STUDY OF EMERGING TECHNOLOGY IN ROBOTICS: AN ASSESSMENT

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Abstract: The automation sector is always developing emerging technologies that provide new chances to enhance product outcomes, expand quality accessibility, and cut costs. A few technological advancements in the 21st century, such as robotics and artificial intelligence, have the potential to automate a variety of jobs in the automation sector, such as manufacturing operations and product assembly. Research has shown that robots may enhance medical outcomes, save expenses, and boost product delivery efficiency. This study employs an exploratory research approach with a theoretical framework based on a survey of the literature to explore the facts and findings of technology and its applications in different industries.

Keywords: Automation Industry, artificial intelligence, Robotics technology.

I. INTRODUCTION

Many frameworks and projects for the growth of manufacturing technology have been presented globally during the last ten years, including in the US, China, Russia, India, and various EU member states. Industry 4.0, which was first presented as a strategic goal in Germany in 2011 and has subsequently gained worldwide adoption, is an early example of such a framework [1]. The development of cyber-physical systems (CPS), which are "physical and engineered systems whose operations are monitored, coordinated, controlled and integrated by a computing and communication core," is the main emphasis of Industry 4.0, commonly referred to as the "Fourth Industrial Revolution." It has arisen as a response to the digitalization of manufacturing as well as a technical and economic force motivating the development of industrial digitization technologies [2].

Manufacturing technologies (such as robotics and other automated systems) and the platforms, infrastructures, and systems that enable coordinated control and connection between them—collectively referred to as the "internet of things" (IoT)—are central to the vision of Industry 4.0 in the manufacturing context. In this paper, we examine the adoption of IoT-based technologies, such as cloud computing systems, simulation systems, and data infrastructures, and robotic technologies, including industrial and service robots, in the context of Industry 4.0. Specifically, we investigate whether these technologies have shown appreciable progress from previous capacities and if, seven or eight years after the advent of Industry 4.0, they are capable of delivering their anticipated advantages. Our research primarily focuses on Germany because the country is the origin of the term "Industry 4.0" and has the highest relative presence of the term in normative and legal state documents among other countries that have adopted it. This suggests that Germany has provided strong governmental and legislative support for the strategy. Furthermore, with 309 industrial robots per 10,000 workers, Germany has the greatest robot density among its European rivals [1] [3].

Robotics innovations are always pushing the limits of what robots can do and how they interact with their environment. Robots are now able to learn from experience, adjust to changing circumstances, and make judgements instantly thanks to developments in artificial intelligence and machine learning. Robots are now able to learn from mistakes and improve their performance thanks to reinforcement learning in particular [4].

Collaborative robots, or Cobots, are machines designed to collaborate with people and support them in a

variety of activities. Physical boundaries are not necessary for these robots to perform securely in shared workplaces since they are outfitted with sensors and safety measures [4].

Autonomous Vehicles: Thanks to advancements in robotics and artificial intelligence, autonomous vehicles—such as drones and self-driving cars—are becoming more and more advanced. These cars have the power to completely transform sectors of the economy including logistics, transportation, and agriculture [5].

The field of soft robotics focuses on creating flexible and pliable robots that can interact with people and fragile things in a safer and more efficient manner. Applications include grippers for handling delicate objects, medical gadgets, and prostheses.

Swarm robotics: Coordinating many robots to accomplish a shared objective is known as swarm robotics. Swarm robots are inspired by the cooperative behaviour of social insects like ants and bees. They may cooperate to explore new areas, carry out search and rescue operations, and even construct buildings on their own [6].

Robotics Inspired by Biology: Scientists studying robotics are increasingly looking to biology for inspiration when creating robots that imitate the composition and actions of biological things. Robots that imitate the agility and mobility of animals like cheetahs and birds are examples, as are those with soft muscles inspired by the movement of octopuses and squids.

II. RELATED WORK

A system known as the Internet of Things (IoT) depends on a collection of actual items communicating with one another on their own. IoT is an evolving global information architecture based on the Internet that makes it easier to interchange products and services. The Internet of Things will primarily focus on four areas: (1) logistics and transportation; (2) healthcare; (3) smart environments (home, workplace, and plant); and (4) personal and social [7].

The majority of robots and robotics in general had industrial uses between the 1960s and the 1990s. Streamlining production at industrial facilities was the main obstacle. These days, robots are getting more and more commonplace and have remarkable strength and powers. Humans are assisted, accompanied, and nursed by service robots. Both in healthcare and in daily life, robots will be helpful. Many novel service robot applications are developed by service industries. In order to do given jobs, service robots share the human environment and display basic cognitive behaviour. That level of autonomy, system complexity, and human-cantered applications are all to be expected [8].

Service robots will be more important in the future. A new use for human-cantered technology and the service economy is service robots. According to recent research, the emergence of personal assistant and home robots portends a collaborative society between humans and robots. Figure 6 presents a three-phase robotics paradigm. The main stages of robotics are shown in this model [9].

It is anticipated that the number of Machine-to-Machine (M2) communication devices would increase gradually until 2020. By 2020, there should be around 50 billion intelligent items that can communicate with one another and work together with people. The Internet of Things (IoT) age will be ushered in by this advancement. The increasing prevalence of robots in many daily activities is contributing to the continuing Internet of Intelligent Things (IoT) revolution, making IoT-assisted robotics applications a genuine possibility in the near future [10].

Many benefits, including improved productivity, safety, convenience, and health as well as more data, information, and knowledge that can be used by individuals and organisations, are being promised by new technologies. Potential drawbacks include threats to individual privacy, exaggerated expectations, and mind-bogglingly sophisticated technology [11].

III. AI TECHNOLOGY USED IN ROBOTICS

Computer Vision: Using OpenCV and Convolutional Neural Networks, computer vision is a fundamental robotics technique. Considerable progress has already been made in robotics and computer vision. NLP, or natural language processing, Voice instructions to a robot may be implemented using NLP. For instance, NLP and robotics are significant fields of study. Understanding Natural Language for Interaction with Human-Robots [12].

Edge Computing: Today's most popular architecture is the cloud. By contrast, Edge Computing applies analytics closer to the source of the data rather than at the centralised nodes. AI is complimentary at the Cloud and Edge. Therefore, edge computing processes data close to its source, or at its place of origin, as opposed to sending it to the cloud. This often indicates that the gadget may not be connected all the time. AI and Edge are being employed in sophisticated robotics applications, such as autonomous vehicles and drones.

Complicated Occurrence Process: In order to react to an occurrence as fast as feasible, Complex Event Processing (CEP) aggregates input from many streaming sources to infer a more complicated event. A Change of State is a description of an occurrence. A complex event is made up of one or more occurrences. An automobile's airbag deployment, for instance, is a complicated event that depends on real-time input from many sensors. Robotics ex Event-Processing in Autonomous Robot Programming makes advantage of this concept [13].

AI and Transfer Learning: Transfer learning is a method that transfers information from one issue solved to another. For instance, an orange may be identified using the same model that was used to identify apples. Transfer learning allows a pre-trained model to be used to a different (similar) image recognition task. Just the last few layers of the new model are trained, saving time and money in comparison. When a model is trained in the cloud and deployed on the edge, transfer learning is applicable to mobile devices for inference at the edge [13].

AI Hardware Acceleration: While hardware acceleration at the microprocessor level is still in its infancy, robotics will likely benefit greatly from it as well [14].

Reinforcement Learning: Robotics can develop and simulate complex and challenging behaviours with the help of reinforcement learning. There is enough potential in the interaction between the disciplines to draw comparisons with the relationship between mathematics and physics. Further insights are provided by an overview of Reinforcement Learning in Robotics [15].

GANs: Generative Adversarial Networks (GANs) are a useful tool for improving data quality, particularly picture data. This may be useful in situations where training requires comparable data that is not readily accessible or when data is difficult to get. Thus, GANs might be used to robotics training.

Mixed Reality: Another newly-emerging field is Mixed Reality. Its primary use is in the area of PbD, or programming by demonstration. PbD uses a mix of real and virtual items to develop an algorithmic prototyping method.

Emotion Research - Affective Computing: The study and creation of tools and systems capable of identifying, deciphering, processing, and simulating human affects (emotions) is known as affective computing. This area is multidisciplinary and encompasses computer science, cognitive science, and psychology. Rosalind Picard's 1995 work on emotional computing served as the impetus for the current field of study. The potential for AI to mimic empathy serves as one of the research's driving forces [16].

IV. APPLICATION OF ROBOTICS TECHNOLOGY

Robotics technology finds application across various industries and sectors, contributing to increased efficiency, productivity, and safety. Here are some key areas where robotics technology is applied [4] [10]:

1. Manufacturing: Robotics has revolutionized manufacturing processes, particularly in industries such as automotive, electronics, and consumer goods. Robots are used for tasks such as assembly, welding, painting, material handling, and quality inspection, leading to higher precision, consistency, and throughput.
2. Healthcare: Robotics technology is increasingly being adopted in healthcare for tasks such as surgery, rehabilitation, patient monitoring, and logistics. Surgical robots enable minimally invasive procedures with greater precision and reduced recovery times, while robotic exoskeletons assist patients with mobility impairments in rehabilitation.
3. Logistics and Warehousing: With the rise of e-commerce, robotics plays a crucial role in logistics and warehousing operations. Autonomous mobile robots (AMRs) and automated guided vehicles (AGVs) are used for goods transportation, picking, packing, and inventory management, improving efficiency and order fulfilment speed.
4. Agriculture: Robotics technology is transforming agriculture through the use of drones, autonomous tractors, and robotic harvesters. These robots help farmers monitor crops, apply pesticides and fertilizers more precisely, and harvest crops efficiently, leading to increased yields and reduced labour costs.
5. Construction: In construction, robots are employed for tasks such as bricklaying, concrete pouring, demolition, and site inspection. Robotic construction equipment improves safety by reducing the need for humans to perform hazardous tasks and accelerates project timelines through automation.
6. Service and Hospitality: Robots are increasingly being deployed in service industries such as hotels, restaurants, and retail stores. Service robots greet guests, deliver room service, and assist with customer inquiries, enhancing the guest experience and freeing up human staff to focus on more complex tasks.
7. Defence and Security: Robotics technology plays a critical role in defence and security applications, including surveillance, reconnaissance, bomb disposal, and border patrol. Unmanned aerial vehicles (UAVs) and unmanned ground vehicles (UGVs) are used for remote monitoring and response in hazardous environments.
8. Education and Research: Robotics technology is used in educational institutions and research laboratories to teach robotics principles, conduct experiments, and develop new robotic systems. Educational robots provide hands-on learning opportunities for students of all ages, fostering interest in science, technology, engineering, and mathematics (STEM) fields.
9. Environmental Monitoring and Exploration: Robots are employed for environmental monitoring, exploration, and disaster response in harsh or inaccessible environments. Autonomous underwater vehicles (AUVs) and unmanned aerial vehicles (UAVs) are used to study marine ecosystems, map terrain, and assess disaster damage.
10. Personal and Domestic Use: Robotics technology is increasingly finding its way into homes for tasks such as vacuuming, lawn mowing, and entertainment. Robotic vacuum cleaners, lawnmowers, and pet feeders automate household chores, while social robots provide companionship and entertainment for users.

These are just a few examples of the diverse applications of robotics technology across different industries and sectors. As technology continues to advance, we can expect to see even greater integration of robotics into various aspects of our lives.

V. CHALLENGES AND LIMITATIONS

Automated procedures are becoming more and more necessary. According to Fortune Business Insights, by 2028, the industrial robot industry is expected to grow to $31.3 billion. The potential financial and

production advantages of robot deployment are becoming more and more apparent to manufacturers. Industrial robots do have certain disadvantages, however. These are a few of the most typical restrictions they have, along with recommendations on how makers might get around them [17].

AFFORDABILITY

Industrial robots often have a high initial cost, as well as ongoing setup and configuration expenses. The necessity for extra components and future maintenance expenses must also be taken into account by manufacturers. Similar to this, the robotics industry is continually changing, and new devices are always coming out. Certain businesses, particularly smaller ones, may find it challenging to make frequent investments in new robots because they risk going bankrupt while attempting to stay up to date with market trends. Industrial robots, however, may assist producers in cutting expenses in a number of ways. By optimising work, they may lower manufacturing costs and boost revenues. Robots are more likely to provide a rapid return on investment if they have a well-defined financial plan and investment strategy. Purchasing reconditioned robots is another wise move. Used robots are still functional and efficient, and they usually cost half as much as new ones.

PRIVACY

Industrial robots have long been thought to be hazardous in manufacturing settings. And for good reason—they are heavy, massive pieces of machinery with high velocity. Older devices are more vulnerable to hazardous collisions and mishaps since they even lack the sensory capacity to identify persons in close proximity. Because of this, a lot of manufacturers use cages or partitions to keep the robots and their human coworkers apart.

Safety has lately risen to the top of the industrial automation priority list, mostly due to the emergence of collaborative robots—smaller, lighter machines designed especially to operate with people. More regulations have been put in place for cobots as well as large industrial robots. While much effort remains to be done to attain comprehensive production safety, there is no doubt about the direction of advancement. It is well acknowledged that the use of new technology to improve human safety includes presence detection systems, light curtains, and laser scanners. Conducting a customised risk assessment of each manufacturing line and providing staff with accident response training is another smart practice for manufacturers.

MORE IMPOSSIBLE TO FORM

Employing skilled technicians and programmers to supervise robot installation is necessary for businesses since industrial robots need specialised programming and training to carry out jobs. Furthermore, when new software is created or robots are introduced to the market, even seasoned employees may need to refresh their knowledge. A robot that has been improperly programmed may malfunction and endanger those around.

But a new approach to robot training has emerged recently: low-code, or no-code, programming. Employees without coding expertise may setup a robot utilising drag-and-drop user interfaces and visual modelling. Because low-code and no-code platforms are so user-friendly, robots may be programmed to carry out many jobs simply by modifying their arm. Companies may now save time, money, and space by having someone without technical expertise make a simple modification instead of using many robots as they formerly did.

With 84% of US, UK, Canadian, and Australian businesses using low-code development platforms to minimise coding requirements, the low-code and no-code platform trend is growing. It has been shown that industrial robots expedite firms' return on investment, reduce labor-intensive tasks for humans, and maximise output. They are not without restrictions, however. They demand large investment and maintenance expenditures, are more difficult to train than people, and present safety risks. Manufacturers have good reason to be concerned about them, but they may be solved with careful planning and

innovative technology.

UPGRADE AND REPAIR

One of the drawbacks of industrial robots and automation is maintenance and repair. Robotic systems may be difficult and need specialised knowledge to operate and repair, despite their numerous benefits, which include lower labour costs and higher production. Numerous parts, including software, electrical, and mechanical ones, make up robotic systems. Regular maintenance is necessary for every component to guarantee the system's dependability and effectiveness. For instance, to stop wear and damage, mechanical parts like motors, gears, and bearings need regular lubrication, inspection, and replacement. Age, wear, and climatic conditions may also cause electrical components including power supplies, controllers, and sensors to malfunction over time. In order to assure correct readings, maintenance of these components usually include testing, replacing, and calibrating malfunctioning components. Another essential component of robotic systems that has to be updated and maintained on a regular basis is the software. Compatibility problems, security flaws, and software bugs may lead to system malfunctions or reduce performance. The system may be kept safe and secure with regular software upgrades and maintenance. Robotic system repair may be a difficult, drawn-out operation that calls for specific knowledge. Because there might be a lot of different components involved, figuring out what caused a breakdown or malfunction can be difficult. Furthermore, certain tools or equipment that are hard to come by or need specialised expertise could be needed to fix a system.

LIMITED ABILITY TO CHANGE

One of the drawbacks of industrial automation and robots is their lack of flexibility. Although robotic systems have numerous benefits, they may not be able to execute jobs requiring complicated decision-making or adapt to changing situations.

Typically, robotic systems are created and configured to carry out certain tasks in a particular manner. For instance, a robot in an assembly line may be designed to carry out the same operation over and over, like welding seams or tightening fasteners. This method may be very dependable and efficient, but it can also restrict the system's capacity to change and adapt. In many industrial applications, robots can make sophisticated decisions or adjust to changing situations. For instance, a robot in a warehouse would have to manoeuvre past obstructions or modify its course when the surroundings change. Programming such jobs may be difficult, and advanced algorithms and sensors may be needed. The challenge of reprogramming or reconfiguring robotic devices is another drawback. Modifying the hardware setup or programming of the system might be laborious and need specialised knowledge. This may make it more difficult for the system to adjust to shifting circumstances or take on additional duties. Some of these constraints have been addressed in recent years by developments in artificial intelligence and machine learning. Robots may be able to learn from and adapt to new activities and situations thanks to these technologies, which may eliminate the need for intricate programming and hardware reconfiguration.

VI. FUTURE RECOMMENDATION

Looking into the future, here are some recommendations for further advancements and applications of robotics technology:

Enhanced AI and Machine Learning Integration: Further integrate artificial intelligence and machine learning algorithms into robotics systems to enable more autonomous decision-making and adaptive behavior. This will improve robots' ability to learn from their environment, make predictions, and optimize performance over time.

Human-Robot Collaboration: Focus on developing robots that can seamlessly collaborate with humans in shared workspaces, combining the strengths of both to enhance productivity and safety. This includes improving human-robot interaction interfaces, safety features, and task allocation algorithms.

Robots for Healthcare Assistance: Continue developing robots for healthcare applications, such as patient care, telemedicine, and medical logistics. These robots can assist healthcare professionals in tasks such as patient monitoring, medication delivery, and physical therapy, particularly in aging populations where there is a growing demand for healthcare services.

Autonomous Vehicles for Transportation and Delivery: Invest in the development of autonomous vehicles for transportation and delivery services, including self-driving cars, trucks, drones, and delivery robots. These vehicles can improve transportation efficiency, reduce traffic congestion, and lower carbon emissions while providing convenient and reliable delivery options for consumers.

Robots for Hazardous Environments: Develop robots specifically designed for working in hazardous environments such as nuclear facilities, offshore oil rigs, and disaster zones. These robots should be able to withstand extreme conditions, perform complex tasks autonomously, and assist in disaster response and recovery efforts while minimizing human exposure to danger.

Personalized and Assistive Robotics: Design robots that cater to individual needs and preferences, particularly in areas such as rehabilitation, eldercare, and disability assistance. These robots should be customizable, adaptable, and capable of providing personalized support to users based on their unique requirements.

Ethical and Responsible Robotics: Prioritize the development of ethical and responsible robotics technologies, including robust safety mechanisms, privacy protections, and fairness considerations in AI algorithms. This will help mitigate potential risks and ensure that robotics technologies are used in ways that benefit society as a whole.

Interdisciplinary Collaboration: Encourage collaboration between robotics researchers, engineers, policymakers, ethicists, and end-users to ensure that robotics technologies address real-world challenges effectively and responsibly. Interdisciplinary approaches can lead to innovative solutions that take into account diverse perspectives and stakeholder needs.

Sustainable Robotics Solutions: Develop robotics solutions that prioritize environmental sustainability, including energy-efficient designs, renewable energy sources, and recyclable materials. By minimizing resource consumption and environmental impact, robotics technologies can contribute to a more sustainable future.

Education and Outreach: Invest in robotics education and outreach initiatives to foster interest and expertise in robotics among students, educators, and the general public. This includes providing access to robotics resources, training programs, and hands-on learning opportunities to inspire the next generation of roboticists and ensure that society is prepared to harness the full potential of robotics technology.

By pursuing these recommendations, we can continue to advance the field of robotics and unlock new opportunities to improve lives, enhance productivity, and address global challenges.

VI. CONCLUSIONS

Enhancing autonomous decision-making and adaptive behaviour in robotics systems requires the integration of machine learning and artificial intelligence technologies. This will enhance robots' capacity for environmental learning, prediction, and long-term performance optimisation. Enhancing interaction interfaces, safety features, and job allocation algorithms are the main goals of human-robot cooperation. Robots are being created to help in healthcare, transportation, and dangerous settings, making delivery dependable and efficient. Individual requirements are being met via the construction of personalised and helpful robots, especially in the areas of rehabilitation and disability support. Prioritisation is being given to ethical and responsible robotics technology, including strong privacy safeguards, safety features, and fairness considerations in AI algorithms. In order to efficiently and ethically handle real-world situations, interdisciplinary cooperation is encouraged. Energy-efficient designs and renewable energy sources are

among the environmental sustainability factors that sustainable robotics solutions prioritise. The field of robotics can progress and the next generation of roboticists may be inspired by investing in outreach and education programmes in robotics.

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