A report on

ROBOTICS

For Dr. Indrajit Bose

Lecturer, GNIT

Technical Report Writing and Language Lab (HU 481)

By

Saikat Banerjee(09143001069)

Rajesh Mishra(09143001068)

Nirupam Muhuri(09143001067)

Of

Computer Science and technology department

Gurunanak institute of technology

Panihati , Sodhpur

West Bengal University of technology

Date of submission: March 22, 2011

SUMMARY

- Robotics is a very active field, worldwide.

- Japan, Korea, and the European Community invest significantly larger funds in robotics research and development for the private sector than the U.S.

- There are numerous start-up companies in robotics, both in the U.S. and abroad. Venture capital appears to be available.

- The U.S. currently leads in such areas as robot navigation in outdoor environments, robot architectures (the integration of control, structure and computation), and in applications to space, defense, underwater systems and some aspects of service and personal robots.

- Japan and Korea lead in technology for robot mobility, humanoid robots, and some aspects of service and personal robots (including entertainment).

- Europe leads in mobility for structured environments, including urban transportation. Europe also has significant programs in eldercare and home service robotics.

- Australia leads in commercial applications of field robotics, particularly in such areas as cargo handling and mining, as well as in the theory and application of localization and navigation.

- In contrast with the U.S., Korea and Japan have national strategic initiatives in robotics; the European community has EC-wide programs. In the U.S., DARPA programs are highly applied and short-term oriented, while its support for basic research in robotics has been drastically reduced in the past year.

- The U.S. lost its pre-eminence in industrial robotics at the end of the 1980s, so that nearly all robots for welding, painting and assembly are imported from Japan or Europe. We are in danger of losing our leading position in other aspects of robotics as well.

- Some examples of funding disparities:
  - In Korea, robotics has been selected as one of 10 areas of technology as “engines for economic growth”; the total funding for robotics is about $80 million per year. By contrast, NSF funding for robotics is under $10 million per year; funding from other agencies is small. DARPA support is restricted to military robotics.
  - In Europe, a new program called “Advanced Robotics” is about to be funded at about $100 million for three years.

A summary of the areas of major strength in various aspects of robotics in the U.S., Asia, and Europe is given in Table 1 below. The “INPUT” section refers to the kinds of resources and organizations that produce R&D, while “OUPUT” refers to the outcomes of research, into key robotic products or applications.

Preface

The emergence of the field of robotics has provided the occasion to analyze, and to attempt to replicate, the patterns of movement required to accomplish useful tasks. On the whole, this has been a sobering experience. Just as the ever-closer examination of the physical world occasionally reveals inadequacies in our vocabulary and mathematics, roboticists have found that it is quite awkward to give precise, succinct descriptions of effective movements using the syntax and semantics in common use. Perhaps it has always proved easier to demonstrate than to describe, but in any case, mankind has reached its present state without the benefit of a particularly expressive means for discussing movement. Yet, this is what is needed if we are to convey our wishes to general-purpose robots capable of doing what we ask them to do.

Because robotics is a broad field, it can be examined with profit from many points of view. The perspectives afforded by computer science, electrical engineering, mechanical engineering, psychology, and neuroscience all yield important insights. Even so, there are pervasive common threads, such as the description of spatial relations and their time evolution. One often finds that ideas from three-dimensional geometry and kinematics are not far from the center of the stage. The concept of a kinematic chain is basic to robotic manipulation, and these objects show up in considerable variety in practical applications. It is, therefore, particularly pleasant to observe that a very natural description of kinematic chains is afforded by a product of one- parameter Lie groups. It turns out that a key step in the design of controllers for
parameter Lie groups. It turns out that a key step in the design of controllers for industrial robots is equivalent to finding an algorithm for converting between coordinates of the first and second type for the group of rigid motions in three dimensions. We mention a second, perhaps unexpected, mathematical fact related to the manipulation of objects. In considering the application of grasping forces to objects, systems of inequalities play a central role because fingers can only push against, and not pull, objects. In fact, the study of grasping involves convex analysis, models of friction and details of the interface between the hand and the object that go considerably beyond simple mechanics. It happens that many tasks, including, but not limited to, grasping, can be done in more than one way. This may happen because the robot has more than the minimal number of degrees of freedom or because the task description is ambiguous. Disposing of such problems is usually called resolution of redundancy, and in some cases it leads to nonlocal questions in geometry.

From the point of view of the programmer, high-level languages are more efficient than low-level ones. Likewise, in directing the motion of a robot the programmer would like to say as little as possible about the means, preferring to focus attention on the ends. In order to make this possible, it is necessary to incorporate automatic path-planning algorithms in the software and to write compilers that are capable of converting high-level directives into the motor control programs needed to execute motion segments. This means that motion-planning algorithms are an important part of any high-level programming environment and that proving correctness of the motion programs produced by such compilers is an issue.

Computing power is far less expensive now then it has been in the past, and there now exists an effective collection of software tools together with a large group of scientists who know how to use them. The emergence of robotics as a practical activity is one consequence of these developments. The field is immature, and at this stage unification is more easily expressed in terms of the goals than methods. The work presented here demonstrates again the effectiveness of mathematics. Even so, many difficult problems remain.

Acknowledgements

I wish to express my sincere gratitude to Dr. Indrajit Bose, lecturer of Applied Science And Humanities (A.S.Hu.) dept. of Guru Nanak Institute Of Technology for his guidance and encouragement in carrying out the technical report on “Robotics”.

This report bears on imprint of many people. I sincerely thank my fellow group members who put in a lot of effort for the completion of the report. Last but not the list I wish to avail myself of this opportunity, express a sense of gratitude and love to my friends and my beloved parents for their manual support, strength, help and for everything.

Contents **Page No.**

Introduction

In the last twenty years, our conception and use of robots has evolved from the stuff of science fiction films to the reality of computer-controlled electromechanical devices integrated into a wide variety of industrial environments. It is routine to see robot manipulators being used for welding and painting car bodies on assembly lines, stuffng printed circuit boards with IC components, inspecting and repairing structures in nuclear, undersea, and underground environments, and even picking oranges and harvesting grapes in agriculture. Although few of these manipulators are anthropomorphic, our fascination with humanoid machines has not dulled, and people still envision robots as evolving into electromechanical replicas of ourselves. While we are not likely to see this type of robot in the near future, it is fair to say that we have made a great deal of progress in introducing simple robots with crude end-effectors into a wide variety of circumstances. Further, it is important to recognize that our impatience with the pace of robotics research and our expectations of what robots can and cannot do is in large part due to our lack of appreciation of the incredible power and subtlety of our own biological motor control systems.

ROBOTICS

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. The word "robot" was introduced to the public by Czech writer Karel Čapek in his play R.U.R. (Rossum's Universal Robots), published in 1920. The term "robotics" was coined by Isaac Asimov in his 1941 science fiction short-story "Liar!"

History

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

In 1921, Czech writer Karel Čapek introduced the word "robot" in his play *R.U.R. (Rossum's Universal Robots)*. The word "robot" comes from the word "robota", meaning, in Czech, "forced labour, drudgery".

In 1927, the Maschinenmensch ("machine-human"), a gynoid humanoid robot, also called "Parody", "Futura", "Robotrix", or the "Maria impersonator" (played by German actress Brigitte Helm), the first and perhaps the most memorable depiction of a robot ever to appear on film, was depicted 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. Today, commercial and industrial robots are in widespread use performing 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, and packing; transport; earth and space exploration; surgery; weaponry; laboratory research; safety; and mass production of consumer and industrial goods.

Date	Significance	Robot Name	Inventor
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-washing automaton, automated moving peacocks	Al-Jazari
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	Palletizer	Fuji Yusoki Kogyo
1973	First industrial robot with six electromechanically driven axes	Famulus	KUKA Robot Group
1975	Programmable universal manipulation arm, a Unimation product	PUMA	Victor Scheinman

Etymology

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. However, 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). 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.

Components

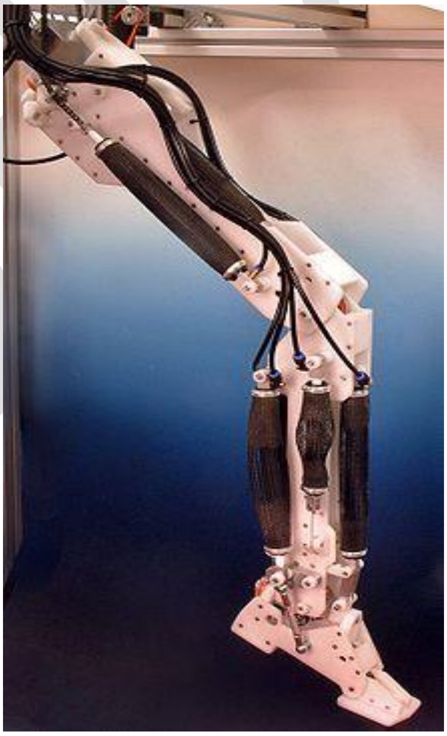
Power source

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*

Actuation

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:



A robotic leg powered by Air Muscles

- 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.

- 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).
- 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.
- Air muscles: (Also known as Pneumatic Artificial Muscles) are special tubes that contract (typically up to 40%) when air is forced inside it. They have been used for some robot applications.
- 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.
- 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.
- Piezo motor: 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.
- Elastic nanotubes: These are a promising artificial muscle technology in early-stage experimental development. The absence of defects incarbon nanotubes enables these filaments to deform elastically by several percent, with energy storage levels of perhaps 10 J/cm^3 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 outjump humans.

Sensing

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.

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.

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.

- 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.
- Vacuum Grippers: Pick and place robots for electronic components and for large objects like car windscreens, will often use very simple vacuum grippers. These are very simple astrictive devices, but can hold very large loads provided the prehension surface is smooth enough to ensure suction.
- 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.[

Locomotion

Rolling robots

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.

- Two-wheeled balancing: 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.

Segway in the Robot museum in Nagoya

.

- One-wheeled balancing: 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.
- 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
- 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.
- 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".

Walking robots

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:

iCub robot, designed by the RobotCub Consortium

- 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.
- 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.
- Dynamic Balancing or 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, which is so stable, it can even jump. Another example is the TU Delft Flame.
- 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 themselves. 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.

Other methods of locomotion

- 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.

RQ-4 Global Hawk unmanned aerial vehicle

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

- 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.
- 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.
- 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 Freelander".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
- Swimming: 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.

Environmental interaction and navigation

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.

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

Human-robot interaction

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.

Kismet can produce a range of facial expressions.

- Speech recognition: Interpreting the continuous flow of sounds coming from a human (speech recognition), 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.[84] 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%.
- 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.
- 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.
- 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.
- 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.

- 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.

Control

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.

A robot-manipulated marionette, with complex control systems

Autonomy levels

Control systems may also have varying levels of autonomy.

1. Direct interaction is used for haptic or tele-operated devices, and the human has nearly complete control over the robot's motion.
2. Operator-assist modes have the operator commanding medium-to-high-level tasks, with the robot automatically figuring out how to achieve them.
3. 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.

1. Teleoperation. A human controls each movement, each machine actuator change is specified by the operator.
2. Supervisory. A human specifies general moves or position changes and the machine decides specific movements of its actuators.
3. Task-level autonomy. The operator specifies only the task and the robot manages itself to complete it.
4. Full autonomy. The machine will create and complete all its tasks without human interaction.

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.

Robotics suite

A **robotics suite** is a visual environment for robot control and simulation. They are typically an end-to-end platform for robotics development and include tools for visual programming and creating and debugging robot applications. Developers can often interact with robots through web-based or visual interfaces.

One objective of a robotics suite is to support a variety of different robot platforms through a common programming interface. The key point about a robotics suite is that the same code will run either with a simulated robot or the corresponding real robot without modification.

Vex Robotics Design System

The **VEX Robotics Design System** is a robotic kit intended to introduce students as well as adults to the world of robotics. The VEX Robotics Design System is centered around the VEX Starter Kit (which retails for about USD $300). This kit comes with the VEX "brain" (a microcontroller), a hobby-grade remote control, various sensors (2 bumper sensor and 2 limiter switches), three electric motors and a servo, wheels (4 small, 2 medium all purpose, and 2 large high traction tires), gears, and structural parts. Additional sensors (ultrasonic, line tracking, optical shaft encoder , bumper switches, limit switches, and light sensors), wheels (small and large omni-directional wheels, small, medium, and large regulars), tank treads, motors, servos, gears (regular and advanced), chain and sprocket sets, extra transmitters and receivers, programming kit (easyC, robotC, MPLab), extra metal, pneumatics, and rechargeable battery power packs, can all be purchased separately.

This award winning platform was developed as part of a partnership between Innovation First, Inc. and IFIrobotics.

This product was originally available for purchase in RadioShack stores, and also on the web. On April 17, 2006 Innovation First announced their acquisition of the VEX Robotics brand name and trademark registrations from RadioShack Corporation. RadioShack stores are no longer selling Vex kits.

Robot 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 an intelligence maybe comparable to that of a mouse. The *third generation* robot should have an 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.

Microsoft Robotics Developer Studio

Microsoft Robotics Developer Studio (Microsoft RDS, **MRDS**) is a Windows-based environment for robot control and simulation. It is aimed at academic, hobbyist, and commercial developers and handles a wide variety of robot hardware.

RDS is based on CCR (Concurrency and Coordination Runtime): a .NET-based concurrent library implementation for managing asynchronous parallel tasks. This technique involves using message-passing and a lightweight services-oriented runtime, DSS (Decentralized Software Services), which allows the orchestration of multiple services to achieve complex behaviors.

Features include: a visual programming tool, Microsoft Visual Programming Language for creating and debugging robot applications, web-based and windows-based interfaces, 3D simulation (including hardware acceleration), easy access to a robot's sensors and actuators and support for a number of languages including C# and Visual Basic .NET, JScript and IronPython.

Microsoft Robotics Developer Studio includes support for packages to add other services to the suite. Those currently available include Soccer Simulation and Sumo Competition by Microsoft, and a community-developed Maze Simulator, a program to create worlds with walls that can be explored by a virtual robot.

Education and training

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.

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.

The SCORBOT-ER 4u - educational robot.

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

Certification

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

Types of robots

Humanoid robots:

- Lara is the first female humanoid robot with artificial muscles (metal alloy strands that instantly contract when heated by electric current) instead of electric motors (2006).
- Asimo is one of the most advanced projects as of 2009.

Modular robots: can be built from standard building blocks that can be combined in different ways.

- Utility fog
- M-Tran - a snake-like modular robot that uses genetic algorithms to evolve walking programs
- Self replicating robots - modular robots that can produce copies of themselves using existing blocks.
- Swarmanoid is a project that uses 3 specialized classes of robots (footbots, handbots and eyebots) to create an effective *swarm*. Such swarm should be able, for example, tidy a bedroom with each robot doing what it is best at.
- Self-Reconfiguring Modular Robotics

Educational toy robots:

- Educational toy robots

Sports robots:

- RoboCup
- TOPIO

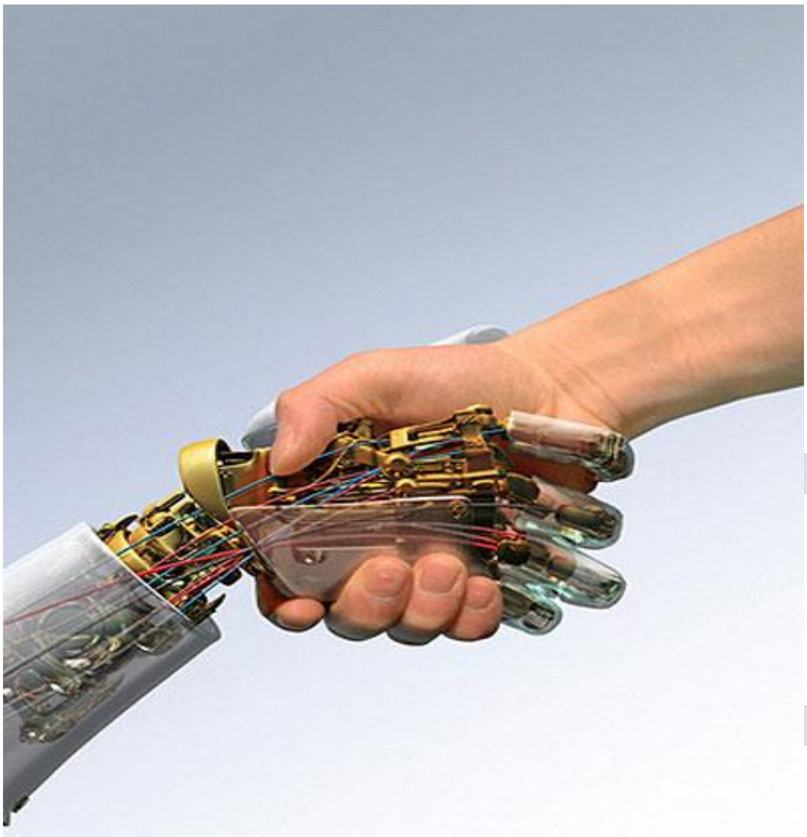
Robotics Timeline

- Robots capable of manual labour tasks--
    - 2009 - robots that perform searching and fetching tasks in unmodified library environment, Professor Angel del Pobil (University Jaume I, Spain), 2004
    - 2015-2020 - every South Korean household will have a robot and many European, The Ministry of Information and Communication (South Korea), 2007
    - 2018 - robots will routinely carry out surgery, South Korea government 2007[
    - 2022 - intelligent robots that sense their environment, make decisions, and learn are used in 30% of households and organizations - TechCast
    - 2030 - robots capable of performing at human level at most manual jobs Marshall Brain
    - 2034 - robots (home automation systems) performing most household tasks, Helen Greiner, Chairman of iRobot
- Military robots
    - 2015 - one third of US fighting strength will be composed of robots - US Department of Defense, 2006
    - 2035 - first completely autonomous robot soldiers in operation - US Department of Defense, 2006
    - 2038 - first completely autonomous robot flying car in operation - US Department of Technology, 2007

- Developments related to robotics from the Japan NISTEP 2030 report :
    - 2013-2014 — agricultural robots (AgRobots).
    - 2013-2017 — robots that care for the elderly
    - 2017 — medical robots performing low-invasive surgery
    - 2017-2019 — household robots with full use.
    - 2019-2021 — Nanorobots
    - 2021-2022 — Transhumanism

Employment in robotics

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.



Relationship to 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.

Future of robotics

What does the future hold for robotics? What is the next step, or the next technological boundary to overcome? The general trend for computers seems to be faster processing speed, greater memory capacity and so on. One would assume that the robots of the future would become closer and closer to the decision-making ability of humans and also more independent. Presently the most powerful computers can't match the mental ability of a low-grade animal. It will be a long time until we're having conversations with androids and have them do all our housework. Another difficult design aspect about androids is their ability to walk around on two legs like humans. A robot with biped movement is much more difficult to build then a robot with, say, wheels to move around with. The reason for this is that walking takes so much balance. When you lift your leg to take a step you instinctively shift your weight to the other side by just the right amount and are constantly alternating your center of gravity to compensate for the varying degrees of leg support. If you were to simply lift your leg with the rest of your body remaining perfectly still you would likely fall down. Try a simple test by standing with one shoulder and one leg against a wall. Now lift your outer leg and observe as you start to fall over.

Indeed, the human skeletal and muscular systems are complicated for many reasons. For now, robots will most likely be manufactured for a limited number of distinct tasks such as painting, welding or lifting. Presumably, once robots have the ability perform a much wider array of tasks, and voice recognition software improves such that computers can interpret complicated sentences in varying accents, we may in fact see robots doing our housework and carrying out other tasks in the physical world.

Telerobotics

Telerobotics is the area of robotics concerned with the control of robots from a distance, chiefly using wireless connections (like Wi-Fi, Bluetooth, the Deep Space Network, and similar), "tethered" connections, or the Internet. It is a combination of two major subfields,

- 1)Teleoperation
- 2)Telepresence.

TOPIO, a robot can play table tennis with humans.

Teleoperation

Teleoperation means "doing work at a distance", although "work" may mean almost anything. The term "distance" is also vague: it can refer to a physical distance, where the operator is separated from the robot by a large distance, but it can also refer to a change in scale, where for example in robotic surgery a surgeon may use micro-manipulator technology to conduct surgery on a microscopic level.

A **telemanipulator** (or **teleoperator**) is a device that is controlled remotely by a human operator. If such a device has the ability to perform autonomous work, it is called a telerobot. If the device is completely autonomous, it is called a robot. In simple cases the controlling operator's command actions correspond directly to actions in the device controlled, as for example in a radio controlled model aircraft or a tethered deep submergence vehicle. Where communications delays make direct control impractical (such as a remote planetary rover), or it is desired to reduce operator workload (as in a remotely controlled spy or attack aircraft) , the device will not be controlled directly, instead being commanded to follow a specified path. At increasing levels of sophistication the device may operate somewhat independently in matters such as obstacle avoidance, also commonly employed in planetary rovers.

Devices designed to allow the operator to control a robot at a distance is sometimes called telecheric robotics.

Two major components of Telerobotics and Telepresence are the visual and control applications. A remote camera provides a visual representation of the view from the robot. Placing the robotic camera in a perspective that allows intuitive control is a recent technique that although based in Science Fiction (Robert A. Heinlein's Waldo 1942) has not been fruitful as the speed, resolution and bandwidth have only recently been adequate to the task of being able to control the robot camera in a meaningful way. Using a head mounted display, the control of the camera can be facilitated by tracking the head as shown in the figure below.

This only works if the user feels comfortable with the latency of the system, the lag in the response to movements, and the visual representation. Any issues such as, inadequate resolution, latency of the video image, lag in the mechanical and computer processing of the movement and response, and optical distortion due to camera lens and head mounted display lenses, can cause the user 'simulator sickness' which is exacerbated by the lack of vestibular stimulation with visual representation of motion.

Mismatch between the users motions such as registration errors, lag in movement response due to overfiltering, inadequate resolution for small movements, and slow speed can contribute to these problems.

The same technology can control the robot, but then the eye–hand coordination issues become even more pervasive through the system, and user tension or frustration can make the system difficult to use.

Ironically the tendency to build robots has been to minimize the degrees of freedom because that reduces the control problems. Recent improvements in computers has shifted the emphasis to more degrees of freedom, allowing robotic devices that seem more intelligent and more human in their motions. This also allows more direct teleoperation as the user can control the robot with their own motions.

Telepresence

Telepresence means "feeling like you are somewhere else". Some people have a very technical interpretation of this, where they insist that you must have head-mounted displays in order to have telepresence. Other people have a task-specific meaning, where "presence" requires feeling that you are emotionally and socially connected with the remote world. The current view of telepresence remains somewhat vague.

Robotics Certification Standards Alliance

The **Robotics Certification Standards Alliance** (RCSA) is a global company that has been actively providing robotics curriculums, training, online testing systems and certification since 1998.

RCSA first started with partnerships with Motoman and Private Career Colleges in Canada. The partnerships grew to have included ABB, Motoman and Panasonic. In 2006 RCSA was invited to join the American Welding Society (AWS) D16 committee to provide robotics and testing expertise in the development of America's first robotic welding exam (CRAW). RCSA accepted this challenge and worked alongside Lincoln Electric Automation, ABB and Wolf Robotics to develop the details and procedures of the CRAW which was launched in June 2008.

In 2009 the RCSA redesigned the AWS CRAW course to fit the needs of a global market. This International Robotic Welding Certification (Certified Robotic Welder - CRW) was developed and launched early 2010.

The RCSA gained recognition in 2009 by the Government of Canada and the Ministry of Training Colleges and Universities (MTCU) as the robotics subject matter experts in North America

FUTURE CHALLENGES

There are many unsolved problems and fundamental challenges for robotics. At a very high level, challenges for industrial and service robotics can be categorized in the following areas.

• **Manipulation and physical interaction with the real world:** We need concerted modeling and control efforts together with the development of good hardware to make arms and hands that can perform anything but the simplest of pick-and-place operations that are prevalent in industry.

• **Perception for unstructured environments:** Most industrial robots have fairly primitive sensing and perception is limited to 2D structured environments. A robot's ability to perceive 3D environments and take actions based on perception currently is limited to very simple tasks.

• **Safety for operation near humans**: Personal robots will have to operate in the vicinity of humans. Even in industry, there are many applications now where robots and humans augment each others' skills. While industrial robotics has had a history of cordoning off robots and not allowing humans to enter robotic work areas, this culture is changing. This means robots will need to be made safe. This in turn leads to both hardware and software challenges.

• **Human-robot interaction:** Robotics applications call for humans operating in proximity to robots and with robots as assistants to humans. The relevant understanding of human machine interaction mostly comes from studies of human-computer interaction. Clearly robots, which perform physical work and operate in a 3D world, are more than computers, and there is a definite need to develop this field further.
• **Networks of robots, sensors, and users:** Most current applications see a robot operating with a human user or with a collection of sensors in a very structured environment in a pre-determined manner. With

the emergence of networked, embedded systems and the increased presence of networks in homes and in factories, robots will need to work with other robots, learn from different types of sensors and interact with different human users depending on their immediate environment. This is particularly true for mobile robotic systems whose environments are constantly changing.

Finally, it is important to note that these challenges call for a concerted effort to develop physical infrastructure (hardware) as well as a basic scientific research agenda. Most high-caliber robotics research programs have a strong experimental program, and progress has been hampered by the lack of affordable instrumentation in all these areas, but particularly in the area of dexterous manipulation.

Applications

- Automotive industry Automotive industry
- Assembly Assembly
- Medical laboratories Medical laboratories
- Medecine Medecine
- Nuclear energy Nuclear energy
- Agriculture Agriculture
- Spatial exploration Spatial exploration
- Underwater inspection Underwater inspection
- Customer service Customer service
- Arts and entertainement Arts and entertainement

Automotive industry automotive industry

One of the most important partners in the development of robotic technologies

- Welding robots
- Robustness and precision of the assembly of pieces
- Manipulate very heavy loads
- Found in painting rooms
- Used for places that are hard to reach

Assembly Assembly

Another strong partners is the assembly of manufactured products

- Execute repetitive sequence of movement, boring, demotivating and dangerous tasks at constant performance.
- Many tools are attached at the extremity of a manipulator
- Use the optimal sequence of operations.
- Can monitor the quality assembly line with adapted enhance sensor technologies

Medical laboratories

Medical laboratories are another place where repetitive tasks must be made.

- Handling a large quantity of samples
- Execution of analyses
- Automatic systems with measurement apparatus.
- Small mobile units can also take charge of moving the samples between different parts of the room or services, thus eliminating the need for the technician to continuously have to walk.

Medecine Medecine

As robots as getting more and more accurate and modern surgery tends to be less invasive,

- robotic systems now start to be developed to assist surgeons in high precision manipulation of devices.
- The development of biomedical applications for robotics is becoming a very important field of research of development
- A social motivation to improve patient cares

Nuclear energy

Nuclear generator installations are places where we can find a large number of robotic applications.

- Used for maintenance of nuclear reactors.
- Used for the replacement of radioactive fuel tubes.
- Seal off radioactive leakages in contaminated zones.
- Cleaning and decontaminating radioactive areas without compromising the health of workers was also necessary.

Agriculture Agriculture

Robots have also found some applications in agriculture

- In Australia a robotic system has been developed for sheep shearing
- Robots for field sowing
- Raisin and apple Gathering

Spatial exploration

Spatial probes sent for many years to explore and discover our universe

- Like the Viking I and II probes sent to explore Mars in 1976,
- Telemanipulator used to collect samples of soil
- The famous Canadian spatial manipulator Canadarm mounted on American spaceships and the new space station remote manipulator system (SSRMS) that is used to assemble the international space station.

- Mars Rover in 1998 explored the neighbor planet while being teleguided from the Earth.
- Provided an incredible amount of new information about this unknown environment.

Underwater inspection

Submersible robots have been used for many years to explore sea beds.

- Rescuing ship-wrecked persons
- Retrieving black boxes of crashed planes.
- Exploring deap sea and old wrecks in order to find their secrets.
- Inspection of the flooded side of dams to detect the cracks
- Inspect and maintain oil digging Platforms

Customer service

Various machines have been develop to serve customers in a semi- automatic or fully automatic way.

- Automatic banking
- Shell Smart Pump

Arts and entertainment

"Playing" with sophisticated toys dedicated for funny applications.

- Robots that are supposed to do house cleaning
- AIBO, built by Sony, that have all the nice characteristics of a real dog but without its obvious disadvantages.
- Remotely controlled robots used to do fun painting
- Considered as a very positive and innnovative way of evolution in robotics.

Market evolution

Evolution Robotics provides a broad range of services to help companies develop intelligent products with its technologies. Some of these include:

- Technology Integration
- Software Platform Customization
- Product Concept & Specification Development
- Product Architecture Consultation
- Contract R&D
- Project Management
- Software Platform Training and Custom Seminars
- Quality Assurance

Conclusion

Today we find most robots working for people in industries, factories, warehouses, and laboratories. Robots are useful in many ways. For instance, it boosts economy because businesses need to be efficient to keep up with the industry competition. Therefore, having robots helps business owners to be competitive, because robots can do jobs better and faster than humans can, e.g. robot can built, assemble a car. Yet robots cannot perform every job; today robots roles include assisting research and industry. Finally, as the technology improves, there will be new ways to use robots which will bring new hopes and new potentials.

Bibliography

We have used the following websites as references to write our report:

[1] INEEL website [online]. Available from: http://www.inel.gov/adaptiverobotics/humanoidrobotics/ Access 12 June 2005.

[2] Foerst Anne, (1999) Artificial sociability: from embodied AI toward new understandings of personhood, Technology in Society, 21, pp. 373–386. T209 Resource CD-ROM, Cyborg, part 2 – Robotics.

[3] ASIMO Honda [online]. Available from: http://world.honda.com/HDTV/ASIMO/ Access 11 June 2005.

[4] MIT website [online]. Available from: http://www.ai.mit.edu/projects/humanoid-robotics-group/ Access 11 June 2005

[5] Jones, A.C. (2002) 'Minds, matter and machines', T209 Resource CD-ROM, Cyborg, part 1 – Robotics.

[6] NASA website [online]. Available from: http://www-aig.jpl.nasa.gov/public/planning/dist-rovers/ Access 12 June 2005.

[7] Bruce, I.S. (1998) 'Man Made', The Scotsman, December 1, Spectrum, p. UP4, T209 Resource CD-ROM, Cyborg, part 1- Bionics.

ASIMO image - T209 Resource CD-ROM, Cyborg, part 1 – Robotics.

We have used the following book as references to write our report:

[1] A Mathematical Introduction to Robotic Manipulation (Richard M.Murray California institute of Technology, Zexiang Li Hong Kong University of Science and Technology, S.Shankar Sastry , University of California, Berkeley)

[2] WTEC Panel Report on INTERNATIONAL ASSESSMENT OF RESEARCH AND DEVELOPMENT IN ROBOTICS
(George Bekey, Robert Ambrose, Vijay Kumar, Art Sanderson, Brian Wilcox, Yuan Zheng)

Glossary

A

ABSO Data: Absolute Data (ABSO Data) is a correction factor for data that establishes an indicated value of zero when the robot is at the predetermined Home (calibration position).

Accuracy: Accuracy is the measurement of the deviation between the command characteristic and the attained characteristic (R15.05-2), or the precision with which a computed or calculated robot position can be attained. Accuracy is normally worse than the arm's repeatability. Accuracy is not constant over the workspace, due to the effect of link kinematics.

Active Compliant Robot: An active compliant robot is one in which motion modification during the performance of a task is initiated by the control system. The induced motion modification is slight, but sufficient to facilitate the completion of a desired task.

Actual Position: The position or location of the tool control point. Note that this will not be exactly the same as the demand position due to a multitude of un-sensed errors (such as link deflection, transmission irregularity, tolerances in link lengths, etc.)

Actuator: A power mechanism used to effect motion, or maintain position of the robot (for example, a motor which converts electrical energy to effect motion of the robot) (R15.07). The actuator responds to a signal received from the control system.

Axis: A direction used to specify the robot motion in a linear or rotary mode. (ISO 8373)

Arm: An interconnected set of links and powered joints comprising a robot manipulator that supports and/or moves a wrist and hand or end-effector through space. The arm itself does not include the end-effector. See Manipulator, End-effector and Wrist.

Articulated Manipulator: A manipulator with an arm that is broken into sections (links) by one or more joints. Each of the joints represents a degree of freedom in the manipulator system and allows translation and rotary motion.

Articulation: Describes a jointed device, such as a jointed manipulator. The joints provide rotation about a vertical axis, and elevation out of the horizontal plane. This allows a robot to be capable of reaching into confined spaces.

Assembly Robot: A robot designed specifically for mating, fitting, or otherwise assembling various parts or components into completed products. Primarily used for grasping parts and mating or fitting them together, such as in assembly line production.

B

Base: The stable platform to which a robot arm is attached.

Base Link: The stationary base structure of a robot arm that supports the first joint.

Burn-In: Burn-In is a robot testing procedure where all components of the robot are operated continuously for an extended period of time. This is done to test movement, and movement programming of the robot at early stages to avoid malfunctions after deployment.

C

CAD: Computer Aided Design. Computer graphic applications designed to allow engineering of objects (or parts), which are to be manufactured. A computer is used as a tool to design schematics and produce blueprints, which enable the accurate production of the object. The CAD system enables the three-dimensional drawings of basic figures, exact sizing and placement of components, making lines of specified length, width, or angle, as well as satisfying varying geometric shapes. This system also allows the designer to test a simulated part under different stresses, loads, etc.

Carousel : A rotating platform that delivers objects to a robot, and serves as an object queuing system. This carousel delivers the objects, or work-pieces to the loading/unloading station of the robot.

Cartesian Topology : A topology, which uses prismatic joints throughout, normally arranged to be perpendicular to each other.

Cartesian Manipulator : A Cartesian Manipulator is a robot arm with prismatic joints, which allows movement along one or more of the three- axes in the x, y, z coordinate system.

Cartesian-Coordinate Robot : A Cartesian-Coordinate robot is a robot whose manipulator-arm degrees of freedom are defined by Cartesian coordinates. This describes motions that are east-west, north-south and up-down, as well as rotary motions to change orientation.

Centrifugal Force : When a body rotates about an axis other than one at it's center of mass, it exerts an outward radial force called centrifugal force upon the axis, which restrains it from moving in a straight tangential line. To offset this force, the robot must exert an opposing torque at the joint of rotation.

Circular Motion Type : A calculated path that the robot executes, and is circular in shape.

Clamp : An end-effector which serves as a pneumatic hand that controls the grasping and releasing of an object. Tactile, and feed-back force sensors are used to mange the applied force to the object by the clamp. See End-Effector.

Closed-Loop : Control achieved by a robot manipulator by means of feed-back information. As a manipulator is in action, it's sensors continually feed-back information to the robot's controller which are used to further guide the manipulator within the given task. Many sensors are used to feed-back information about the manipulator's placement, speed, torque, applied forces, as well as the placement of a targeted moving object, etc. See feedback.

Control Command : An instruction fed to the robot by means of the human-to-machine input device. See Pendant (Teaching). This command is received by the robot's controller system and is interpreted. Then, the proper instruction is fed to the robot's actuators, which enable it to react to the initial command. Many times the command must be interpreted with the use of logic units and specific algorithms. See Input Device and Instruction Cycle.

Command Interpreter : A module or set of modules that determines what the received command means. The command is broken down into parts (parsed) and processed.

Command Position : The endpoint position of a robot motion that the controller is trying to achieve

Compliance : Displacement of a manipulator in response to a force or torque. A high compliance means the manipulator moves a good bit when it is stressed. This is called spongy or springy. Low compliance would be a stiff system when stressed.

Compliant Robot: A robot that performs tasks, with respect to external forces, by modifying its motions in a manner that minimizes those forces. The indicated or allowed motion is accomplished through lateral (horizontal), axial (vertical) or rotational compliance.

Configuration : The arrangement of links created by a particular set of joint positions on the robot. Note that there may be several configurations resulting in the same endpoint position

Contact Sensor : A device that detects the presence of an object or measures the amount of applied force or torque applied on the object through physical contact with it. Contact sensing can be used to determine location, identity, and orientation of work-pieces.

Continuous Path : Describes the process where by a robot is controlled over the entire path traversed, as opposed to a point-to-point method of traversal. This is used when the trajectory of the end-effector is most important to provide a smooth movement, such as in spray painting etc. See Point-to-Point.

Control Algorithm : A monitor used to detect trajectory deviations in which sensors detect such deviations and torque applications are computed for the actuators.

Control Device : Any piece of control hardware providing a means for human intervention in the control of a robot or robot system, such as an emergency-stop button, a start button, or a selector switch. (R15.06)

Control Mode : The means by which instructions are communicated to the robot.

Controlability : The property of a system by which an input signal can take the system from an initial state to a desired state along a predictable path within a predetermined period of time.
Controller : An information processing device whose inputs are both the desired and measured position, velocity or other pertinent variables in a process and whose outputs are drive signals to a controlling motor or actuator. (R15.02)
Controller System: The robot control mechanism is usually a computer of some type, which is used to store data (both robot and work environment), and store and execute programs, which operate the robot. The controller system contains the programs, data, algorithms; logic analysis, and various other processing activities, which enable it to perform. See Robot.
CPU (Central Processing Unit) : The main circuit board and processor of the Controller System.
Cycle : A single execution of a complete set of moves and functions contained within a robot program. (R15.05-2)
Cyclic Coordinate System : A coordinate system that defines the position of any point in terms of an angular dimension, a radial dimension, and a height from a reference plane. These three dimensions specify a point on a cylinder.
Cylindrical Topology : A topology where the arm follows a radius of a horizontal circle, with a prismatic joint to raise or lower the circle. Not popular in industry.
Cyclo Drive: A brand name for a speed reduction device that converts high speed low torque to low speed high torque, usually used on the major axis (larger).
D
Dead Man Switch : See Enabling Device.
Degrees Of Freedom : The number of independent directions or joints of the robot (R15.07), which would allow the robot to move its end effector through the required sequence of motions. For arbitrary positioning, 6 degrees of freedom are needed: 3 for position (left-right, forward-backward, and up- down) and 3 for orientation (yaw, pitch and roll).
Direct-Drive : Joint actuation including no transmission elements i.e. the link is bolted onto the output of the motor.
Downtime : A period of time in which a robot, or production line is shut down due to malfunction or failure. See Uptime.
Drive: A speed (gear) reducer to convert high speed low torque to low speed high torque (see Harmonic Drive, Cyclo Drive, Rotary Vector Drive).
Drop Delivery : A method of introducing an object to the workplace by gravity. Usually, a chute or container is so placed that, when work on the part is finished, it will fall or drop into a chute or onto a conveyor with little or no transport by the robot.
Dynamics: The study of motion, the forces that cause the motion, and the forces due to motion. The dynamics of a robot arm are very complicated as they result from the kinematical behavior of all masses within the arm's structure. The robot arm kinematics are complicated in themselves.
E
Emergency Stop : The operation of a circuit using hardware-based components that overrides all other robot controls, removes drive power from the robot actuators, and causes all moving parts to stop. (R15.06)
Enabling Device : A manually operated device which when continuously activated, permits motion. Releasing the device shall stop robot motion and motion of associated equipment that may present a hazard. (R15.06)
Encoder: A feedback device in the robot manipulator arm that provides current position (and orientation of the arm) data to the controller. A beam of light passes through a rotating code disk that contains a precise pattern of opaque and transparent segments on its surface. Light that is transmitted through the disk strikes photo-detectors, which convert the light pattern to electrical signals. See Feedback, Closed-Loop Control , and Feedback Sensor.
End-Effector : An accessory device or tool specifically designed for attachment to the robot wrist or tool mounting plate to enable the robot to perform its intended task. (Examples may include gripper, spot weld gun, arc weld gun, spray point gun, or any other application tools.) (R15.06)
Endpoint: The nominal commanded position that a manipulator will attempt to achieve at the end of a path of motion. The end of the distal link.
Error: The difference between the actual response of a robot and a command issued.
Expandability: Being able to add resources to the system, such as memory, larger hard drive, new I/O card, etc.
F
Feedback: The return of information from a manipulator, or sensor to the processor of the robot to provide self-correcting control of the manipulator. See Feedback Control, and Feedback Sensor.
Feedback Control : A type of system control obtained when information from a manipulator, or sensor is returned to the robot controller in order to obtain a desired robot effect. See Feedback, Closed-Loop Control and Feedback Sensor.
Feedback Sensor: A mechanism through which information from sensing devices is fed back to the robot's control unit. The information is utilized in the subsequent direction of the robot's motion. See Closed-Loop Control and Feedback Control.
Flexibility: The ability of a robot to perform a variety of different tasks.
Force Feedback : A sensing, technique using electrical signals to control a robot end-effector during the task of the end-effector. Information is fed from the force sensors of the end-effector to the robot control unit during the particular task to enable enhanced operation of the end-effector. See Feedback, Feedback Sensor and Force Sensor.
Force Sensor : A sensor capable of measuring the forces and torque exerted by a robot and it's wrist. Such sensors usually contain strain gauges. The sensor provides information needed for force feedback. See Force Feedback, Strain, Stress, and Strain Gauge.
Forward Kinematic Solution : The calculation required to find the endpoint position given the joint positions. For most robot topologies this is easier than finding the inverse kinematic solution.
Forward Kinematics: Procedures which determine where the end effector of a robot is located in space. The procedures use mathematical algorithms along with joint sensors to determine its location.
Frame: A coordinate system used to determine a position and orientation of an object in space, as well as the robot's position within its model.
G
Gantry : An adjustable hoisting machine that slides along a fixed platform or track, either raised or at ground level along the x, y, z axes.
Gantry Robot : A robot which has three degrees of freedom along the X, Y, and Z coordinate system. Usually consists of a spooling system (used as a crane) which when reeled or unreeled provides the up and down motion along the Z axis. The spool can slide from left to right along a shaft which provides movement along the Z axis. The spool and shaft can move forward and back along tracks which provide movement along the Y axis. Usually used to position it's end-effector over a desired object and pick it up.
Gravity Loading : The force exerted downward, due to the weight of the robot arm and/or the load at the end of the arm. The force creates an error with respect to position accuracy of the end-effector. A compensating force can be computed and applied bringing the arm back to the desired position.
Gripper: An end effector that is designed for seizing and holding (ISO 8373), and "grips" or grabs an object. It is attached to the last link of the arm. It may hold an object using several different methods, such as: applying pressure between it's "fingers", or may use magnetization or vacuum to hold the object, etc. See End-Effector.
H
Hand : A clamp or gripper used as an end-effector to grasp objects. See End Effector, Gripper.
Harness: Usually several wires, bundled together to deliver power and/or signal communications to/from devices. For example the robot motors are connected to the controller through a wire harness.
Harmonic Drive: Compact lightweight speed reducer that converts high speed low torque to low speed high torque. Usually found on the minor axis (smaller).
Hazardous Motion : Unintended/unexpected robot motion that may cause injury.

Hold: A stopping of all movements of a robot during its sequence, in which some power is maintained on the robot. For example, program execution stops, however power to the servomotors remain on if restarting is desired.
Home Position: A known and fixed location on the basic coordinate axis of the manipulator where it comes to rest, or to an indicated zero position for each axis. This position is unique for each model of manipulator. On Motoman robots there are indicator marks that show the Home position for the respective axis.
I
Inductive Sensors : The class of proximity sensors, which has half of a ferrite core, whose coil is part of an oscillator circuit. When a metallic object enters this field, at some point the object will absorb enough energy from the field to cause the oscillator to stop oscillating. This signifies that an object is present in a given proximity. See Proximity Sensor.
Interpolation: The method by which endpoint paths are created. In general to specify a motion a few knot points are defined and then all the intermediate positions between them are calculated by mathematical interpolation. The interpolation algorithm used therefore has a dramatic effect of the quality of motion.
Industrial Robot : A re-programmable multifunctional manipulator designed to move material, parts, tools, or specialized devices, through variable programmed motions for the performance of a variety of tasks (R15.06). The principle components are: one or more arms that can move in several directions; a manipulator; a computer controller that gives detailed movement instructions.
Input Devices : A variety of devices, which allow a human to machine interface. This allows the human to program, control, and simulate the robot. Such devices include programming pendant, computer keyboards, a mouse, joy-sticks, push buttons, operator panel, operator pedestal etc.
Instruction: A line of programming code that causes action from the System Controller. See Command.
Instruction Cycle : The time it takes for a robot controller system's cycle to decode a command or instruction before it is executed. The Instruction Cycle must be analyzed very closely by robotic programmers to enable speedy and proper reaction to varying commands.
Integrate: To fit together different subsystems, such as robots and other automation devices, or at least different versions of subsystems in the same control shell.
Intelligent Robot: A robot that can be programmed to make performance choices contingent on sensory inputs with little or no help from human intervention. See Robot.
J
Jacobian Matrix : The Jacobian matrix relates the rates of change of joint values with the rates of change of endpoint co-ordinates. Essentially it is a set of algorithm calculations that are processed to control the positioning of a robot.
Joint: A part of the manipulator system, which allows a rotation and/or translational degree of freedom of a link of end-effector.
Joints: The parts of the robot arm which actually bend or move.
Joint Motion Type: Also known as Point to Point motion, is a method of path interpolation that commands the movement of the robot by moving each joint directly to the commanded position so that all axis arrive to the position at the same time. The path is predictable, however the path will not be linear.
Joint-Interpolated Motion : A method of coordinating the movement of the joints, such that all joints arrive at the desired location simultaneously. This method of servo control produces a predictable path regardless of speed and results in the fastest pick and place cycle time for a particular move. See Pick and Place Cycle, Servo-system.
Joint Space: The set of joint positions.
K
Kinematics: The relationship between the motion of the endpoint of a robot and the motion of the joints. For a Cartesian robot this is a set of simple linear functions (linear tracks that may be arranged in X, Y, Z directions), for a revolute topology (joints that rotate) however, the kinematics are much more complicated involving complicated combinations of trigonometry functions. The kinematics of an arm is normally split into forward and inverse solutions.
L
Ladle Gripper: An end-effector, which acts as a scoop. It is commonly used to scoop up liquids, transfer it to a mold and pour the liquid into the mold. Common for handling molten metal under hazardous conditions. See End-Effector.
Laser: Acronym for Light Amplification by Stimulated Emission of Radiation. A device that produces a coherent monochromatic beam of light which is extremely narrow and focused but still within the visible light spectrum. This is commonly used as a non-contact sensor for robots. Robotic applications include: distance finding, identifying accurate locations, surface mapping, bar code scanning, cutting, welding etc.
Linear Motion Type: Is a method of path interpolation that commands the movement of the robot by moving each joint in a coordinated motion so that all axis arrive to the position at the same time. The path of the tool control point (TCP) is predictable and will be linear.
Link: A rigid part of a manipulator, which connects adjacent joints.
Links: The static material, which connects the joints of an arm together thereby forming a kinematical chain. In a human body, the links are the bones.
Load Cycle Time: A manufacturing or assembly line process term, which describes the complete time to unload the last work-piece and load the next one.
M
Magnetic Detectors: Robot sensors that can sense the presence of ferromagnetic material. Solid-state detectors with appropriate amplification and processing can locate a metal object to a high degree of precision. See Sensor.
Manipulator: A machine or robotic mechanism of which usually consists of a series of segments jointed or sliding relative to one another, for the purpose of grasping and/or moving objects (pieces or tools) usually in several degrees of freedom. The control of the manipulator may be by an operator, a programmable electronic controller, or any logic system (for example cam device, wired, etc.) (ISO 8373) See Arm, Wrist, and End-Effector, Master-Slave Manipulator
Material Handling: The process by which a robotic arm transfers materials from one place to another.
Material Processing Robot: A robot designed and programmed so that it can machine, cut, form, or change the shape, function or properties of materials it handles between the time the materials are first grasped and the time they are released in a manufacturing process.
Modularity: The property of flexibility built into a robot and control system by assembling separate units, which can be easily joined to or arranged with other parts or units.
Module: Self-contained component of a package. This component may contain sub-components known as sub-modules.
Motion Axis: The line defining the axis of motion either linear or rotary segment of a manipulator.
Motor: See Servo Motor.
O
Off-Line Programming: A programming method where the task program is defined on devices or computers separate from the robot for later input of programming information to the robot. (ISO 8373)
On-Line Programming: A means of programming a robot while the robot is functioning. This becomes important in manufacturing and assembly line production due to keeping productivity high while the robot is being programmed for other tasks.
Operator: The person designated to start, monitor and stop the intended productive operation of a robot or robot system. An operator may also interface with a robot for productive purposes. (R15.06)
Optical Encoder: A detection sensor, which measures linear or rotary motion by detecting the movement of markings past a fixed beam of light. This can be used to count revolutions, identify parts, etc.
Optical Proximity Sensors: Robot sensors which measures visible or invisible light reflected from an object to determine distance. Lasers are used for greater accuracy.

Orientation: The angle formed by the major axis of an object relative to a reference axis. It must be defined relative to a three-dimensional coordinate system. Angular position of an object with respect to the robot's reference system. See Roll, Pitch, and Yaw.

P

Path: The continuous locus of positions (or points in three dimensional space) traversed by the tool center point and described in a specified coordinate system. (R15.05-2)

Payload - Maximum: The maximum mass that the robot can manipulate at a specified speed, acceleration/deceleration, center of gravity location (offset), and repeatability under continuous operation over a specified working space. Maximum payload is specified in kilograms. (R15.05-2)

Pendant [Teach Pendant]: A hand-held input device linked to the control system with which a robot can be programmed or moved. (ISO 8373) This enables the human operator to stand in the most favorable position to observe, control, and record the desired movements in the robot's memory.

Pendant Teaching: The mapping and recording of the position and orientation of a robot and/or manipulator system as the robot is manually moved in increments from an initial state along a path to a final goal state. The position and orientation of each critical point (joints, robot base, etc.) is recorded and stored in a database for each taught position the robot passes through on its path toward its final goal. The robot may now repeat the path on its own by following the path stored in the database.

Pick And Place Cycle: The amount of time it takes for a manipulator to pick up an object and place it in a desired location, then return to it's rest position. This includes time during the acceleration and deceleration phases of a particular task. The robots movement is controlled from one point location in space to another in a point-to-point (PTP) motion system. Each point is programmed into the robot's control memory and then played back during the work cycle.

Pick-And-Place Task: A repetitive part transfer task composed of a picking action followed by a placing action.

Pitch: Rotation of the end-effector in a vertical plane around the end of the robot manipulator arm. See Roll, and Yaw.

Point-To-Point : Manipulator motion in which a limited number of points along a projected path of motion is specified. The manipulator moves from point to point rather than a continuous smooth path.

Pose: Alternative term for robot configuration, and describes the linear and angular position. The linear position includes the azimuth, elevation, and range of the object. The angular position includes the roll, pitch, and yaw of the object. See Roll, Pitch, and Yaw.

Position: The definition of an object's location in 3-D space, usually defined by a 3-D coordinate system using X, Y, and Z coordinates.

Presence-Sensing Safeguarding Device: A device designed, constructed, and installed to create a sensing field to detect an intrusion into such field by people, robots, or objects. See Sensor.

Programmable Logical Controller (PLC): A solid-state control system, which has a user programmable memory for storage of instructions to implement specific functions such as: I/O control logic, timing, counting arithmetic, and data manipulation. A PLC consists of a central processor, input/output interface, memory, and programming device, which typically uses relay equivalent symbols. The PLC is purposely designed as an industrial control system, which may perform functions equivalent to a relay panel or a wired solid-state logic control system, and may be integrated into the robot control system.

Programmable Robot: A feature that allows a robot to be instructed to perform a sequence of steps and then to perform this sequence in a repetitive manner. It can then be reprogrammed to perform a different sequence of steps if desired.

Proximity Sensor: A non-contact sensing device used to sense when objects are a short distance away, and determine the distance of the object. Several types include: radio frequency, magnetic bridge, ultrasonic, and photoelectric. Commonly used for: high speed counting, sensing metal objects, level control, reading coding marks, and limit switches. See Inductive Sensor.

Q

Quality Assurance (QA): Describes the methods, policies, and procedures necessary to conduct quality assurance testing during design, manufacturing and deliver phases of creating, reprogramming, or maintaining robots.

R

Reach: The volume of space (envelope), which a robot's end-effector can reach in at least one orientation.

Real-Time System: A computer system in which the computer is required to perform its tasks within the time restraints of some process simultaneously with the system it is assisting. The computer processes system data (input) from the sensors for the purpose of monitoring and computing system control parameters (outputs) required for the correct operation of a system or process. The computer is required to do its work fast enough to keep pace with an operator interacting with it through a terminal device (such as a screen or keyboard). The operator interacting with the computer has access, retrieval, and storage capability through a database management system. System access allows the operator to intervene and alter the system's operation.

Record-Playback Robot: A manipulator for which the critical points along desired trajectories are stored in sequence by recording the actual values of the joint-position encoders of the robot as it is moved under operational control. To perform the task, these points are played back to the robot's Servo-system. See Servo-system.

Rectangular-Coordinate Robot: A robot whose manipulator arm moves in linear motions along a set of Cartesian or rectangular axis in X, Y, and Z directions. The shape of the work envelope forms a rectangular figure. See Work Envelope.

Reliability: The probability or percentage of time that a device will function without failure over a specified time period or amount of usage (R15.02). Also called the robot's uptime or the Mean Time Between Failure (MTBF).

Repeatability: A measure of how close an arm can repeatedly obtain a taught position. For instance: once a manipulator is manually placed in a particular location and this location is resolved by the robot, the repeatability specifies how accurately the manipulator can return to that exact location. The degree of resolution within the robot control system determines the repeatability. In general an arm's repeatability can never be better than its resolution. See Teach, and Accuracy.

Remanufacture: To upgrade or modify robots to the revised specifications of the manufacturer. (R15.06)

Resolution: The amount of robot joint motion required for the position sensing to change by 1 count. Although the resolution of each joint feedback sensor is normally constant, the resolution of the endpoint in world coordinates is not constant for revolute arms, due to the non-linearity of the arm's kinematics.

Revolute Joint : The joints of a robot, which are capable of rotary motion.

Robot: A re-programmable, multifunctional manipulator designed to move material, parts, tools, or specified devices through variable programmed motions for the performance of a variety of tasks. Common elements which make up a robot are: controller, manipulator, and end-effector. See Manipulator, Controller, and End-Effector.

Robot Programming Language: An interface between a human user and a robot, which relates humans commands to the robot.

Robot Simulation: A method for emulating and predicting the behavior and the operation of a robotic system based on the model (e.g. computer graphics) of the physical system. (R15.07)

Roll: Rotation of the robot end-effector in a plane perpendicular to the end of the manipulator arm. See Pitch, and Yaw.

Rotary Joint: A joint which twists, swings or bends about an axis

Rotary Vector Drive (RV): A brand name for a speed reduction device that converts high speed low torque to low speed high torque, usually used on the major axis (larger). See Cyclo Drive, Harmonic Drive.

S

Safeguard: A barrier guard, device or safety procedure designed for the protection of personnel. (R15.06)

SCARA Robot: A cylindrical robot having two parallel rotary joints (horizontally articulated) and provides compliance in one selected plane. (ISO 8373) Note: SCARA derives from Selectively Compliant Arm for Robotic Assembly

Sensor: Instruments used as input devices for robots, which enable it to determine aspects regarding the robot's environment, as well as the robot's own positioning. Sensors respond to physical stimuli (such as heat, light, sound, pressure, magnetism, motion) and transmit the resulting signal or data for providing a measurement, operating a control, or both. (R15.06)
Sensory Feedback: Variable data measured by sensors and relayed to the controller in a closed-loop system. If the controller receives feedback that lies outside an acceptable range, then an error has occurred. The controller sends an error signal to the robot. The robot makes the necessary adjustments in accordance with the error signal.
Servo Control: The process by which the control system of the robot checks if the attained pose of the robot corresponds to the pose specified by the motion planning with required performance and safety criteria. (ISO 8373)
Servo-Controlled Robot: The control of a robot through the use of a closed loop Servo-system, in which the position of the robot axis is measured by feedback devices and is stored in the controller's memory. See Closed-Loop System, and Servo-system.
Servo Motor: An electrical power mechanism used to effect motion, or maintains position of the robot (for example, a motor which converts electrical energy to effect motion of the robot) (R15.07). The motor responds to a signal received from the control system and often incorporates an encoder to provide feedback to the control loop.
Servo Pack: An alternating current electrical power mechanism that is controlled through logic to convert electrical supply power that is in a sine wave form to a Pulse Width Modulated (PWM) square form, delivered to the motors for motor control: speed; direction; acceleration; deceleration; and braking control.
Servo-System: A system in which the controller issues commands to the motors, the motors drive the arm, and an encoder sensor measures the motor rotary motions and signals the amount of the motion back to the controller. This process is continued many times per second until the arm is repositioned to the point requested. See Servo-controlled Robot
Simulation: A graphical computer program that represents the robot and its environment, which emulates the robot's behavior during a simulated run of the robot. This is used to determine a robot's behavior in certain situations, before actually commanding the robot to perform such tasks. Simulation items to consider are: the 3-D modeling of the environment, kinematics emulation, path-planning emulation, and simulation of sensors. See Sensor, Forward Kinematics, and Robot.
Singularity: A configuration where two joints of the robot arm become co-axial (aligned along a common axis). In a singular configuration, smooth path following is normally impossible and the robot may loose control. The term originates from the behavior of the Jacobian matrix, which becomes singular (i.e. has no inverse) in these configurations.
Spline: A smooth, continuous function used to approximate a set of functions that are uniquely defined on a set of sub-intervals. The approximating function and the set of functions being approximated intersect at a sufficient number of points to insure a high degree of accuracy in the approximation. The purpose for the smooth function is to allow a robot manipulator to complete a task without jerky motion.
Spline Motion Type: A calculated path that the robot executes, and may be parabolic in shape. A Spline motion may also accomplish a free form curve with mixtures of circular and parabolic shapes.

T

Teach: To program a manipulator arm by manually guiding it through a series of motions and recording the position in the robot controller memory for playback.
Teach Pendant: A handheld control box, which is used by an operator to remotely guide a robot through the motions of its tasks. The motions are recorded by the robot control system for future playback. See Accuracy, Pendant Control, Playback Accuracy, Repeatability, and Teach.
Through-Beam: An object detection system used within a robot's imaging sensor system. A finely focused beam of light is mounted at one end and a detector at the other. When the beam of light is broken, an object is sensed.
Tool: A term used loosely to define a working apparatus mounted to the end of the robot arm, such as a hand, gripper, welding torch, screw driver, etc. See Arm, Gripper, and End-Effector.
Tool Frame: A coordinate system attached to the end-effector of a robot (relative to the base frame).
Touch Sensor: Sensing device, sometimes used with the robot's hand or gripper, which senses physical contact with an object, thus giving the robot an artificial sense of touch. The sensors respond to contact forces that arise between themselves and solid objects.
Trajectory Generation (Calculation): The computation of motion functions that allow the movement of joints in a smooth controlled manner.
Transducer: A device that converts energy from one form to another. Generally, a device that converts an input signal into an output signal of a different form. It can also be thought of as a device which converts static signals detected in the environment (such as pressure) into an electrical signal that is sent to a robot's control system.

U

Uptime: A period of time in which a robot, or production line is operating or available to operate, as opposed to downtime. See Downtime.

V

Vacuum Cup Hand: An end-effector for a robot arm which is used to grasp light to moderate weight objects, using suction, for manipulation. Such objects may include glass, plastic; etc. Commonly used because of its virtues of reduced object slide slipping while within the grasp of the vacuum cup. See End-Effector.
Vision Guided: Control system where the trajectory of the robot is altered in response to input from a vision system.
Vision Sensor: A sensor that identifies the shape, location, orientation, or dimensions of an object through visual feedback, such as a television camera.

W

Work Envelope: The set of all points which a manipulator can reach without intrusion. Sometimes the shape of the work space, and the position of the manipulator itself can restrict the work envelope.
Work-Piece: Any part which is being worked, refined, or manufactured prior to its becoming a finished product.
Workspace: The volume of space within which the robot can perform given tasks.
World Coordinates: A reference coordinate system in which the manipulator arm moves in linear motions along a set of Cartesian or rectangular axis in X, Y, and Z directions. The shape of the work envelope forms a rectangular figure. See Rectangular Coordinates.
World Model: A three dimensional representation of the robot's work environment, including objects and their position and orientation in this environment, which is stored in robot memory. As objects are sensed within the environment the robot's controller system continually updates the world model. Robots use this world model to aid in determining its actions in order to complete given tasks.
Wrist [Secondary Axis]: An interconnected set of links and powered joints between the arm and end effector, which supports, positions and orientates the end effector. (ISO 8373)
Wrist: A set of rotary joints between the arm and the robot end-effector that allow the end-effector to be oriented to the work-piece. In most cases the wrist can have degrees of freedom which enable it to grasp an object with roll, pitch, and yaw orientation. See Arm, End-effecfor, Roll, Pitch, Yaw, and work piece.

Y

Yaw: Rotation of the end-effector in a horizontal plane around the end of the manipulator arm. Side to side motion at an axis. See Roll, and Pitch.