The role and challenges of robots in the Fourth Industrial Revolution from technological, social, and economic perspectives.

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Abstract. As the Fourth Industrial Revolution(4IR) is increasingly associated with our lives. This marks a cross-domain fusion of various technologies, and robots can link those technologies together. This thesis will briefly introduce the core technologies related to robots and the challenges robots face. In social fields, there are numerous benefits of robotization brings to humankind, but still some ethical problems, such as how to arrange the workers replaced by robots. Economically, robotization massively increases productivity in industry. However, the funding issues when setting up the robotization may increase unbalance in competition between small and big companies. Additionally, this article analyses some of the successful applications of robots to show the advantages of robotization. Mainly, the positive impact is more than the drawbacks. With the ongoing innovation of technologies and gradually improving laws and policies, the challenges will finally be solved. In conclusion, this paper summarizes the opportunities and challenges of robots and gives some advice on how to overcome them.

Keywords: 4IR; robotization; productivity; replacement; efficiency.

1. Introduction

The 4IR is characterised by the innovation of advanced technologies such as Robotics, the Internet of Things (IoT), artificial intelligence (AI), nanotechnologies, and autonomous cars into industrial processes. Robotics played a crucial role in this advancement. Lead to improved efficiency, precision, and automation in manufacturing and other fields. With the aid of AI, they can perform complex tasks with minimal human intervention, which is reshaping industries and redefining traditional workflows.

With the aid of robotics, many companies enhance their production efficiency by 30% and reduce expenses by 50% [1]. An article applies the OEE (overall equipment effectiveness) metric to compare the efficiency of a robot-operated manufacturing line with that of a manpower-operated one. In conclusion, robots are almost 60% faster than humans [2].

Although robots have diverse advantages, the implementation of robotic automated production still faces significant challenges.

For example, if robots increase nearly 60% of production ability, why can we not use robotics to replace most of the human workers and only leave essential maintenance personnel? From the author's perspective, this is the most important and inevitable challenge. It is about ethical concerns. According to an article, in the coming decades, robots may replace about half of all occupations in the US [3]. However, the job opportunities created by the robot industry are primarily aimed at highly skilled professionals. Medium-skilled workers are going to bear the consequences of robotisation [4]. This will cause an increase in unemployment, but medium-skilled workers cannot afford and get a chance to get a further education.

The cost of robotisation is highly unaffordable for small companies. Employers need training to adapt to working with machines. The cost will increase with the intelligence of the machine. This causes small companies to lag behind large enterprises in automation upgrades, thus affecting their market competitiveness. Also, in the short term, it decreases labour costs. Equipment maintenance, software upgrades, and component replacement still require a lot of investment.

Technically, 4IR highly relies on IoT, such as the process of vehicle tracking, transport safety, and efficiency. Cybersecurity issues are becoming one of the primary tasks of IoT in the coming years

[5]. The author will summarise the attack type. Another issue is to ensure that robots do not cause harm to humans when operating remains a challenge.

Therefore, this article will review the role and challenges of robotics in the Fourth Industrial Revolution from social, economic, and technological perspectives and give some suggestions.

2. Robotics in the Fourth Industrial Revolution

2.1. New Technologies Related to Robots in the 4IR

Numerous new robotics-related technologies are available in the 4IR. Firstly, the Industrial Internet of Things (IIoT) is any machine that can transfer data with other devices on the Internet. Big companies that need a system to track the location of all products in the commodity chain have motivated the development of IIoT. They will benefit greatly from this kind of foresight and predictability [6]. Before the invention of IIoT, the most frequently used communication types were Supervisory Control and Data Acquisition (SCADA) or the Distributed Control System (DCS). Neither of them can adapt to complex manufactory processes nowadays. Specifically, SCADA often faces software and hardware compatibility issues and is expensive to set up [7]. DCS is unable to share data across systems. IIoT absorbs the advantages of the above systems. IIoT systems offer significant efficiency and cost advantages [7]. It is one of the most important technologies in the 4IR. Secondly, artificial intelligence (AI) and machine learning. Both have a big impact on smart factories and automated warehouses. They differ in that machine learning cannot replicate human intelligence, whereas artificial intelligence (AI) does. By spotting patterns, machine learning aims to train a machine how to carry out a certain task and produce precise results [8]. Training the AI with big data can make the robot autonomously learn the environment to improve decision-making capabilities to decrease the chance of human intervention. The final expectation is that AI can make correct decisions based on situations that it was not included in the big data. Thirdly, robots combine with the above technologies, such as automated guided vehicles (AGV), Unmanned aerial vehicles (UAV), medical robots, and so on. With the aid of AI, machine learning, and IIoT. Automated warehouses massively decrease the requirement for manpower. UAVs can be used in the delivery system for agriculture. It needs 50 workers, 45 days to complete a 912-hectare plantation. Seven Agras T50 drones, on the other hand, can finish the same task in 21 days. Providing a 50% increase in efficiency [9].

2.2. Social Impact

Robots have a great positive impact on our societies. Occupational injuries are the most serious during the manufacturing process. With the innovation of technologies, robots can do repeated and dangerous work and reduce the possibility of human casualties.

From civilian to military use, disaster robots can handle nuclear disasters instead of human repair. There is a new type of navigation that detects and generates maps depending on the radiation, making robot repair in the reactor available [10]. Nuclear power is one of the new and renewable sources of energy. Currently, there are about 65 reactors under construction, and 90 further reactors are planned [11]. If there is another nuclear disaster, like Chernobyl or Fukushima. Robots can do repairs near the reactors, decreasing the effect on humans. Another research study states that a one standard deviation increase in robot exposure reduces work-related injuries by 1.2 cases per 100 full-time workers [12]. Also implies the significance of robotisation benefits society.

In military use, drones are widely used in the Russo-Ukrainian War. In theory, it will massively decrease the own soldier casualties. Drones provide unprecedented awareness, even down to the infantry level. Their real-time view of the battlefield allows troops to discover enemy positions and monitor adversary movements without risking the lives of human special forces [13].

2.3. Economic Impact

Robotisation also has a positive impact on the economy. With the combination of robots, AI, and big data, intelligence is realised.

The process of completely automating factory output is known as "lights-out manufacturing.". It requires no human presence on-site, which means the working environment can reduce the cost of light, space, and increase working hours. Firstly, in repeated work, the path of the robot is preset, and it can use infrared sensors in a dark space. Turning the light off can reduce electricity costs. Secondly, without considering the land requirements for humans. A factory can accommodate more compact cells in the same area to boost output. Thirdly, the machine does not need to rest. The maximum working hours are 48 hours in the UK [14]. In extreme conditions, the machine can work 158 hours a week if taken out of an average of 10 hours of maintenance. The working hour increases an average of 2.3 times. The efficiency of the robot is 1.6 times that of human workers. Increase 3.68 times in total, and do not need to pay the salary. In conclusion, it can significantly increase the production ability and reduce the disbursement.

3. Application

3.1. Orisol Robotisation and Insights Hub

Since 1990, Orisol, a manufacturer of complete footwear, has introduced its first computerised sewing machine. Orisol is now at the forefront of shoe automation. In the past, the production of shoes was done by hand using manual labour. Because hardcopy records are used, managers are unable to verify the location or functioning state of the workstations. As a result, it is unable to identify the causes of production delays and make prompt decisions.

Most significantly, conventional shoemakers rely on the knowledge and instincts of skilled employees to make the best choices. A large portion of their knowledge departs with them when they retire, creating a skills gap that is noticeable when newer employees are hired.

Orisol is aware that automation, the IoT, and digitisation may all aid in overcoming those challenges. Hence, they cooperate with Siemens and FarEasTone (FET). First can provide industrial automation solutions, and the other can help with setting up IoT.

With the aid of 5G, IoT, and new industrial robots. Expert workers can adjust and store each manufactory process on the cloud. Then the younger workers can operate the machine and produce the same quality as experts. The production state of the entire line, as well as the operational status of every piece of equipment, is also visible to Insight Hub. Managers can optimise the production line's efficiency based on the equipment's idle capacity, even in the event of an unexpected urgent order [15].

3.2. KAD Models light off manufacturing

Manual Computer Numerical Control (CNC) loading requires operators 24 7 for small prototype shops. The parts needing CNC machining are usually diverse and have low volume requirements. Therefore, those shops typically do not automate. But that results in a slow prototype and production turnaround, which can lead to customers placing orders elsewhere.

A prototype company, KAD Models, wants an automation platform that takes unique part numbers and runs them on a system that does not need to know what is on a pallet. Then, the FANUC provides two automation cells, FANUC M-710i/50 and R-1000/100F robots.

Their systems provide a machine-tending automation solution with a unique spin. The only thing the operator needs to do is select a part number associated with the part that has been loaded. Then it puts the part into a queue. When the milling machine is ready, it moves the particular part and runs it through the automated system.

After proving out prototype parts during the day, it enables the programmers to build the machines that run components at night. Hence, there is no need for men to run the second or third shift. Therefore, reduces man cost and the programmers will receive complete parts in the morning. The system is already pre-programmed, and the solution is simple to understand and can be quickly deployed.

Following automation, KAD quickly established the prototyping shop from the West Coast to the East Coast. Additionally, local producers seeking specialised components might use KAD models [16].

3.3. Tea Farming with DJI Agriculture Drone Solutions

The difficulties faced by conventional tea-growing techniques, like manual labour and fixed-wing planes. There are a lot of limitations, such as labour-intensive processes, environmental issues, and workers' safety risks. A sizable labour force is frequently required for fertiliser application in tea production. Traditional fertilisers may contain dangerous compounds that irritate skin or compromise respiratory health. Unfavourable weather conditions, such as muddy conditions, might cause farming efforts to be further delayed. Then, DJI combines the precision, efficiency, and sustainability of Drones and provides a solution.

With the aid of new technologies in the 4IR. With the use of sophisticated weighing sensors, the drones can distribute fertilisers and nutrients uniformly throughout crops while preventing overapplication on adjacent highways or rivers. Seven drones can do the work in 21 days, in contrast to 50 manual workers who need 45 days. Additionally, drones use battery power instead of fuel, therefore reducing greenhouse gas emissions. Even in muddy situations, DJI drones can work right away after rain to guarantee that plants receive fertiliser on schedule and without weather-related delays [9].

4. The challenges robots face

4.1. Technology challenge

Despite a lot of technical issues having been solved but there are still some challenges we need to overcome until the success of the fifth industrial revolution.

The first major issue is the cyber-attack, research indicates that attacks will occur more frequently due to the advances of 5G and related IoT [17]. Nowadays, AI can be used to enhance the security of the system, but it can also be used by attackers to harm the system. Especially when more self-driving vehicles start to operate in the city and begin to connect via a massive network in the future. Massive networks are harder to protect with a multitude of attack surfaces [18]. The consequence may be significant, hackers can get full access to the car and disable the brakes to cause accidents.

The second issue is motion control accuracy and energy consumption optimization. When the robot is running at high speed, eliminating inertia and vibration suppression is still improving. A 6-degree-of-freedom (dof) industrial robot is a better alternative to the CNC machine tool for milling of large parts. However, 6-dof robots are more compliant than CNC machines, which makes them more likely to vibrate during milling [19]. The consequence of milling is that it will increase the wear of bearings, gears, and connecting parts, resulting in a shortened lifespan. During manufacturing, it may increase the processing errors and affect the qualification rate, leading to less profit and more energy consumption to balance the vibration losses.

4.2. Social challenges

With the progress of technologies, the efficiency, working hours, and versatility of robots have significantly increased. However, robotisation will harm both the employment rate and wages. Mainly, there will be a bigger impact on the industrial industry than the service industry. Therefore, the author will focus on the impact on workers. Another research indicates that each additional robot per thousand workers reduces the local employment-to-population ratio by 0.2% and wages by about 0.42% in the USA [20]. The average cost to live in the USA per day is around $211.73 per day [21]. The national average salary is $66,622, which is $182.52 daily [22]. In the meantime, the United States installed 39.6k robots in 2023. According to the above statistics, the employment-to-population ratio is expected to decrease by 0.792%, and wages are projected to decrease by 1.67%. Increasing the imbalance in spending, which makes the civilians' lives even harder. Additionally, there is no way to pay for further education without loans to increase salary. The most in-demand jobs all require coding skills, and to learn them systematically, the cheapest one costs $3,750. The rest cost an average of $11,879[23]. After completing the course, the average salary will increase by $15,082 per year, which is slightly higher than the daily cost. In conclusion, if workers lose their jobs, they must take the risk to loan money to learn and then can balance their daily costs.

4.3. Economic Challenges

Despite the advantages of the production of a smart factory, a major economic challenge remains unsolved. Setting up a full automation or half automation factory is very expensive and usually needs a big investment, which small to medium companies may not be able to afford. Then big companies can use the efficiency advantage to annex them. Specifically, a half-automated factory requires extra infrastructure such as AGV for transporting materials and products. The price of one AGV car is from $14,000 to $70,000[24]. A standard forklift costs in the range of $25,000-45,000[25]. Usually, a factory needs 5-15 AGV cars, and the traditional needs around 3. Smart factory requires Intelligent control systems and software, such as SCADA, to connect each machine to form IIoT. An Authorisation fee needs to be paid and depends on the mode, one-time authorisation or Software as a Service (SaaS). Both will cost more than traditional methods, and machines need to be equipped with AI visual inspection equipment, cameras, and sensor arrays to monitor product quality in real-time. The workers also need to be trained to manipulate the machine. In contrast, the older worker would teach the apprentice in the traditional factory. In conclusion, a half or full automated factory will cost much more than a traditional factory in the short term. In the long term, the productivity will exceed the traditional factory, whose rate of return will be higher.

5. Conclusion

As the Fourth Industrial Revolution continues to change the world, robots and other core technologies of the 4IR combine to benefit mankind. This thesis has reviewed the role of robotics across social, economic, and technological dimensions, providing an exhaustive understanding of both the opportunities and challenges robots face.

From a technological perspective, robotics has made remarkable improvements, integrating advancements of AI, machine learning, and IIoT. These technologies have enabled robots to perform complex tasks with precision and improve their ability to deal with unexpected situations. Massively improve the efficiency in agriculture. However, this rapid development also presents challenges such as data security, energy efficiency, and vibrations. Still a need for ongoing innovation to keep up with increasingly complex environments.

On a social level, robots are reshaping the nature of work. They can reduce the chance of work-related injuries by replacing humans to do dangerous work in both peacetime and wartime. While they create new employment in robotics engineering and maintenance, they also disrupt traditional employment structures. Many of the low to medium-skilled workers will lose their jobs and difficult to find another job. It is highly unlikely to promote to a high-skilled worker due to the expensive education fees. Governments need to implement policies to ensure they can still be able to afford daily costs until they find another job.

Economically, robotics contributes significantly to productivity, efficiency, and cost reduction in industries. Robotization brings new manufacturing modes such as light-off manufacturing, which enhance output quality and enable continuous operation, therefore upgrading industrial competitiveness. Nonetheless, for small to medium companies, the price of robotization is hard to afford compared to the traditional mode. The big enterprise may use its wealth to invest in robotics and use the advantage to monopoly the customers and annex them.

In conclusion, robotics plays a critical role in the Fourth Industrial Revolution by massively increasing efficiency, transforming manufacturing modes, and reducing work-related injuries. However, these benefits are accompanied by significant challenges that must be overcome through strategic planning, policymaking, and continuous improvement. Robotics will inevitably participate in our lives; it is important to balance technological advancement with ethical responsibility. Future research should be focused on the impact of robotics on the labour market over the long term, especially in developing countries.

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