Unit 13 Robotics

Structure:

13.1 Introduction
Objectives
13.2 An Introduction to Robotics
Definitions
Characteristics
13.3 Contemporary Uses of Robots
Increased productivity, accuracy, and endurance
Dirty, dangerous, dull or inaccessible tasks
13.4 Robot Hardware
Sensors
Effectors
Movements
Power sources
Bits and pieces
13.5 Robotic Perception
13.6 Summary
13.7 Terminal Questions
13.8 Answers

13.1 Introduction

In the last unit, you have learnt the concept of learning and its models and the concept of discovery and analogy. In this unit you are going to learn the new concept called robotics. The Robot Institute of America defines a robot as *a programmable, multifunction manipulator designed to move material, parts, tools, or specific devices through variable programmed motions for the performance of a variety of tasks.* This definition is not very demanding; a conveyer belt with a two-speed switch would arguably satisfy it. We can define robot as *an active, artificial agent whose environment is the physical world.* The *active* part rules out rocks, the *artificial* part rules out animals, and the *physical* part rules out pure software agents, whose environment consists of computer file systems, databases and networks.

Objectives:

After studying this unit, you should be able to

- define robot and robotics
- list robotics characteristics
- explain the contemporary uses of robots
- explain various robot hardware like sensors and effectors.

13.2 An Introduction to Robotics

A robot is a mechanical or virtual artificial agent. In practice, it is usually an electro-mechanical system which, by its appearance or movements, conveys a sense that it has intent or agency of its own. The word *robot* can refer to both physical robots and virtual software agents, but the latter are usually referred to as robots. There is no consensus on which machines qualify as robots, but there is general agreement among experts and the public that robots tend to do some or all of the following: move around, operate a mechanical arm, sense and manipulate their environment, and exhibit intelligent behavior, especially behavior which mimics humans or animals.

Artificial intelligence (AI) is arguably the most exciting field in robotics. It's certainly the most controversial: Everybody agrees that a robot can work in an assembly line, but there’s no consensus on whether a robot can ever be intelligent. Like the term “robot’’ itself, artificial intelligence is hard to define. Ultimate AI would be a recreation of the human thought process -- a man-made machine with our intellectual abilities. This would include the ability to learn just about anything, the ability to reason, the ability to use language and the ability to formulate original ideas. Roboticists are nowhere near achieving this level of artificial intelligence, but they have made a lot of progress with more limited AI. Today's AI machines can replicate some specific elements of intellectual ability. Computers can already **solve problems** in limited realms. The basic idea of AI problem-solving is very simple, though its execution is complicated. First, the AI robot or computer gathers facts about a situation through sensors or human input. The computer compares this information to stored data and decides what the information signifies. The computer runs through various possible actions and predicts which action will be most successful based on the collected information. Of course, the computer can only solve problems it’s programmed to solve -- it doesn’t have any generalized analytical ability. Chess computers are one example of this sort of machine.

Stories of artificial helpers and companions have a long history, but fully autonomous machines only appeared in the 20th century. The first digitally operated and programmable robot, the Unimate, was installed in 1961 to lift hot pieces of metal from a die casting machine and stack them. Today, commercial and industrial robots are in widespread use performing jobs more cheaply or with greater accuracy and reliability than humans. They are also employed for jobs which are too dirty, dangerous or dull to be suitable for humans. Robots are widely used in manufacturing, assembly and packing, transport, earth and space exploration, surgery, weaponry, laboratory research, and mass production of consumer and industrial goods. Thus Robots are physical agents that perform tasks by manipulating the physical world. They are equipped with sensors to perceive their environment and effectors to assert physical forces on it. Robots can be put into three main categories: manipulators, mobile robots and humanoid robots.

Some modern robots also have the ability to learn in a limited capacity. Learning robots recognize if a certain action (moving its legs in a certain way, for instance) achieved a desired result (navigating an obstacle). The robot stores this information and attempts the successful action the next time it encounters the same situation. Again, modern computers can only do this in very limited situations. They can't absorb any sort of information like a human can. Some robots can learn by mimicking human actions. In Japan, roboticists have taught a robot to dance by demonstrating the moves themselves. Some robots can **interact socially**. Kismet, a robot at M.I.T's Artificial Intelligence Lab, recognizes human body language and voice inflection and responds appropriately. Kismet's creators are interested in how humans and babies interact, based only on tone of speech and visual cue. This low-level interaction could be the foundation of a human-like learning system.

Robotics are based on two *enabling technologies*: Telemanipulators and the ability of numerical control of machines. *Telemanipulators* are remotely controlled machines which usually consist of an arm and a gripper. The movements of arm and gripper follow the instructions the human gives through his control device. First telemanipulators have been used to deal with radio-active material. *Numeric control* allows to control machines very precisely in relation to a given coordinate system. It was first used in 1952 at the MIT and led to the first programming language for machines (called APT: Automatic Programmed Tools). The combination of both of these techniques led to the first programmable telemanipulator. The first industrial robot using these principles was installed in 1961. These are the robots one knows from industrial facilities like car construction plants. The development of *mobile robots* was driven by the desire to automate transportation in production processes and autonomous transport systems. The former lead to driver-less transport systems used on factory floors to move objects to different points in the production process in the late seventies. New forms of mobile robots have been constructed lately like insectoid robots with many legs modeled after examples nature gave us or autonomous robots for underwater usage. Since a few years wheel-driven robots are commercially marketed and used for services like "Get and Bring'' (for example in hospitals).

Humanoid robots are being developed since 1975 when Wabot-I was presented in Japan. The current Wabot-III already has some minor cognitive capabilities. Another humanoid robot is "Cog'', developed in the MIT-AI-Lab since 1994. Honda's humanoid robot became well known in the public when presented back in 1999. Although it is remote controlled by humans it can walk autonomously (on the floor and stairs). In science fiction robots are already human's best friend but in reality we will only see robots for specific jobs as universal programmable machine slave in the near future.

The hardest thing for a robot to do is to walk. This is hard for the creators of the robot as well, since the act of walking involves hundreds of specific motions. Also, a large part of walking time is spent on one leg, so it is important for the robot to have good balance, just like a child learning to walk! Some real robots must walk on uneven surfaces, like the surface of Mars, so these robots need sensors in their legs to find good footholds.

There are many benefits to using robots instead of humans. Can you imagine working in a factory all day, every day, doing the exact same thing over and over again? The good thing about robots is that they will never get bored, and they will do things more efficiently than people.

Also, robots never get sick, or need to rest. This means they can work for 24 hours a day, 7 days a week. They will never need time off, or lunch breaks. Sometimes, when a task is too dangerous or difficult for a human, a robot will be able to do it without any risks or problems. Some interesting places robots have travelled include space, the depths of the ocean, inside volcanoes, into buildings containing bombs, and others. Robots are sent out when the “mission’’ may be too dangerous for a human. Robots are regularly used by police forces around the world to disarmbombs, and by scientists to venture inside volcanoes to gather important data. A robot-camera named Jason was also involved in the discovery and exploration of the Titanic shipwreck in 1986. Jason was attached to a mini-submarine, and the crew up above directed the minisubmarine throughout the wreck, obtaining some great pictures. Robots have revolutionized the manufacturing industry by increasing the production rate and improving accuracy in production. Robots are being used in a variety of production units, especially automotive units, for carrying out drilling, welding, bolt tightening, etc.

13.2.1 Definitions

There are different definitions of what a “robot’’ is. The International Organization for Standardization gives a definition of robot in ISO 8373: “an automatically controlled, reprogrammable, multipurpose, manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications.’’ This definition is used by the International Federation of Robotics, the European Robotics Research Network (EURON), and many national standards committees.

The Robotics Institute of America (RIA) uses a broader definition: a robot is a “re-programmable multi-functional manipulator designed to move materials, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks’’. The RIA subdivides robots into four classes: devices that manipulate objects with manual control, automated devices that manipulate objects with predetermined cycles, programmable and servo-controlled robots with continuous point-to-point trajectories, and robots of this last type which also acquire information from the environment and move intelligently in response.

The Oxford English Dictionary defines a robot as:

a. One of the mechanical men and women in Capek's play; hence, a machine (sometimes resembling a human being in appearance) designed to function in place of a living agent, esp. one which carries out a variety of tasks automatically or with a minimum of external impulse.
b. A person whose work or activities are entirely mechanical; an automaton.

Alan Mackworth, defines a robot as:

“It’s a machine that can sense and act and react in the world and possibly involves some reasoning for performing these actions, and it does so autonomously. By that definition a thermostat would be a robot. Though it's not ‘aware’ it has a goal, that awareness isn’t required.’’

Robotics

Robotics is the science and technology of robots, and their design, manufacture, and application. Robotics Engineers also study electronics, mechanics and software. Today’s robotics systems operate by means of hydraulic, pneumatic, and electrical power. Robots are comprised of several different elements, depending on their purpose. The hand of a robot is usually referred to as an "end effector”. End effectors may be specialized tools, such as spot welders or spray guns, or more general-purpose grippers. Common grippers include fingered and vacuum types.

Laws of Robotics

The term *robotics* was coined in the 1940s by science fiction writer Isaac Asimov. In a series of stories and novels, he imagined a world in which mechanical beings were mankind's devoted helpmates. They were constrained to obey what have become known as Asimov's Laws of Robotics:

1. A robot may not injure a human being, or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

13.2.2 Characteristics

While there is no single correct definition of "robot", a typical robot will have several or possibly all of the following properties.

- It is artificially created.
- It can sense its environment, and manipulate or interact with things in it.
- It has some ability to make choices based on the environment, often using automatic control or a preprogrammed sequence.
- It is programmable.
- It moves with one or more axes of rotation or translation.
- It makes dexterous coordinated movements.
- It moves without direct human intervention.
- It appears to have intent or agency.

The last property, the appearance of agency, is important when people are considering whether to call a machine a robot, or just a machine.

Self Assessment Questions

1. _________ is an active, artificial agent whose environment is the physical world.
2. When was the first digitally operated and programmable robot, the Unimate, installed?

   ____
3. ___________ robots are being developed since 1975 when Wabot-I was presented in Japan.

13.3 Contemporary Uses of Robots

There were more than one million robots in operation worldwide in the first half of 2008, with roughly half in Asia, 32% in Europe, 16% in North America, 1% in Australia and 1% in Africa. Industrial and service robots can be placed into roughly two classifications based on the type of job they do. The first category includes tasks which a robot can do with greater productivity, accuracy, or endurance than humans; the second category consists of dirty, dangerous or dull jobs which humans find undesirable.

13.3.1 Increased productivity, accuracy, and endurance

Many factory jobs are now performed by robots. This has led to cheaper mass-produced goods, including automobiles and electronics. Stationary manipulators used in factories have become the largest market for robots.

- **Car production:** Over the last three decades automobile factories have become dominated by robots. A typical factory contains hundreds of industrial robots working on fully automated production lines, with one robot for every ten human workers. On an automated production line, a vehicle chassis on a conveyor is welded, glued, painted and finally assembled at a sequence of robot stations.
- **Packaging:** Industrial robots are also used extensively for palletizing and packaging of manufactured goods, for example for rapidly taking drink cartons from the end of a conveyor belt and placing them into boxes, or for loading and unloading machining centers.
- **Electronics:** Mass-produced printed circuit boards (PCBs) are almost exclusively manufactured by pick-and-place robots, typically with SCARA manipulators, which remove tiny electronic components from strips or trays, and place them on to PCBs with great accuracy. Such robots can place hundreds of thousands of components per hour, far out-performing a human in speed, accuracy, and reliability.
- **Automated guided vehicles (AGVs):** Mobile robots, following markers or wires in the floor, or using vision or lasers, are used to transport goods around large facilities, such as warehouses, container ports, or hospitals. Early AGV-style robots were limited to tasks that could be accurately defined and had to be performed the same way every time. Very little feedback or intelligence was required, and the robots needed only the most basic exteroceptors (sensors).

13.3.2 Dirty, dangerous, dull or inaccessible tasks

There are many jobs which humans would rather leave to robots. The job may be boring, such as domestic cleaning, or dangerous, such as exploring inside a volcano. Other jobs are physically inaccessible, such as exploring another planet, cleaning the inside of a long pipe, or performing laparoscopic surgery.

- **Domestic robots:** As prices fall and robots become smarter and more autonomous, robots are increasingly being seen in the home where they are taking on simple but unwanted jobs, such as floor cleaning and lawn mowing.
- **Telerobots:** When a human cannot be present on site to perform a job because it is dangerous, far away, or inaccessible, teleoperated robots,

or telerobots are used. Rather than following a predetermined sequence of movements, a telerobot is controlled from a distance by a human operator. The robot may be in another room or another country, or may be on a very different scale to the operator. For instance, a laparoscopic surgery robot allows the surgeon to work inside a human patient on a relatively small scale compared to open surgery, significantly shortening recovery time. Several authors have been using a device called the Longpen to sign books remotely.

- **Military robots:** Teleoperated robot aircraft, like the Predator Unmanned Aerial Vehicle, are increasingly being used by the military. These pilotless drones can search terrain and fire on targets. Hundreds of robots such as iRobot's Packbot and the Foster-Miller TALON are being used in Iraq and Afghanistan by the U.S. military to defuse roadside bombs or Improvised Explosive Devices (IEDs) in an activity known as explosive ordnance disposal (EOD).
- **Home automation for the elderly and disabled:** The average age of the population is increasing in many countries, especially in Japan, meaning that there are more elderly people to care for and fewer people available to care for them.

13.4 Robot Hardware

Now we will make you familiarize with various hardware required for robot.

13.4.1 Sensors

Sensors are the perceptual interface between robots and their environment. On the one hand we have *passive sensors* like cameras, which capture signals that are generated by other sources in the environment. On the other hand we have *active sensors* (for example sonar, radar, laser) which emit energy into the environment. This energy is reflected by objects in the environment. These reflections can then be used to gather the information needed. Generally active sensors provide more information than passive sensors. But they also consume more power. This can lead to a problem on mobile robots which need to take their energy with them in batteries.

We have three types of sensors (no matter whether sensors are active or passive). These are sensors that either *record* distances to objects or generate an entire image of the environment or measure a property of the robot itself.

Many mobile robots make use of *range finders*, which measure distance to nearby objects. A common type is the sonar sensor. Alternatives to sonar include radar and laser. Some range sensors measure very short or very long distances. Close-range sensors are often *tactile sensors* such as whiskers, bump panels and touch-sensitive skin. The other extreme are long-range sensors like the Global Positioning System (GPS).

The second important class of sensors are *imaging sensors*. These are cameras that provide images of the environment that can then be analyzed using computer vision and image recognition techniques.

The third important class are *proprioceptive sensors*. These inform the robot of its own state. To measure the exact configuration of a robotic joint motors are often equipped with shaft decoders that count the revolution of motors in small increments. Another way of measuring the state of the robot is to use force and torque sensors. These are especially needed when the robot handles fragile objects or objects whose exact shape and location is unknown. Imagine a ton robot manipulator screwing in a light bulb.

13.4.2 Effectors

Effectors are the means by which robots manipulate the environment, move and change the shape of their bodies. To understand the ability of a robot to interact with the physical world we will use the abstract concept of a *degree of freedom (DOF)*. We count one degree of freedom for each independent direction in which a robot, or one of its effectors can move. As an example let's contemplate a rigid robot like an autonomous underwater vehicle (AUV). It has six degrees of freedom, three for its (*x;y; z*) location in space and three for its angular orientation (also known as yaw, roll and pitch). These DOFs define the kinematic state of the robot. This can be extended with another dimension that gives the rate of change of each kinematic dimension. This is called dynamic state. Robots with nonrigid bodies may have additional DOFs. For example a human wrist has three degrees of freedom – it can move up and down, side to side and can also rotate. Robot joints have 1, 2, or 3 degrees of freedom each. Six degrees of freedom are required to place an object, such as a hand, at a particular point in a particular orientation.

13.4.3 Movement

For mobile robots a special group of effectors are the mechanisms the robot uses for locomotion, including wheels, tracks, and legs. The *differential* drive consists of two independently actuated wheels – one on each side. If both wheels move at the same velocity, the robot moves on a straight line. If they move in opposite directions, the robot turns on the spot. An alternative is the *synchro drive*, in which each wheel can move and turn around its own axis. This could easily lead to chaos. But if you assure the constraint that all wheels always point in the same direction and move with the same speed your robot is save. Both differential and synchro drives are nonholonomic. Some more expensive robots use holonomic drives, which usually involve three or more wheels and can be oriented and moved independently.

13.4.4 Power sources

Robots need a power source to drive their effectors. The most popular mechanism for both manipulator actuation and locomotion is the *electric motor*. Other possible ways are *pneumatic actuation* using compressed gas and *hydraulic actuation* using pressurized fluids. They have their application niches but are not widely used.

13.4.5 Bits and pieces

Most robots have some kind of digital communication like wireless networks. Especially today those modules get cheaper. They can be used for communication between robots or for some kind of back link to the robots home station. Finally you need a body frame to hang all the bits and pieces.

13.5 Robotic Perception

A robot receives raw sensor data from its sensors. It has to map those measurements into an internal representation to formalize this data. This process is called *robotic perception*. This is a difficult process since in general the sensors are noisy and the environment is partially observable, unpredictable, and often dynamic. Good representation should meet three criteria: They should ^{2} contain enough information for the robot to make a right decision ^{2} be structured in a way that it can be updated efficiently be natural, meaning that internal variables correspond to natural state variables in the physical world.

Self Assessment Questions

4. EOD stands for ________________________.
5. ____ are the perceptual interface between robots and their environment.
6. Which is the most popular mechanism for both manipulator actuation and locomotion?

13.6 Summary

A robot is a mechanical or virtual artificial agent. Artificial intelligence (AI) is arguably the most exciting field in robotics. Telemanipulators are remotely controlled machines which usually consist of an arm and a gripper. Robotics is the science and technology of robots, and their design, manufacture, and application. Many factory jobs are now performed by robots. Sensors are the perceptual interface between robots and their environment. *Effectors* are the means by which robots manipulate the environment, move and change the shape of their bodies. A robot receives raw sensor data from its sensors. It has to map those measurements into an internal representation to formalize this data. This process is called *robotic perception*.

13.7 Terminal Questions

1. What do you mean by the term “Robotics?’’
2. Explain the term “Robot’’ as described by ISO and Oxford Dictionary
3. What are the Characteristics of robot?
4. What are the contemporary uses of Robots?
5. Write a note on a) sensors b) Effectors
6. What is robotic perception? Explain briefly.

13.8 Answers

Self Assessment Questions

1. Robot
2. In 1961
3. Humanoid
4. Explosive Ordnance Disposal
5. Sensors
6. Electric motor

Terminal Questions

1. Robotics is the science and technology of robots, and their design, manufacture, and application. (Refer sub-section 13.2.1)
2. The International Organization for Standardization gives a definition of robot in ISO 8373: "an automatically controlled, reprogrammable, multipurpose, manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications." (Refer sub-section 13.2.1)
3. Characteristics
   - It is artificially created.
   - It can sense its environment, and manipulate or interact with things in it. (Refer sub-section 13.2.2)
4. Many factory jobs are now performed by robots. This has led to cheaper mass-produced goods, including automobiles and electronics. (Refer sub-sections 13.3.1 and 13.3.2)
5. Sensors are the perceptual interface between robots and their environment. Effectors are the means by which robots manipulate the environment, move and change the shape of their bodies.
   (Refer sub-sections 13.4.1 and 13.4.2)
6. A robot receives raw sensor data from its sensors. It has to map those measurements into an internal representation to formalize this data. This process is called *robotic perception*. (Refer the section 13.5)