Modern History of Robotics

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Introduction:

This section of the course on history of machines and mechanisms is devoted to an industrial and technical history of modern robotics. This relates to the development in the robotic field in the 20th and 21st century. Although the concept of robotics goes back to antiquity and some technical developments on mechanical systems that can be viewed as robotic devices have been made in pre-industrial revolution much of the technological development in the field have been due to integration of computing, sensing, and mechanical design technologies and have occurred after world war II and since 1950's due to the development of solid state electronics making computers, computer control, and sensing technologies economically more feasible. This tutorial is limited mostly to the history of the industrial robot manipulator technology.

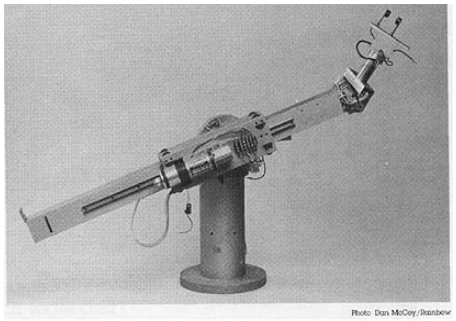
Modern Industrial History:

There were two very important developments that provided the basis for the first industrial robot. The first was the development of Numerical Control (NC) for machine tools. NC is a method of controlling machine tool axes by means of numerical data or numbers that have been coded on punched paper tape or other media. This technology was developed through funding from the United States Air force at the Massachusetts Institute of Technology (MIT) during the late 1940s and early 1950s. The first numerical control machine tool was demonstrated at MIT in 1952. Subsequently, research at MIT led to the development of the APT (Automatically Programmed Tools) programming language for machine tools. The second important technology that provided the basis for the first industrial robots was the mechanical arm or manipulator technology. Initial version of this technology was developed by Raymond Goertz [1] in the form of the first tele-operated articulated arm for the Atomic Energy Commission in France which was first utilized in 1951. The design was based on mechanical coupling between the master and slave arms and was the first real industrial example of a manipulator. In 1954, George C. Devol made the first patent application for an industrial robot which he called a programmable manipulator (the patent was issued in 1961). In 1956, Devol and Joseph Engelberger met and seeded the plants of formation of a company that they named Unimation Inc. In 1961, their company Unimation Inc. was able to successfully install a Unimate robot (Figure 1) for die-casting application in a General Motors (GM) plant. Later many more Unimate robots were installed at GM plants for spot welding applications. These first applications were commercially very successful and Unimation as a company became profitable by 1975. In 1960, American Machine and Foundry (AMF) Corporation, markets the first cylindrical robot, called the Versatran. This robot

was designed by Harry Johnson and Veljko Milenkovic Figure 2). In 1967, the AMF Versatran robot is the first robot to be imported to Japan. Later in 1968, Kawaski Heavy Industries of Japan obtained license for all Unimation Inc.'s technologies and by 1971, fever for industrial robots had spread to be the highest in Japan among all industrial nations. In 1969, Victor Scheinman a Mechanical Engineering researcher at the Artificial Intelligence Laboratory at Stanford University develops the Stanford Arm (Figure 3). Later in 1974, he forms the Vicarm Inc. to market a minicomputer controlled version of the Stanford arm for industrial applications. This is however not the first industrial manipulator available commercially that uses a mini-computer. A year earlier in 1973, Cincinnati Milacron markets a robot named T3 (Figure 4) designed by Richard Hohn. This is the first commercially available minicomputer-controlled industrial robot. In 1977, ASEA, a European robot company, offers two sizes of electric powered and micro-computer controlled industrial robots (Figures 5 and 6). In the same year Unimation purchases Vicarm Inc., the company formed by Victor Scheinman in 1974. The technology from Vicarm Inc. provides the basis for the development of PUMA (Programmable Universal Machine for Assembly) which was also micro-computer controlled (see Figure 7). In 1979, Sankyo and IBM market a simple robot that was developed by Yamanashi University in Japan. This robot (Figure 8) was called the SCARA (selective compliant articulated robot arm) robot and provided some of the basis for the later important development of the direct drive robot (Figure 9) by Adept technology Inc. in 1983. The direct drive concept was also originally developed by Takeo Kanade at Carnegie Mellon University (CMU) in 1981. The CMU direct drive arm was the first robot to have motors installed directly into the joints of the arm

Figure 1. Unimate Robot

Figure 2. The Versatan Arm



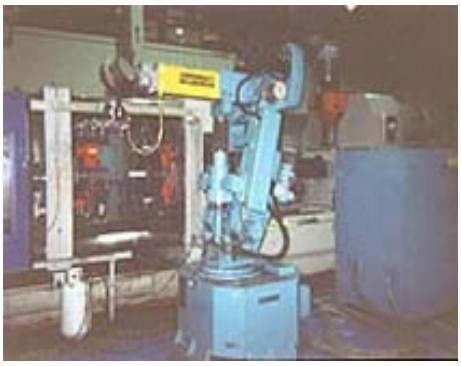


Figure 3. The Stanford Arm.

Figure 4. Cincinnati Milacron T3 robot.

Figure 5. ASEA Robot

Figure 6. ASEA Robot

Figure 7. PUMA Robot Arm

Figure 8. IBM SCARA Robot

Figure 8. Adept Direct Drive Robot

Figure 9. Adept Articulated Arm

It was not until the early 80's that the robotics industry grew significantly in the United States. This rapid growth was, mostly, due to large investment in this field especially by the Automotive Industry. During this period many robotic companies were formed and some other companies added a robotic line to their products. Probably the most significant of these were the formation of GMF (GM-Fanuc) in Michigan in 1982 and

Adept Technology Inc. in California in 1983. GMF was formed as a joint venture between GM and Fanuc of Japan to market robots in North America and is no longer in existence but Adept still remains in operation.

During the 1980's, there was a push for creation of factories of the future with many robots providing the backbone of a flexible automation system for such factories. This quick leap into the factory of the future unfortunately turned into a plunge when integration of these robotics systems proved to be prone to technical difficulties and economically unrealizable. Many companies bought robotic devices and put them in laboratories trying to fit their industrial tasks to the robots rather than fitting the robots to their tasks. Their decision to purchase or select a specific robot typically had little to do with the real tasks for which the robot was going to be utilized. There was a shake up of US robotic industry and only one US Company, Adept Technology Inc., remains in industrial manipulator (Figures 8 and 9 above) business today. US Robot industry has only recently recovered to the same revenue levels of mid 1980's. Other existing US robotic companies today are application oriented and do not manufacture general purpose robotic arms. These companies include surgical robotics companies, those involved in underwater technologies, and system houses that integrate existing robots with other devices, sensors and systems to develop application specific systems.

For space applications the first real manipulator arm that was fully utilized was the Canadian Shuttle Remote Manipulator System (SRMS), known as Canadarm which was first utilized aboard U.S. Space Shuttle Columbia in 1981 and reliably since then. This arm (Figure 10) was developed by MD Robotics of Canada and one of its most notable missions was the repair of the Hubble Space Telescope.

Figure 10. SRMS or Candaarm on the Space Shuttle

In 1986 Honda corporation of Japan started research program in general robotics with the premise that a robot should coexist and cooperate with humankind, by doing what a person cannot do and by cultivating a new dimension in mobility to ultimately benefit society. In 1996, Honda released its P3 humanoid robot (Figure 10). This is the most

complex biped humanoid robot with 16 joints where each joint can be controlled individually. It is capable of complex movement and balance control on uneven surfaces. In 2001 Honda debut the ASIMO (Figure 11) which is the next generation of P3. This humanoid robot can respond to about 30 action commands and it is the most sophisticated humanoid robot that has been commercially introduced to date.

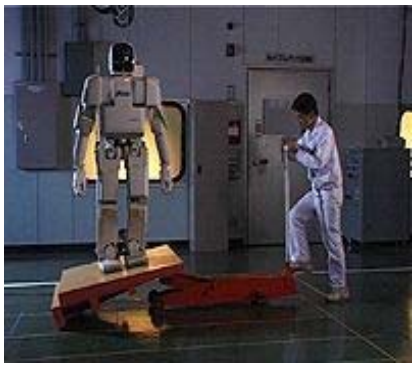


Figure 10. Honda's P3 robot

Figure 11. Honda's ASMIO robot

Roots of the Terminology and Robotics in Theatrics:

The word "robot" was coined in English language for the first time by Karel Capek (1890-1938) (pronounced "chop'ek"; phonetic: ŠCapek), a Czech playwright (Figure 12), in his play R.U.R (Rossum's Universal Robot). The play was written in 1920 and was first opened in Prague in January 1921. Due to its big success, R.U.R (Figure 13) was opened throughout Europe and in America with its production in New York in 1922 and in London in 1923. The play involves a scientist named Rossum who discovers the secret of creating a human like machine and manufacturing them for mass distribution. The theme of R.U.R was, in part, dehumanization of human in a technological society and the word robot (Czech word "robota") was used for forced labor or compulsory service.

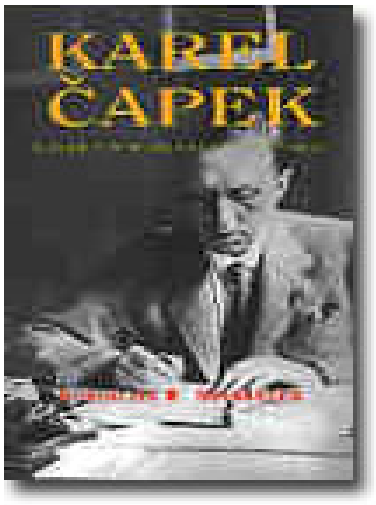


Figure 12. Karel Capek

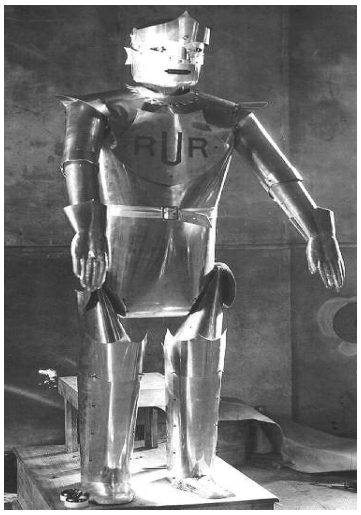


Figure 13. A robot in R.U.R

There are two English translations of R.U.R.: one is the early translation from 1920 by P. Selver and the second is contained in translation of a collection of Capek's writings called Towards the Radical Center. The next theatrical presentation of robots was in a movie from Fritz Lang called "Metopolis" released in 1926. The female robot "Maria" in the film (Figure 14) is the first robot to be projected on a movie screen.

Figure 14. Maria, Female Robot in the movie Metropolis

The term Robotics was introduced by the (Russian born) American science fiction writer Issac Asimov (1920 – 1992) in his story Runaround published in 1942. Asimov (Figures 15 and 16) is credited with popularizing the concept of robotics through a series of short stories about robots starting with a story called "A Strange Playfellow" which he wrote for Super Science Stories magazine. This story is about a robot and its affection for a child that it is protecting. He later renamed this story calling it "Robbie". Asimov generated many other stories about robots which are compiled into a book volume called "I, Robot" published in 1950. One of the most important contributions of Asimov, in history of robotics, is probably his introduction of three laws of robotics. He introduced the three laws in his story Runaround and later added another law which he called the zeroth law to the first three laws. These laws are stated as follows:

Zeroth law: A robot may not injure humanity, or, through inaction, allow humanity to come to harm.

First Law: A robot may not injure a human being, or, through inaction, allow a human being to come to harm.

Second Law: A robot may not injure a human being, or, through inaction, allow a human being to come to harm.

Third Law: A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

Figure 15. Issac Asimov

Figure 16. Asimov and Joseph Engleberger

It should be pointed out that there is an important distinction between the Capek and Asimov concepts of the roles that robots can take in our society. Capek's R.U.R conveys robots as humanoid servants who turn on their masters when given emotions. Asimov concept includes circuitry in the robots that would assure the humankind that their robots will be benevolent.

The next theatrical or fictional exposure to robotics is the movie "The Day the Earth Stood Still" which premiered in theaters in 1951. The movie featured an alien named Klaatu and his robot named Gort. In 1968, Arthur's C. Clark's movie: 2001: a Space Odyssey opened in theaters. This movie which was made by Stanley Kubrick featured a computer named "HAL" which decides it does not need its human counterparts any longer following thinking similar to that of Capek. Next, the film "Silent Running" is released where the co-stars of the movie are three robots named Huey, Dewey, and Louie (See Figure 17). The star of this movie is Bruce Dern. In 1977, George Lucas film "Star Wars" is released with great success. The movie introduces two robots R2-D2 and C-3PO (Figure 18). The movie creates a vision of the future where robots help the humankind and work together with them. Star Wars in followed by two other Star War movies in its sequel where the robots R2-D2 ad C-3PO are used in all of them. In 1982, the movie "Blade Runner" is released staring Harrison Ford. This movie is based on Philip K. Dick story: "Do Androids Dream of Electric Sheep?" Harrison Ford plays a retired blade runner that hunts illegl mutinous androids.

Figure 17. Robot drones Huey, Dewey, and Louie Figure 18. R2-D2 and C-3PO Robots

Definition:

At the present time, the most used definition of an industrial robot is the one developed by the Robotics Institute of America: "An industrial robot is a reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks." It should be pointed out that this definition refers to devices that are for the most part quite different from the androids, or humanlike robots used in science fictions such as the concepts used by Capek and Asimov. They rarely take human form, they perform only a limited number of tasks, and have limited (if any) decision making capabilities. A slightly different definition that can encompass some of the attributes of the robot concepts used in the fiction work of Capek or Asimov is that of Webster dictionary which defines a robot as "an automatic apparatus or device that performs functions ordinarily ascribed to humans or operates with what appears to be almost human intelligence."

It is interesting to note from a historical perspective that although industrial robotic arm technologies first became available commercially in the United States, the world's first robot association was formed in Japan. This was the Japan Industrial Robot Association (JIRA) which was formed in 1971. The Robotic Institute of America was formed in 1975. The first International Symposium on Industrial Robotics (ISIR) was held in Chicago in 1970.