

Editorial

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Introduction to AI-driven surgical robots

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WHY

The word “robot” was invented 100 years ago by Czech playwright Karel Čapek. It meant an artificial human, i.e., a device with certain physical and intellectual capabilities. That is why I believe that AI is part of a robot, specifically a medical one. Therefore, another act of this play is currently taking place on the stage: operating theatre.

AI and robots relate to a new paradigm of work. When it comes to work in the healthcare sector, it is a matter of utmost importance. According to the OECD report “Health at a Glance 2021”^[1], health and social care systems in OECD countries currently employ more workers than ever before. Over the past two decades, the percentage of those employed in this sector has increased from less than 9 to 10 percent of the total workforce, and in Scandinavia and the Netherlands, it already accounts for more than 15 percent of all jobs. In Norway, it is 20%. In Poland, for comparison, employment in the healthcare and social support sectors accounts for only 6% of the total workforce. In the United States, according to the Census Bureau’s 2019 American Community Survey (ACS), there were 22 million workers in the healthcare industry, one of the largest and fastest-growing sectors that accounts for 14% of all US workers.



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The number of doctors and nurses is also important. In Norway, there are 5.1 medical doctors per 10,000 people and 18.05 nurses. In the US, there are 2.6 and 11.79, respectively^[2]. If we want robots to accompany patients and doctors to be more efficient through the use of devices, we need real engineering support. So, it means expanding the professional team responsible for taking care of the patient. Overall, I believe that automation and robotization in industry and services are intended to allow people to return to their basic, natural duties - taking care of another human being in sickness or health.

WHAT DO PHILOSOPHERS THINK ABOUT THIS?

All significant evolutionary changes and all civilizational revolutions have been associated with changes in work. From the ability to cultivate plants and breed animals, through the mastery of water in the form of steam pressure and river dynamics - which gave us independence in terms of access to food and energy, to tools from stone to silicon processors that allowed us to record, collect, and analyze information.

Philosophers have been concerned with the topic of work since ancient times, and their thoughts on this topic have varied depending on the cultural and historical context with which they were dealing. Aristotle believed that work is necessary for sustaining life, but at the same time, he believed that people should do what interests them and what gives them satisfaction. Plato believed that work should be divided among people according to their abilities and skills and that each person should do their specialization. Georg Wilhelm Friedrich Hegel, a German philosopher from the 19th century, also had a lot to say about work and its significance in human life. According to Hegel, work is the basic way in which a person realizes their freedom and ability to act. It is also worth noting his considerations on slavery.

Karl Marx believed that work was a means of production and that it was exploited by capitalists for their gain. Hannah Arendt believed that work allowed individuals to express their unique talents and abilities and that it was necessary for the creation of a sense of purpose and belonging in society.

What would each of them say about the work of a surgeon? In the case of a surgeon's work, Arendt might point out how the surgeon uses their skills and knowledge to help others while also developing themselves as individuals. Of course, no medical service can be separated from ethics. In general, ethics in surgery involves considerations related to the rights, dignity, and welfare of patients, as well as the responsibilities and obligations of healthcare professionals who are involved in surgical procedures. New technologies, especially those that affect decision-making and working methods, also present challenges to ethics and the economic and legal environment of business. As the use of AI in healthcare continues to evolve, it is important for healthcare providers, regulators, and policymakers to address these ethical challenges and ensure that the use of AI in surgery is safe, effective, and ethical.

Patients must be informed about the use of AI in their surgical procedure, including any potential risks and benefits. Patients should have the option to decline the use of AI in their surgery. Patients must be informed about how their data will be utilized. Surgeons and healthcare providers must be accountable for any decisions made based on AI recommendations or output. Surgeons and healthcare providers must ensure that AI systems are designed and trained to avoid bias.

Surgeons specialize in treating diseases and injuries through surgical interventions, which are often associated with risks to the patient's life. The work of a surgeon is highly demanding, both technically and emotionally. It is a profession that requires a great deal of dedication but also provides a lot of satisfaction and a sense of professional fulfillment.

Let us leave satisfaction to the surgeons and the work to the robots.

AI

The size of the global digital healthcare market was estimated to be USD 332.53 billion in 2022 and is expected to reach a value of approximately USD 1694.21 billion by 2032, growing at a CAGR of 19.4% during the forecast period 2023-2032^[3].

Digital health is described as the integration of information technology and electronic communication used in various healthcare processes for the overall health and well-being of people. The revolutionary development in the healthcare industry is due to the combination of digital data and machine learning. We have entered a rare period in history where all technologies are ready - fast computers, sensors, AI, and robots too. Health competencies are beginning to play a key role, as technological change is not enough. It is necessary to increase health awareness and competencies in parallel.

The surgeon works in the information transfer space, which has a decisive influence on the success and safety of the operation. Intelligence is our own evolutionarily developed device for optimizing decisions made in this multidimensional information space. The work of AI and robots creates synergy - medical robots - because of communication: fast, accurate, and digital^[4]. The less invasive the surgery, the less visual and sensory information we have - the more the role of AI increases^[5].

When a surgeon operates, focused on a small area of the operative field and removing the effects of disease or injury, their brain can work in parallel with diagnostic data (old and new), online observation of all measurements from devices connected to the patient during the surgery, and even model, simulate prognoses, and formulate advice based on data from similar operations performed around the world.

Artificial intelligence can lead to the discovery of new information and accelerate the acquisition of available evidence. By incorporating artificial intelligence into clinical training and research, surgeons can improve patient care.

Intelligence binds and processes data and information obtained from sensors to make a decision, which becomes new information. However, in surgery, the decision is not the end of the task, but the beginning of mechanical work. When a surgeon's hand is connected to a robot with a computer, an ideologically surgical telemanipulator means a synergistic cooperation between a human and a hand prosthesis with a tool and an artificial brain. This means that the more sensors, computing power, and context-specific knowledge and experience, the greater the chance of success for the doctor and their patient. Artificial intelligence is designed to complement, supplement, or replace human communication with the robot when it is interrupted. I see the main advantage of introducing AI in the ability to use the universe of global experience compared to individual and parallel analysis of all current patient data (including anesthesia, perfusion, etc.) entered into diagnostic data. Similarly, a car or airplane driver can focus on driving in specific geographic and weather conditions while being supported by computers monitoring a network of sensors and drives.

Currently, we are witnessing incredibly interesting developments in both the fields of AI and robotics. ChatGPT^[6] has changed everything. What used to be achievements of machine learning or algorithms hidden in increasingly intelligent devices or computer games has become an almost universal tool, from an interactive search engine to a program that writes computer programs to a legal consultant. The mission-driven nature of its creation and financing also speaks to the uniqueness of this project. OpenAI is a non-

profit organization that has attracted investors and co-founders such as Elon Musk, Sam Altman, Greg Brockman, and Reid Hoffman. In July 2019, OpenAI and Microsoft announced that they would work closely together in the field of artificial intelligence and cloud computing. Microsoft also invested \$1 billion in OpenAI, allowing the organization to develop advanced AI technologies. OpenAI employs Polish scientists such as Wojciech Zaremba, who is one of the co-founders of OpenAI and works on the development of neural networks and machine learning, and Karol Kurach, who is researching text generation using artificial intelligence. I mention them because a document was recently released showing the role that ChatGPT can play in the development of robotics. (In fact, I used it as a language expert when preparing this article).

“The use of ChatGPT for robotics is not a fully automated process but rather acts as a tool to augment human capacity. Natural language processing (NLP) has long been recognized as a crucial component of human-robot interaction. There are many applications where robots can benefit from NLP, including but not limited to task instruction, navigation, and information retrieval. The Transformer architecture has revolutionized NLP and has also shown great promise in robotics (for robot control and planning, object recognition, and robot navigation). Obtained thanks to ChatGPT conversational ability allows the user to interactively improve and correct the robot’s behavior (as opposed to re-engineering the prompt from scratch and generating another zero-shot answer). While the traditional symbolic AI approach presented difficulties in new knowledge acquisition and dealing with out-of-distribution data, models such as ChatGPT can compose new primitive functions based on the context and generate code for them automatically. Authors^[7] presented a framework for using ChatGPT for robotics applications. The framework entails designing and implementing a library of APIs (Application Programming Interfaces) that for robot control which are amenable to prompt engineering for ChatGPT. The proposed framework allows the generated code to be tested, verified, and validated by a user on the loop via a range of methods including simulation and manual inspection. The authors demonstrated how the framework can be used for multiple applications ranging from simple common-sense robotics knowledge tasks to deployments in aerial robotics, manipulation, and visual navigation”^[7].

We treat the human body as a biological, physical, chemical, and biocybernetic (IT) system^[5]. Robots are increasingly essential in healthcare.

ROBOTS

So, here we go with robots. It is hard to think of a surgical area where robots have not been tried today. It started with neurosurgery and orthopaedics, then the lucrative market of cardiac surgery was targeted. Today, we can find robots from ophthalmology to transplantology, from diagnostics to rehabilitation. More and more robots are entering the medical market, and more contenders are ready to enter the market. As specialists claim, about 20% of minimally invasive surgeries could already be performed with the help of robots. The current 1.5 million annual surgeries represent only a few percent of the market potential. That is why business organizations in many countries are investing in robots today. In the field of soft tissue surgery alone, the once solitary leader Intuitive da Vinci has now been joined by Asensus Senhance (designed by TransEnterix, renamed from the Alf - X in 2016, developed by Italian SOFAR SpA), CMR Versius, Medtronic Hugo, Medcaroid Hinotori, MeerCompany Revo-i, Harbin Sagebot KangDuo, Memic-Hominis system, and Distalmotion Dexter, Avatera Medical, Medbot Toumai, SSI Mantra, RobSurgical Bitrack, RiverField, Asahi ANSUR, Micro Hand S (Tianjin Univ.), Sina Flex-Sina Robotics, Edge Medical Robotics, Carina-Ronovo Surgical, MIRA surgical system, Luna-Asensus, and Vicarious-Vicarious Surgical are also ready. Today, most developed countries have the ambition and the ability to develop their surgical robots. In Poland, I have also been developing the Robin Heart robot since 2000, believing that it will be

able to compete on the market with other robots presented. The authors of the Fletcher Spaght report counted 26 soft tissue platforms, 21 of which have regulatory approval^[8].

Many of these companies rely on the proven da Vinci robot model, but they are also trying to develop innovations related to telecommunications and AI technologies. J & J took a big step in robotic surgery in 2019 when it paid \$3.4 billion upfront for Auris and took full control of the joint venture Verb, which it had founded a few years earlier with Alphabet's Verily (believing that they could quickly create a fully AI surgical robot). However, despite the enormous costs of the robot, we will still have to wait for Ottawa.

The pioneers of surgical robotics, such as Richard Satava and Volkmar Falk, have already pointed out that the robot is a digital device with great potential for implementing AI in medicine.

The authors of^[9] make a distinction between Console and non-console surgery. Robotic surgical systems (da Vinci, Versius, and HUGO) are telemanipulators. Examples of handheld robotic-assisted surgical devices include robotically controlled laparoscope holders that can be autoclavable and connected directly to the OR table (ViKY), handheld powered articulating instruments (Jaimy and HandX), and some powered staplers (Signia). The concept of autonomy, or independent decision-making, is central to AI in surgery and the future of surgical robotics. True independent decision-making would need to be driven by AI and optimally learn from its mistakes (ML).

AI-DRIVEN, AI-POWERED MEDICAL ROBOTS - WHAT DOES IT MEAN?

What is the definition of work? The definition of work can vary depending on the context in which it is used. However, in general, work can be defined as the physical or mental effort exerted to achieve a goal or produce a result. Work typically involves the use of energy to perform tasks, whether through physical labor or cognitive processes. The work of a surgeon is characterized by a unique combination of technical expertise, attention to detail, ability to work under pressure, communication skills, and empathy and compassion. These characteristics are essential to ensure that surgical procedures are performed safely and effectively and that patients receive the best possible care.

The term "surgery" is derived from the Greek word "cheirurgia" (from greek "cheir" - hand and "ergon" - action, "cheirurgia" - manual work), which means "hand work". Surgery can be defined as the branch of medicine that deals with the treatment of disease, injury, or deformity by manual or operative methods.

Surgery is a medical specialty that involves the use of surgical techniques to diagnose, treat, and manage a wide range of medical conditions. Surgery is typically performed by a surgeon, who is trained to use a variety of surgical tools, techniques, and technologies to perform invasive procedures on the body.

The task remains - only the tools change.

Why does AI help surgeons? AI can help to improve surgical outcomes by providing surgeons with real-time information and feedback, enhancing surgical planning and decision-making, and reducing the risk of complications during surgery.

Why do robots need AI? Robots need AI to be able to operate autonomously, make decisions, and perform complex tasks. AI allows robots to learn from experience and adapt to new situations, making them more flexible and versatile in their abilities. Without AI, robots would be limited to performing a predefined set of

tasks and would require constant human intervention and programming to adapt to new environments or situations. However, with AI, robots can learn from their interactions with the environment, and use that knowledge to make decisions and perform tasks more efficiently.

Intelligence means the right reaction to the information received. Humans need strong senses, and robots need sensors. AI-powered medical robots are equipped with advanced sensors, cameras, and other imaging devices, which allow them to collect and process vast amounts of data in real time. They use this data to perform complex computations, make decisions, and execute actions autonomously, without human intervention.

Some of the benefits of using AI-powered medical robots include improved precision and accuracy, faster and more efficient procedures, reduced recovery time, and decreased risk of complications. These robots can also perform repetitive or physically demanding tasks, allowing medical professionals to focus on more complex aspects of patient care.

Overall, AI is a critical component of robotic technology, allowing robots to operate autonomously, learn from experience, and adapt to new situations, making them more versatile and capable of performing a wider range of tasks.

IS IT SAFE?

Just like using any diagnostic, surgical, or rehabilitative tool, AI can cause errors. However, we already have developed methods and standard procedures for such situations:

1. Validation and verification processes involve testing the AI system against a gold standard or benchmark dataset to ensure that it meets performance requirements.
2. Clinical trials involve testing the AI system in a real clinical condition to determine its effectiveness and identify any potential risks or side effects.
3. Regulatory agencies such as the FDA (US), Medical Device Regulation (MDR, EU), ISO (International Organization for Standardization), European Data Protection Board (EDPB), and the European Medicines Agency (EMA).
4. Ethical guidelines provide recommendations for the responsible and ethical use of AI in medicine. These guidelines often address issues such as privacy, transparency, fairness, and accountability. As an example, The Ethics Guidelines for Trustworthy AI developed by The European Commission.
5. Post-market surveillance involves monitoring the performance and safety of AI-based medical devices and systems after they have been approved and deployed. This process helps to identify any potential safety issues or performance problems that were not identified during the pre-market testing and approval process.

Overall, these methods help to ensure that AI-based medical devices and systems are safe, effective, and used in a responsible and ethical manner.

CONCLUSION

The process of change has already begun and is irreversible. We have no other option. Soon, if something hurts you, the robot will process this information, estimate the risks, optimize the process paths, and arrange for you to meet the appropriate doctor. A transport robot will be sent to take you to the hospital, where a robot will greet you and guide you to the appropriate place. Robots and people will do everything in their power and knowledge, in line with the achievements of civilization at that time. The robot will provide you with food, prepare medicines and measure appropriate doses, and will take you home and take care of you if you no longer have a family. Let us only hope that we have enough energy and ingenuity to secure the system's operation.

That is why let us create robots, and the most important ones will be medical robots! Thanks to robots, hospitals will be greener and we will be more humane. We will free our hands and heads to better serve those in need.

Until now, medical devices and tools were primarily oriented toward service providers such as doctors and nurses. However, we are now seeing a shift towards patient-oriented technology, which represents a fundamental change in the way medical services are provided^[4].

From the latest report^[10] from Stanford University covering AI in research and development, technical performance, technical ethics of AI, economy, education, politics and management, diversity, and public opinion, I noticed the following conclusions:

- (1) Industry has taken over science.
- (2) AI models are developing rapidly, and their training is becoming increasingly expensive.
- (3) Artificial intelligence systems can have a serious impact on the environment. However, new reinforcement learning models show that artificial intelligence systems can be used to optimize energy consumption.

For example, for the popular chat AI GPT-3, it was calculated: Power Consumption of 1,287 MWh & CO₂ Equivalent Emissions of 502 tonnes.

Currently, medical robots and AI support medical services in the richest countries in the world. The capitalist system, of course, requires a return on investment and an opportunity for shareholders to enrich themselves. However, the real breakthrough will occur when medical robots begin to help those who cannot afford "normal healthcare services", when an added group of beneficiaries appears. We have already had several good examples of this because, after all, we remember that the creation of world-renowned programs requires the talent, knowledge, and work of many excellent people, but also the energy to power and sustain the system. Thanks to such organizations and AI, we can navigate our cars for free in any country in the world and translate, for example, this text that I am writing into almost any language. I have no doubt that without AI, robots will never overcome this barrier - the barrier of interest and business.

AI is here to communicate with human intelligence, to free up human hands, and to enable humans to return to being human.

This special edition of AI Surgery is meant for us to see if our shared dream among doctors and patients - to provide efficient and accessible surgical services with the help of intelligent robots - will come true tomorrow or ... the day after tomorrow.

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