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Machine Learning in Robotics

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ABSTRACT
The field of robotics is heterogeneous and multi-disciplinary. The community of robotics consists of robotics engineers, biologists, computer scientists, mathematicians, to mention a few. The goal of robotics is to create intelligent machines (called robots) that behave and think like humans. Machine learning in robots makes them more efficient with self-learning ability to recognize the new objects. The rapidly advancing capabilities of machine learning are helping robots learn specific tasks. With the current rise of humanoid robots in robotics research, the need for machine learning in robotics has grown significantly. The paper provides various uses of machine learning in robotics.

KEYWORDS: *robots, robotics, machine learning, deep learning, artificial intelligence*

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INTRODUCTION
A robot is a system that contains sensors, control systems, power supplies, and software, all working together to perform a task. An autonomous robot has a basic body structure (the chassis), sensors, a central control system (microprocessor), actuators (motors), a power supply and a software to control its behavior. It functions as an intelligent machine, meaning that, it can be programmed to take actions or make choices based on input from sensors. In jobs with repetitive and monotonous functions, robots might even completely replace humans. Robotics and autonomous systems is regarded as the fourth industrial revolution [1].

Robots are commonly used in dangerous environments where humans cannot survive situations such as defusing bombs, finding survivors in unstable ruins, welding, and exploring mines and shipwrecks. Today, robots perform important functions in homes, hospitals, industries, military institutions, education, entertainment, and outer space. They are designed to perform a wide variety of programmed tasks. Robots can support, assist, and extend the services of healthcare professionals. Robots are rapidly changing the face of manufacturing. They may help manufacturers increase precision, repeatability, and productivity [2].

Both robotics and machine learning (ML) are important components of artificial intelligence (AI). The history of ML is tightly interwoven with the history of AI. AI and ML are establishing the door to entirely new automation possibilities. The relationship between AI and machine learning is illustrated in Figure 1 [3]. Earlier robots were developed without any artificial intelligence (AI) to perform only repetitive tasks. Today, AI in getting integrated into robots to develop the advanced level of robotics that can perform multiple tasks and also learn new things with a better perception of the environment. Robots are developed and trained through machine learning in order to improve robotics performance.

WHAT IS A ROBOT?
The word "robot" was coined by Czech writer Karel Čapek in his play in 1920. Isaac Asimov coined the

term "robotics" in 1942 and came up with three rules to guide the behavior of robots [4]:

1. Robots must never harm human beings;
2. Robots must follow instructions from humans without violating rule 1,
3. Robots must protect themselves without violating the other rules.

Robotics has advanced and taken many forms including fixed robots, collaborative robots, mobile robots, industrial robots, medical robots, police robots, military robots, officer robots, service robots, space robots, social robots, personal robots, and rehabilitation robots [5,6]. Robots are becoming increasingly prevalent in almost every industry, from healthcare to manufacturing.

Although there are many types of robots designed for different environments and for different purposes/applications, they all share four basic similarities [7]: (1) All robots have some form of mechanical construction designed to achieve a particular task; (2) They have electrical components which power and control the machinery; (3) All robots must be able to sense its surroundings; a robot may have light sensors (eyes), touch and pressure sensors (hands), chemical sensors (nose), hearing and sonar sensors (ears), etc. (4) All robots contain some level of computer programming code. Programs are the core essence of a robot since they provide intelligence. There are three different types of robotic programs: remote control, artificial intelligence, and hybrid. Some robots are programmed to faithfully carry out specific actions over and over again (repetitive actions) without variation and with a high degree of accuracy. Some advantages and disadvantages of robots are shown in Figure 2 [8].

Robotics evolved to allow human- or animal-like functions to be carried out by machines, with greater strength, speed, and accuracy, in a roughly human- or animal-shaped machine. Early robots were simple mechanical automated machines. Modern robots employ microprocessors and computer technology. They can be programmed and "taught" to perform certain tasks. They are taking on more "human" traits such as sensing, dexterity, remembering, and trainability.

BACKGROUND ON MACHINE LEARNING

Machine Learning is a branch of artificial intelligence that helps in building automated systems that can learn by themselves. It may be regarded as the study of computer algorithms that can improve through experience and by the use of data. It is the process of training an AI model to make it intelligent enough to perform specific tasks. All machine-learning technologies basically involve taking in data, train a model on that data, and then use the derived model to make predictions on new data. Training a model is a learning process where the model is exposed to unfamiliar data at each step and is asked to make predictions. The training is terminated when the model's predictions reach a point at which the error does not improve [9]. At that stage, the machine no longer needs continuous time-intensive teaching from humans. Learning would occur as a consequence of continuous use. Machine learning thrives on abundant data and leans toward pattern recognition. It is self-learning in nature and becomes "smarter" over time.

The majority of machine learning scenarios generally fall into three categories: supervised learning, unsupervised learning, or reinforcement learning. The supervised learning task is to predict some additional aspect of an input object. It is usually characterized by using explicit examples with labels that the system should use to learn to predict labels of previously unseen data. Supervised learning problems, such as regression and classification are more common in robotics applications. In unsupervised learning, the model is provided with unlabeled data and asked to segment the elements into groups. The goal of unsupervised learning is to find useful representations of data based on regularities of data without labels. Reinforcement learning (RL) enables a robot to autonomously discover an optimal behavior through trial-and-error interactions with its environment. It embraces the full complexity of these problems by requiring both interactive, sequential prediction as in imitation learning as well as complex reward structures.

Machine learning has been used successfully in numerous other applications, from drones to assistive robots. It is currently identified as one of the major research areas in robotics. The key application of machine learning in robotics is perception of the environment, i.e., enable the robot to react appropriately to the input from cameras and sensors or recognize objects in the surrounding environment. Machine learning mainly trains a robot to recognize the wide-ranging objects visible in different shapes, sizes , and various scenarios. It helps robots interact dynamically and avoid obstacles. It is capable of improving the efficiency in various fields such as pick and place operations, drone systems, manufacturing assembly, and quality control. It can be used to translate text into another language instantaneously. In a manufacturing setting, machine learning is preventing factory machine breakdowns.

APPLICATIONS OF ROBOTS

Robots can perform feats no current machines can accomplish. Robotics systems are being applied to

real-world situations. Machine learning is widely used in diverse fields such as investment, banking and finance, information technology, media and entertainment, gaming, healthcare, military, and automotive industry. The breadth of current and potential applications of machine learning is vast. The powerful combination of robotics and machine learning opens the door to completely new possibilities. We are yet to reach the full potential of robotics and machine learning, but the current applications are promising. Some of these applications are discussed as follows.

- **Industrial Robots:** This kind of robots are utilized in industries for diverse purposes. Machine learning is increasing the capabilities of industrial robot systems. It will have a transformative impact on industrial robots. It will continue to push the boundaries of what is possible with industrial robotic automation for decades to come. Industrial robots trained by machine learning become more aware of people and surroundings. They can assist companies to get things done with fewer errors. Some industrial robots combines *computer vision*, AI, and *sensors*. There are numerous advantages for combining AI, industrial robotics, and machine learning in one system for manufacturing production. Such combination reduces programming time and increases productivity and uptime as a result of predictive maintenance. A growing number of businesses worldwide are waking up to the potentially transformative capabilities of machine learning on robots. Major companies such as Google, Tesla, Mercedes Benz, Nissan, and Ford that have invested heavily in machine learning.
- **Warehouse Robots:** Warehouse needs manpower to manage the huge amount of inventory. Robots can be trained to handle such inventories, reducing the human workforce in performing such repetitive tasks. A typical warehouse robot is shown in Figure 3 [10].
- **Assistive Robots:** The healthcare industry is taking advantage of machine learning methodologies and applying them to robotics. Assistive robot is a device that can process information and implement actions that can help people with disabilities. Movement robots give you a therapeutic or diagnostic benefit. A robotic arm is a recent example of machine learning-based robotic assistive technologies.
- **Surgical Robots:** Potential applications of machine learning in the surgical field are many. Automation works well for routine processes. To mitigate avoidable errors, automation is now being considered as a potential tool for improved surgical workflow. It can potentially reduce the length of surgical procedures, minimize surgeon fatigue, and decrease hospital costs. This is particularly important in remote operations or telesurgery, where any lag between human surgical commands and robot responses can cause complications. Through training, robots will be capable of doing life-saving surgical procedures and different medical approaches. When surgeries are performed by trained robots, they would perform the surgery with the utmost precision. Machine learning can be used to evaluate surgeon performance in robot-assisted surgery. Figure 4 presents a typical use of surgical robot [11].

BENEFITS AND CHALLENGES

The advantages of robotics include heavy-duty jobs with precision and repeatability.

Through machine learning, robotics applications may have the identical potential as people to get smarter through experience. For example, there is one doctor specialist for every 10,189 individuals in India. This is where machine learning comes in. Machine Learning systems can be developed for healthcare services, what can change the diagnosis and treatment of diseases and guarantee that patients get the correct treatment at the right time.

Robotics has faced numerous challenges, notably questions regarding efficacy, safety, and cost-effectiveness. Traditional robots have some disadvantages due to their stiffness and rigidity. Robotics challenges can inspire and motivate new machine learning research as well as being an interesting field of application of standard ML techniques.

CONCLUSION

Progress in AI and machine learning robotics is taking rapidly. Machine learning is poised to disrupt almost every sector conceivable. It will push robots to do physical work at their best. It will accelerate the processing power of the automation system used in various technologies. It will occupy an increasingly pivotal position in the creation of the next generation of commercial and industrial systems Researchers around the world are using AI, ML, computer vision, and other related technologies to develop robots that mimic the human brain.

Becoming a machine learning professional is a good idea. Machine Learning is one of the best lucrative career of the 21st century due to plenty of available job opportunities with a high-paying income. Pursuing a graduate degree in machine learning provides students with the core a state-of-the-art opportunity

knowledge needed to succeed in the field of artificial intelligence. It has been estimated that 58 million new jobs will be available in the AI sector in 2022, affording you with a wide variety of opportunities [12]. More information about the use of machine learning in robotics can be found in the books in [13,14] and the following journals devoted to robot-related issues:

- Robotica
- Robitics and Autonomous Systems
- Advanced Robotics
- Journal of Robotic Systems
- Journal of Robotics
- Journal of Robotic Surgery
- Journal of Intelligent & Robotic Systems
- Journal of Mechanisms and Robotics-Transactions of the ASME
- Industrial Robots
- Intelligent Service Robotics
- IEEE Journal on Robotics and Automation
- IEEE Robotics & Automation Magazine
- IEEE Robotics and Automation Letters
- IEEE Transactions on Robotics
- International Journal of Medical Robotics and Computer Assisted Surgery
- International Journal of Robotics Research
- International Journal of Social Robotics
- International Journal of Humanoid Robotics

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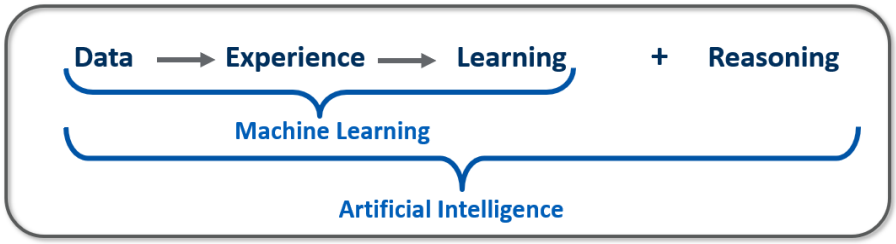

Figure 1 The relationship between AI and machine learning [3].

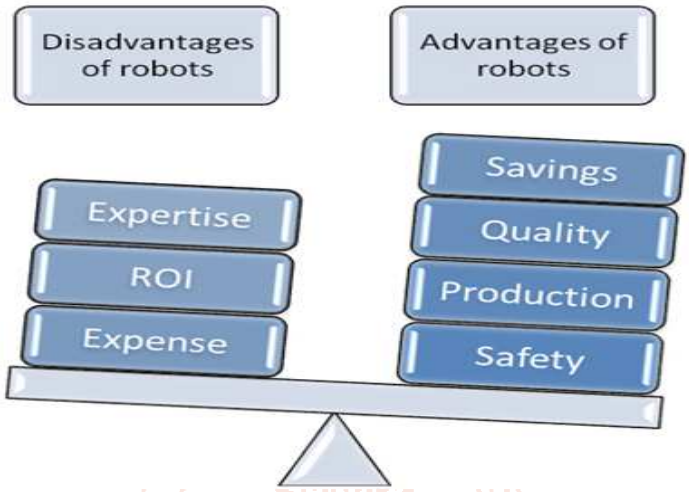

Figure 2 Some advantages and disadvantages of robots [8].

Figure 3 Robotics in warehouse [10].

Figure 4 A typical use of surgical robot [11]