Robot

From Wikipedia, the free encyclopedia

ASIMO, a humanoid robot manufactured by Honda.

A **robot** is a mechanical or virtual, artificial agent. It is usually an electromechanical system, which, by its appearance or movements, conveys a sense that it has intent or agency of its own. The word *robot* can refer to both physical robots and virtual software agents, but the latter are usually referred to as *bots* to differentiate.[1]

While there is still discussion about which machines qualify as robots,[2][3][4] a typical robot will have several, though not necessarily all of the following properties.

- is not 'natural' i.e. artificially created
- can sense its environment, and manipulate or interact with things in it
- has some degree of intelligence or ability to make choices based on the environment, or automatic control / preprogrammed sequence
- is programmable
- moves with one or more axes of rotation or translation
- makes dexterous coordinated movements
- appears to have intent or agency (reification, anthropomorphisation or Pathetic fallacy.[5])

Contents

- 1 Defining characteristics
- 2 Official definitions and classifications of robots
  - 2.1 Robotics Institute of America
  - 2.2 Japanese Industrial Robot Association
  - 2.3 International Standards Organization
- 3 Other definitions of robot
- 4 Etymology
- 5 History
  - 5.1 Ancient developments
  - 5.2 Medieval developments
  - 5.3 Early modern developments
  - 5.4 Modern Developments
  - 5.5 Robot Fatalities
- 6 Timeline
- 7 Contemporary uses
  - 7.1 Increased productivity, accuracy, and endurance
  - 7.2 Dirty, dangerous, dull or inaccessible tasks
  - 7.3 Unusual Robots
- 8 Dangers and fears
- 9 Literature
- 10 Competitions
- 11 See also
  - 11.1 Research areas
  - 11.2 Additional topics
- 12 References
  - 12.1 General references
- 13 External links

Defining characteristics

The last property (above), the appearance of agency, is important when people are considering whether to call a machine a robot. In general, the more a machine has the appearance of agency, the more it is considered a robot.

Mental agency

KITT is mentally anthropomorphic

For robotic engineers, the physical appearance of a machine is less important than the way its actions are controlled.[6] The more the control system seems to have agency of its own, the more likely the machine is to be called a robot. An important feature of agency is the ability to make choices. So the more a machine could feasibly choose to do something different, the more agency it has. For example:

- a clockwork car is never considered a robot[7]
- a remotely operated vehicle is sometimes considered a robot[8] (or telerobot).
- a car with an onboard computer, like Bigtrak, which could drive in a programmable sequence might be called a robot.
- a self-controlled car, like the 1990s driverless cars of Ernst Dickmanns, or the entries to the DARPA Grand Challenge, which could sense its environment, and make driving decisions based on this information would quite likely be called robot.
- a sentient car, like the fictional KITT, which can take decisions, navigate freely and converse fluently with a human, is usually considered a robot.

Physical agency

ASIMO is physically anthropomorphic

However, for many laymen, if a machine looks anthropomorphic or zoomorphic (e.g. ASIMO and Aibo), especially if it is limb-like (e.g. a simple robot arm), or has limbs, or can move around, it would be called a robot.

For example, even if the following examples used the same control architecture:

- a player piano is rarely characterized as a robot[9]
- a CNC milling machine is very occasionally characterized as a robot.
- a factory automation arm is almost always characterized as a robot or an industrial robot.
- an autonomous wheeled or tracked device, such as a self-guided rover or self-guided vehicle, is almost always characterized as a robot, a mobile robot or a service robot
- a zoomorphic mechanical toy, like Roboraptor, is usually characterized as a robot.[10][11]
- a humanoid, like ASIMO, is almost always characterized as a robot or a service robot.

Interestingly, while a 3-axis CNC milling machine may have a very similar or identical control system to a robot arm, it is the arm which is almost always called a robot, while the CNC machine is usually just a machine. Having a limb can make all the difference. Having eyes too gives people a sense that a machine is aware (the eyes are the windows of the soul). However, simply being anthropomorphic is not sufficient for something to be called a robot. A robot must do something, whether it is useful work or not. So, for example, a rubber dog chew, shaped like ASIMO, would not be considered a robot.

Official definitions and classifications of robots

Robotics Institute of America

Countries have different definitions of what it means to be a robot. For example, the Robotics Institute of America

(RIA) defines a robot as:

> A re-programmable multi-functional manipulator designed to move materials, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks.[12]

and also recognizes four classes of robot:

- A: Handling devices with manual control
- B: Automated handling devices with predetermined cycles
- C: Programmable, servo-controlled robots with continuous of point-to-point trajectories
- D: Capable of Type C specifications, and also acquires information from the environment for intelligent motion

Japanese Industrial Robot Association

In contrast, the Japanese Industrial Robot Association (http://www.jara.jp/e/h/jara01.html) (JIRA) recognizes as many as six classes:[13]

- 1: Manual - Handling Devices actuated by an operator
- 2: Fixed Sequence Robot
- 3: Variable-Sequence Robot with easily modified sequence of control
- 4: Playback Robot, which can record a motion for later playback
- 5: Numerical Control Robots with a movement program to teach it tasks manually
- 6: Intelligent robot: that can understand its environment and able to complete the task despite changes in the operation conditions

International Standards Organization

Such variation makes it difficult to compare numbers of robots in different countries. Japan has so many robots partly because it counts more machines as robots. For this reason, the International Standards Organization gives a single definition to be used when counting the number of robots in each country.[14] International standard ISO 8373 defines a "robot" as:

> An automatically controlled, reprogrammable, multipurpose, manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications.[15]

Other definitions of robot

There is no one definition of robot which satisfies everyone, and many people have their own. [16] For example,

Joseph Engelberger, a pioneer in industrial robotics, once remarked:

> I can't define a robot, but I know one when I see one.[17]

The Cambridge Advanced Learner's Dictionary (http://dictionary.cambridge.org/) defines "robot" as:

> A machine used to perform jobs automatically, which is controlled by a computer[18]

Etymology

The word *robot* was introduced by Czech writer Karel Čapek in his play *R.U.R. (Rossum's Universal Robots)*, which premiered in 1920. The play begins in a factory that makes 'artificial people' - they are called *robots*, but are closer to the modern idea of androids or even clones, creatures who can be mistaken for humans. They can plainly think for themselves, though they seem happy to serve. At issue is whether the "Robots" are being exploited and, if so, what follows? (see also Robots in literature for details

of the play)[19]

Karel Čapek who introduced the word *robot* in his 1920 play R.U.R. (Rossum's Universal Robots).

However, Karel Čapek was not the originator of the word; he wrote a short letter in reference to an article in the *Oxford English Dictionary* etymology in which he named his brother, painter and writer Josef Čapek, as its actual inventor.[20] In an article in the Czech journal *Lidové noviny* in 1933, he also explained that he had originally wanted to call the creatures *laboři* (from Latin *labor*, work). However, he did not like the word, seeing it as too artificial, and sought advice from his brother Josef, who suggested "roboti".

The word *robot* comes from the word *robota* meaning literally serf labor, and, figuratively, "drudgery" or "hard work" in Czech and Slovak. The origin of the word is the Old Church Slavonic *rabota* "servitude" ("work" in contemporary Russian), which in turn comes from the Indo-European root **orbh-* (http://www.bartleby.com/61/roots/IE363.html). *Robot* is cognate with the German word *Arbeiter* (worker).

History

Cadmus Sowing the Dragon's teeth, by Maxfield Parrish, 1908

Ancient developments

The idea of artificial people dates at least as far back as the ancient legends of Cadmus, who sowed dragon teeth that turned into soldiers, and the myth of Pygmalion, whose statue of Galatea came to life. In Greek mythology, the deformed god of metalwork (Vulcan or Hephaestus) created mechanical servants, ranging from intelligent, golden handmaidens to more utilitarian three-legged tables that could move about under their own power. Medieval Persian alchemist Jabir ibn Hayyan, included recipes for creating artificial snakes, scorpions, and humans in his coded *Book of Stones*. Jewish legend tells of the Golem, a clay creature animated by Kabbalistic magic. Similarly, in the Younger Edda, Norse mythology tells of a clay giant, Mökkurkálfi or Mistcalf, constructed to aid the troll Hrungnir in a duel with Thor, the God of Thunder.

In ancient China, a curious account on automata is found in the *Lie Zi* text, written in the 3rd century BC. Within it there is a description of a much earlier encounter between King Mu of Zhou (1023-957 BC) and a mechanical engineer known as Yan Shi, an 'artificer'. The latter proudly presented the king with a life-size, human-shaped figure of his mechanical handiwork.

> The king stared at the figure in astonishment. It walked with rapid strides, moving its head up and down, so that anyone would have taken it for a live human being. The artificer touched its chin, and it began singing, perfectly in tune. He touched its hand, and it began posturing, keeping perfect time...As the performance was drawing to an end, the robot winked its eye and made advances to the ladies in attendance, whereupon the king became incensed and would have had Yen Shih [Yan Shi] executed on the spot had not the latter, in mortal fear, instantly taken the robot to pieces to let him see what it really was. And, indeed, it turned out to be only a construction of leather, wood, glue and lacquer, variously coloured white, black, red and blue. Examining it closely, the king found all the internal organs complete—liver, gall, heart, lungs, spleen, kidneys, stomach and intestines; and over these again, muscles, bones and limbs with their joints, skin, teeth and hair, all of them artificial...The king tried the effect of taking away the heart, and found that the mouth could no longer speak; he took away the liver and the eyes could no longer see; he took away the kidneys and the legs lost their power of locomotion. The king was delighted.[21]

Concepts akin to a robot can be found as long ago as the 4th century BC, when the Greek mathematician Archytas of Tarentum postulated a mechanical bird he called "The Pigeon" which was propelled by steam. Yet another early automaton was the clepsydra, made in 250 BC by Ctesibius of Alexandria, a physicist and inventor from Ptolemaic Egypt.[22] Hero of Alexandria (10-70 AD) made numerous innovations in the field of automata, including one that allegedly could speak.

Medieval developments

Al-Jazari's programmable humanoid robots.

Al-Jazari (1136-1206), an Arab Muslim inventor during the Artuqid dynasty, designed and constructed a number of automatic machines, including kitchen appliances, musical automata powered by water, and the first programmable humanoid robot in 1206. Al-Jazari's robot was a boat with four automatic musicians that floated on a lake to entertain guests at royal drinking parties. His mechanism had a programmable drum machine with pegs (cams) that bump into little levers that operate the percussion. The drummer could be made to play different rhythms and different drum patterns by moving the pegs to different locations.[23]

One of the first recorded designs of a humanoid robot was made by Leonardo da Vinci (1452-1519) in around 1495. Da Vinci's notebooks, rediscovered in the 1950s, contain detailed drawings of a mechanical knight able to sit up, wave its arms and move its head and jaw. [19] The design is likely to be based on his anatomical research recorded in the *Vitruvian Man*. It is not known whether he attempted to build the robot (see: Leonardo's robot).

Early modern developments

An early automaton was created 1738 by Jacques de Vaucanson, who created a mechanical duck that was able to eat and digest grain, flap its wings, and excrete. [19]

The Japanese craftsman Hisashige Tanaka, known as "Japan's Edison," created an array of extremely complex mechanical toys, some of which were capable of serving tea, firing arrows drawn from a quiver, or even painting a Japanese *kanji* character. The landmark text *Karakuri Zui* (*Illustrated Machinery*) was published in 1796. (T. N. Hornyak, *Loving the Machine: The Art and Science of Japanese Robots* [New York: Kodansha International, 2006])

In 1898 Nikola Tesla publicly demonstrated a radio-controlled (teleoperated) boat, similar to a modern ROV. Based on his patents U.S. Patent 613,809 (http://patft.uspto.gov/netacgi/nph-Parser?patentnumber=613,809), U.S. Patent 723,188 (http://patft.uspto.gov/netacgi/nph-Parser?patentnumber=723188) and U.S. Patent 725,605 (http://patft.uspto.gov/netacgi/nph-Parser?patentnumber=725,605) for "teleautomation", Tesla hoped to develop the "wireless torpedo" into a weapon system for the US Navy. (Cheney 1989) See also the PBS website article (with photos): Tesla - Master of Lightning (http://www.pbs.org/tesla)

Modern Developments

In the 1930s, Westinghouse Electric Corporation made a humanoid robot known as Elektro, exhibited at the 1939 and 1940 World's Fairs.

The first electronic autonomous robots were created by William Grey Walter of the Burden Neurological Institute at Bristol, England in 1948 and 1949. They were named *Elmer* and *Elsie*. These robots could sense light and contact with external objects, and use these stimuli to navigate. [24]

The first truly modern robot, digitally operated, programmable, and teachable, was invented by George Devol in 1954 and was ultimately called the Unimate. It is worth noting that not a single patent was cited against his original robotics patent (U.S. Patent 2,988,237 (http://patft.uspto.gov/netacgi/nph-Parser?patentnumber=2,988,237)).

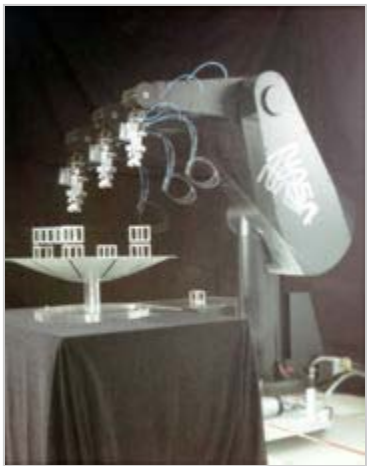
George C. Devol *circa* 1982

The first Unimate was personally sold by Devol to General Motors in 1960 and installed in 1961 in a plant in Trenton, New Jersey to lift hot pieces of metal from a die casting machine and stack them.[22]

Robot Fatalities

The first human to be killed by a robot was Robert Williams who died at a casting plant in Flat Rock, MI (Jan. 25, 1979). [25]

A better known case is that of 37 year-old Kenji Urada, a Japanese factory worker, in 1981. Urada was performing routine maintenance on the robot, but neglected to shut it down properly, and was accidentally pushed into a grinding machine.[26]



Unimate's PUMA arm

Timeline

Date	Significance	Robot Name	Inventor
Third century B.C.	Automata activated by clocks at preset times		Ctesibius of Alexandria
Third century B.C.	During a parade organized by Ptolemy II Philadelphus, a statue of Nysa could stand up by itself from a sitting position, pour libations of milk and sit down again.		Ctesibius of Alexandria?
First century A.D.	In two works (Pneumatica and Automata) Heron of Alexandria describes many machines and automata (mainly from previous sources)		Ctesibius of Alexandria, Philo of Byzantium, Heron of Alexandria
1206	First programmable humanoid robot	mechanical boat with four automatic musicians	Al-Jazari
~1495	One of the first recorded designs of a humanoid robot	mechanical knight	Leonardo da Vinci
1738	Early automaton, a mechanical duck that was able to eat grain, flap its wings, and excrete.		Jacques de Vaucanson
1920	Word *robot* coined.[27]		Josef Čapek
1921	The term "robot" used in a play called "R.U.R." or "Rossum's Universal Robots"		Karel Čapek
1930s	Early humanoid robot. It was exhibited at the 1939 and 1940 World's Fairs	Elektro	Westinghouse Electric Corporation
1942	The word *robotics* appears in the science fiction short story Runaround.[28]		Isaac Asimov
1948	Simple robots which exhibit biological like behaviours.[29]	Elsie and Elmer	William Grey Walter
1954	Patent submitted for first digitally controlled robot and first teachable robot, (U.S. Patent 2,988,237 (http://patft.uspto.gov/netacgi/nph-Parser?patentnumber=2,988,237))		George Devol

1956	First robot company, Unimation, is founded by George Devol and Joseph Engelberger based on Devol's seminal patents; first commercial robot.[30]	Unimate	George Devol
1956	Phrase *artificial intelligence* is coined at a conference in Dartmouth, Massachusetts.[31]		Marvin Minsky and John McCarthy
1961	First industrial robot installed.	Unimate	
1963	First Palletizing Robot.		Fuji Yusoki Kogyo
1975	Programmable Universal Manipulation Arm (a Unimation product)	Programmable Universal Machine for Assembly	Victor Scheinman
1981	Kenji Urada, a Japanese factory worker, is killed by a robot.[32]		
2000	A humanoid robot that can recognize human faces, see stereoscopically, walk and run on different types of ground (including stairs), and respond (in words and in actions) to English and Japanese commands.	ASIMO	Honda Corporation

Contemporary uses

Robots can be placed into roughly two categories based on the type of job they do:

- Jobs which a robot can do better than a human. Here, robots can increase productivity, accuracy, and endurance.
- Jobs which a human could do better than a robot, but it is desirable to remove the human for some reason. Here, robots free us from dirty, dangerous and dull tasks.

Increased productivity, accuracy, and endurance

Jobs which require speed, accuracy, reliability or endurance can be performed far better by a robot than a human. Hence many jobs in factories which were traditionally performed by people are now robotized. This has led to cheaper mass-produced goods, including automobiles and electronics. Robots have now been working in factories for more than fifty years, ever since the Unimate robot was installed to automatically remove hot metal from a die casting machine. Since then, factory automation in the form of large stationary manipulators has become the largest market for robots. The number of installed robots has grown faster and faster, and today there are more than 800,000 worldwide (42% in Japan, 40% in the European Union and 18% in the USA).[33]

German KUKA Industrial robots doing vehicle under body assembly

Pick and Place robot, Contact Systems C5 Series[34]

Some examples of factory robots:

- **Car production:** This is now the primary example of factory automation. Over the last three decades automobile factories have become dominated by robots. A typical factory contains hundreds of industrial robots working on fully automated production lines - one robot for every ten human workers. On an automated production line a vehicle chassis is taken along a conveyor to be welded, glued, painted and finally assembled by a sequence of robot stations.
- **Packaging:** Industrial robots are also used extensively for palletizing and packaging of manufactured goods,

for example taking drink cartons from the end of a conveyor belt and placing them rapidly into boxes, or the loading and unloading of machining centers.

- **Electronics:** Mass produced printed circuit boards (PCBs) are almost exclusively manufactured by pick and place robots, typically with "SCARA" manipulators, which remove tiny electronic components from strips or trays, and place them on to PCBs with great accuracy.[35] Such robots can place several components per second (tens of thousands per hour), far out-performing a human in terms of speed, accuracy, and reliability.[36]

- **Automated Guided Vehicles (AGVs):** Mobile robots, following markers or wires in the floor, or using vision[37] or lasers, are used to transport goods around large facilities, such as warehouses, container ports, or hospitals.[38] Early AGV-style robots were limited to tasks that could be accurately defined and must be performed the same every time. Very little feedback or intelligence was required, and the robots may need only the most basic of exteroceptors to sense things in their environment, if any at all. However, newer AGV's, such as the Speci-Minder[39], ADAM [40], Tug [41], and PatrolBot Gofer [42] qualify under the JIRA definition of "Intelligent Robots". They use some form of natural features recognition to navigate. Scanning lasers, stereovision or other means of sensing the environment in two- or three-dimensions is combined with standard dead-reckoning calculations in a probabilistic manner to continuously update the AGV's current location, eliminating cumulative error. This means that the "Self-Guided Vehicle" or SGV can navigate a space autonomously once it has learned it or been provided with a map of it. Such new robots are able to operate in complex environments and perform non-repetitive and non-sequential tasks such as carrying tires to presses in factories, delivering masks in a semi-conductor lab, delivering specimens in hospitals and delivering goods in warehouses.

ADAM carries steel samples in a factory without following lines or triangulating from beacons.

Dirty, dangerous, dull or inaccessible tasks

There are many jobs which a human could perform better than a robot but for one reason or another the human either does not want to do it or cannot be present to do the job. The job may be too boring to bother with, for example domestic cleaning; or be too dangerous, for example exploring inside a volcano[43]. These jobs are known as the "dull, dirty, and dangerous" jobs. Other jobs are physically inaccessible. For example, exploring another planet[44], cleaning the inside of a long pipe or performing laparoscopic surgery.[45]

The Roomba domestic vacuum cleaner robot does a menial job

- **Robots in the home:** As their price falls, and their performance and computational ability rises[46], making them both affordable and sufficiently autonomous, robots are increasingly being seen in the home where they are taking on simple but unwanted jobs, such as vacuum cleaning, floor cleaning and lawn mowing. While they have been on the market for several years, 2006 saw an explosion in the number of domestic robots sold. Currently, more domestic robots have been sold than any other single type of robot.[47] They tend to be relatively autonomous, usually only requiring a command to begin their job. They then proceed to go about their business in their own way. At such, they display a good deal of agency, and are considered true robots.

- **Telerobots**: When a human cannot be present on site to perform a job because it is dangerous, far away, or inaccessible, teleoperated robots, or telerobots are used. Rather than following a predetermined sequence of movements a telerobot is controlled from a distance by a human operator. The robot may be in another room or another country, or may be on a very different scale to the operator. A laparoscopic surgery robot such as da Vinci

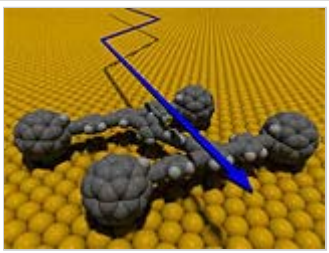

A laparoscopic robotic surgery machine.

(http://www.intuitivesurgical.com/products/davincissurgicalsystem/index.aspx) allows the surgeon to work inside a human patient on a relatively small scale compared to open surgery, significantly shortening recovery time.[45] An interesting use of a telerobot is by the author Margaret Atwood, who has recently started using a robot pen (the Longpen) to sign books remotely. The Longpen is similar to the Autopen of the 1800s. This saves the financial cost and physical inconvenience of traveling to book signings around the world.[48] At the other end of the spectrum, iRobot ConnectR robot is designed to be used by anyone to stay in touch with family or friends from far away. Such telerobots may be little more advanced than radio controlled cars. Some people do not consider them to be true robots because they show little or no agency of their own.

- **Military robots**: Teleoperated robot aircraft, like the Predator Unmanned Aerial Vehicle, are increasingly being used by the military. These robots can be controlled from anywhere in the world allowing an army to search terrain, and even fire on targets, without endangering those in control.[49] Many of these robots are teleoperated, but others are being developed that can make decisions automatically; choosing where to fly or selecting and engaging enemy targets.[50] Hundreds of robots such as iRobot's Packbot and the Foster-Miller TALON are being used in Iraq and Afghanistan by the U.S. military to defuse roadside bombs or improvised explosive devices (IEDs) in an activity known as Explosive Ordnance Disposal (EOD).[51] Autonomous robots such as MDARS and Seekur are being developed to perform security and surveillance tasks at military facilities to address manpower shortages as well as keeping troops out of harm's way.
- **Elder Care:** The population is aging in many countries, especially Japan, meaning that there are increasing numbers of elderly people to care for but relatively fewer young people to care for them.[52][53] Humans make the best carers, but where they are unavailable, robots are gradually being introduced.[54] One robot in use today, Intouchhealth's RP-7 remote presence robot, is being used by doctors to communicate with patients, allowing the doctor to be anywhere in the world. This increases the number of patients a doctor can monitor.

Unusual Robots

Much of the research in robotics focuses not on specific industrial tasks, but on investigations into new types of robot, alternative ways to think about or design robots, and new ways to manufacture them. It is expected that these new types of robot will be able to solve real world problems when they are finally realised.


A nanocar made from a single molecule[55]

- **Nanorobots:** Nanorobotics is the still largely hypothetical technology of creating machines or robots at or close to the scale of a nanometre (10^{-9} metres). Also known as **nanobots** or **nanites**, they would be constructed from molecular machines. So far, researchers have mostly produced only parts of these complex systems, such as bearings, sensors, and Synthetic molecular motors, but functioning robots have also been made such as the entrants to the Nanobot Robocup contest.[56] Researchers also hope to be able to create entire robots as small as viruses or bacteria, which could perform tasks on a tiny scale. Possible applications include micro surgery (on the level of individual cells), utility fog[57], manufacturing, weaponry and cleaning.[58] Some people have suggested that if nanobots were made which could reproduce, they could have serious negative consequences, turning the earth into grey goo, while others argue that this is nonsense.[59][60]
- **Soft Robots:** Most robots, indeed most man made machines of any kind, are made from hard, stiff materials; especially metal and plastic. This is in contrast to most natural organisms, which are mostly soft tissues. This difference has not been lost on robotic engineers, and some are trying to create robots from soft materials (rubber, foam, gel), soft actuators (air muscles, electroactive polymers, ferrofluids), and exhibiting soft behaviours (fuzzy logic, neural networks).[61] Such robots are expected to look, feel, and behave differently

from traditional hard robots.

- **Reconfigurable Robots:** A few researchers have investigated the possibility of creating robots which can alter their physical form to suit a particular task,[62] like the fictional T-1000. Real robots are nowhere near that sophisticated however, and mostly consist of a small number of cube shaped units, which can move relative to their neighbours, for example SuperBot (http://www.isi.edu/robots/superbot.htm). Algorithms have been designed in case any such robots become a reality.[63]

Molecubes in motion

A swarm of robots from the Open-source micro-robotic project[64]

- **Swarm robots:** Inspired by colonies of insects such as ants and bees, researchers hope to create very large swarms (thousands) of tiny robots which together perform a useful task, such as finding something hidden, cleaning, or spying. Each robot would be quite simple, but the emergent behaviour of the swarm would be more complex.[65] The whole set of robots can be considered as one single distributed system, in the same way an ant colony can be considered a superorganism. They would exhibit swarm intelligence. The largest swarms so far created include the iRobot swarm, and the Open-source micro-robotic project (http://www.swarmrobot.org/) swarm, which are being used to research collective behaviours.[66] Swarms are also more resistant to failure. Whereas one large robot may fail and ruin the whole mission, the swarm can continue even if several robots fail. This makes them attractive for space exploration missions, where failure can be extremely costly.[67]
- **Evolutionary Robots:** is a methodology that uses evolutionary computation to help design robots, especially the body form, or motion and behaviour 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 behaviours 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,[68] and to explore the nature of evolution.[69] 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.[70]
- **Virtual Reality:** Robotics has also application in the design of virtual reality interfaces. Specialized robots are in widespread use in the haptic research community. These robots, called "haptic interfaces" allow touch-enabled user interaction with real and virtual environments. Robotic forces allow simulating the mechanical properties of "virtual" objects, which users can experience through their sense of touch.[71]

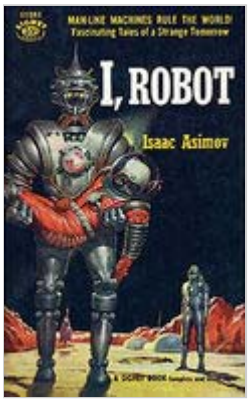
Dangers and fears

Although current robots are not believed to have developed to the stage where they pose any threat or danger to society,[72] fears and concerns about robots have been repeatedly expressed in a wide range of books and films. The principal theme is the robots' intelligence and ability to act could exceed that of humans, that they could develop a conscience and a motivation to take over or destroy the human race. (See *The Terminator, The Matrix, I, Robot*) Robots would be dangerous if they were programmed to kill or if they are programmed to be so smart that they make their own software, build their own hardware to upgrade themselves or if they change their own source code.

Frankenstein (1818), sometimes called the first science fiction novel, has become synonymous with the theme of a robot or monster advancing beyond its creator. Probably the best known author to have worked in this area is Isaac Asimov who placed robots and their interaction with society at the center of many of his works. Of particular interest are Asimov's Three Laws of Robotics. Currently, malicious programming or unsafe use of robots may be the biggest danger. Although industrial robots may be smaller and less powerful than other industrial machines, they are just as

capable of inflicting severe injury on humans. However, since a robot can be programmed to move in different trajectories depending on its task, its movement can be unpredictable for a person standing in its reach. Therefore, most industrial robots operate inside a security fence which separates them from human workers. Manuel De Landa has theorized that humans are at a critical and significant juncture where humans have allowed robots, "smart missiles," and autonomous bombs equipped with artificial perception to make decisions about killing us. He believes this represents an important and dangerous trend where humans are transferring more of our cognitive structures into our machines.[73] Even without malicious programming, a robot, especially a future model moving freely in a human environment, is potentially dangerous because of its large moving masses, powerful actuators and unpredictably complex behavior. A robot falling on someone or just stepping on his foot by mistake could cause much more damage to the victim than a human being of the same size. Designing and programming robots to be intrinsically safe and to exhibit safe behavior in a human environment is one of the great challenges in robotics. Some theorists, such as Eliezer Yudkowsky, have suggested that developing a robot with a powerful conscience may be the most prudent course of action in this regard.

Literature



Isaac Asimov's book I, Robot

See also: List of fictional robots and androids

Robots have frequently appeared as characters in works of literature; the word *robot* comes from Karel Čapek's play *R.U.R. (Rossum's Universal Robots)*, premiered in 1920. Isaac Asimov wrote many volumes of science fiction focusing on robots in numerous forms and guises, contributing greatly to reducing the Frankenstein complex, which dominated early works of fiction involving robots. His three laws of robotics have become particularly well known for codifying a simple set of behaviors for robots to remain at the service of their human creators.

The first reference in Western literature to mechanical servants appears in The Iliad of Homer. In Book XVIII, Hephaestus, god of fire, creates new armour for the hero Achilles. He is assisted by robots. According to the Rieu translation, "Golden maidservants hastened to help their master. They looked like real women and could not only speak and use their limbs but were endowed with intelligence and trained in handwork by the immortal gods." Of course, the words "robot" or "android" are not used to describe them, but they are nevertheless mechanical devices human in appearance.

Numerous words for different types of robots are now used in literature. Robot has come to mean mechanical humans, while android is a generic term for artificial humans. Cyborg or "bionic man" is used for a human form that is a mixture of organic and mechanical parts. Organic artificial humans have also been referred to as "constructs" (or "biological constructs").

In science fiction, the Three Laws of Robotics are a set of three rules written by Isaac Asimov, which almost all positronic robots appearing in his fiction must obey. Introduced in his 1942 short story "Runaround", although foreshadowed in a few earlier stories, the Laws state the following:

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

Later, Asimov added the Zeroth Law: "A robot may not harm humanity, or, by inaction, allow humanity to come to harm"; the rest of the laws are modified sequentially to acknowledge this.

According to the Oxford English Dictionary, the first passage in Asimov's short story "Liar!" (1941) that mentions the

First Law is the earliest recorded use of the word robotics.[1] Asimov was not initially aware of this; he assumed the word already existed by analogy with mechanics, hydraulics, and other similar terms denoting branches of applied knowledge.[2]

Competitions

See also: Robot competition

Robot Plen practicing for Robocup

Botball is a LEGO-based competition between fully autonomous robots. There are two divisions. The first is for high-school and middle-school students, and the second (called "Beyond Botball") is for anyone who chooses to compete at the national tournament. Teams build, program, and blog about a robot for five weeks before they compete at the regional level. Winners are awarded scholarships to register for and travel to the national tournament. Botball is a project of the KISS Institute for Practical Robotics, based in Norman, Oklahoma.

The FIRST Robotics Competition (FRC) is a multinational competition that teams professionals and young people to solve an engineering design problem. These teams of mentors (corporate, teachers, or college students) and high school students collaborate in order to design and build a robot in six weeks. This robot is designed to play a game that is developed by FIRST and changes from year to year. FIRST, or For Inspiration and Recognition of Science and Technology, is an organization founded by inventor Dean Kamen in 1992 as a way of getting high school students involved in and excited about engineering and technology.

The FIRST Vex Challenge (FVC) is a mid-level robotics competition targeted toward high-school aged students. It offers the traditional challenge of a FIRST competition but with a more accessible and affordable robotics kit. The ultimate goal of FVC is to reach more young people with a lower-cost, more accessible opportunity to discover the excitement and rewards of science, technology, and engineering.

FIRST LEGO League (also known by its acronym FLL) is a robotics competition for elementary and middle school students (ages 9-14, 9-16 in Europe), arranged by FIRST. Each year the contest focuses on a different topic related to the sciences. Each challenge within the competition then revolves around that theme. The students then work out solutions to the various problems that they're given and meet for regional tournaments to share their knowledge and show off their ideas.

Competitions for robots are gaining popularity and competitions now exist catering for a wide variety of robot builders ranging from schools to research institutions. Robots compete at a wide range of tasks including combat, fire-fighting [74], playing games [75], maze solving, performing tasks [76] and navigational exercises (eg. DARPA Grand Challenge).

A contest for fire-fighting is the Trinity College Fire-Fighting Robot Contest.[77] The competition in April 2007 was the 14th annual. There are many different divisions for all skill levels. Robots in the competition are encouraged to find new ways to navigate through the rooms, put out the candle and save the "child" from the building. Robots can be composed of any materials, but must fit within certain size restrictions.

Most recently, Duke University announced plans to host the Duke Annual Robo-Climb Competition aimed to challenge students to create innovative wall-climbing robots that can autonomously ascend vertical surfaces.[78]

Since 2004, DARPA Grand Challenge tests driverless cars in an obstacle course across the desert.

See also

Main list: List of basic robotics topics

Robotics Portal

For classes and types of robots see Category:Robots.

Research areas

- Artificial consciousness
- Automated planning and scheduling
- Behavior based robotics and Subsumption architecture
- Cognitive robotics
- Cybernetics
- Navigation
- Localization
- Developmental robotics
- Epigenetic robotics
- Evolutionary robotics
- Future of robotics
- Mechatronics
- Nanotechnology and MEMS
- NASA and robotics
- Neural networks
- Robot control
- Robot baseball
- Robot soccer
- Robot software
- Social robots
- Swarm robotics
- Telerobotics / Telepresence

Additional topics

- Android
- Android science
- Autonomous robots, including autonomous foraging
- Boe-Bot
- Carbon chauvinism (see: Alternative biochemistry)
- Clanking replicator
- Cyborg
- Disabled robotics: Artificial powered exoskeleton
- Domestic robot
- Gynoid
- Hybrot
- Japanese robotics
- List of fictional robots and androids
- Leonardo's robot
- Mecha
- Microbotics
- Nanorobotics
- Microsoft Robotics Studio
- Mindstorms
- Qfix robot kit
- Open robot
- Rapid prototyping
- Robot kits
- Robot locomotion
- Robotic mapping
- Robotics suite
- Roombatics (see:Roomba)
- RooTooth
- Snake-arm robot
- Technocracy movement
- Uncanny Valley
- URBI
- Utility fog
- Vex
- Vocoder

References

1. ^ Telecom glossary "bot" (http://www.atis.org/tg2k/_bot.html). Alliance for Telecommunications Solutions (2001-02-28). Retrieved on 2007-09-05.
2. ^ Your View: How would you define a robot? (http://www.cbc.ca/technology/technology-blog/2007/07/your_view_how_would_you_define.html). CBC News (2007-07-16). Retrieved on 2007-09-05.
3. ^ What does "robot" mean to YOU? (http://www.botmag.com/forum/showthread.php?t=240). Botmag forum (2006-08-26). Retrieved on 2007-09-05.
4. ^ What does 'robot' mean to you (http://www.botmag.com/forum/showthread.php?t=285). Botmag forum (2006-10-15). Retrieved on 2007-09-05.
5. ^ Even Robot Suicide Is No Laughing Matter (http://www.technologymarketing.com/bw/magazine/current/article_display.jsp?vnu_content_id=1003541524). Brandweek (2007-02-05). Retrieved on 2007-09-06.
6. ^ Is THIS a robot? (http://www.robotbuilder.co.uk/forum/topic.asp?TOPIC_ID=968). RobotBuilder Forum (2007-02-03). Retrieved on 2007-09-06.
7. ^ Google search "clockwork robot car" (http://www.google.co.uk/search?q=%22clockwork+robot+car)
8. ^ Real Robots on the Web (http://ranier.hq.nasa.gov/telerobotics_page/realrobots.html). NASA Space Telerobotics Program (1999-10-15). Retrieved on 2007-09-06.
9. ^ The Grand Piano Series: The History of The Robot (http://www.wyastone.co.uk/nrl/gp_robot.html). Nimbus Records. Retrieved on 2007-09-08.
10. ^ Robots Rule: Roboraptor Product Information (http://www.robotsrule.com/html/roboraptor.php) which refers to Roboraptor as a 'robot'

11. ^ BBC News: A robot in every home? (http://news.bbc.co.uk/1/hi/technology/4164189.stm) in which Art Janis from WowWee refers to Robosapien as a "real robot"
12. ^ Lee, Dai Gil (2005). *Axiomatic Design and Fabrication of Composite Structures (http://books.google.com/books?id=JDOfVxRC8x8C&pg=PA513&lpg=PA513&source=web&ots=_iMgIErG60&sig=uo7dgICtMBdETyNieUmktCBSnHI)*. Oxford University Press. ISBN 0195178777. Retrieved on 2007-10-22.
13. ^ Bodur, Mehmet (2006), *Computational Principles of Robotics, Course Notes (http://cmpe.emu.edu.tr/mbodur/COUR/CMPE528/CPR528C1.pdf)*, Department of Computer Engineering, Eastern Mediterranean University, pp. 2, <http://cmpe.emu.edu.tr/mbodur/COUR/CMPE528/CPR528C1.pdf>. Retrieved on 2007-09-09
14. ^ European Robotics Research Network (http://www.euron.org/resources/standards.html)
15. ^ Definition of a robot (http://www.dira.dk/pdf/robotdef.pdf) (PDF). Dansk Robot Forening. Retrieved on 2007-09-10.
16. ^ Polk, Igor (2005-11-16). RoboNexus 2005 robot exhibition virtual tour (http://www.virtuar.com/click/2005/robonexus/index.htm). Robonexus Exhibition 2005. Retrieved on 2007-09-10.
17. ^ Harris, Tom. How Robots Work (http://science.howstuffworks.com/robot.htm). How Stuff Works. Retrieved on 2007-09-10.
18. ^ Robot (http://dictionary.cambridge.org/define.asp?key=68311&dict=CALD). Cambridge Advanced Learner's Dictionary. Retrieved on 2007-09-10.
19. ^ ***a b c*** A Brief History of Robotics (http://robotics.megagiant.com/history.html), MegaGiant Robotics, 2005.
20. ^ Zunt, Dominik. Who did actually invent the word "robot" and what does it mean? (http://capek.misto.cz/english/robot.html). The Karel Čapek website. Retrieved on 2007-09-11.
21. ^ Needham, Joseph (1991). *Science and Civilisation in China: Volume 2, History of Scientific Thought*. Cambridge University Press. ISBN 0521058007.
22. ^ ***a b*** Currie, Adam (1999). The History of Robotics (http://www.faculty.ucr.edu/~currie/roboadam.htm). Retrieved on 2007-09-10.
23. ^ A 13th Century Programmable Robot (http://www.shef.ac.uk/marcoms/eview/articles58/robot.html). University of Sheffield (2007). Retrieved on 2007-09-11.
24. ^ The Grey Walter Online Archive (http://www.ias.uwe.ac.uk/Robots/gwonline/gwonline.html), Owen Holland; Accessed April 30, 2007
25. ^ Kiska, Tim. "Death on the job: Jury awards $10 million to heirs of man killed by robot at auto plant (http://docs.newsbank.com/g/GooglePM/PI/lib00187,0EB295F7D995F801.html)", Philadelphia Inquirer, 1983-08-11, pp. A10. Retrieved on 2007-09-11. (English)
26. ^ "Trust me, I'm a robot (http://www.economist.com/displaystory.cfm?story_id=7001829)", The Economist, 2006-06-08. Retrieved on 2007-04-30. (English)
27. ^ **Cite error 8; No text given.**
28. ^ Kube-McDowell, Michael; Mike McQuay (1987). *Isaac Asimov's Robot City 1 (http://www.ereader.com/product/book/excerpt/6629?book=Isaac_Asimovs_Robot_City_1)*. Byron Preiss Visual Publications, Inc. Retrieved on 2007-10-15.
29. ^ Imitation of Life: A History of the First Robots (http://www.cerebromente.org.br/n09/historia/turtles_i.htm)
30. ^ Waurzyniak, Patrick (2006-07). "Masters of Manufacturing: Joseph F. Engelberger (http://www.sme.org/cgi-bin/find-articles.pl?&ME06ART39&ME&20060709#article)". *Society Of Manufacturing Engineers* **137** (1).
31. ^ Emeritus (2006). Annual Report: Profile of John McCarthy (http://soe.stanford.edu/AR04-05/profiles_mccarthy.html). Stanford Engineering , Stanford University. Retrieved on 2007-09-13.
32. ^ (2007-01) "Robotics safety: avoid exchanging hazards (http://www.iapa.ca/apmag/2007_enews_jan.asp#c)". *Industrial Accident Prevention Association* **2** (1).
33. ^ United Nations Economic Commission for Europe (2004-10-20). *World Robotics 2004 survey (http://www.unece.org/press/pr2004/04stat_p01e.pdf)*. Press release. Retrieved on 2007-09-13.
34. ^ Contact Systems Pick and Place robots (http://www.contactsystems.com/). Retrieved on 2007-09-13.
35. ^ The C5 Series SMD Placement Machine (http://www.contactsystems.com/C7Series.htm). Contact Systems (2005). Retrieved on 2007-09-13.
36. ^ A-Series specification (http://www.assembleon.com/InformationCenter/Assembleon/FTaboverview.asp?lNodeId=2958&lActiveTabArticleId=4005). Assembleon. Retrieved on 2007-09-13.
37. ^ web|url=http://www.smartcaddy.net|title=Smart Caddy|publisher=Seegrid|accessdate=2007-09-13
38. ^ The Basics of Automated Guided Vehicles (http://www.agvsystems.com/basics/vehicle.htm). Savant Automation, AGV Systems. Retrieved on 2007-09-13.
39. ^ [web|url=http://www.ccsrobotics.com/speciminder.htm]
40. ^ [web|url=http://www.rmtrobotics.com/tire_agv.html]
41. ^ [web|url=http://www.aethon.com]
42. ^ [web|url=http://www.mobilerobots.com/AGV.html]
43. ^ Dante II, list of published papers (http://www.ri.cmu.edu/projects/project_163.html). The Robotics Institute of Carnegie Mellon University. Retrieved on 2007-09-16.
44. ^ Mars Pathfinder Mission: Rover Sojourner (http://mars.jpl.nasa.gov/MPF/rover/sojourner.html). NASA (1997-07-08). Retrieved on 2007-09-19.

45. ^ **a** **b** Robot assisted surgery: da Vinci® Surgical System (http://biomed.brown.edu/Courses/BI108/BI108_2005_Groups/04/davinci.html). Brown University Division of Biology and Medicine. Retrieved on 2007-09-19.
46. ^ Brain, Marshall (2003). Robotic Nation (http://marshallbrain.com/robotic-nation.htm). Retrieved on 2007-09-23.
47. ^ iRobot Corp (2006-05-22). *Sales of iRobot Roomba Vacuuming Robot Surpass 2 Million Units (http://findarticles.com/p/articles/mi_m0EIN/is_2006_May_22/ai_n16373781)*. Press release. Retrieved on 2007-09-23.
48. ^ "Bookworm: Sign Of The Times (http://thescotsman.scotsman.com/critique.cfm?id=2162732005)", The Scotsman, 2005-10-29. Retrieved on 2007-09-23.
49. ^ Graham, Stephen. "America's robot army (http://www.newstatesman.com/200606120018)", New Statesman, 2006-06-12. Retrieved on 2007-09-24.
50. ^ "Battlefield Robots: to Iraq, and Beyond (http://www.defenseindustrydaily.com/battlefield-robots-to-iraq-and-beyond-0727)", Defense Industry Daily, 2005-06-20. Retrieved on 2007-09-24.
51. ^ Shachtman, Noah (2005-11), *The Baghdad Bomb Squad (http://www.wired.com/wired/archive/13.11/bomb.html?pg=3&topic=bomb)*, Wired Magazine, <http://www.wired.com/wired/archive/13.11/bomb.html?pg=3&topic=bomb>. Retrieved on 2007-09-14
52. ^ Jeavans, Christine. "Welcome to the ageing future (http://news.bbc.co.uk/1/hi/uk/4012797.stm)", BBC News, 2004-11-29. Retrieved on 2007-09-26.
53. ^ Statistical Handbook of Japan: Chapter 2 Population (http://www.stat.go.jp/english/data/handbook/c02cont.htm). Statistics Bureau & Statistical Research and Training Institute. Retrieved on 2007-09-26.
54. ^ Robotic future of patient care (http://www.e-health-insider.com/comment_and_analysis/250/robotic_future_of_patient_care). E-Health Insider (2007-08-16). Retrieved on 2007-09-26.
55. ^ Rice University: Rice scientists build world's first single-molecule car (http://www.media.rice.edu/media/NewsBot.asp?MODE=VIEW&ID=7850&SnID=971109686)
56. ^ Techbirbal: Nanobots Play Football (http://www.techbirbal.com/viewtopic.php?p=3687&sid=7faaeeb64eaf84880b23755fea7fa7cd)
57. ^ KurzweilAI.net: Utility Fog: The Stuff that Dreams Are Made Of (http://www.kurzweilai.net/meme/frame.html?main=/articles/art0220.html?)
58. ^ (Eric Drexler 1986) Engines of Creation, The Coming Era of Nanotechnology (http://www.e-drexler.com/d/06/00/EOC/EOC_Chapter_11.html)
59. ^ Chris Phoenix (2003-12). Of Chemistry, Nanobots, and Policy (http://www.crnano.org/Debate.htm). Center for Responsible Nanotechnology. Retrieved on 2007-10-28.
60. ^ (2004-06-07) "Nanotechnology pioneer slays “grey goo” myths (http://www.iop.org/EJ/news/-topic=763/journal/0957-4484)". Institute of Physics Electronics Journals. Retrieved on 2007-10-28.
61. ^ Tufts Biomemetic Devices Laboratory: Robots That Slink and Squirm (http://ase.tufts.edu/bdl/news.asp)
62. ^ (1996) LEGO(TM)s to the Stars: Active MesoStructures, Kinetic Cellular Automata, and Parallel Nanomachines for Space Applications (http://www.islandone.org/MMSG/9609lego.htm)
63. ^ (Robert Fitch, Zack Butler and Daniela Rus) Reconfiguration Planning for Heterogeneous Self-Reconfiguring Robots (http://groups.csail.mit.edu/drl/publications/papers/MeltSortGrow.pdf)
64. ^ Open-source micro-robotic project (http://www.swarmrobot.org/). Retrieved on 2007-10-28.
65. ^ I-Swarm Micromechatronics and Microrobotics Group (http://i60p4.ira.uka.de/tiki/tiki-index.php?page=I-Swarm+overview)
66. ^ Swarm (http://www.irobot.com/sp.cfm?pageid=149). iRobot Corporation. Retrieved on 2007-10-28.
67. ^ Knapp, Louise (2000-12-21), *Look, Up in the Sky: Robofly (http://www.wired.com/science/discoveries/news/2000/12/40750)*, Wired Magazine, <http://www.wired.com/science/discoveries/news/2000/12/40750>. Retrieved on 2007-10-28
68. ^ Sandhana, Lakshmi (2002-09-05), *A Theory of Evolution, for Robots (http://www.wired.com/science/discoveries/news/2002/09/54900)*, Wired Magazine, <http://www.wired.com/science/discoveries/news/2002/09/54900>. Retrieved on 2007-10-28
69. ^ *Experimental Evolution In Robots Probes The Emergence Of Biological Communication (http://www.sciencedaily.com/releases/2007/02/070222155713.htm)*, Science Daily, 2007-02-24, <http://www.sciencedaily.com/releases/2007/02/070222155713.htm>. Retrieved on 2007-10-28
70. ^ The Latest Technology Research News: Evolution trains robot teams (http://www.trnmag.com/Stories/2004/051904/Evolution_trains_robot_teams_051904.html)
71. ^ MIT Technology review article "The Cutting Edge of Haptics" (http://www.technologyreview.com/read_article.aspx?id=17363&ch=biotech&sc=&pg=1)
72. ^ Jeanne Dietsch, CEO, MobileRobots Inc: Will Robots Ever Take Over The World? (http://www.mobilerobots.com/ethicalRobotics.html)
73. ^ *Manuel de Landa, *War in the Age of Intelligent Machines*, New York: Zone Books, 1991, 280 pages, Hardcover, ISBN 0-942299-76-0; Paperback, ISBN 0-942299-75-2.
74. ^ Trinity College: Fire fighting home robot contest (http://www.trincoll.edu/events/robot)
75. ^ ME412: AUTONOMOUS MOBILE ROBOTS (http://www.cooper.edu/~mar/mobile_robots_fall2005.html)

76. ^ Maslab: An Advanced IAP Robotics Competition (http://maslab.csail.mit.edu/)
77. ^ Trinity College Fire-Fighting Robot Contest (http://www.trincoll.edu/events/robot)
78. ^ Duke Annual Robo-Climb (http://robotics.pratt.duke.edu/roboclimb)

General references

- Cheney, Margaret [1989:123] (1981). *Tesla, Man Out of Time*. Dorset Press. New York. ISBN 0-88029-419-1
- Craig, J.J. (2005). Introduction to Robotics. Pearson Prentice Hall. Upper Saddle River, NJ.
- Flanagan, J.R., Lederman, S.J. Neurobiology: Feeling bumps and holes (http://brain.phgy.queensu.ca/flanagan/papers/FlaLed_NAT_01.pdf) (Portable Document Format), News and Views, *Nature*, 2001 Jul. 26;412(6845):389-91.
- Hayward V, Astley OR, Cruz-Hernandez M, Grant D, Robles-De-La-Torre G. Haptic interfaces and devices (http://www.roblesdelatorre.com/gabriel/VH-OA-MC-DG-GR-04.pdf) (Portable Document Format). *Sensor Review* 24(1), pp. 16-29 (2004).
- Needham, Joseph (1986). *Science and Civilization in China: Volume 2*. Taipei: Caves Books Ltd.
- Robles-De-La-Torre G. & Hayward V. Force Can Overcome Object Geometry In the perception of Shape Through Active Touch (http://www.roblesdelatorre.com/gabriel/GR-VH-Nature2001.pdf). Nature 412 (6845):445-8 (2001).
- Robles-De-La-Torre G. The Importance of the Sense of Touch in Virtual and Real Environments (http://www.roblesdelatorre.com/gabriel/GR-IEEE-MM-2006.pdf) (Portable Document Format). IEEE Multimedia 13(3), Special issue on Haptic User Interfaces for Multimedia Systems, pp. 24-30 (2006).
- Sotheby's New York. The Tin Toy Robot Collection of Matt Wyse, (1996)
- Tsai, L.-W. (1999). *Robot Analysis*. Wiley. New York.
- DeLanda, Manuel. *War in the Age of Intelligent Machines*. 1991. Swerve. New York.

External links

Research societies

- IEEE Robotics and Automation Society (RAS) (http://www.ieee-ras.org/) and its wiki (http://wiki.ieee-ras.org/).
- International Foundation of Robotics Research (IFRR) (http://www.ifrr.org/)
- Robotics (http://www.dmoz.org/Computers/Robotics//) at the Open Directory Project
- http://robots.net – Daily news about robots, robotics, and AI
- A brief history of robotics (http://robotics.megagiant.com/history.html)
- A giant list of known robots (http://www.communistrobot.com/robots.php)
- NASA and robots (http://www.nasa.gov/worldbook/robot_worldbook.html)
- NASA Robotics Division (http://robotics.nasa.gov/)
- International Federation of Robotics (http://www.ifr.org/)
- Should we be worried by the rise of robots? (http://www.yellowzeppelin.info/Robots/worried_9211.html)
- Ten Best Robots (http://www.toptentubes.com/toptenrobots) Ten videos of robots.
- Podcast 'Talking Robots' - interviews with high-profile professionals in Robotics and Artificial Intelligence (http://lis.epfl.ch/podcast)
- French collection of toy robot (http://pozor.corps.free.fr/robots/index.html)
- Introduction to Robotics (http://www.elegantdirectory.com/articles/introduction-to-robotics.html)
- HUAR (http://www.humansunitedagainstrobots.com/)
- Robot World News (http://www.robotworldnews.com/)
- Robot news, robot tutorials, robot videos and robot chatbox (http://www.personalrobotics.nl/)
- Robot news, theory of robotics (http://www.robotyka.com/)

Categories: Robotics | Robots | Applications of computer vision