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INTRODUCTION TO INDUSTRIAL ROBOTS

History

"A robot is a re-programmable, multi-functional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks."

Contents

Origin of the word “ROBOT”

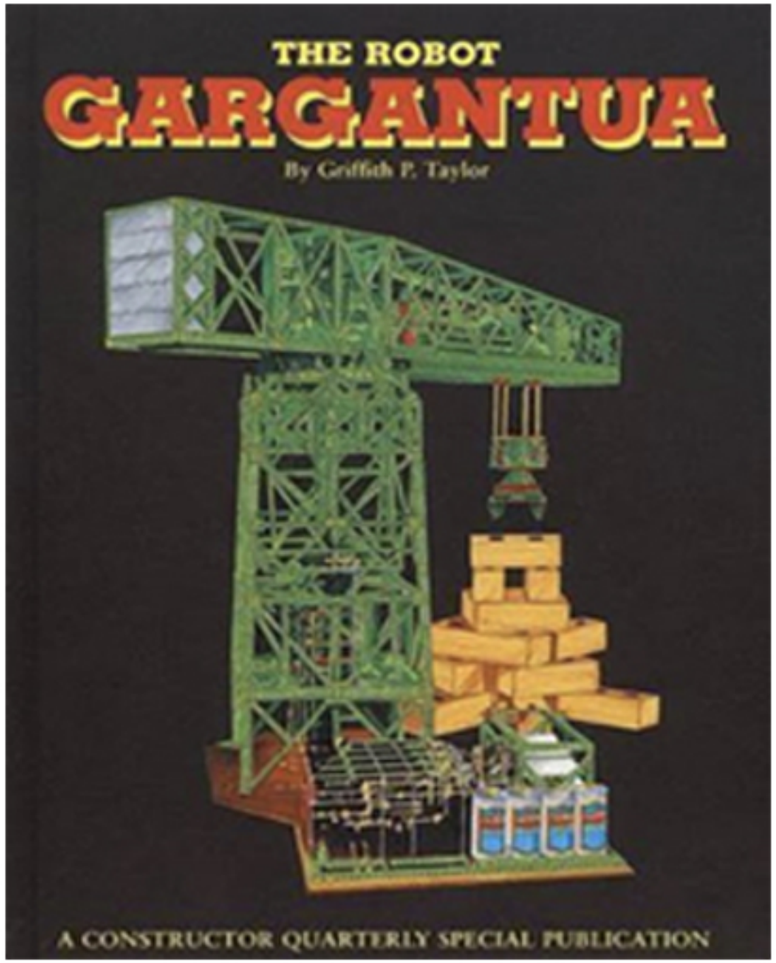
The word robot is drawn from an old Church Slavonic word, robota, for “servitude,” “forced labor” or “drudgery.” The word robot was first utilized and popularized by a Czech playwright, novelist and journalist named Karel Čapek (1880-1938) who introduced it in his 1920 hit play, R.U.R. (Rossum's Universal Robots).

The play premiered in Prague in 1921. In the play, the robots helped with the work humans would normally do until the robots revolted, killed their master, and destroyed all life on earth. The R.U.R. was written to take place in the 1960s, which is the actual period when the industrial robots made their first appearance.

The first robot was a toy!

The earliest known robot, conforming to the definition on the introductory page, was made from a toy. The crane-like device was built almost entirely using Meccano parts by "Bill" Griffith P. Taylor in 1937. The description was published in Meccano Magazine in March 1938. It was powered by a single electric motor and had five axes of movement, including grab and grab rotation. It was sadly never patented.

Automation was achieved using punched paper tape to energize solenoids, which would facilitate the movement of the crane's control levers. The robot could stack wooden blocks in pre-programmed patterns. The number of motor revolutions required for each desired movement was first plotted on graph paper. This information was then transferred to the paper tape, which was also driven by the robot's single motor. Chris Shute built a complete replica of the robot in 1997.



The first Industrial Robot

1961 Danbury, Connecticut. Unimate Number 001 is put through its paces before shipping to the General Motors plant in Trenton, NJ. (Joseph Engelberger, engineers George Munson and Maurice Dunne.)

In 1954, the inventor George Devol submitted a patent for a Programmed Article Transfer Device. It was a rudimentary Pick & Place industrial robot and the machine would eventually become recognized as the first industrial robots. The patent was formally granted in 1961 to George Devol.

The first deliverable material handling robot employed in industrial production work was created in a small Connecticut, USA machine shop and brought to life by a handful of ingenious, persistent young men led by the patent-holder George Devol and the entrepreneur physicist, engineer, and businessman Joseph Engelberger.

In 1956, Engelberger met Devol at a cocktail party where the two discussed the writer Isaac Asimov's robot philosophies and Devol's patent-pending Programmed Article Transfer Device. Engelberger immediately identified the device as a robot, the first ever, and was conceived that it could be used in manufacturing to perform jobs dangerous to humans.

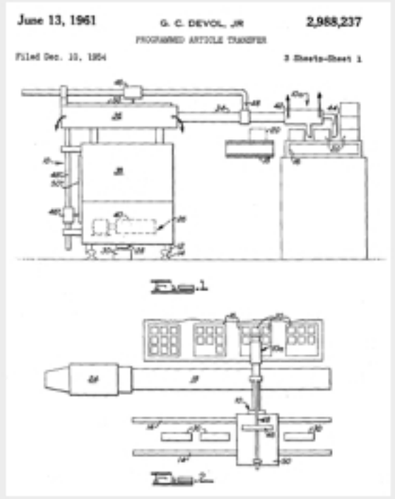
The two formed a synergistic alliance: Devol had a patented, viable product and Engelberger had the manufacturing plant and crew of competent engineers. Forging a historic partnership, Engelberger began work with Devol to get his robotic device developed. In 1957 Engelberger convinced Norman Schafer, CEO of Condec Corp., the parent company of Consolidated Controls, a firm that was founded by Engelberger, to finance the initial development of Devol's invention.

In 1961, once his partner George Devol was awarded US Patent No. 2,988,237 for his robotic invention, Engelberger established Unimation Inc., a Condec Corp. subsidiary. Located in a small building in Danbury, Connecticut and would grow to over 1000 employees before it was sold. Devol's wife, Evelyn, coined the word "Unimation" by combining "universal" and "automation." The world's first robotics company, Unimation, was born, with Joseph Engelberger as its charismatic president.

In 1962, angel investor Pullman Inc., developer of the famous railroad car of the same name, put up $3M for a 51% share in Unimation, Inc. ($3M in 1962 equals $25M in today's dollars), a company that wouldn't turn a profit for fifteen years.

The grand-father of robots, George Devol

The creative genius George Devol (February 1912 - August 2011) was born in Louisville, Kentucky, USA.



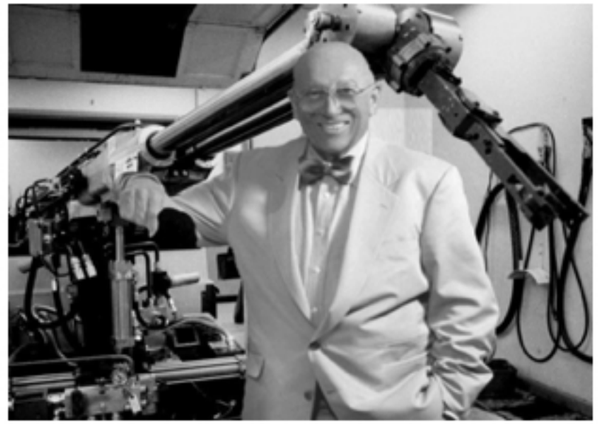
Devol was a self-taught brilliant engineer/inventor who, at age 20, formed United Cinephone, producing recording equipment using photocells. He developed the revolutionary barcode and patented hundreds of inventions, including digital magnetic recording.

During his time spent in development and manufacturing, Devol had observed mountains of scrap tooling, created by product design changes. The mounds of scrapped tooling inspired his revolutionary idea of universal automation; automation that would not become obsolete but would adapt to product changes.

In 1954 he submitted the patent for the Programmed Article Transfer Device. As soon as the patent was granted in 1961 he founded Unimation with Joseph F. Engelberger. On the right is the original patent application drawing.

The father of robots, Joseph F. Engelberger

If George Devol was the grandfather of the industrial robot, Joseph Engelberger was the father.
Joseph Frederick Engelberger (26 July 1925 -1 December 2015) was born in Brooklyn, New York.



He grew up in Connecticut during the Great Depression but later returned to New York City for his college education. Engelberger received his B.S. in physics in 1946, and M.S. in Electric Engineering in 1949 from Columbia University.

In the early 1950s he was working as an engineer with Manning, Maxwell, & Moore in central Connecticut. Engelberger serendipitously met inventor George Devol at a Westport, Connecticut cocktail party one evening in 1956. However, later that year, Manning, Maxwell & Moore was soon sold to another company after their chance meeting and Engelberger's division was closed soon after.

Finding himself jobless but partners with a man who owned a potential gold mine patent, Engelberger co-founded Unimation with Devol. Unimation was the world's first robotics company and was a division of the Consolidated Controls Corporation, which Engelberger founded in 1957. As president of Unimation and with Consolidated Controls providing the R&D funding, Engelberger collaborated with Devol to engineer and produce an industrial robot under the brand name Unimate.

Their beginnings were very modest, only six engineers were assigned to the project. They knew the robot had to be anthropomorphic, but they had to decide which configuration would provide the greatest flexibility for the applications they foresaw.

Research & Development of the first Industrial Robot

The team first conducted market surveys to determine the parameters, considering four basic configurations: polar, cylindrical, Cartesian, and revolute coordinates.

Their decision was to proceed with a polar coordinate design. They also decided them to build to a 5-degree of freedom machine (5-axis), having just two rather than three wrist axes.

While a 6-axis machine would have best emulated the flexibility of the human arm and wrist, the expense and complication forced them to limit the first machine to 5-axis.

A self-contained hydraulic supply operating at about 70bar (1,000 psi) was selected to provide sufficient power since it would require fewer gears, thus, less backlash, than an electric motor.

However, hydraulic power technology was not advanced enough, and the demands for speed, stability and accuracy challenged every design aspect of the 1,220kg (2,700lbs) behemoth.

The team had to engineer:

1. A digitally controlled system based on the binary system. (Remember, this was in 1956!)

2. A nonvolatile solid-state memory system, which didn't yet exist.

3. Shaft position optical digital encoders, which also didn't exist.

4. A digital servo controller capable of dynamic control with a wide range of payloads.

5. High-performance hydraulic servo valves.

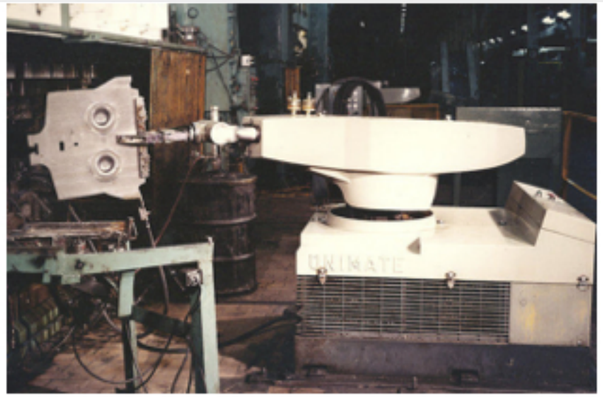
6. Self-contained electrical and hydraulic power supplies.

Under Devol's guidance, the team developed a ferroresonant sensor, the basis for a self-styled memory system, patented as "Dynastat." They also developed an optical shaft position encoder to provide the necessary position feedback to close the loop between the robot arm's actual position and its command positions.

By 1965 they had perfected an optical Gray code encoder they called 'Spirodisk." Derivations of this device are the basis of position encoders used in every modern robot.

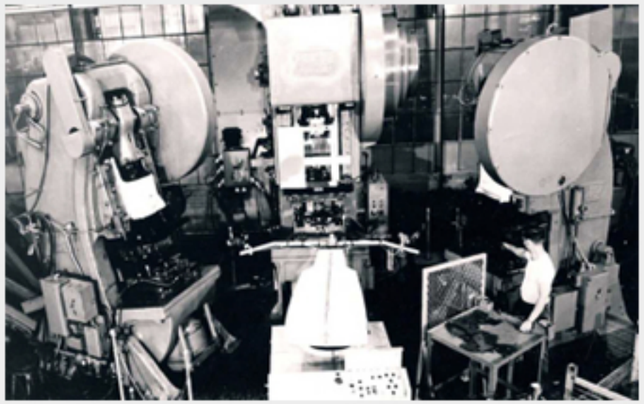
By 1959 the first robot prototype was ready, the Unimate #001. The Unimation robots were also called programmable transfer machines since their initial & primary use was to transfer objects from one point to another, less than a dozen feet or so apart. They used hydraulic actuators to move the arm and were programmed in joint coordinates (e.g. the angles of the various joints). The joint coordinates were created by manual teaching then replayed during operation. As soon as they were close to having a final product, Engelberger immediately set out to convince the top American manufacturers in the automotive industry of the unlimited benefits of the Unimate robot.

The Killer App



General Motors was the first to take an interest in robots, installing the Unimate #001 on its production line at its Trenton, New Jersey die-casting plant in 1960. The die-cast machine operators thought the robot was curiosity destined to fail. They were horribly wrong as no other industry encouraged the proliferation of the industrial robot as much as the die-industry.

Until the application of the robotic spot-welding of automobile bodies was developed in the late 1960s, most of the Unimate robots sold were used in the pick & place of die-castings. The die-casting industry inherently required all the attributes the Unimate robot had to offer. Eventually, some 450 Unimate robots were employed in die-casting.



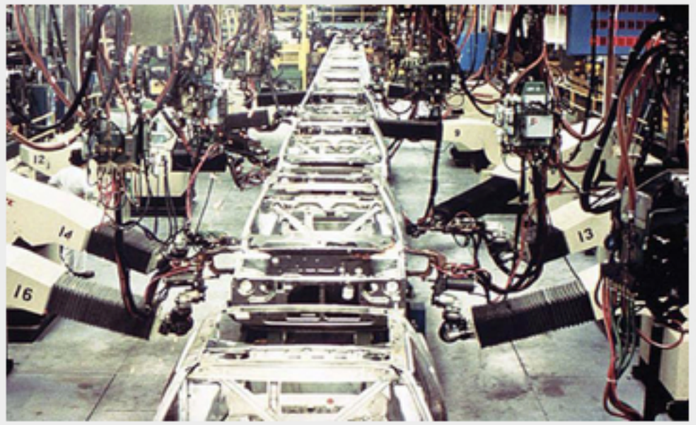
The installation of the first robot was a monumental event that revolutionized manufacturing, marked the birth of the robotics industry. The introduction of robotics to the manufacturing process effectively transformed the automotive industry, with Chrysler and the Ford Motor Company soon following General Motors' lead by installing Unimate robots in their manufacturing facilities.

The rapid adoption of the new technology also provided Unimation with a working business model. After selling the first Unimate for $18,000 but costing $65,000 to manufacture (a $400,000 loss in equivalent 2018 dollars), demand radically increased. Soon the company was able to begin manufacturing the robotic arms for significantly less and began to turn a substantial profit on each machine.

Around 1966 Engelberger expanded Unimation's distribution internationally. By granting licenses to Nokia of Finland and Kawasaki Heavy Industries (now Kawasaki Robotics) of Japan to manufacture and market the Unimate, Engelberger ushered in the European and Asian robotic markets respectively.

Over the next two decades, the Japanese took the lead by investing heavily in robots to replace people performing certain tasks. Kawasaki would produce more than 2,400 Unimates under license from Unimation. In Japan, Engelberger was widely hailed and awarded multiple times by the Japanese as a key player in the postwar ascendancy of Japanese manufacturing quality and efficiency.

The First Payoff



Unimation knew that the big payoff would come with the development and modification of their robots to meet the requirements for spot-welding automobile sheet-metal frames. This dream came true in 1969 when Unimation's robots were chosen to do all the sheet-metal spot welding at the General Motors assembly plant in Lordstown, Ohio.

It was the most automated automotive plant in the world, building 110 cars per hour, twice the rate of any plant then in existence. The Lordstown fabricated the GM Vega, the car that was to be the answer to the Japanese onslaught of quality built low-cost compact cars. The plant, using the Unimate robots, produced over 1,966,157 Vegas that would satisfy the American public at a competitive cost, putting GM back on top.

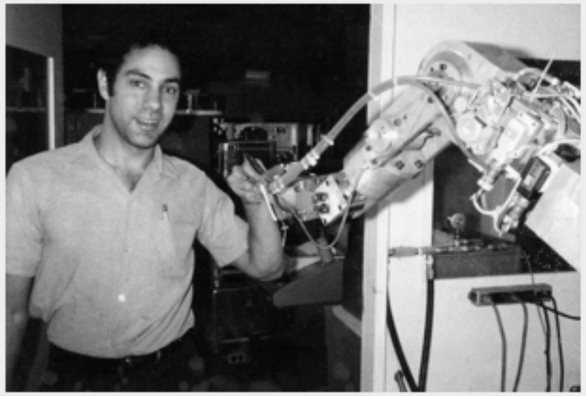
From the inception of the automobile assembly line in December 1913 until 1969, the line was a moving conveyor on which major body subassemblies were hung and assembled manually. The sheet-metal assemblies were manually welded with a manually operated spot-welding machine.

It was the worst job on the assembly line that no one wanted. The line worker had to be very strong and have the endurance to manipulate the heavy spot-welding machine even though they were counter-weighted. The spot weld area was pure hell due to the constantly flying sparks and the thick leather clothing to prevent spark burns made the a hot environment unbearable.

Since the welding was done manually the build quality varied on each vehicle. The worst days were Mondays when absenteeism was the highest. It was common knowledge to never to purchase a car built on Monday since the cars built on Monday were poorly welded due to replacement workers missing spot welds. The missing spot welds would eventually cause the car to rattle endlessly with no possible repair.

The technological impact of the Lordstown experiment revolutionized automobile making and secured the robots future in manufacturing. It wasn't long before other companies turned to robotics and indexing systems for a more disciplined approach to manufacturing. At the same time, the European market came alive with Unimates at Fiat, Volvo, Mercedes Benz, British Leyland, BMW. Their unions welcomed robots performing all the dangerous jobs.

The father of the 6-axis robot, Victor Scheinman



Another equally important person in the development of the electric 6-axis robot that we see everywhere in manufacturing facilities, was another brilliant engineer, Victor Scheinman (December 1942 - September 2016).

In 1969, as a student at Stanford University, he invented the Stanford arm, an all-electric, 6-axis articulated robot designed to permit an arm solution in closed form. This allowed the robot to accurately follow arbitrary paths in space under computer control and widened the potential use of the robot to more sophisticated applications such as assembly, spot welding and complex path arc welding.

In contrast to the heavy, hydraulically driven Unimate robots, his Stanford Arm was lightweight, electric and proved that it was possible to build a machine that could be as versatile as it was autonomous.

In 1973, Victor Scheinman formed Vicarm to manufacture robotic arms and concurrently developed the VAL programming language that is still used by Stäubli Robots today. He also went on to help found Automatix, another early robotics company, in 1980.

In 1977 Unimation purchased Vicarm Inc. and with Scheinman's help, created and began producing the Programmable Universal Machine for Assembly (PUMA), and a new model of a robotic arm using Scheinman's cutting-edge VAL programming language.

For some time Unimation's only competitor was Cincinnati Milacron Inc. of Ohio. This changed radically in the late 1970s when several big Japanese conglomerates began producing similar industrial robots but utilized electric step-motors. Sadly, Engelberger vehemently opposed electric motors.

In the early 1980s the automotive companies, who had been Unimation's earliest and most reliable clients, began moving away from hydraulically powered robotic arms in favor of electric motors. This market change and Engelberger’s resistance to change eventually drove the downfall of Unimation.

A market growing rapidly and evolving

Industrial robotics took off quickly in Europe with ABB Robotics and KUKA Robotics bringing robots to the market in 1973. ABB Robotics (formerly ASEA) introduced IRB 6, among the world's first commercially available all-electric microprocessor-controlled robot. The first two IRB 6 robots were sold to Magnusson in Sweden for grinding and polishing pipe bends were installed in production in January 1974. They are still in use today! Also, in 1973 KUKA Robotics built its first robot, known as FAMULUS, also one of the first articulated robots to have six electromechanically driven axes.

Interest in robotics increased in the late 1970s and many US companies entered the field, including large firms like General Electric, and General Motors (which formed joint venture FANUC Robotics with FANUC of Japan). U.S. startup companies included Automatix and Adept Technology, Inc.

In the 1980's, automotive companies showered robotic companies with investments. The enthusiasm and funding were not always matched with understanding. General Motors Corporation spent more than $40 billion on new technology in the 1980's, but a lack of understanding led to costly robot fiascos. In 1988, robots at the Hamtramck Michigan plant wreaked havoc - smashing windows and painting one another. Unfortunately, the premature introduction of robotics began to create financial instability.

At the height of the robot boom in 1984, Unimation was acquired by Westinghouse Electric Corporation for 107 million U.S. dollars. In 1988 Westinghouse sold Unimation to Stäubli Faverges SCA of France for an undisclosed amount. Stäubli, who still produces articulated robots for general industrial and cleanroom applications also bought the robotic division of Bosch in late 2004.

It wasn't until recently that the robotics industry has regained mid-1980 revenue levels. The American producers of robots disappeared quickly in the 1980s as the Japanese and Europeans merged with or bought up companies during a period of consolidation. Only a few non-Japanese companies ultimately managed to survive in this market, the major producers being: Adept Technology (USA), Stäubli (France), ABB (Sweden), Universal Robots (Denmark), Comau (Italy) and Kuka (German).

Japan entered the industrial robot revolution beginning with Kawasaki delivering their first Robot, built under a Unimation license, in 1969. From the first Kawasaki-Unimate in 1969 until present day, Japan has become one the major producers of industrial robots. Fanuc, Yaskawa, Kawasaki, Mitsubishi, Denso, Nachi, OTC, Epson and Panasonic are the major manufacturers of robots in Japan.

2010 brought a huge acceleration in demand due to the continued innovative development and improvement of industrial robots. By 2014, there was a 29% increase in robot sales across the globe.

Together Japan and Western Europe produce the majority of industrial robot but robot production in China is growing rapidly. In late 2016, Midea, known for electrical appliances, paid US$5 billion to take over the Kuka (Germany). Both Kuka and ABB manufacture robots in Shanghai.

China is expected to have 1 million industrial robots in operation by 2025, up from approximately 300,000 units in 2016, according to the International Federation of Robotics. The Chinese government is currently investing heavily in promoting the production and implementation of industrial robots. To be able to compete in the world market China knows that they must improve manufacturing efficiency, move their products up the value chain, mitigate increasing salaries and adapt to an aging population where the availability of labor is decreasing.

It is an exciting time to be a part of the robotic world as our globe becomes more aware of the amazing benefits of industrial robots.

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