ten categories. The better on the world level is only Vietnam, with a score of 339.

The results of the Digital Riser Index confirm the trend observed in previous analyses, which emphasizes that the speed of transformation varies significantly between countries, such as between China and the United States, or between the European countries such as France, Italy and Germany. While this does not mean that the gain of one is the loss of the other, it clearly shows that the governments of slow-moving countries should encourage the management of strategic development policies; they should enable an ecosystem and mindset that supports the digital economy. The fight against the Covid-19 pandemic has significantly accelerated the adoption of digital technologies. By the end of 2020, companies have improved the digitalization of the interaction of their products, customers and supply chain. Readiness for digital transformation is considered to be the most important factor of development.

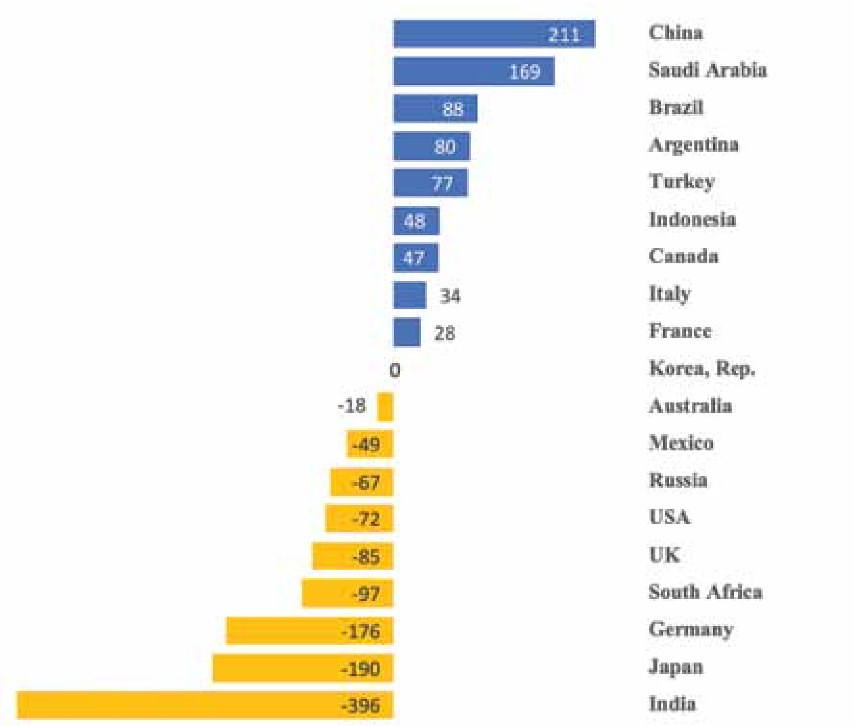

Figure 20. Digital Riser Report for G20 [108]
Slika 20. Izvješće o digitalnom usponu za G20 [108]

For example, Vietnam plans its digital economy to account for 30% of the GDP by 2030, and Hungary has defined its goal of becoming one of the 10 leading countries in Europe in digital technologies by the end of the decade. Italy, for example, has launched Repubblica Digitale, a new program to bridge the digital divide, promote digital inclusion, and strengthen the development of digital skills among citizens. Two-speed transformation continues in Europe. France has made significant progress in its digital competitiveness, while Germany has lost quite significantly in the same period.

An extremely important development potential of each country is the level of its technological development and technological skills of the young population that will shape the technological, economic and cultural future. Interestingly, young people in developing countries are very optimistic about their professional future [109]. They have more confidence in their own abilities than many young people in developed countries. However, many developing countries face the problem of the level of digital readiness, which significantly affects the potential for improving their technological skills. Interestingly, a major advantage in many developing countries is the share of women who have access to education. In the UAE, for example, most university graduates are women. Especially in male-dominated economic systems, opening up the labor market has been a great opportunity for highly skilled professionals. Women are more likely to have better developed "soft skills", which makes them an important capacity – especially in developing countries.

Accelerated development by artificial intelligence alone is expected to increase the world GDP by 14% by 2030, the equivalent of an additional US$ 15,000 billion [110], [111].

4.1. Potential losers of the digital transformation

For a long time, countries like Brazil, Russia, India and China (known as BRIC countries) have been an important investment area of the global economy. Due to increased exploitation of raw materials and "outsourcing" to countries with low labor costs, many Western industries and their investors expect long-term profits. However, the demand for raw materials is trying to decrease, so Brazil and Russia are becoming less and less attractive. With the technical development of manufacturing robots, many companies producing in low-cost countries will relocate their manufacturing sector to the countries from which they originally came [112]. Developing countries in Central and South America will not benefit from the digital transformation of the fourth or the fifth industrial revolution either. It is feared that these countries are not ready for automation and digitalization due to lack of: education of the majority of the population; investment in (digital) infrastructure; and legislation.

The rising birth rates in North African and Arab countries complicate the situation further, causing high youth unemployment rates [113]. Only 40 percent of the younger generation is employed in these countries, and most of these jobs are low-paid, with no social security in the third sector. Therefore, the availability of competitive higher education, especially for women, is necessary for the development and competitiveness of these countries.

Due to all these factors, there is danger that digital transformation will divide the world into two speeds. Countries with lack of modern education and no access to the necessary high technologies will become obvious losers, both technologically and economically. Countries that remain at a slower pace will be further pushed to the margins and into poverty.

4.2. Potential winners

The winners of the digital revolution are likely to be highly developed Asian and Scandinavian countries with advanced education systems, Figure 21. These countries have long been researching and working to find digital solutions to complex issues. The digital connectivity of people in these countries has also advanced greatly. Therefore, it is logical to expect a lower risk of unemployment in these countries, which is only about six percent.

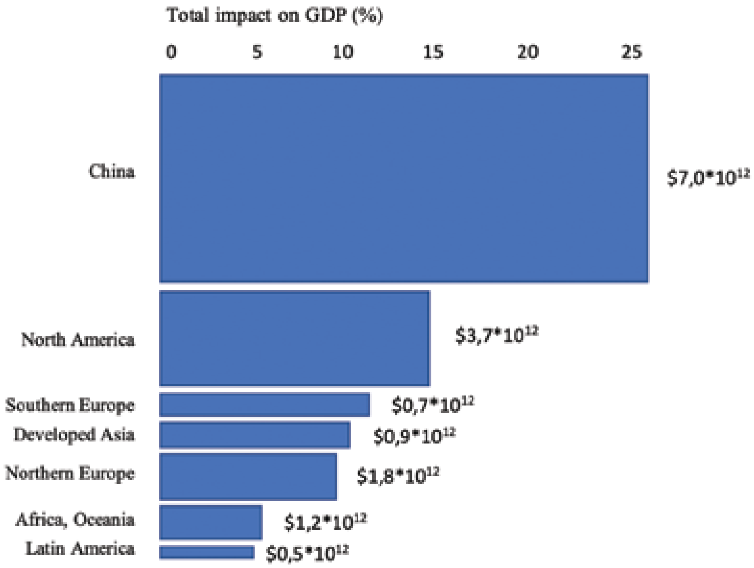

Figure 21. Regions that will gain the most from the AI by 2030 (Source: PWC, © FT)
Slika 21. Regije koje će najviše dobiti od AI do 2030. (Izvor: PWC, © FT)

In addition, when robotic production becomes cheaper than human production in low-cost countries, Western developed countries will benefit from the return of manufacturing companies. This will create new jobs in these countries and challenge many routine jobs in low-cost countries. Another positive trend can be observed with regard to India and China, which are considered to be very suitable candidates to take part in the digital revolution, as the majority of the population is well versed in English and IT skills.

5. QUO VADIS CROATIA?

For Croatia, which experienced mass deindustrialization in the 1990s, new technological trends and digital transformation represent new opportunities to join the world's leading economy. Currently, Croatia is at the bottom of the list of the European countries in terms of the use of robots in industry, Figure 22. The Croatian Ministry of the Economy estimates that there are about 20 robots per 10,000 employees in the Croatian manufacturing industry, which is a standard indicator of the so-called "Robot Density". This is far beyond the EU average.

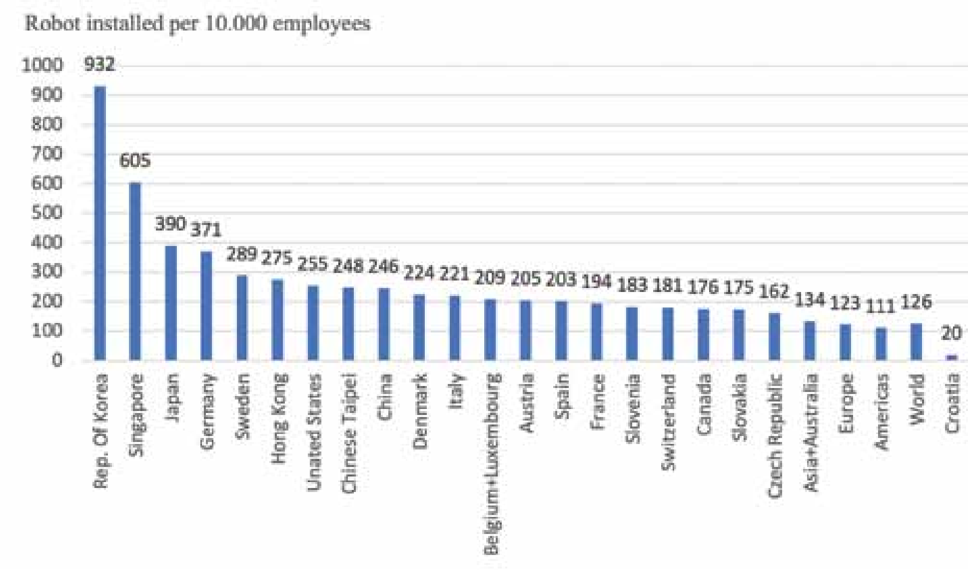

Figure 22. Robot density in manufacturing industry, 2020. (Source: World Robotics 2021)
Slika 22. Gustoća robota u prerađivačkoj industriji, 2020. (Izvor: World Robotics 2021)

The robot density primarily refers to the conventional use of robots in routine or repetitive tasks. In terms of advanced robot applications, often associated with the Fourth Industrial Revolution, which includes the use of artificial intelligence methods, autonomous systems and large database analytics, Croatia has also lagged far behind [114].

Croatia needs to look for its own opportunities in the development of the smart industry. Smart industry is especially oriented to the production of individualized products or very complex products that extend modern economy to the entire product life cycle. It should be emphasized that smart industry relies to a large extent on the development of smart products, which have the ability to store and process data, as well as the ability to communicate. We often call such products the "Internet of Things" (IoT). We should focus on them and start the game with the developed economies in the area, since Croatia disposes of the necessary knowledge and resources. New technological paradigms are turning all industries into beginners, and tradition is often not a necessary advantage. Therefore, it is very important to raise the level of readiness for digital transformation, because this capacity will be a crucial prerequisite for joining modern technological economies. In the IMD factor Future readiness for 2018, the highest-ranked EU countries were Denmark, the UK and the Netherlands. Croatia ranked 54th, with only Bulgaria, Romania and Hungary showing lower performance among the EU countries, as shown in Figure 23 [115].

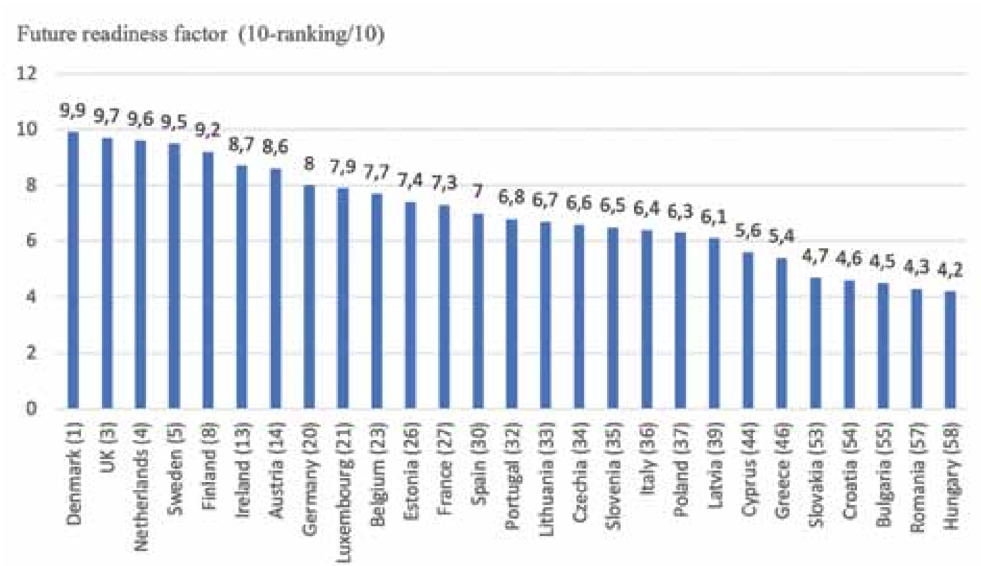

Figure 23. The EU Member States' rankings in the Future readiness factor (Source: 2018 IMD World Digital Competitiveness Ranking)

Slika 23. Rangiranje država članica EU-a prema "faktoru spremnosti za budućnost" (Izvor: 2018 IMD World Digital Competitiveness Ranking)

Thanks to the development of sensors, computer vision and the so-called physical intelligence machines, we can expect more and more intelligent robots in shops, restaurants, hospitals, and in general in places where people seem irreplaceable today. This is where Croatia should look for its opportunity. Therefore, the society ought to find the right mechanisms to encourage innovation development, especially in the segment of the development of smart technical systems that are the backbone of the technological development of modern society and its economy.

The Scientific Council for Technological Development (ZVTR) of the Croatian Academy of Sciences and Arts monitors the movement of new industries and new entrepreneurship in the world, and points out the possibilities of modernizing the existing industry in the Republic of Croatia. As part of its activities, in 2019, this Council organized a round table under the title *European Statement on Cooperation in the Field of Artificial Intelligence – How to Coordinate in Croatia?*, together with the Scientific Council for Research Infrastructure of the Croatia of the Croatian Academy of Sciences and Arts and in cooperation with the Scientific Center of Excellence for Data Science and Cooperative Systems, which includes researchers from partner institutions (Faculty of Electrical Engineering and Computing, Faculty of Transport Sciences, Faculty of Mechanical Engineering and Naval Architecture and Faculty of Science, University of Zagreb, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, University of Split, Center for Advanced Computing and Modeling, Faculty of Civil Engineering and Faculty of Engineering, University of Rijeka, Faculty of Electrical Engineering, Computing and Information Technologies Osijek, University of Dubrovnik, Croatian Catholic University, Ruđer Bošković Institute Zagreb, Ericsson Nikola Tesla Zagreb). The round table was motivated by the European Commission initiatives about the AI: *Communication on Artificial Intelligence for Europe* (COM (2018) 237 final, [2]) and *Coordinated Plan on Artificial Intelligence* (COM (2018) 795 final, the review is issued 2021 [1]) . The conclusions and recommendations are summarized in the report on the work of the ZVTR in 2019, and published in the Yearbook of the Croatian Academy of Sciences and Arts, Book 123, Zagreb 2020, p. 324-328, [116], as well as in the brochure about *25 years of the Department of Technical Sciences of the Croatian Academy of Sciences and Arts 1997–2022* [117]. The recommendations were accepted by the Presidency of the Academy at the proposal of the Department of Technical Sciences.

A study conducted by the Croatian Association for Artificial Intelligence (CroAI, https://www.croai.org) shows that the number of startups in Croatia, whose artificial intelligence is core technology, is growing rapidly. In one year, the number of the AI startups increased from 170 to 330 startups, reaching a growth of 60%. The CroAI is in favor of the new AI Landscape 2.0, the second list of "inhabitants" of the Croatian artificial intelligence ecosystem. Last year, the income of the Croatian startups was slightly more than €460 mil. Euros, whilst this year, investments in startups exceeded €733 mil. Euros. Investors are still predominantly local, but there are more and more co-fundings or entirely foreign investments. The share of founders or co-founders in the Croatian startups has also increased from 15 to 17%, and women today form an integral part of the AI team in 50% of the surveyed startups. The Croatian IT industry is growing 4 times faster than Croatia's GDP. The biggest challenges for the Croatian companies are finding artificial intelligence experts, salespeople and employees abroad, but there is also lack of cooperation with local university teams present. In Croatia, the role of university institutions is crucial, since they are the main drivers of digital transformations and the adoption of artificial intelligence. They maintain the scientific and technological level with their European counterparts, and have shown great ability in attracting the EU funds to finance development and capital construction, such as the AI and robotic laboratories and high-performance computing infrastructures. It is worth mentioning at least some of them:

- University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, with:
  - Department for Robotics and Automation of Production Systems, with chairs for:
    - Automation
    - Autonomous Systems and Artificial Intelligence
    - Manufacturing and Assembly System Planning
  - CRTA - Regional Center of Excellence for Robotic Technologies, with laboratories for:
    - Autonomous Systems
    - Artificial Intelligence
    - Medical Robotics
    - Programming Automata
- University of Zagreb, Faculty of Electrical Engineering and Computing, with:
  - Department for Automation and Computer Engineering
  - Nikola Tesla Innovation Center - ICENT
  - Center for Artificial Intelligence, with 19 laboratories, including e.g.:
    - LARICS - Laboratory for Robotics and Intelligent Control Systems, which in its beginnings was mostly engaged in industrial robotics, and today is primarily engaged in the development and application of

drones, heterogeneous robotic systems and humanoid and biomimetic robots in industrial production, inspection of nuclear facilities, agriculture, medicine.
    - LABUST - Laboratory for Underwater Systems and Technologies
    - LAMOR - Mobile Robotics Laboratory.
- Ruđer Bošković Institute, Department of Electronics, AI4Health.
- University of Rijeka, Faculty of Engineering, Center for Artificial Intelligence and Cybersecurity.
- J. J. Strossmayer University of Osijek, Faculty of Electrical Engineering.
- University of Dubrovnik, Department of Electrical Engineering and Computing.
- University of Zagreb, Faculty of Organization and Informatics, Varaždin, Laboratory for Artificial Intelligence.
- University of Split
- Algebra University College
- RIT Croatia
- University of Zagreb, SRCE - University Computing Centre

…

In addition, it is important to highlight the efforts of the mentioned educational and scientific institutions in creating new teaching content related to robotics and artificial intelligence. Since 2021, the Faculty of Mechanical Engineering and Naval Architecture has launched a new **Study of Mechatronics and Robotics** (https://robotika.fsb.hr), which includes six graduate courses:

- Robotics
- Automation
- Automation of production systems
- Mechatronics of transport systems
- Cybernetics and bioinspired systems
- Autonomous systems and computer intelligence

The Faculty of Electrical Engineering and Computing has launched a new qualification framework for biomedical engineering, as well as a new interfaculty graduate **Study of Biomedical Engineering** (https://hko-bi.fer.hr/hko-bi/o_projektu#), which includes the following institutions:

- University of Zagreb, Faculty of Electrical Engineering and Computing (FER), Beneficiary
- University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture (FSB)

- University of Zagreb, Faculty of Medicine
- Croatian Society for Biomedical Engineering and Medical Physics
- Croatian Employers' Association.

According to CroAI, it is obvious that Croatia has a unique opportunity to become a European digital hub that could bring together the EU innovators and test their innovations. This can significantly contribute not only to the positioning of Croatia as a country open to innovation, but also to the development of startups that are today the most efficient and dynamic drivers of new technologies.

6. CONCLUDING REMARKS

It is evident that robotics and artificial intelligence induce strong progress in human society in all segments, thereby significantly changing our daily life and culture. This is mostly caused by the digital transformation, which is primarily characterized by the transformation of digital technology from virtual to physical. A robot is the best example of this transformation, since it represents a computer with hands, which transforms information and/or knowledge into (physical) action. Due to the complexity of the interaction of robotic mechanics with the surrounding world or with humans, the application of control methods that rely on procedures that imply intelligence is inevitable. This is why robotics and artificial intelligence are inextricably related and often imply each other.

The paper considers the challenges and socio-economic impact of robotics and artificial intelligence through 18 topics identified within the AI100 Committee, led by Stanford University. Furthermore, opportunities are analyzed in the most important areas, such as manufacturing, transport, healthcare, service activities and education. Special attention is paid to the challenges arising as a result of changes in the labor market and particularly the redistribution of economic and technological influence and power. The mass digitalization of human society increases the possible impact of artificial intelligence on our perception of social, ethical and cultural values through numerous applications we communicate with. Therefore, ethical challenges require a redefinition of the existing laws, social habits, and even existing civilizational concepts in order to protect human rights and freedoms.

For Croatia, new technological trends and digital transformation represent new opportunities to join the world's leading economies. Thanks to the centuries-old tradition of higher education in Croatia, we can still be proud of human resources with high digital and technological competences, which is an important prerequisite for the race in the course of the current scientific and technological revolution. Croatia should look for its own opportunities in the development of smart industry and smart products with high added innovation value.

The AI research community itself has a key role in the development of the new bio-technological society. Our success will be measured by how much we improve the quality of life of the entire human population, not just individual groups, and how much we manage to preserve our planet for future generations.

REFERENCES

1. ANNEXES to the Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, Fostering a European approach to Artificial Intelligence, COM(2021) 205 final, Brussels, 2021. [Online] Available at: https://www.eciia.eu/wp-content/uploads/2021/05/1_en_annexe_autre_acte_part1_v8_vf_C4B261EB-ABA4-5C30-1555482869410384_75787.pdf. Accessed on May 6 2022.
2. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, Fostering a European approach to Artificial Intelligence, COM(2018) 237 final, Brussels, 2018. [Online] Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0237&from=EN. Accessed on May 6 2022.
3. McCarthy, J, Minsky, M, Rochester, N, Shannon, CE. A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence, August 1955. [Online] Available at: http://raysolomonoff.com/dartmouth/boxa/dart564props.pdf. Accessed on May 6 2022.
4. Malone B, Devol, G. A Life Devoted to Invention, and Robots, *IEEE Spectrum*, 26-09-2011.
5. Smolensky, P, Connectionist AI, symbolic AI, and the brain, *Artificial Intelligence Review*, 1.2, pp. 95-109, 1987.
6. Öztürk, P, Tidemann, A. A review of case-based reasoning in cognition–action continuum: a step toward bridging symbolic and non-symbolic artificial intelligence, *The Knowledge Engineering Review*, 29.1, pp. 51-77, 2014.
7. Tu, G, Wen, J, et al. Context-and Sentiment-Aware Networks for Emotion Recognition in Conversation, *IEEE Transactions on Artificial Intelligence*, 2022.
8. Stone, P, Altman, R, Brynjolfsson, E, Conitzer, V, Gray, ML, Grosz, B, Howard, A, Liang, P, Lin, P, Manyika, J, McIlraith, S, Sonenberg, L, Wajcman, J. Gathering

Strength, Gathering Storms: The One Hundred Year Study on Artificial Intelligence (AI100) 2021 Study Panel Report, 2021. [Online] Available at: https://ai100.stanford.edu/sites/g/files/sbiybj18871/files/media/file/AI100Report_MT_10.pdf. Accessed on May 6 2022.
9. Studebaker, W. Robotics and AI Trends: The 2021 Edition, *Robo Global*, December 9, 2020. [Online] Available at: https://insights.roboglobal.com/robotics-and-ai-trends-the-2021-edition, Accessed on May 6 2022.
10. Strickland, E. 15 Graphs You Need to See to Understand AI in 2021, *IEEE Spectrum*, April 2021.
11. Artificial Intelligence Index Report 2021, Stanford University, 2021. [Online] Available at: https://aiindex.stanford.edu/wp-content/uploads/2021/11/2021-AI-Index-Report_Master.pdf. Accessed on May 6 2022.
12. Guo, Y, Liu, Y, Oerlemans, A, Lao, S, Wu, S, Lew, MS. Deep learning for visual understanding: A review, *Neurocomputing*, 187, pp. 27-48, 2016.
13. Ravì, D, Wong, C, Deligianni, F, Berthelot, M, Andreu-Perez, J, Lo, B, & Yang, GZ. Deep learning for health informatics, *IEEE Journal of Biomedical and Health Informatics*, 21(1), pp. 4-21, 2016.
14. Thompson, N., Greenewald, K, Lee, K, Manso, G.F. The computational limits of deep learning, arXiv preprint arXiv:2007.05558, 2020.
15. Wang, X, Zhao, Y, & Pourpanah, F. Recent advances in deep learning, *International Journal of Machine Learning and Cybernetics*, 11(4), pp. 747-750, 2020.
16. Nwankpa, C, Ijomah, W, Gachagan, A, Marshall, S. Activation functions: Comparison of trends in practice and research for deep learning. arXiv preprint arXiv:1811.03378, 2018.
17. Hitzler, P, Sarker, MK. Neuro-Symbolic AI= Neural+ Logical+ Probabilistic AI, *Neuro-Symbolic Artificial Intelligence: The State of the Art*, 342, 173, 2022.
18. Rao, V, Madireddy, S, Graziani, C, Xue, P, Maulik, R. Probabilistic Machine Learning and Data Assimilation, No. AI4ESP1110, AI4ESP, 2021.
19. Eleuterio, VV, de Souza, LE. UAV mission planning and execution via non-deterministic AI planning on ROS, *In Congresso Brasileiro de Automática-CBA*, Vol. 1, No. 1, 2019.
20. Asaro, PM, The Liability Problem for Autonomous Artificial Agents, *Association for the Advancement of Artificial Intelligence*, 2015. [Online] Available at: www.aaai.org. Accessed on May 6 2022.
21. Baum, SD. Social choice ethics in artificial intelligence. *AI & Society*, 35(1), pp. 165-176, 2020.

22. Veruggio, G. Roboethics Workshop, *ICRA 2005, IEEE International Conference on Robotics and Automation Workshop on Robo-Ethics*, Barcelona, April 18, 2005.
23. Veruggio, G. The EURON Roboethics Roadmap In 2006, *6th IEEE-RAS International Conference on Humanoid Robots*, pp. 612-617, Piscataway, 2006.
24. Veruggio, G, Operto, F. Roboethics: Social and ethical implications of robotics, in Siciliano, B and Khatib, O eds. Springer Handbook of Robotics, Berlin, Springer, pp. 1499-1524, 2008.
25. Bernhard, I. Ethical Acts in Robotics, *29 IRIE International Review of Information Ethics*, *Ubiquity*, Volume 7, Issue 34, 2006. [Online] Available at: www.acm.org/ubiquity. Accessed on May 6 2022.
26. Wallach, W, Colin Allen, C. Moral Machines: Teaching Robots Right from Wrong, Published to Oxford Scholarship, Print publication date: 2009, Print ISBN-13: 9780195374049, Online: January 2009, DOI: 10.1093/acprof:oso/9780195374049.001.0001
27. Bringsjord S, Taylor, J. The Divine-Command Approach to Robot Ethics, in Robot Ethics – The Ethical and Social Implications of Robotics, by Lin, P, Abney, K, Bekey, GA, The MIT Press, Cambridge, Massachusetts London, England, 2012.
28. Bringsjord, S, Arkoudas, K, Bello P. Toward a general logicist methodology for engineering ethically correct robots. *IEEE Intelligent Systems* 21 (4), pp. 38-44, 2006.
29. Brey, P, Jansen, P, Maas, J, Lundgren, B, Resseguier, A. D4.7: An Ethical framework for the development and use of AI and robotics technologies, WP4: Artificial Intelligence and Robotics – Ethical, Legal and Social Analysis, SIENNA project, H2020, No 741716, 2020. [Online] Available at: https://www.sienna-project.eu/digitalAssets/801/c_801912-l_1-k_d4.7_ethical-framework-for-ai--robotics_v2.pdf. Accessed on May 17 2022.
30. Human-machine Collaboration Moves Towards a Safe and Smart Factory, Mar 31, 2022. [Online] Available at: https://www.market-prospects.com/articles/human-machine-collaboration-and-smart-factory. Accessed on May 6 2022.
31. Brandolisio, A, Leitl, M, Golta, KJ. The AI Toolbook, Murmann Publishers, 2021.
32. Bloom, N, Jones, CI, Van Reenen, J, Webb, M. Are Ideas Getting Harder to Find, American Economic Review, 110(4), pp. 1104-1144, 2020. [Online] Available at: https://doi.org/10.1257/aer.20180338. Accessed on May 6 2022.
33. Rotman, D. AI is reinventing the way we invent, MIT Technology Review, 2019.
34. Vinuesa, R, Azizpour, H, Leite, I, Balaam, M, Dignum, V, Domisch, S, Felländer, A, Langhans, SD, Tegmark, M, Nerini, FF. The role of artificial intelligence in achieving the Sustainable Development Goals, Nature Communications, 11:233,

2020. [Online] Available at: https://doi.org/10.1038/s41467-019-14108-y, www.nature.com/naturecommunications. Accessed on May 6 2022.

35. Olsen, TL, Tomlin, B. Industry 4.0: Opportunities and challenges for operations management, *Manufacturing & Service Operations Management*, 22(1), 113-122, 2020.
36. Javaid, M, Haleem, A, Singh, RP, Suman, R. Substantial capabilities of robotics in enhancing industry 4.0 implementation, *Cognitive Robotics*, Volume 1, pp. 58-75, https://doi.org/10.1016/j.cogr.2021.06.001, 2021.
37. Özdemir, V, Hekim, N. Birth of industry 5.0: Making sense of big data with artificial intelligence, "the Internet Of Things" and next-generation technology policy, *Omics: a Journal of Integrative Biology*, 22(1), pp. 65-76, 2018.
38. Mardani, A (ed.). The Fifth Industrial and Technological Revolutions: Dancing of Humans and Machines, *Journal of Innovation & Knowledge*, ISSN: 2444-569X, 2022.
39. Mourtzis, D. Towards the 5th Industrial Revolution: A Literature Review and a Framework for Process Optimization Based on Big Data Analytics and Semantics, *Journal of Machine Engineering*, Vol. 21, pp. 5-39 ISSN 1895-7595 (Print) ISSN 2391-8071 (Online), 2021.
40. Chui, M, Manyika, J, Miremadi, M, Henke, N, Chung, R, Nel, P, Malhotra, S. Notes from the AI frontier: Applications and value of deep learning, McKinsey Global Institute, April 17, 2018 | Discussion Paper
41. Bughin, J, Seong, J, Manyika, J, Chui, M, Joshi, R. Notes from the AI frontier: Modeling the impact of AI on the world economy, McKinsey Global Institute, September 4, 2018 | Discussion Paper
42. The data-driven enterprise of 2025, McKinsey, Quantum black, AI by McKinsey, 2022. [Online] Available at: https://www.mckinsey.com/business-functions/quantumblack/our-insights/the-data-driven-enterprise-of-2025. Accessed on May 14 2022.
43. Moret-Bonillo, V, Magaz-Romero, S, Mosqueira-Rey, E. Quantum Computing for Dealing with Inaccurate Knowledge Related to the Certainty Factors Model, *Mathematics*, 10.2: 189, 2020.
44. [Online] Available at: https://joint-research-centre.ec.europa.eu/scientific-activities-z/transport-sector-economic-analysis_en. Accessed on May 6 2022.
45. Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles J3016_201806, 2018. [Online] Available at: https://www.sae.org/standards/content/j3016_201806/. Accessed on May 6 2022.

46. Park, YH, Choi, WS, Oh, JY, Park, CJ, Choi, SG. Implementation of Dynamic HSV Adjusting Method for Lane Detection, *24th International Conference on Advanced Communication Technology (ICACT)*, IEEE, pp. 167-171, February, 2022.
47. Debner, A. Performance evaluation of a machine learning environment for intelligent transportation systems, Master thesis, Aalto University, 2019.
48. Stark, CR, Pyke, LM. Dynamic pathfinding for a swarm intelligence based UAV control model using particle swarm optimisation, *Frontiers in Applied Mathematics and Statistics*, 7, 744955, 2021.
49. Park, YH, Choi, SG. Reinforcement Learning base DR Method for ESS SoC Optimization and Users Satisfaction, *24th International Conference on Advanced Communication Technology (ICACT)*, IEEE, pp. 160-166, February 2022.
50. Rhim, J, Lee, JH, Chen, M, Lim, A. A deeper look at autonomous vehicle ethics: an integrative ethical decision-making framework to explain moral pluralism, *Frontiers in Robotics and AI*, 8, 108, 2021.
51. Tamas, L, Murar, M. Smart CPS: vertical integration overview and user story with a cobot, *International Journal of Computer Integrated Manufacturing*, 32(4-5), pp. 504-521, 2019.
52. El Zaatari, S, Marei, M, Li, W, Usman, Z. Cobot programming for collaborative industrial tasks: An overview, *Robotics and Autonomous Systems*, 116, pp. 162-180, 2019.
53. Cohen, Y, Shoval, S, Faccio, M, Minto, R. Deploying cobots in collaborative systems: major considerations and productivity analysis, *International Journal of Production Research*, 60(6), pp. 1815-1831, 2022.
54. Isbell, C, Shelton, C. Cobot: A social reinforcement learning agent, *Advances in neural information processing systems*, 14, 2001.
55. Xiao L, Kumar V. Robotics for Customer Service: A Useful Complement or an Ultimate Substitute?, *Journal of Service Research*, 24(1), pp. 9-29, 2021. doi:10.1177/1094670519878881
56. Chiang, AH, Trimi, S. Impacts of service robots on service quality, *Service Business*, 14, pp. 439-459, 2020. [Online] Available at: https://doi.org/10.1007/s11628-020-00423-8. Accessed on May 6 2022.
57. Zalama E, García-Bermejo J, Marcos S, Domínguez S, Feliz R, Pinillos R, López J. SACARINO, a service robot in a hotel environment, *First Iberian Robotics Conference in ROBOT 2013*, Springer, Cham, Switzerland, pp. 3-14, 2014.
58. Novak T, Hoffman D. Relationship journeys in the Internet of Things: a new framework for understanding interactions between consumers and smart objects, J Acad Mark Sci 47(2), pp. 216-237, 2019.

59. Lechevalier S, Nishimura J, Storz C. Diversity in patterns of industry evolution: how an entrepreneurial regime contributed to the emergence of the service robot industry. Res Policy 43(10), pp. 1716-1729, 2014.
60. Huang, D, Chen, Q, Huang, J, Kong, S, Li, Z. Customer-robot interactions: Understanding customer experience with service robots, *International Journal of Hospitality Management*, Volume 99, 103078, 2021. ISSN 0278-4319
61. Calderone L. What are service robots? *RoboticsTomorrow*, 2019. [Online] Available at: https://www.roboticstomorrow.com/article/2019/02/what-are-service-robots/13161. Accessed on 30 April 2020.
62. Darling K. Extending legal protection to social robots: the effects of anthropomorphism, empathy, and violent behavior towards robotic objects, *We Robot Conference*, University of Miami, Coral Gables, 23 April, 2012. [Online] Available at: https://gunkelweb.com/coms647/texts/darling_robot_rights.pdf. Accessed on May 6 2022.
63. Leite I, Pereira A, Mascarenhas S, Martinho C, Prada R, Paiva A. The influence of empathy in human-robot relations, *International Journal of Human-Computer Studies*, 71(3), pp. 250-260, 2013.
64. Streets, J. 10 examples of AI in customer service, Scoreboard Group Consulting, 2021. [Online] Available at: https://www.techtarget.com/searchcustomerexperience/feature/10-examples-of-AI-in-customer-service. Accessed on May 6 2022.
65. Courbin, A. Why robots are expanding in customer service, 2021. [Online] Available at: https://calldesk.ai/blog/robot-customer-service. Accessed on May 6 2022.
66. [Online] Available at: https://www.grandviewresearch.com/industry-analysis/professional-service-robots-market. Accessed on May 6 2022. Accessed on May 6 2022.
67. [Online] Available at: https://www.marketsandmarkets.com/Market-Reports/service-robotics-market-681.html?gclid=EAIaIQobChMIiN2Yi9uu9wIVL4KDBx0DvQAVEAAYASAAEgJIpvD_BwE. Accessed on May 6 2022.
68. George, Evalyn I et al. Origins of Robotic Surgery: From Skepticism to Standard of Care, *JSLS: Journal of the Society of Laparoendoscopic Surgeons*, vol. 22, 4, 2018. e2018.00039. doi:10.4293/JSLS.2018.00039
69. Corliss WR, Johnson EG. Teleoperators and Human Augmentation, *An AEC-NASA Technology Survey*, Washington, DC: Office of Technology Utilization, National Aeronautics and Space Administration, 1967.
70. Paul HA, Bargar WL, Mittlestadt B, et al. Development of a surgical robot for cementless total hip arthroplasty, *Clinical orthopaedics and related research*, (285), pp. 57-66, 1992.
71. Davies BL, Ng W, Hibberd RD. Prostatic resection: an example of safe robotic surgery, *Robotica*, 11, pp. 561-566, 1993.

72. Harris S, Arambula-Cosio F, Mei Q, et al. The Probot - an active robot for prostate resection, *Proceedings of the Institution of Mechanical Engineers*, Part H. N Engl J Med, 211, pp. 317-325, 1997.
73. Green PS, Satava R, Hill J, Simon I. Telepresence: advanced teleoperator technology for minimally invasive surgery, *Soc. Am. Gastrointestinal Surgeons*, 6:91, 1992.
74. Bowersox JC, Cordts PR, LaPorta AJ. Use of an intuitive telemanipulator system for remote trauma surgery: an experimental study, *Journal of the American College of Surgeons*, 186, pp. 615-621, 1998.
75. Bowersox JC, Cornum RL. Remote operative urology using a surgical telemanipulator system: preliminary observations, *Urology*, 52, pp. 17-22, 1998.
76. Hill JW, Jensen JF. Telepresence technology in medicine: principles and applications, Proceedings of the IEEE, 86, pp. 569-580, 1998.
77. DiMaio S, Hanuschik M, Kreaden U. The da Vinci Surgical System, *Surgical Robotics*, New York, NY: Springer; pp. 199-217, 2017.
78. Topol, E. Medicine: How Artificial Intelligence Can Make Healthcare Human Again, Basic Books Inc., New York, 2019, ISBN-10 1541644638
79. Jerbić, B, et al., RONNA G4 - Robotic Neuronavigation: A Novel Robotic Navigation Device for Stereotactic Neurosurgery, Handbook of Robotic and Image-Guided Surgery, Elsevier, pp. 599-625, 2020.
80. Šuligoj, F, Jerbić, B, Švaco, M, Šekoranja, B. Fully automated point-based robotic neurosurgical patient registration procedure, *International Journal of Simulation Modelling*, vol. 17, no. 3, pp. 458-471, 2018.
81. Vidaković, J, Jerbić, B, Švaco, M, Šuligoj, F, Šekoranja, B. Position planning for collaborating robots and its application in neurosurgery, *Tehnički vjesnik*, vol. 24, no. 6, pp. 1705-1711, 2017.
82. Vidaković, J, Jerbić, B, Šuligoj, F, Švaco, M, Šekoranja, B. Simulation for robotic stereotactic neurosurgery, *Annals of DAAAM and Proceedings of the International DAAAM Symposium*, vol. 1, no. 5, pp. 562-568, 2016.
83. Švaco M, et al. Stereotactic Neuro-Navigation Phantom Designs: A Systematic Review, *Frontiers in neurorobotics*, vol. 14, p. 81, 2020.
84. Dlaka, D, et al. Clinical application of the RONNA G4 system – preliminary validation of 23 robotic frameless brain biopsies, *Croatian Medical Journal*, vol. 62, no. 4, pp. 318-327, Aug. 2021, doi: 10.3325/cmj.2021.62.318.
85. Dlaka, D, et al., Frameless stereotactic brain biopsy: A prospective study on robot-assisted brain biopsies performed on 32 patients by using the RONNA G4 system, *The International Journal of Medical Robotics and Computer Assisted Surgery*, vol. 17, no. 3, pp. e2245, 2021.

86. Dlaka, D, et al., Brain biopsy performed with the RONNA G3 system: a case study on using a novel robotic navigation device for stereotactic neurosurgery, *The International Journal of Medical Robotics and Computer Assisted Surgery*, vol. 14, no. 1, pp. e1884, 2018.
87. Bates, T, Cobo, C, Mariño, O, Wheeler, S. Can artificial intelligence transform higher education?, *International Journal of Educational Technology in Higher Education*, 2020. [Online] Available at: https://doi.org/10.1186/s41239-020-00218-x. Accessed on May 6 2022.
88. Demartini, C, Benussi, L. Do Web 4.0 and Industry 4.0 Imply Education X.0?, *IT Pro*, pp. 4-7, 2017.
89. [Online] Available at: https://www.prnewswire.com/news-releases/ai-in-education-market-revenue-to-cross-20b-by-2027-global-market-insights-inc-301318889.html. Accessed on May 6 2022.
90. Cox, AM. Exploring the impact of Artificial Intelligence and robots on higher education through literature-based design fictions, *International Journal Educational Technology in Higher Education*, 18, 3, 2021. [Online] Available at: https://doi.org/10.1186/s41239-020-00237-8. Accessed on May 6 2022.
91. Reid, P. Categories for barriers to adoption of instructional technologies, *Education and Information Technologies*, 19(2), pp. 383-407, 2014.
92. Baker, T, Smith, L, Anissa, N. Educ-AI-tion Rebooted? Exploring the future of artificial intelligence in schools and colleges, *NESTA*, 2019. [Online] Available at: https://www.nesta.org.uk/report/education-rebooted/. Accessed on May 6 2022.
93. Holmes, W, Bialik, M, Fadel, C. Artificial Intelligence in Education, The center for curriculum redesign, Boston, MA, 2019.
94. Zawacki-Richter, O, Marín, V, Bond, M, Gouverneur, F. Systematic review of research on artificial intelligence applications in higher education – where are the educators? *International Journal of Educational Technology in Higher Education*, 2019. [Online] Available at: https://doi.org/10.1186/s41239-019-0171-0. Accessed on May 6 2022.
95. Luckin, R, Holmes, W, Griffiths, M, Pearson, L. Intelligence unleashed an argument for AI in Education, Pearson, 2016. [Online] Available at: https://www.pearson.com/content/dam/one-dot-com/one-dot-com/global/Files/about-pearson/innovation/open-ideas/Intelligence-Unleashed-v15-Web.pdf. Accessed on May 6 2022.
96. Lowendahl, JM, Williams, K. 5 Best Practices for Artificial Intelligence in Higher Education, Gartner, Research note, 2018.
97. Strobl, C, Ailhaud, E, Benetos, K, Devitt, A, Kruse, O, Proske, A, Rapp, C. Digital support for academic writing: A review of technologies and pedagogies, Computers and Education, 131, pp. 33-48, 2019.

98. Hussein, M, Hassan, H, Nassef, M. Automated language essay scoring systems: A literature review, *PeerJ Computer Science*, 2019. [Online] Available at: https://doi.org/10.7717/peerj-cs.208. Accessed on May 6 2022.
99. Hockly, N. Automated writing evaluation, *ELT Journal*, 73(1), pp. 82-88, 2019.
100. Winkler, R, Söllner, M. Unleashing the potential of chatbots in education: A state-of-the-art analysis, Academy of Management Annual Meeting (AOM), Chicago, USA, 2019.
101. Martha, ASD, Santoso, HB. The design and impact of the pedagogical agent: A systematic literature review, *Journal of Educators Online*, 16(1), n1, 2019.
102. Luckin, R. Towards artificial intelligence-based assessment systems, *Nature Human Behaviour*, 1(3), pp. 1-3, 2017.
103. Catlin, D, Kandlhofer, M, Holmquist, S. EduRobot Taxonomy a provisional schema for classifying educational robots, *9th International Conference on Robotics in Education*, Qwara, Malta, 2018.
104. Belpaeme, T, Kennedy, J, Ramachandran, A, Scassellati, B, Tanaka, F. Social robots for education: A review, 2018. [Online] Available at: https://doi.org/10.1126/scirobotics.aat5954. Accessed on May 6 2022.
105. World Economic Forum 2020, The Future Jobs Report, October 2020. [Online] Available at: https://www3.weforum.org/docs/WEF_Future_of_Jobs_2020.pdf. Accessed on May 6 2022.
106. [Online] Available at: https://www.getsmarter.com/blog/wp-content/uploads/2020/09/FOW-report-_-22_09_2020.pdf. Accessed on May 14 2022.
107. Breene, K. The 10 countries best prepared for the new digital economy, World Economic Forum, 2016. [Online] Available at: https://www.weforum.org/agenda/2016/07/countries-best-prepared-for-the-new-digital-economy. Accessed on May 6 2022.
108. Digital Riser Report 2021, European Center for Digital Competitiveness, 2021, [Online] Available at: https://digital-competitiveness.eu/wp-content/uploads/Digital_Riser_Report-2021.pdf. Accessed on May 6 2022.
109. Charlton, E. Children in wealthy countries are less optimistic about their future than those in developing nations – here's why, World Economic Forum, 2021. [Online] Available at: https://www.weforum.org/agenda/2021/12/children-economic-optimism-poorer-nations/. Accessed on May 6 2022.
110. Sizing the prize – What's the real value of AI for your business and how can you capitalise?, PWC, 2017. [Online] Available at: https://www.pwc.com/gx/en/issues/analytics/assets/pwc-ai-analysis-sizing-the-prize-report.pdf. Accessed on May 14 2022.

111. Salih MS. The artificial intelligence and its global economic growth impact, World Economics and Finance Bulletin, 9, pp. 16-24, 2022. [Online] Available at: https://scholarexpress.net/index.php/wefb/article/view/774. Accessed on May 6 2022.
112. Jones, E, Kalantery, N, Glover, B. Research 4.0 Interim Report. Demos, 2019.
113. Schwab, K. The Fourth Industrial Revolution, World Economic Forum, ISBN-10 9781524758868, 2017.
114. Švaco, M, Jerbić, B, Župančić, I, Vitez, N, Šekoranja, B, Šuligoj, F, Vidaković, J. The Case of Industrial Robotics in Croatia, *International Conference on Robotics in Alpe-Adria Danube Region,* Springer, Cham, pp. 607-617, 2018.
115. Jurčević, M, Lulić, L, Mostarac, V. The Digital Transformation of Croatian Economy Compared with EU Member Countries, *Ekonomski Vjesnik*, 33(1), pp. 151-164, 2020.
116. Vretenar, D, (Ed.). Ljetopis HAZU, Knjiga 123, pp. 324-328, Zagreb 2020.
117. Lovrek, I, Piližota V, (Eds.). 25 years of the Department of Technical Sciences of the Croatian Academy of Sciences and Arts 1997–2022, Croatian Academy of Sciences and Arts, pp. 10, 2022.

UMJETNA INTELIGENCIJA I ROBOTIKA KAO POKRETAČKA SNAGA MODERNOG DRUŠTVA

Sažetak

U sinergiji s drugim tehnologijama AI značajno ubrzava znanstveni i tehnološki razvoj ljudskog društva. Neprestano se otvaraju nove mogućnosti primjene tehnoloških dostignuća, kako u industriji, zdravstvu tako i u svakodnevnom životu. Robotika temeljena na umjetnoj inteligenciji glavni je pokretač sadašnje industrijske revolucije. Roboti su već odigrali važnu ulogu u proizvodnji i promijenili proizvodnu ekonomiju tijekom posljednjih desetak godina. Nove generacije pametnih robota, ili općenito pametnih tehničkih sustava, okreću se novim primjenama, posebno u uslužnim djelatnostima, medicini i kućnoj uporabi. Autonomni i mobilni roboti u budućnosti će moći pomagati starijim i nepokretnim osobama, pomagati u kućanskim poslovima, djelovati kao njegovatelji i obavljati ponavljajuće, dosadne ili opasne poslove u staračkim domovima, bolnicama, vojnim okruženjima, mjestima katastrofe i školama. Potencijalne prednosti su velike, ali također predstavljaju značajne etičke izazove. Naša autonomija može biti ugrožena, a društvena interakcija opstruirana. Prošireno korištenje robota može dovesti do smanjenog kontakta među ljudima i mogućih ograničenja osobnih sloboda. Strojevi ove vrste oblikuju radikalno novi svijet, što dovodi do značajnih ekonomskih i kulturoloških promjena, stvarajući jednako pobjednike kao i gubitnike na globalnoj svjetskoj razini.

Ključne riječi: robotika; umjetna inteligencija.

Bojan Jerbić
University of Zagreb
Faculty of Mechanical Engineering and Naval Architecture
Ivana Lučića 5, HR10002 Zagreb, Croatia
E-mail: bojan.jerbic@fsb.hr

Marko Švaco
University of Zagreb
Faculty of Mechanical Engineering and Naval Architecture
Ivana Lučića 5, HR 10002 Zagreb, Croatia
E-mail: marko.svaco@fsb.hrr