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A Primer on Robotics

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ABSTRACT

Robotics is the discipline of designing and constructing machines, called robots.

A robot is an autonomous mechanical device that is designed to sense its environment, carry out computations to make decisions, and perform actions like humans in the real world. It is a system that contains sensors, control systems, power supplies, and software, all working together to perform a task. Robotics is a relatively young field with highly ambitious goals. It is producing a huge range of devices, from autonomous vacuum cleaners to military drones. This paper is a primer of robotics and robots.

KEYWORDS: *robots, robotics, artificial intelligence, applications*

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INTRODUCTION

Popular interest in robotics has increased in recent years. Robots are already a part of our lives. They are becoming more and more common in our society and more integrated into our lives. This is due to the fact that they are becoming smarter, smaller, cheaper, faster, more flexible, and more autonomous than ever before, largely due in part by incorporating artificial intelligence. Robotics technology has been implemented in a variety of fields including medicine, elderly care, rehabilitation, education, home appliances, search and rescue, car industry and more. Robotics constitutes one of the most exciting fields of technology today, presenting new applications for autonomous systems that can impact everyday life. Today, there are robots that can autonomously sense, reason, plan, act, move, communicate, and collaborate with other robots. The robotics revolution is going to change us as humans [1,2].

WHAT ARE ROBOTS?

The word "robot" was coined by Czechriter 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 and later added the zeroth law [3]:

- Law 0: A robot may not injure humanity or through inaction, allow humanity to come to harm.
- Law 1: Robots must never harm human beings,
- Law 2: Robots must follow instructions from humans without violating rule 1,
- Law3: Robots must protect themselves without violating the other rules.

Robots are becoming increasingly prevalent in almost every industry, from healthcare to manufacturing. Figure 1 indicates that robotics is one of the branches of artificial intelligence.

Although there are many types of robots designed for different environments and for different purposes/applications, they all share four basic similarities [4]: (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.

TYPES OF ROBOTICS

Robotics can take on a number of forms, leading to many types of robots. They are designed for different environments and various applications. The commonly used types of robots are the following [4-6]:

- *Humanoid Robots:* These are robots that mimic human behavior. They usually perform human-like activities (like walking, running, jumping, and carrying objects).
- *Autonomous Robots:* These operate independently of human operators. They require no human supervision. An example of an autonomous robot is the vacuum cleaner, shown in Figure 2 [7].
- *Teleoperated Robots:* These are semi-autonomous bots that allow human control from a safe distance using wireless networks.
- *Collaborative Robots:* These robots (known as cobots) are flexible and easily reprogrammable on the fly. They can learn complex tasks and then act as a collaborator with the skilled workers. They are capable of avoiding unwanted collisions and they can recognize when they have bumped into something. Collaborative robots may be regarded as the friendly face of workplace automation.
- *Drones:* DRONE (Dynamic Remotely Operated Navigation Equipment) is commonly referred as unmanned aerial vehicle (UAV). Drones are equipped with all the software, sensors, and hardware that a farmer will need to check the health of crop and survey farmland. A drone typically consists of propulsion and navigation systems, GPS, sensors, infrared cameras, software, and programmable controllers. Drones are flying robots, a type of robots, that are poised to proliferate in certain commercial sectors. Drones can help utility crews after a storm by quickly and safely identifying areas in need of repair. Drones can also help with maintenance tasks, such as surveying solar panels for damage.
- *Chatbots:* These robots carry out simple conversations such as in a customer service setting. Chatbots have empowered the banks and other financial institutions by simplifying the complex processes. We interact with Facebook Messenger bots all the time. Messenger bots are revolutionizing the small business world. Messenger bots can answer customers' questions, collect user's info, organize meetings, reduce overhead costs, and engage in other business tasks. Big companies like Walmart, Alibaba, and Amazon have been benefitting the help of bots.
- *Industrial Robots*: The most common use of robots in industry is for simple and repetitive tasks. The role of robots is becoming substantial for industrial applications. Examples of industrial robots include assembly line processes, picking and packing, welding, and similar functions. Robots can reduce risk of injury to humans in dangerous work environments.
- *Military Robots:* In the military sectors, robotic technology is being applied in many areas. More recent developments mean that military forces worldwide use robots in areas such as UAVs (Unmanned Aerial Vehicle), UGVs (Unmanned Ground Vehicle), drones, and surveillance. Military drones flying over areas of war and conflict, in hostage situations, and for natural and manmade disasters. The military also employs robots to (1) locate and destroy mines on land and in water, (2) enter enemy bases to gather information, and (3) spy on enemy troops.
- *Exploration Robots:* Robots are often used to reach hostile or inaccessible areas. A good example of exploratory robots is in space exploration. Robots can go to the planets. They can be used to explore space.
- *Entertainment Robots*: Robots can be used in entertaining audiences. Increasingly (particularly during the pandemic), people are buying robots for enjoyment. There are several popular toy robots, and there are even robot restaurants and giant robot statues.

Other types include manipulators, medical robots, agriculture robots, nanorobots, construction robots, swarm robots, domestic robots, educational robots, mobile robots, fixed robots, service robots, social robots, rehabilitation robots, underwater robots, field robots, self-driving vehicles, cloud robots, police robots, officer robots, space robots, personal robots, and sailboat robots [8].

HISTORY OF ROBOTICS

The history of robotics is a history rich with cinematic creativity, scientific ingenuity, and entrepreneurial vision. The advent of motion pictures brought to life many mythical creatures. The field of robotics has evolved over several millennia, without reference to the word *robot* until the early 20th Century. Leonardo da Vinci created many human-inspired, robot-like sketches, designs, and models in the 1500s.

The word "robot" was coined by a Czechoslovakian playwright, 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. He popularized the term robotics through many science-fiction novels and short stories. In 1954, Joseph Engleberger and George Devoe created the first robot. They were the fathers of industrial robots. Their company, Unimation, built the first industrial robot, the PUMA (Programmable Universal Manipulator Arm) in 1961. From 1966 to 1972 Shakey, the Robot, was developed at the AIC by Charles Rosen and his team. Shakey was the first mobile robot to reason its way about its surroundings and had a far-reaching influence on AI and robotics. In 1981 Japanese created Scara arm which is especially designed for product assembly. The idea of this robot is to do what human does and sony walk man was the first robot assembly. The International Space Station (ISS), coordinated by Boeing and involving nations from around the globe, is the largest and most expensive space mission ever undertaken. In 2001, the Space Station Remote Manipulator System (SSRMS), built by MD Robotics of Canada, was successfully launched to complete the assembly operations of the ISS. In 2002, a Predator UAV(unmanned aerial vehicle or drone) fired a Hellfire missile to destroy a car carrying six suspected al Qaeda operatives. This strike marked a milestone in the use of robotics in military settings. At Sandia National Laboratory's Intelligent Systems and Robotics Center, there is an ongoing development of robotic sentries, under funding from DARPA [9].

ROBOTICS ENGINEER

Although the robotic revolution is just beginning, new applications for robots are being discovered every day. As a result of this, there is a considerable need for skilled robotics engineers. Robotics engineering is a developing field that combines data analysis, engineering, and computer science. If you love working with machines and are fascinated by robots, then you may consider becoming a robotics engineer. Robotics engineer deal with the conception, design, manufacture, and operation of robots. They are responsible for designing, testing, and building robots that are productive, safe, and economical to purchase and maintain [9]. They create robots and systems to improve the efficiency, output, and safety of a wide range of tasks. Figure 3 shows a robot engineer at work [10].

Like any engineering discipline, robotics engineering requires being strong in math and sciences. This discipline has a vast range of job opportunities for graduates in robotics engineering. Robotic engineers can take jobs in manufacturing, maintenance, research of nuclear power plants, space exploration, power plant, maintenance, automobile industry, petroleum exploring places, and many other areas. Reasons for becoming a robotics engineer include using your creativity, collaboration, and high-paying job.

APPLICATIONS

More and more robots are designed for specific applications. Today, robots perform vital functions in manufacturing, homes, industries, entertainment, education, healthcare, business, customer service, security, agriculture, outer space, hospitals, and on military instillations. Common applications of robotics are presented as follows [11-13]

- *Automation:* Most robots are used in automobile industries to perform repetitive tasks. Rapid advances in technology have led to an interest in automation and robotics. Robotic automation has become one of the key areas for modern manufacturing systems. Robotic automation is applicable to virtually any industry imaginable, just as automotive, electronics, food, and manufacturing. It is used in manufacturing to change the industry landscape by increasing productivity, repeatability, and precision while protecting employees from unsafe working environments. Several economists believe employment in routine occupations has declined and automation is a wave of technological change that could lead to a structural shift in the labor market and lead to "job polarization."
- *Manufacturing:* The manufacturing sector represents the largest private industry in the United States. It is well known to be a major contributor in both economic good times and economic recessions. To boost productivity, manufacturing companies turn to advanced technology such as robotic automation. Automation refers to any technology that reduces the need for human assistance. It essentially describes mechanization, machines replacing human labor or human decision-making. It can have far-reaching consequences in manufacturing. Automotive industry is the largest user of robots

in advanced nations around the world. In particular, it is the largest customer of industrial robots. Robots are used in almost every aspect of automotive manufacturing. Robots are more efficient, accurate, flexible, and dependable on production lines.

- *Education:* There are many robots available with some keys to promoting robotics learning in the classroom. These are known as educational robots. Educational robots (also known as pedagogical robots) teaches the design, analysis, application, and operation of robots. Educational robotics can be taught from elementary school to graduate programs. They are used to allow students to pick up skills in a range of Science, Technology, Engineering, and Mathematics (STEM) disciplines. Educational robotics is considered as a means of forming the engineering thinking and creativity in schoolchildren. Educational robots enable students of all ages to become familiar with and deepen their knowledge of robotics and programming. The robots facilitate learning and introduce students to robotics at a young age. As students grow older, more advanced robots can be used that can perform more complex tasks and are more complicated to program.
- *Agriculture:* A farming robot revolution is imminent, with robots ready to roll into the fields and start replacing human workers. Robots are already roaming the fields amid farmers, performing a variety of tasks from crop-harvesting to risk management. Automation in agriculture can provide greater and smarter control to the farmers. An increasing number of companies are working on robotics innovation to develop drones, autonomous tractors, robotic harvesters, automatic watering, and seeding robots. Robots have many fields of application in agriculture. Drones can provide sustainable farming, improve yield, and increase farm productivity, and profitability. Drone technology is currently being used for a variety of applications such as monitoring, mapping, irrigation, crop inspection, spraying, and surveying entire fields. Figure 4 shows farming automation [14].
- *Healthcare:* Robots have moved from science fiction to your local hospital, where they are changing healthcare. Robots play an important role in healthcare as they can improve diagnosis, lower the number of medical errors, and improve the overall quality and effectiveness of healthcare delivery. They hold the promise of addressing major healthcare issues in surgery, diagnostics, prosthetics, physical and mental therapy, monitoring, and support. Robots can support, assist, and extend the services of healthcare professionals. In jobs with repetitive and monotonous functions they might even completely replace humans. Robots have the potential to provide assistance to healthcare providers in daily caregiving tasks. Transport, telemedicine, and service robots in healthcare promise to create a new level of quality healthcare by providing experts to patients. A specific application using the da Vinci robot for surgery is shown in Figure 5 [15].
- *Business:* Advances in automation, robotics, and artificial intelligence are revolutionizing how businesses are run. Modern robots are far more capable than their early predecessors. They have transitioned beyond the production line to see widespread use in homes, restaurants, hotels, offices, retail outlets, and hospitals. Small, medium, and large businesses have integrated robotics in order to achieve higher levels of efficiency and productivity. Businesses are increasingly adopting robots to meet different operational challenges brought about by new technologies. More and more businesses are turning to robots to help with various tasks. Businesses around the world are increasing their use of robots.
- *Space:* Commercial space robots have been designed for servicing satellites and performing construction on the moon. The goal is to allow for space-based manufacturing, which will reduce the complexity and cost of building large structures that can support human life. Some robots will effectively eliminate some of the problems that have limited our exploration of space. Robots would enable the repair and construction of simple structures being built in space. NASA's Johnson Space Center is designing the next generation of autonomous robots that will help humans explore the solar system. While autonomous robots have conducted scientific missions in the past, NASA's team is focused on advancing human space exploration. The goal is to enable human beings to visit other planets and do meaningful work there.

BENEFITS AND CHALLENGES

Robotics is the design, repair, and maintenance of robots. Robots are machines designed to perform tasks done traditionally by human beings. There are signs all around us indicating that the field of robotics is going through a major transformation

The field of robotics is facing many challenges based on its hardware and software capabilities. These challenges have to do with autonomy, navigation, new materials, applications, and social interactions. As robots become increasingly integrated into society, ethics and security will become important.

FUTURE OF ROBOTS

Robotics is a diverse industry with many variables. Its future is filled with uncertainty: nobody can predict which way. While robotic workers are now commonplace in manufacturing, the future should see increasingly adoption across food production, retail, business, construction, entertainment, hospitality, healthcare, and distribution operations.

There is no doubt that robots will play a major role in the future of the economy, both local and global. However, it is hard to predict how prevalent robots will be in upcoming years. Understanding where the field of robotics is heading is basically using our insights on the impact robots might make in the near future. Due to the incredible potential of robotic technology, application opportunities are limitless in the future. Current trends lead many people to believe they will take over the workforce in many sectors and there will be increase in demand for automation [16].

The robotics industry worldwide keeps innovating, combining artificial intelligence and vision and other sensory technologies. There are numerous predictions for the future of robotics. After decades of research, it is now possible to make predictions about the future evolution of robotics and the robotics industry. Integrating recent developments in machine learning and artificial intelligence in robotics means that we may see an increase in human-to-robot interactions in the future.

Future applications of robots will be amazing due to increasing demand, popularity, and usability. Since robotics can be applied to almost every industry, it will somewhat disrupt them. Although some challenges need to be addressed, the future of robotics is bright**.** Robotics in the future will be dominated by industries such as manufacturing, pharmaceutical, and packaging.

CONCLUSION

Robotics is design, construction, and use of machines (robots) to perform tasks done traditionally by human beings. The field is accelerating at an increasingly rapid rate and is showing no signs of slowing down. Robotics education should be compulsory since robotics is closely intertwined in our lives. Students need to learn the fundamental basic of robot programming and operation. For more information about robot and robotics, one should consult the books in [8,17-32] and the following related journals devoted to robotics:

- Robotica
- Robotics
- Robitics and Autonomous
- Robotics and Computer-Integrated Manufacturing,
- Advanced Robotics
- Autonomous Robots
- Journal of Robotics
- Journal of Robotic Systems
- Journal of Robotic Surgery
- Journal of Robotics and Mechatronics
- Journal of Intelligent & Robotic Systems
- Journal of Mechanisms and Robotics-Transactions of the ASME
- Journal of Automation, Mobile Robotics and Intelligent Systems
- Journal of Future Robot Life
- 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
- International Journal of Advanced Robotic Systems

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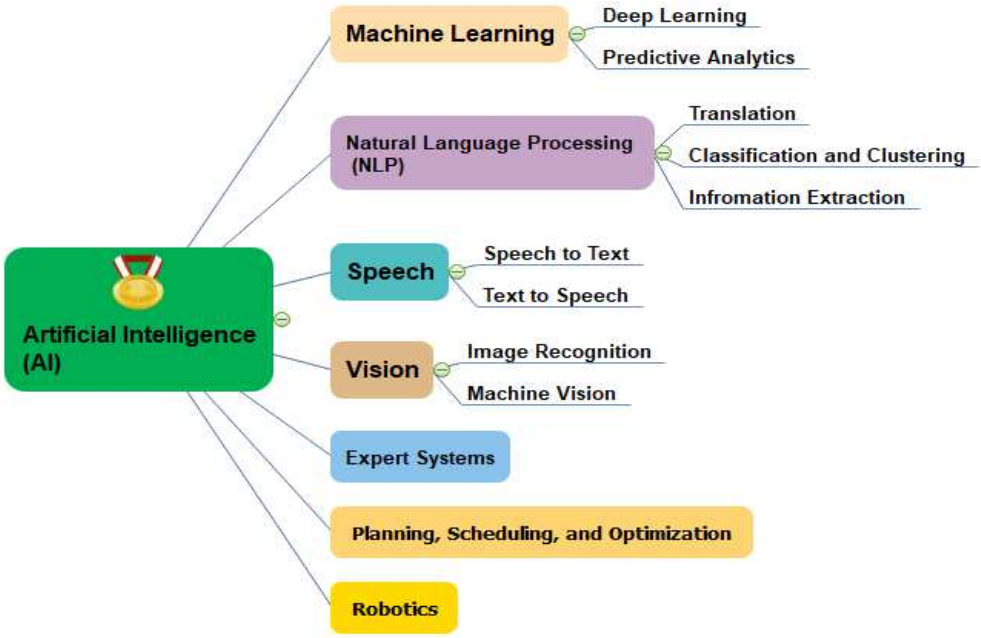

Figure 1 Robotics is one of the branches of artificial intelligence.

Figure 2 An autonomous robot is a vacuum cleaner [7].

Figure 3 A robot engineer at work [10].

Figure 4 Farming automation [14].

Figure 5 Using the da Vinci robot for surgery [15].