

UNIT 2 ROBOTICS

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1.0 INTRODUCTION

Robotics is the branch of technology that deals with the design, construction, operation, structural disposition, manufacture and application of robots. Robotics is related to the sciences of electronics, engineering, mechanics, and software.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

explain the word robotics
list 4 types of robotics you know
describe the history of robotics.

3.0 MAIN CONTENT

3.1 What is a Robot?

The word robotics was derived from the word robot, which was introduced to the public by Czech writer Karel Čapek in his play R.U.R. (Rossum's Universal Robots), which premiered in 1921.

According to the Oxford English Dictionary, the word robotics was first used in print by Isaac Asimov, in his science fiction short story "Liar!", published in May 1941 in Astounding Science Fiction. Asimov was unaware that he was coining the term; since the science and technology of electrical devices is electronics, he assumed robotics already referred to the science and technology of robots. In some of Asimov's other works, he states that the first use of the word robotics was in his short story Runaround (Astounding Science Fiction, March 1942). However, the word robotics appears in "Liar!"

3.1.1 Types of Robots

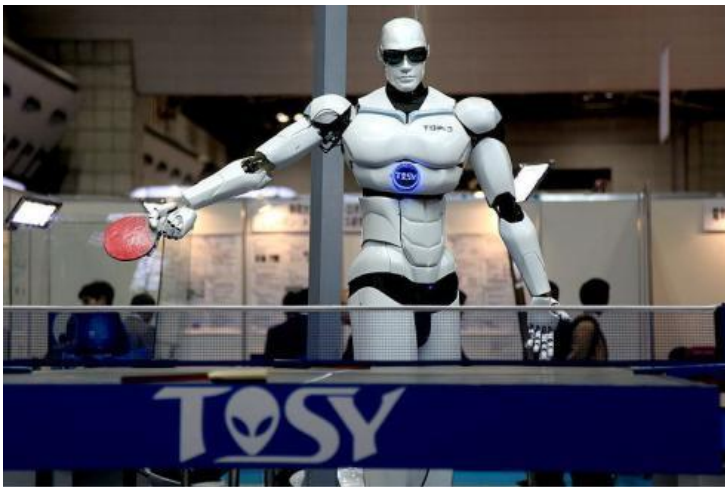


Figure 1: TOPIO, a humanoid robot, played ping pong at Tokyo International Robot Exhibition (IREX)



Figure 2: The Shadow robot hand system

Figure 3: A Pick and Place robot in a factory



3.1.2 History of Robots

Stories of artificial helpers and companions and attempts to create them have a long history.



Figure 4: A scene from Karel Čapek's 1920 play R.U.R. (Rossum's Universal Robots), showing three robots.

The word robot was introduced to the public by the Czech writer Karel Čapek in his play R.U.R. (Rossum's Universal Robots), published in 1920. The play begins in a factory that makes artificial people called robots creatures who can be mistaken for humans – though they are closer to the modern ideas of androids. Karel Čapek himself did not coin the word. He wrote a short letter in reference to an etymology in the Oxford English Dictionary in which he named his brother Josef Čapek as its actual originator.

In 1927 the Maschinenmensch ("machine-human") gynoid humanoid robot (also called "Parody", "Futura", "Robotrix", or the "Maria impersonator") was the first and perhaps the most memorable depiction of a robot ever to appear on film was played by German actress Brigitte Helm) in Fritz Lang's film *Metropolis*.

In 1942 the science fiction writer Isaac Asimov formulated his Three Laws of Robotics and, in the process of doing so, coined the word "robotics" (see details in "Etymology" section below).

In 1948 Norbert Wiener formulated the principles of cybernetics, the basis of practical robotics.

Fully autonomous robots only appeared in the second half of 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. Commercial and industrial robots are widespread today and used to perform jobs more cheaply, or more accurately and reliably, than humans. They are also employed in jobs which are too dirty, dangerous, or dull to be suitable for humans. Robots are widely used in manufacturing, assembly, packing and packaging, transport, earth and space exploration, surgery, weaponry, laboratory research, safety, and the mass production of consumer and industrial goods.

Date	Significance	Robot Name	Inventor
Third century B.C. and earlier	One of the earliest descriptions of automata appears in the Lie Zi text, on a much earlier encounter between King Mu of Zhou (1023-957 BC) and a mechanical engineer known as Yan Shi, an 'artificer'. The latter allegedly presented the king with a life-size, human-shaped figure of his mechanical handiwork.		Yan Shi
First century A.D. and earlier	Descriptions of more than 100 machines and automata, including a fire engine, a wind organ, a coin-operated machine, and a steam-powered engine, in Pneumatica and Automata by Heron of Alexandria		Ctesibius, Philo of Byzantium, Heron of Alexandria, and others
1206	Created early humanoid automata, programmable automaton band	Robot band, hand-	Al-Jazari

		washing automaton,[11] automated moving peacocks[12]	
1495	Designs for a humanoid robot	Mechanical knight	Leonardo da Vinci
1738	Mechanical duck that was able to eat, flap its wings, and excrete	Digesting Duck	Jacques de Vaucanson
1898	Nikola Tesla demonstrates first radio-controlled vessel.	Teleautomaton	Nikola Tesla
1921	First fictional automatons called "robots" appear in the play R.U.R.	Rossum's Universal Robots	Karel Čapek
1930s	Humanoid robot exhibited at the 1939 and 1940 World's Fairs	Elektro	Westinghouse Electric Corporation
1948	Simple robots exhibiting biological behaviors	Elsie and Elmer	William Grey Walter
1956	First commercial robot, from the Unimation company founded by George Devol and Joseph Engelberger, based on Devol's patents	Unimate	George Devol
1961	First installed industrial robot.	Unimate	George Devol
1963	First palletizing robot http://www.ask.com/wiki/Robotics - cite_note-14	Palletizer	Fuji Yusoki Kogyo
1973	First industrial robot with six electromechanically driven axes	Famulus	KUKA Robot Group
1975	Programmable universal manipulation arm, a product	Unimation PUMA	Victor Scheinman

3.2 Components

3.2.1 Power source

At present; mostly (lead-acid) batteries are used, but potential power sources could be:

pneumatic (compressed gases)

hydraulics (compressed liquids)

flywheel energy storage

organic garbage (through anaerobic digestion)

faeces (human, animal); may be interesting in a military context as faeces of small combat groups may be reused for the energy requirements of the robot assistant (see DEKA's project Slingshot Stirling engine on how the system would operate)

still unproven energy sources: for example Nuclear fusion, as yet not used in nuclear reactors whereas Nuclear fission is proven (although there are not many robots using it as a power source apart from the Chinese rover tests).

radioactive source (such as with the proposed Ford car of the '50s); to those proposed in movies such as Red Planet

3.2.2 Actuation

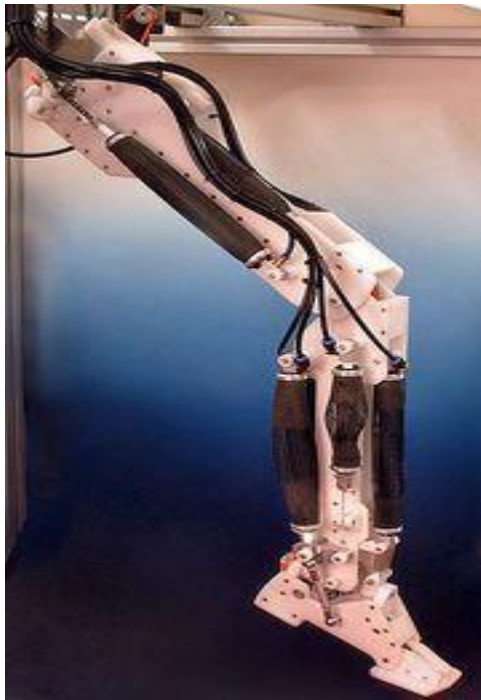


Figure 5: A robotic leg powered by Air Muscles

Actuators are like the "muscles" of a robot, the parts which convert stored energy into movement. By far the most popular actuators are electric motors that spin a wheel or gear, and linear actuators that control industrial robots in factories. But there are some recent advances in alternative types of actuators, powered by electricity, chemicals, or compressed air:

3.2.2.1 Electric motors

The vast majority of robots use electric motors, often brushed and brushless DC motors in portable robots or AC motors in industrial robots and CNC machines.

3.2.2.2 Linear Actuators

Various types of linear actuators move in and out instead of by spinning, particularly when very large forces are needed such as with industrial robotics. They are typically powered by compressed air (pneumatic actuator) or an oil (hydraulic actuator).

3.2.2.3 Series Elastic Actuators

A spring can be designed as part of the motor actuator, to allow improved force control. It has been used in various robots, particularly walking humanoid robots.

3.2.2.4 Air Muscles

Pneumatic artificial muscles, also known as air muscles, are special tubes that contract (typically up to 40%) when air is forced inside it. They have been used for some robot applications.

3.2.2.5 Muscle Wire

Muscle wire, also known as Shape Memory Alloy, Nitinol or Flexinol Wire, is a material that contracts slightly (typically under 5%) when electricity runs through it. They have been used for some small robot applications.

3.2.2.6 Electroactive Polymers

EAPs or EPAMs are a new plastic material that can contract substantially (up to 400%) from electricity, and have been used in facial muscles and arms of humanoid robots, and to allow new robots to float, fly, swim or walk.

3.2.2.7 Piezo Motors

A recent alternative to DC motors are piezo motors or ultrasonic motors. These work on a fundamentally different principle, whereby tiny piezoceramic elements, vibrating many thousands of times per second, cause linear or rotary motion. There are different mechanisms of operation; one type uses the vibration of the piezo elements to walk the motor in a circle or a straight line. Another type uses the piezo elements to cause a nut to vibrate and drive a screw. The advantages of these motors are nanometer resolution, speed, and available force for their size. These motors are already available commercially, and being used on some robots.

3.2.2.8 Elastic Nanotubes

Elastic Nanotubes are a promising artificial muscle technology in early-stage experimental development. The absence of defects in carbon nanotubes enables these filaments to deform elastically by several percent, with energy storage levels of perhaps 13 J/cm³ for metal nanotubes. Human biceps could be replaced with an 8 mm diameter wire of this material. Such compact "muscle" might allow future robots to outrun and out jump humans.

3.3 Sensing

3.3.1 Touch

Current robotic and prosthetic hands receive far less tactile information than the human hand. Recent research has developed a tactile sensor array that mimics the mechanical properties and touch receptors of human fingertips. The sensor array is constructed as a rigid core surrounded by conductive fluid contained by an elastomeric skin. Electrodes are mounted on the surface of the rigid core and are connected to an impedance-measuring device within the core. When the artificial skin touches an object the fluid path around the electrodes is deformed, producing impedance changes that map the forces received from the object. The researchers expect that an important function of such artificial fingertips will be adjusting robotic grip on held objects.

Scientists from several European countries and Israel developed a prosthetic hand in 2009, called SmartHand, which functions like a real one—allowing patients to write with it, type on a keyboard, play piano and perform other fine movements. The prosthesis has sensors which enable the patient to sense real feeling in its fingertips.

3.3.2 Vision

Computer vision is the science and technology of machines that see. As a scientific discipline, computer vision is concerned with the theory behind artificial systems that extract information from images. The image data can take many forms, such as video sequences and views from cameras.

In most practical computer vision applications, the computers are pre-programmed to solve a particular task, but methods based on learning are now becoming increasingly common.

Computer vision systems rely on image sensors which detect electromagnetic radiation which is typically in the form of either visible light or infra-red light. The sensors are designed using solid-state physics. The process by which light propagates and reflects off surfaces is explained using optics. Sophisticated image sensors even require quantum mechanics to provide a complete understanding of the image formation process.

There is a subfield within computer vision where artificial systems are designed to mimic the processing and behavior of biological systems, at different levels of complexity. Also, some of the learning-based methods developed within computer vision have their background in biology.

3.4 Manipulation

Robots which must work in the real world require some way to manipulate objects; pick up, modify, destroy, or otherwise have an effect. Thus the "hands" of a robot are often referred to as end effectors, while the "arm" is referred to as a manipulator. Most robot arms have replaceable effectors, each allowing them to perform some small range of tasks. Some have a fixed manipulator which cannot be replaced, while a few have one very general purpose manipulator, for example a humanoid hand.

For the definitive guide to all forms of robot end-effectors, their design, and usage consult the book "Robot Grippers".

3.4.1 Mechanical Grippers

One of the most common effectors is the gripper. In its simplest manifestation it consists of just two fingers which can open and close to pick up and let go of a range of small objects. Fingers can for example be made of a chain with a metal wire run through it. See Shadow Hand.

3.4.2 Vacuum Grippers

Vacuum grippers are very simple attractive devices, but can hold very large loads provided the prehension surface is smooth enough to ensure suction.

Pick and place robots for electronic components and for large objects like car windcreens, often use very simple vacuum grippers.

3.4.3 General Purpose Effectors

Some advanced robots are beginning to use fully humanoid hands, like the Shadow Hand, MANUS, and the Schunk hand. These highly dexterous manipulators with as many as 20 degrees of freedom and hundreds of tactile sensors.

3.5 Locomotion

3.5.1 Rolling Robots



Figure 6: Segway in the Robot museum in Nagoya.

For simplicity most mobile robots have four wheels or a number of continuous tracks. Some researchers have tried to create more complex wheeled robots with only one or two wheels. These can have certain advantages such as greater efficiency and reduced parts, as well as allowing a robot to navigate in confined places that a four wheeled robot would not be able to.

3.5.1.1 Two-Wheeled Balancing Robots

Balancing robots generally use a gyroscope to detect how much a robot is falling and then drive the wheels proportionally in the opposite direction, to counter-balance the fall at hundreds of times per second, based on the dynamics of an inverted pendulum. Many different balancing robots have been designed. While the Segway is not commonly thought of as a robot, it can be thought of as a component of a robot, such as NASA's Robonaut that has been mounted on a Segway.

3.5.1.2 One-Wheeled Balancing Robots

A one-wheeled balancing robot is an extension of a two-wheeled balancing robot so that it can move in any 2D direction using a round ball as its only wheel. Several one-wheeled balancing robots have been designed recently, such as Carnegie Mellon University's "Ballbot" that is the approximate height and width of a person, and Tohoku Gakuin University's "BallIP". Because of the long, thin shape and ability to maneuver in tight spaces, they have the potential to function better than other robots in environments with people.

3.5.1.3 Spherical Orb Robots

Several attempts have been made in robots that are completely inside a spherical ball, either by spinning a weight inside the ball, or by rotating the outer shells of the sphere. These have also been referred to as an orb bot or a ball bot.

3.5.1.4 Six-Wheeled Robots

Using six wheels instead of four wheels can give better traction or grip in outdoor terrain such as on rocky dirt or grass.

3.5.1.5 Tracked Robots

Tank tracks provide even more traction than a six-wheeled robot. Tracked wheels behave as if they were made of hundreds of wheels, therefore are very common for outdoor and military robots, where the robot must drive on very rough terrain. However, they are difficult to use indoors such as on carpets and smooth floors. Examples include NASA's Urban Robot "Urbie".

3.5.2 Walking Applied to Robots



Figure 6: iCub robot, designed by the RobotCub Consortium

Walking is a difficult and dynamic problem to solve. Several robots have been made which can walk reliably on two legs; however none have yet been made which are as robust as a human. Many other robots have been built that walk on more than two legs, due to these robots being significantly easier to construct. Hybrids too have been proposed in movies such as *I, Robot*, where they walk on 2 legs and switch to 4 (arms+legs) when going to a sprint. Typically, robots on 2 legs can walk well on flat floors and can occasionally walk up stairs. None can walk over rocky, uneven terrain. Some of the methods which have been tried are:

3.5.2.1 ZMP Technique

The Zero Moment Point (ZMP) is the algorithm used by robots such as Honda's ASIMO. The robot's onboard computer tries to keep the total inertial forces (the combination of earth's gravity and the acceleration and deceleration of walking), exactly opposed by the floor reaction force (the force of the floor pushing back on the robot's foot). In this way, the two forces cancel out, leaving no moment (force causing the robot to rotate and fall over). However, this is not exactly how a human walks, and the difference is obvious to human observers, some of whom have pointed out that ASIMO walks as if it needs the lavatory. ASIMO's walking algorithm is not static, and some dynamic balancing is used (see below). However, it still requires a smooth surface to walk on.

3.5.2.2 Hopping

Several robots, built in the 1980s by Marc Raibert at the MIT Leg Laboratory, successfully demonstrated very dynamic walking. Initially, a robot with only one leg, and a very small foot, could stay upright simply by hopping. The movement is the same as that of a person on a pogo stick. As the robot falls to one side, it would jump slightly in that direction, in order to catch itself. Soon, the algorithm was generalised to two and four legs. A bipedal robot was demonstrated running and even performing somersaults. A quadruped was also demonstrated which could trot, run, pace, and bound. For a full list of these robots, see the MIT Leg Lab Robots page.

3.5.2.3 Dynamic Balancing (Controlled Falling)

A more advanced way for a robot to walk is by using a dynamic balancing algorithm, which is potentially more robust than the Zero Moment Point technique, as it constantly monitors the robot's motion, and places the feet in order to maintain stability. This technique was recently demonstrated by Anybots' Dexter Robot, http://www.ask.com/wiki/Robotics_-_cite_note-64 which is so stable, it can even jump. Another example is the TU Delft Flame.

3.5.2.4 Passive Dynamics

Perhaps the most promising approach utilizes passive dynamics where the momentum of swinging limbs is used for greater efficiency. It has been shown that totally unpowered humanoid mechanisms can walk down a gentle slope, using only gravity to propel them. Using this technique, a robot need only supply a small amount of motor power to walk along a flat surface or a little more to walk up a hill. This technique promises to make walking robots at least ten times more efficient than ZMP walkers, like ASIMO.

3.5.3 Other methods of locomotion



Figure 7: RQ-4 Global Hawk unmanned aerial vehicle

3.5.3.1 Flying

A modern passenger airliner is essentially a flying robot, with two humans to manage it. The autopilot can control the plane for each stage of the journey, including takeoff, normal flight, and even landing. Other flying robots are uninhabited, and are known as unmanned aerial vehicles (UAVs). They can be smaller and lighter without a human pilot onboard, and fly into dangerous territory for military surveillance missions. Some can even fire on targets under command. UAVs are also being developed which can fire on targets automatically, without the need for a command from a human. Other flying robots include cruise missiles, the Entomopter, and the Epson micro helicopter robot. Robots such as the Air Penguin, Air Ray, and Air Jelly have lighter-than-air bodies, propelled by paddles, and guided by sonar.



Figure 8: Two robot snakes. Left **one** has 64 motors (with 2 degrees of freedom per segment), the right one 10.

3.5.3.2 Snaking

Several snake robots have been successfully developed. Mimicking the way real snakes move, these robots can navigate very confined spaces, meaning they may one day be used to search for people trapped in collapsed buildings. The Japanese ACM-R5 snake robot can even navigate both on land and in water.

3.5.3.3 Skating

A small number of skating robots have been developed, one of which is a multi-mode walking and skating device. It has four legs, with unpowered wheels, which can either step or roll. Another robot, Plen, can use a miniature skateboard or rollerskates, and skate across a desktop.

3.5.3.4 Climbing

Several different approaches have been used to develop robots that have the ability to climb vertical surfaces. One approach mimicks the movements of a human climber on a wall with protrusions; adjusting the center of mass and moving each limb in turn to gain leverage. An example of this is Capuchin, built by Stanford University, California. Another approach uses the specialised toe pad method of wall-climbing geckoes, which can run on smooth surfaces such as vertical glass. Examples of this approach include Wallbot and Stickybot. China's "Technology Daily" November 15, 2008 reported New Concept Aircraft (ZHUHAI) Co. Ltd. Dr. Li Hiu Yeung and his research group have recently successfully developed the bionic gecko robot "Speedy Freeland". According to Dr. Li introduction, this gecko robot can rapidly climbing up and down in a variety of building walls, ground and vertical wall fissure or walking upside down on the ceiling, it is able to adapt on smooth glass, rough or sticky dust walls as well as the various surface of metallic materials and also can automatically identify obstacles, circumvent the bypass and flexible and realistic movements. Its flexibility and speed are comparable to the natural gecko. A third approach is to mimick the motion of a snake climbing a pole.

3.5.3.5 Swimming (like a Fish)

It is calculated that when swimming some fish can achieve a propulsive efficiency greater than 90%. Furthermore, they can accelerate and maneuver far better than any man-made boat or submarine, and produce less noise and water disturbance. Therefore, many researchers studying underwater robots would like to copy this type of locomotion. Notable examples are the Essex University Computer Science Robotic Fish, and the Robot Tuna built by the Institute of Field Robotics, to analyze and mathematically model thunniform motion. The Aqua Penguin, designed and built by Festo of Germany, copies the streamlined shape and propulsion by front "flippers" of penguins. Festo have also built the Aqua Ray and Aqua Jelly, which emulate the locomotion of manta ray, and jellyfish, respectively.

3.6 Environmental interaction and navigation



Figure 9: RADAR, GPS, LIDAR, ... are all combined to provide proper navigation and obstacle avoidance

Though a significant percentage of robots in commission today are either human controlled, or operate in a static environment, there is an increasing interest in robots that can operate autonomously in a dynamic environment. These robots require some combination of navigation hardware and software in order to traverse their environment. In particular unforeseen events (e.g. people and other obstacles that are not stationary) can cause problems or collisions. Some highly advanced robots as ASIMO, EveR-1, Meinü robot have particularly good robot navigation hardware and software. Also, self-controlled cars, Ernst Dickmanns' driverless car, and the entries in the DARPA Grand Challenge, are capable of sensing the environment well and subsequently making navigational decisions based on this information. Most of these robots employ a GPS navigation device with waypoints, along with radar, sometimes combined with other sensory data such as LIDAR, video cameras, and inertial guidance systems for better navigation between waypoints.

3.7 Human-Robot Interaction



Figure 10: Kismet can produce a range of facial expressions.

If robots are to work effectively in homes and other non-industrial environments, the way they are instructed to perform their jobs, and especially how they will be told to stop will be of critical importance. The people who interact with them may have little or no training in robotics, and so any interface will need to be extremely intuitive. Science fiction authors also typically assume that robots will eventually be capable of communicating with humans through speech, gestures, and facial expressions, rather than a command-line interface. Although speech would be the most natural way for the human to communicate, it is unnatural for the robot. It will probably be a long time before robots interact as naturally as the fictional C-3PO.

3.7.1 Speech Recognition

Interpreting the continuous flow of sounds coming from a human, in real time, is a difficult task for a computer, mostly because of the great variability of speech. The same word, spoken by the same person may sound different depending on local acoustics, volume, the previous word, whether or not the speaker has a cold, etc.. It becomes even harder when the speaker has a different accent. Nevertheless, great strides have been made in the field since Davis, Biddulph, and Balashek designed the first "voice input system" which recognized "ten digits spoken by a single user with 100% accuracy" in 1952. Currently, the best systems can recognize continuous, natural speech, up to 160 words per minute, with an accuracy of 95%.

3.7.2 Robotic Voice

Other hurdles exist when allowing the robot to use voice for interacting with humans. For social reasons, synthetic voice proves suboptimal as a communication medium, making it necessary to develop the emotional component of robotic voice through various techniques.

3.7.3 Gestures

One can imagine, in the future, explaining to a robot chef how to make a pastry, or asking directions from a robot police officer. In both of these cases, making hand gestures would aid the verbal descriptions. In the first case, the robot would be recognizing gestures made by the human, and perhaps repeating them for confirmation. In the second case, the robot police officer would gesture to indicate "down the road, then turn right". It is likely that gestures will make up a part of the interaction between humans and robots. A great many systems have been developed to recognize human hand gestures.

3.7.4 Facial Expression

Facial expressions can provide rapid feedback on the progress of a dialog between two humans, and soon it may be able to do the same for humans and robots. Robotic faces have been constructed by Hanson Robotics using their elastic polymer called Frubber, allowing a great amount of facial expressions due to the elasticity of the rubber facial coating and imbedded subsurface motors (servos) to produce the facial expressions. The coating and servos are built on a metal skull. A robot should know how to approach a human, judging by their facial expression and body language. Whether the person is happy, frightened, or crazy-looking affects the type of interaction expected of the robot. Likewise, robots like Kismet and the more recent addition, Nexi can produce a range of facial expressions, allowing it to have meaningful social exchanges with humans.

3.7.5 Artificial Emotions

Artificial emotions can also be imbedded and are composed of a sequence of facial expressions and/or gestures. As can be seen from the movie *Final Fantasy: The Spirits Within*, the programming of these artificial emotions is complex and requires a great amount of human observation. To simplify this programming in the movie, presets were created together with a special software program. This decreased the amount of time needed to make the film. These presets could possibly be transferred for use in real-life robots.

3.7.6 Personality

Many of the robots of science fiction have a personality, something which may or may not be desirable in the commercial robots of the future. Nevertheless, researchers are trying to create robots which appear to have a personality: i.e. they use sounds, facial expressions, and body language to try to convey an internal state, which may be joy, sadness, or fear. One commercial example is Pleo, a toy robot dinosaur, which can exhibit several apparent emotions.

3.8 Control



Figure 11: A robot-manipulated marionette, with complex control systems

The mechanical structure of a robot must be controlled to perform tasks. The control of a robot involves three distinct phases - perception, processing, and action (robotic paradigms). Sensors give information about the environment or the robot itself (e.g. the position of its joints or its end effector). This information is then processed to calculate the appropriate signals to the actuators (motors) which move the mechanical.

The processing phase can range in complexity. At a reactive level, it may translate raw sensor information directly into actuator commands. Sensor fusion may first be used to estimate parameters of interest (e.g. the position of the robot's gripper) from noisy sensor data. An immediate task (such as moving the gripper in a certain direction) is inferred from these estimates. Techniques from control theory convert the task into commands that drive the actuators.

At longer time scales or with more sophisticated tasks, the robot may need to build and reason with a "cognitive" model. Cognitive models try to represent the robot, the world, and how they interact. Pattern recognition and computer vision can be used to track objects. Mapping techniques can be used to build maps of the world. Finally, motion planning and other artificial intelligence techniques may be used to figure out how to act. For example, a planner may figure out how to achieve a task without hitting obstacles, falling over, etc.

3.8.1 Autonomy Levels

Control systems may also have varying levels of autonomy.

Direct interaction is used for haptic or tele-operated devices, and the human has nearly complete control over the robot's motion.

Operator-assist modes have the operator commanding medium-to-high-level tasks, with the robot automatically figuring out how to achieve them.

An autonomous robot may go for extended periods of time without human interaction. Higher levels of autonomy do not necessarily require more complex cognitive capabilities. For example, robots in assembly plants are completely autonomous, but operate in a fixed pattern.

Another classification takes into account the interaction between human control and the machine motions.

Teleoperation. A human controls each movement, each machine actuator change is specified by the operator.

Supervisory. A human specifies general moves or position changes and the machine decides specific movements of its actuators.

Task-level autonomy. The operator specifies only the task and the robot manages itself to complete it.

Full autonomy. The machine will create and complete all its tasks without human interaction.

3.9 Robotics Research

Much of the research in robotics focuses not on specific industrial tasks, but on investigations into new types of robots, alternative ways to think about or design robots, and new ways to manufacture them but other investigations, such as MIT's cyberflora project, are almost wholly academic.

A first particular new innovation in robot design is the opensourcing of robot-projects. To describe the level of advancement of a robot, the term "Generation Robots" can be used. This term is coined by Professor Hans Moravec, Principal Research Scientist at the Carnegie Mellon University Robotics Institute in describing the near future evolution of robot technology. First generation robots, Moravec predicted in 1997, should have an intellectual capacity comparable to perhaps a lizard and should become available by 2010.

Because the first generation robot would be incapable of learning, however, Moravec predicts that the second generation robot would be an improvement over the first and become available by 2020, with intelligence maybe comparable to that of a mouse. The third generation robot should have intelligence comparable to that of a monkey. Though fourth generation robots, robots with human intelligence, professor Moravec predicts, would become possible, he does not predict this happening before around 2040 or 2050.

The second is Evolutionary Robots. This is a methodology that uses evolutionary computation to help design robots, especially the body form, or motion and behavior controllers. In a similar way to natural evolution, a large population of robots is allowed to compete in some way, or their ability to perform a task is measured using a fitness function. Those that perform worst are removed from the population, and replaced by a new set, which have new behaviors based on those of the winners. Over time the population improves, and eventually a satisfactory robot may appear. This happens without any direct programming of the robots by the researchers. Researchers use this method both to create better robots, and to explore the nature of evolution. Because the process often requires many generations of robots to be simulated, this technique may be run entirely or mostly in simulation, then tested on real robots once the evolved algorithms are good enough. Currently, there are about 1 million industrial robots toiling around the world, and Japan is the top country having high density of utilizing robots in its manufacturing industry.

3.9.1 Dynamics and Kinematics

The study of motion can be divided into kinematics and dynamics. Direct kinematics refers to the calculation of end effector position, orientation, velocity, and acceleration when the corresponding joint values are known. Inverse kinematics refers to the opposite case in which required joint values are calculated for given end effector values, as done in path planning. Some special aspects of kinematics include handling of redundancy (different possibilities of performing the same movement), collision avoidance, and singularity avoidance. Once all relevant positions, velocities, and accelerations have been calculated using kinematics, methods from the field of dynamics are used to study the effect of forces upon these movements. Direct dynamics refers to the calculation of accelerations in the robot once the applied forces are known. Direct dynamics is used in computer simulations of the robot. Inverse dynamics refers to the calculation of the actuator forces necessary to create a prescribed end effector acceleration. This information can be used to improve the control algorithms of a robot. In each area mentioned above, researchers strive to develop new concepts and strategies, improve existing ones, and improve the interaction between these areas. To do this, criteria for "optimal" performance and ways to optimize design, structure, and control of robots must be developed and implemented.

3.10 Education and Training



Figure 12: The SCORBOT-ER 4u - educational robot.

Robots recently became a popular tool in raising interests in computing for middle and high school students. First year computer science courses at several universities were developed which involves the programming of a robot instead of the traditional software engineering based coursework.

3.10.1 Career training

Universities offer Bachelors, Masters and Doctoral degrees in the field of robotics. Select Private Career Colleges and vocational schools offer robotics training to train individuals towards being job ready and employable in the emerging robotics industry.

3.10.2 Certification

The Robotics Certification Standards Alliance (RCSA) is an international robotics certification authority who confers various industry and educational related robotics certifications.

3.11 Employment



Figure 13: A robot technician builds small all-terrain robots.
(Courtesy: MobileRobots Inc)

Robotics is an essential component in any modern manufacturing environment. As factories increase their use of robots, the number of robotics related jobs grow and have been observed to be on a steady rise.

3.11.1 Effects on Unemployment

Some analysts, such as Martin Ford, argue that robots and other forms of automation will ultimately result in significant unemployment as machines begin to match and exceed the capability of workers to perform most jobs. At present the negative impact is only on menial and repetitive jobs, and there is actually a positive impact on the number of jobs for highly skilled technicians, engineers, and specialists. However, these highly skilled jobs are not sufficient in number to offset the greater decrease in employment among the general population, causing structural unemployment in which overall (net) unemployment rises.

As robotics and artificial intelligence develop further, some worry even many skilled jobs may be threatened. In conventional economic theory this should merely cause an increase in the productivity of the involved industries, resulting in higher demand for other goods, and hence higher labour demand in these sectors, off-setting whatever negatives are caused. Conventional theory describes the past well but may not describe the future due to shifts in the parameter values that shape the context.

4.0 CONCLUSION

Robotics is an essential component in any modern manufacturing environment. As factories increase their use of robots, the number of robotics related jobs grow and have been observed to be on a steady rise. As robotics and artificial intelligence develop further, some worry even many skilled jobs may be threatened.

5.0 SUMMARY

In this unit, you learnt:

Robots and Types of Robots

History of Robots

Components of Robots

Robotics research

Education and training

Robots and Employment.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the word Robotics.
2. List five (5) areas where Robots can be used.
3. List three (3) areas where Robots can be used for now.

7.0 REFERENCES/FURTHER READING

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