Robot

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Jump to navigation

Jump to search

This article is about mechanical robots. For software agents, see Bot. For other uses of the term, see Robot (disambiguation).

A **robot** is a machine—especially one programmable by a computer—capable of carrying out a complex series of actions automatically.[2] A robot can be guided by an external control device, or the control may be embedded within. Robots may be constructed to evoke human form, but most robots are task-performing machines, designed with an emphasis on stark functionality, rather than expressive aesthetics.

Robots can be autonomous or semi-autonomous and range from humanoids such as Honda's *Advanced Step in Innovative Mobility* (ASIMO) and TOSY's *TOSY Ping Pong Playing Robot* (TOPIO) to industrial robots, medical operating robots, patient assist robots, dog therapy robots, collectively programmed *swarm* robots, UAV drones such as General Atomics MQ-1 Predator, and even microscopic nano robots. By mimicking a lifelike appearance or automating movements, a robot may convey a sense of intelligence or thought of its own. Autonomous things are expected to proliferate in the coming decade,[3] with home robotics and the autonomous car as some of the main drivers.[4]

The branch of technology that deals with the design, construction, operation, and application of robots,[5] as well as computer systems for their control, sensory feedback, and information processing is robotics. These technologies deal with automated machines that can take the place of humans in dangerous environments or manufacturing processes, or resemble humans in appearance, behavior, or cognition. Many of today's robots are inspired by nature contributing to the field of bio-inspired robotics. These robots have also created a newer branch of robotics: soft robotics.

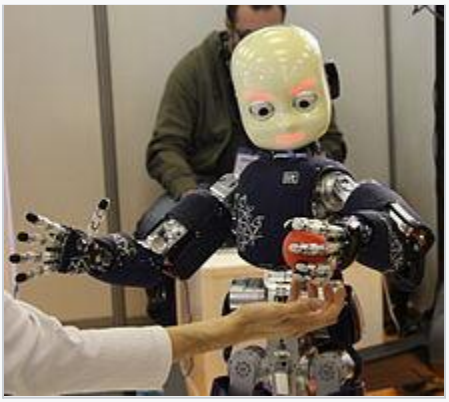
From the time of ancient civilization, there have been many accounts of user-configurable automated devices and even automata resembling humans and other animals, designed primarily as entertainment. As mechanical techniques developed through the Industrial age, there appeared more practical applications such as automated machines, remote-control and wireless remote-control.

The term comes from a Slavic root, *robot-*, with meanings associated with labor. The word 'robot' was first used to denote a fictional humanoid in a 1920 Czech-language play *R.U.R. (Rossumovi Univerzální Roboti – Rossum's Universal Robots)* by Karel Čapek, though it was Karel's brother Josef Čapek who was the word's true inventor.[6][7][8] Electronics evolved into the driving force of development with the advent of the first electronic autonomous robots created by William Grey Walter in Bristol, England in 1948, as well as Computer Numerical Control (CNC) machine tools in the late 1940s by John T. Parsons and Frank L. Stulen. The first commercial, digital and programmable robot was built by George Devol in 1954 and was named the Unimate. It was sold to General Motors in 1961 where it was used to lift pieces of hot metal from die casting machines at the Inland Fisher Guide Plant in the West Trenton section of Ewing Township, New Jersey.[9]

Robots have replaced humans[10] in performing repetitive and dangerous tasks which humans prefer not to do, or are unable to do because of size limitations, or which take place in extreme environments such as outer space or the bottom of the sea. There are concerns about the increasing use of robots and their role in society. Robots are blamed for rising technological unemployment as they replace workers in increasing numbers of functions.[11] The use of robots in military combat raises ethical concerns. The possibilities of robot autonomy and potential repercussions have been addressed in fiction and may be a realistic concern in the future.

Summary

KITT (a fictional robot) is mentally anthropomorphic.



iCub is physically anthropomorphic.

The word *robot* can refer to both physical robots and virtual software agents, but the latter are usually referred to as bots.[12] There is no consensus on which machines qualify as robots but there is general agreement among experts, and the public, that robots tend to possess some or all of the following abilities and functions: accept electronic programming, process data or physical perceptions electronically, operate autonomously to some degree, move around, operate physical parts of itself or physical processes, sense and manipulate their environment, and exhibit intelligent behavior, especially behavior which mimics humans or other animals.[13][14] Closely related to the concept of a *robot* is the field of Synthetic Biology, which studies entities whose nature is more comparable to beings than to machines.

History

Main article: History of robots

The idea of automata originates in the mythologies of many cultures around the world. Engineers and inventors from ancient civilizations, including Ancient China,[15] Ancient Greece, and Ptolemaic Egypt,[16] attempted to build self-operating machines, some resembling animals and humans. Early descriptions of automata include the artificial doves of Archytas,[17] the artificial birds of Mozi and Lu Ban,[18] a "speaking" automaton by Hero of Alexandria, a washstand automaton by Philo of Byzantium, and a human automaton described in the *Lie Zi*.[15]

Early beginnings

Many ancient mythologies, and most modern religions include artificial people, such as the mechanical servants built by the Greek god Hephaestus[19] (Vulcan to the Romans), the clay golems of Jewish legend and clay giants of Norse legend, and Galatea, the mythical statue of Pygmalion that came to life. Since circa 400 BC, myths of Crete include Talos, a man of bronze who guarded the island from pirates.

In ancient Greece, the Greek engineer Ctesibius (c. 270 BC) "applied a knowledge of pneumatics and hydraulics to produce the first organ and water clocks with moving figures."[20][21] In the 4th century BC, the Greek mathematician Archytas of Tarentum postulated a mechanical steam-operated bird he called "The Pigeon". Hero of Alexandria (10–70 AD), a Greek mathematician and inventor, created numerous user-configurable automated devices, and described machines powered by air pressure, steam and water.[22]

Al-Jazari – A Musical Toy

The 11th century Lokapannatti tells of how the Buddha's relics were protected by mechanical robots (bhuta vahana yanta), from the kingdom of Roma visaya (Rome); until they were disarmed by King Ashoka.[23]

In ancient China, the 3rd-century text of the *Lie Zi* describes an account of humanoid automata, involving a much earlier encounter between Chinese emperor King Mu of Zhou and a mechanical engineer known as Yan Shi, an 'artificer'. Yan Shi proudly presented the king with a life-size, human-shaped figure of his mechanical 'handiwork' made of leather, wood, and artificial organs.[15] There are also accounts of flying automata in the *Han Fei Zi* and other texts, which attributes the 5th century BC Mohist philosopher Mozi and his contemporary Lu Ban with the invention of artificial wooden birds (*ma yuan*) that could successfully fly.[18]

Su Song's astronomical clock tower showing the mechanical figurines which chimed the hours.

In 1066, the Chinese inventor Su Song built a water clock in the form of a tower which featured mechanical figurines which chimed the hours.[24][25][26] His mechanism had a programmable drum machine with pegs (cams) that bumped into little levers that operated percussion instruments. The drummer could be made to play different rhythms and different drum patterns by moving the pegs to different locations.[26]

Samarangana Sutradhara, a Sanskrit treatise by Bhoja (11th century), includes a chapter about the construction of mechanical contrivances (automata), including mechanical bees and birds, fountains shaped like humans and animals, and male and female dolls that refilled oil lamps, danced, played instruments, and re-enacted scenes from Hindu mythology.[27][28][29]

13th century Muslim Scientist Ismail al-Jazari created several automated devices. He built automated moving peacocks driven by hydropower.[30] He also invented the earliest known automatic gates, which were driven by hydropower,[31] created automatic doors as part of one of his elaborate water clocks.[32] One of al-Jazari's humanoid automata was a waitress that could serve water, tea or drinks. The drink was stored in a tank with a reservoir from where the drink drips into a bucket and, after seven minutes, into a cup, after which the waitress appears out of an automatic door serving the drink.[33] Al-Jazari invented a hand washing automaton incorporating a flush mechanism now used in modern flush toilets. It features a female humanoid automaton standing by a basin filled with water. When the user pulls the lever, the water drains and the female automaton refills the basin.[34]

Mark E. Rosheim summarizes the advances in robotics made by Muslim engineers, especially al-Jazari, as follows:

Unlike the Greek designs, these Arab examples reveal an interest, not only in dramatic illusion, but in manipulating the environment for human comfort. Thus, the greatest contribution the Arabs made, besides preserving, disseminating and building on the work of the Greeks, was the concept of practical application. This was the key element that was missing in Greek robotic science.[35]

Model of Leonardo's robot with inner workings. Possibly constructed by Leonardo da Vinci around 1495.[36]

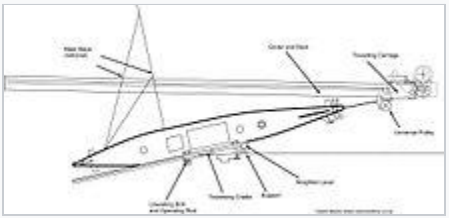
In Renaissance Italy, Leonardo da Vinci (1452–1519) sketched plans for a humanoid robot around 1495. Da Vinci's notebooks, rediscovered in the 1950s, contained detailed drawings of a mechanical

knight now known as Leonardo's robot, able to sit up, wave its arms and move its head and jaw.[37] The design was probably based on anatomical research recorded in his *Vitruvian Man*. It is not known whether he attempted to build it. According to *Encyclopædia Britannica*, Leonardo da Vinci may have been influenced by the classic automata of al-Jazari.[30]

In Japan, complex animal and human automata were built between the 17th to 19th centuries, with many described in the 18th century *Karakuri zui* (*Illustrated Machinery*, 1796). One such automaton was the karakuri ningyō, a mechanized puppet.[38] Different variations of the karakuri existed: the *Butai karakuri*, which were used in theatre, the *Zashiki karakuri*, which were small and used in homes, and the *Dashi karakuri* which were used in religious festivals, where the puppets were used to perform reenactments of traditional myths and legends.

In France, between 1738 and 1739, Jacques de Vaucanson exhibited several life-sized automatons: a flute player, a pipe player and a duck. The mechanical duck could flap its wings, crane its neck, and swallow food from the exhibitor's hand, and it gave the illusion of digesting its food by excreting matter stored in a hidden compartment.[39]

Remote-controlled systems



The Brennan torpedo, one of the earliest 'guided missiles'

Remotely operated vehicles were demonstrated in the late 19th century in the form of several types of remotely controlled torpedoes. The early 1870s saw remotely controlled torpedoes by John Ericsson (pneumatic), John Louis Lay (electric wire guided), and Victor von Scheliha (electric wire guided).[40]

The Brennan torpedo, invented by Louis Brennan in 1877, was powered by two contra-rotating propellors that were spun by rapidly pulling out wires from drums wound inside the torpedo. Differential speed on the wires connected to the shore station allowed the torpedo to be guided to its

target, making it "the world's first *practical* guided missile".[41] In 1897 the British inventor Ernest Wilson was granted a patent for a torpedo remotely controlled by "Hertzian" (radio) waves[42][43] and in 1898 Nikola Tesla publicly demonstrated a wireless-controlled torpedo that he hoped to sell to the US Navy.[44][45]

Archibald Low, known as the "father of radio guidance systems" for his pioneering work on guided rockets and planes during the First World War. In 1917, he demonstrated a remote controlled aircraft to the Royal Flying Corps and in the same year built the first wire-guided rocket.

Origin of the term 'robot'

'Robot' was first applied as a term for artificial automata in the 1920 play *R.U.R.* by the Czech writer, Karel Čapek. However, Josef Čapek was named by his brother Karel as the true inventor of the term robot.[7][8] The word 'robot' itself was not new, having been in the Slavic language as *robota* (forced labor), a term applied to peasants obligated to compulsory service under the feudal system (see: Robot Patent).[46][47] Čapek's fictional story postulated the technological creation of artificial human bodies without souls, and the old theme of the feudal *robota* class eloquently fit the imagination of a new class of manufactured, artificial workers.

English pronunciation of the word has evolved relatively quickly since its introduction. In the U.S. during the late '30s to early '40s the second syllable was pronounced with a long "O" like "row-boat."[48][*better source needed*] By the late '50s to early '60s, some were pronouncing it with a short "U" like "row-but" while others used a softer "O" like "row-bought."[49] By the '70s, its current pronunciation "row-bot" had become predominant.

Early robots

W. H. Richards with "George", 1932

In 1928, one of the first humanoid robots, Eric, was exhibited at the annual exhibition of the Model Engineers Society in London, where it delivered a speech. Invented by W. H. Richards, the robot's frame consisted of an aluminium body of armour with eleven electromagnets and one motor powered by a twelve-volt power source. The robot could move its hands and head and could be controlled through remote control or voice control.[50] Both Eric and his "brother" George toured the world.[51]

Westinghouse Electric Corporation built Televox in 1926; it was a cardboard cutout connected to various devices which users could turn on and off. In 1939, the humanoid robot known as Elektro was debuted at the 1939 New York World's Fair.[52][53] Seven feet tall (2.1 m) and weighing 265 pounds (120.2 kg), it could walk by voice command, speak about 700 words (using a 78-rpm record player), smoke cigarettes, blow up balloons, and move its head and arms. The body consisted of a steel gear, cam and motor skeleton covered by an aluminum skin. In 1928, Japan's first robot, Gakutensoku, was designed and constructed by biologist Makoto Nishimura.

Modern autonomous robots

The first electronic autonomous robots with complex behaviour were created by William Grey Walter of the Burden Neurological Institute at Bristol, England in 1948 and 1949. He wanted to prove that rich connections between a small number of brain cells could give rise to very complex behaviors – essentially that the secret of how the brain worked lay in how it was wired up. His first robots, named

Elmer and *Elsie*, were constructed between 1948 and 1949 and were often described as *tortoises* due to their shape and slow rate of movement. The three-wheeled tortoise robots were capable of phototaxis, by which they could find their way to a recharging station when they ran low on battery power.

Walter stressed the importance of using purely analogue electronics to simulate brain processes at a time when his contemporaries such as Alan Turing and John von Neumann were all turning towards a view of mental processes in terms of digital computation. His work inspired subsequent generations of robotics researchers such as Rodney Brooks, Hans Moravec and Mark Tilden. Modern incarnations of Walter's *turtles* may be found in the form of BEAM robotics.[54]

U.S. Patent 2,988,237, issued in 1961 to Devol.

The first digitally operated and programmable robot was invented by George Devol in 1954 and was ultimately called the Unimate. This ultimately laid the foundations of the modern robotics industry.[55] Devol sold the first Unimate to General Motors in 1960, and it was installed in 1961 in a plant in Trenton, New Jersey to lift hot pieces of metal from a die casting machine and stack them.[56] Devol's patent for the first digitally operated programmable robotic arm represents the foundation of the modern robotics industry.[57]

The first palletizing robot was introduced in 1963 by the Fuji Yusoki Kogyo Company.[58] In 1973, a robot with six electromechanically driven axes was patented[59][60][61] by KUKA robotics in Germany, and the programmable universal manipulation arm was invented by Victor Scheinman in 1976, and the design was sold to Unimation.

Commercial and industrial robots are now in widespread use performing jobs more cheaply or with greater accuracy and reliability than humans. They are also employed for jobs which are too dirty, dangerous or dull to be suitable for humans. Robots are widely used in manufacturing, assembly and packing, transport, earth and space exploration, surgery, weaponry, laboratory research, and mass production of consumer and industrial goods.[62]

Future development and trends

External video
Atlas, The Next Generation

Further information: Robotics

Various techniques have emerged to develop the science of robotics and robots. One method is evolutionary robotics, in which a number of differing robots are submitted to tests. Those which perform best are used as a model to create a subsequent "generation" of robots. Another method is developmental robotics, which tracks changes and development within a single robot in the areas of problem-solving and other functions. Another new type of robot is just recently introduced which acts both as a smartphone and robot and is named RoboHon.[63]

As robots become more advanced, eventually there may be a standard computer operating system designed mainly for robots. Robot Operating System is an open-source set of programs being developed at Stanford University, the Massachusetts Institute of Technology and the Technical University of Munich, Germany, among others. ROS provides ways to program a robot's navigation and limbs regardless of the specific hardware involved. It also provides high-level commands for items like image recognition and even opening doors. When ROS boots up on a robot's computer, it would obtain data on attributes such as the length and movement of robots' limbs. It would relay this

data to higher-level algorithms. Microsoft is also developing a "Windows for robots" system with its Robotics Developer Studio, which has been available since 2007.[64]

Japan hopes to have full-scale commercialization of service robots by 2025. Much technological research in Japan is led by Japanese government agencies, particularly the Trade Ministry.[65]

Many future applications of robotics seem obvious to people, even though they are well beyond the capabilities of robots available at the time of the prediction.[66][67] As early as 1982 people were confident that someday robots would:[68] 1. Clean parts by removing molding flash 2. Spray paint automobiles with absolutely no human presence 3. Pack things in boxes—for example, orient and nest chocolate candies in candy boxes 4. Make electrical cable harness 5. Load trucks with boxes—a packing problem 6. Handle soft goods, such as garments and shoes 7. Shear sheep 8. prosthesis 9. Cook fast food and work in other service industries 10. Household robot.

Generally such predictions are overly optimistic in timescale.

New functionalities and prototypes

In 2008, Caterpillar Inc. developed a dump truck which can drive itself without any human operator.[69] Many analysts believe that self-driving trucks may eventually revolutionize logistics.[70] By 2014, Caterpillar had a self-driving dump truck which is expected to greatly change the process of mining. In 2015, these Caterpillar trucks were actively used in mining operations in Australia by the mining company Rio Tinto Coal Australia.[71][72][73][74] Some analysts believe that within the next few decades, most trucks will be self-driving.[75]

A literate or 'reading robot' named Marge has intelligence that comes from software. She can read newspapers, find and correct misspelled words, learn about banks like Barclays, and understand that some restaurants are better places to eat than others.[76]

Baxter is a new robot introduced in 2012 which learns by guidance. A worker could teach Baxter how to perform a task by moving its hands in the desired motion and having Baxter memorize them. Extra dials, buttons, and controls are available on Baxter's arm for more precision and features. Any regular worker could program Baxter and it only takes a matter of minutes, unlike usual industrial robots that take extensive programs and coding to be used. This means Baxter needs no programming to operate. No software engineers are needed. This also means Baxter can be taught

to perform multiple, more complicated tasks. Sawyer was added in 2015 for smaller, more precise tasks.[77]

Etymology

See also: Glossary of robotics

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

The word *robot* was introduced to the public by the Czech interwar writer Karel Čapek in his play *R.U.R. (Rossum's Universal Robots)*, published in 1920.[78] The play begins in a factory that uses a chemical substitute for protoplasm to manufacture living, simplified people called *robots.* The play does not focus in detail on the technology behind the creation of these living creatures, but in their appearance they prefigure modern ideas of androids, creatures who can be mistaken for humans. These mass-produced workers are depicted as efficient but emotionless, incapable of original thinking and indifferent to self-preservation. At issue is whether the robots are being exploited and the consequences of human dependence upon commodified labor (especially after a number of specially-formulated robots achieve self-awareness and incite robots all around the world to rise up against the humans).

Karel Čapek himself did not coin the word. He wrote a short letter in reference to an etymology in the *Oxford English Dictionary* in which he named his brother, the painter and writer Josef Čapek, as its actual originator.[78]

In an article in the Czech journal *Lidové noviny* in 1933, he explained that he had originally wanted to call the creatures *laboři* ("workers", from Latin *labor*). However, he did not like the word, and sought advice from his brother Josef, who suggested "roboti". The word *robota* means literally "corvée", "serf labor", and figuratively "drudgery" or "hard work" in Czech and also (more general) "work", "labor" in many Slavic languages (e.g.: Bulgarian, Russian, Serbian, Slovak, Polish,

Macedonian, Ukrainian, archaic Czech, as well as *robot* in Hungarian). Traditionally the *robota* (Hungarian *robot*) was the work period a serf (corvée) had to give for his lord, typically 6 months of the year. The origin of the word is the Old Church Slavonic (Old Bulgarian) *rabota* "servitude" ("work" in contemporary Bulgarian and Russian), which in turn comes from the Proto-Indo-European root **orbh-*. *Robot* is cognate with the German root *Arbeit* (work).[79][80]

The word robotics, used to describe this field of study,[5] was coined by the science fiction writer Isaac Asimov. Asimov created the "*Three Laws of Robotics*" which are a recurring theme in his books. These have since been used by many others to define laws used in fiction. (The three laws are pure fiction, and no technology yet created has the ability to understand or follow them, and in fact most robots serve military purposes, which run quite contrary to the first law and often the third law. "People think about Asimov's laws, but they were set up to point out how a simple ethical system doesn't work. If you read the short stories, every single one is about a failure, and they are totally impractical," said Dr. Joanna Bryson of the University of Bath.[81])