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Evolution of Industrial Robots and their Applications

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***Abstract*--The advancement of industrial robotics has caused robots to become more widespread across various industries ranging from manufacturing to health care. Robots offer speed and accuracy that can't be achieved with human labour. Robots can also reduce operating costs, reduce scrap and are flexible for future changes. Few other manufacturing solutions can reduce waste as well as robots when designed into the system properly. Robotics' capabilities have only increased with time, while costs have continued to fall. Major robot manufacturers are constantly upgrading their robots with increased payload capacity, greater accuracy, increased reach and range of motion, improved speed and acceleration, faster communication with external equipment, better safety features and lower operational costs. Many people believe the misconception that robots have taken away jobs from workers, but that is not necessarily true. Robots have created new jobs for those who were once on production lines with programming. They have pulled employees from repetitive, monotonous jobs and put them in better, more challenging ones. Today robots are user-friendly, intelligent, and affordable. This paper briefly describes robot technology and goes into more depth about where robots are used. A chronology of robotics technology and use of future robots is also given.**

***Keywords*— robot, chronology of robot, robot's component, applications, future robot.**

I. INTRODUCTION

An Industrial robot is 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. Industrial robots are used as transporting devices (material handling of work pieces between machines) or in some kind of additive- (e.g. assembly, welding, gluing, painting etc.) or subtractive- manufacturing process (e.g. milling, cutting, grinding, de-burring, polishing etc.). Also the industrial robot controller has good capability of I/O communication and often acts as cell controller in a typical set-up of a flexible manufacturing cell or system [1]. Until now, driven by the need from the car manufactures, material handling and welding has been the most focused area of industrial robot development.

It has been reported that material handling and the additive processes of welding counted for 80% of the industrial robot based applications in 2003, but foresights an extension into subtractive manufacturing applications. It has also been predicted that a lightweight type robot, capable of both subtractive and additive manufacturing, will have an impact on the car industry and the small and medium sized enterprises (SMEs) [2].

In the past, factory production lines were automated for mass production, and many industrial robots and specialized machines were introduced. Recently, flexible manufacturing systems, such as the cell production system (unlike in the line production method, an entire product is assembled by one worker), are being introduced in an increasing number of production sites in order to deal with differentiation of products and to meet diversified needs. However, many of the tasks in flexible manufacturing systems rely heavily on workers because the number of parts to be handled is larger so the time and costs required to switch product types on robots and specialized machines is greater [3].

Robots are valued in industry for the usual qualities of machines: untiring availability, predictability, reliability, precision and (relative) imperviousness to hostile environments. They do not, as yet, possess several important capabilities which come naturally to humans: the ability to react to unforeseen circumstances or changing environments, and the ability to improve performance based on prior experience. State-of-the art robots (mostly in, research labs) do have crude senses of "sight" and "touch", and limited capability to coordinate their manipulators with sensory input. Because of current limitations, today's robots are usefully employed in highly structured industrial environments where practically all of the variability and decision making can be engineered out of the workplace [4]. Existing uses of industrial robots all involve repetitive preprogrammable tasks such as spot welding, spray painting, palletizing, and the loading and unloading of many types of metal forming and metal cutting machines. The next generation of sensor based robots will be able to perform a broader range of tasks under less structured conditions, in addition to becoming cheaper and easier to use.

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Expected uses of robots with vision and improved feedback control will include inspection, assembly, heat treatment, grinding and buffing, and electroplating [5].

II. Classification Of Robot

The most commonly used robot configurations are articulated robots, SCARA robots, Delta robots and Cartesian coordinate robots, (aka gantry robots or x-y-z robots)[6]. In the context of general robotics, most types of robots would fall into the category of robotic arms. Robots exhibit varying degrees of autonomy:

- Some robots are programmed to faithfully carry out specific actions over and over again (repetitive actions) without variation and with a high degree of accuracy. These actions are determined by programmed routines that specify the direction, acceleration, velocity, deceleration, and distance of a series of coordinated motions.
- Other robots are much more flexible as to the orientation of the object on which they are operating or even the task that has to be performed on the object itself, which the robot may even need to identify. For example, for more precise guidance, robots often contain machine vision sub-systems acting as their "eyes", linked to powerful computers or controllers. Artificial intelligence, or what passes for it, is becoming an increasingly important factor in the modern industrial robot.

III. Chronology Of Robot Developments

George Devol and Joseph Engelberger developed first industrial robot in 1959. It weighed two tons and was controlled by a program on a magnetic drum. They used hydraulic actuators and were programmed in joint coordinates, i.e. the angles of the various joints were stored during a teaching phase and replayed in operation. Unimation, USA, installed the first industrial robot at General Motor in 1961.The world's first industrial robot was used on a production line at the GM Ternstedt plant in Trenton, NJ, which made door and window handles, gearshift knobs, light fixtures and other hardware for automotive interiors. Obeying step-by-step commands stored on a magnetic drum.

The first cylindrical robot, the Versatran was installed by American Machine and Foundry (AMF) in 1962 at the Ford factory in Canton, USA. It was named the Versatran from the words "versatile transfer."

GM installed the first spot-welding robots at its Lordstown assembly plant in 1969. The Unimation robots boosted productivity and allowed more than 90 percent of body welding operations to be automated vs. only 20 percent to 40 percent at traditional plants, where welding was a manual, dirty and dangerous task dominated by large jigs and fixtures. Trallfa, Norway, offers the first commercial painting robot in1969. The robots were developed for in-house use in 1967 to spray paint wheelbarrows during a Norwegian labor shortage.

KUKA moves from using Unimate robots to developing their own robots in1973. Their robot, the Famulus was the first robot to have six electromechanically driven axes. Hitachi, Japan, developed the automatic bolting robot for concrete pile and pole industry in 1973. This robot was the first industrial robot with dynamic vision sensors for moving objects. It recognized bolts on a mold while it is moving and fastened/loosened the bolts in synchronization with the mold motion.

The first commercially available minicomputer-controlled industrial robot was developed by Richard Hohn in 1974 for Cincinnati Milacron Corporation. The robot was called the T3, The Tomorrow Tool.

Kawasaki, Japan, developed a version of the Unimate to be used for spot-welding, fabricating Kawasaki motorcycle frames in 1974. They also added touch and force-sensing capabilities in their Hi-T-Hand robot, enabling the robot to guide pins into holes at a rate of one second per pin. The Olivetti "SIGMA" a cartesian-coordinate robot was one of the first used in Italy for assembly operations with two hands in 1975.

Programmable Universal Machine for Assembly (PUMA) was developed in 1978 by Unimation/Vicarm, USA, with support from General Motors. The PUMA was adapted to GM specifications for a small parts handling line robot that maintained the same space intrusion of a human operator. Hiroshi Makino, University of Yamanashi, Japan, developed the SCARA-Robot (Selective Compliance Assembly Robot Arm) in 1978. By virtue of the SCARA's parallel axis joint layout, the arm is slightly compliant in the X-Y direction but rigid in the 'Z' direction.

KUKA, Germany, introduces a new Z-shaped robot arm whose design ignores the traditional parallelogram in 1985. It achieves total flexibility with three translational and three rotational movements for a total of six degrees of freedom. Demaurex, Switzerland, sold its first Delta robot packaging application to Roland in 1992.

EXPLORING RESEARCH AND INNOVATIONS

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The first application was a landmark installation of 6 robots loading pretzels into blister trays. It was based on the delta robot developed by Reymond Clavel, Federal Institute of Technology of Lausanne (EPFL).

ABB, Sweden, developed the FlexPicker, the world's fastest picking robot based on the delta robot developed by Reymond Clavel, Federal Institute of Technology of Lausanne (EPFL) in 1998. It was able to pick 120 objects a minute or pick and release at a speed of 10 meters per second, using image technology. Reis, Germany, introduces integrated laser beam guiding within the robot arm and launches the RV6L-CO_2 laser robot model in 1999. This technology replaces the need of an external beam guiding device thus allowing to use laser in combination with a robot at high dynamics and no collision contours.

Motoman, Japan, introduced the improved robot control system (NX_{100}) which provided the synchronized control of four robots, up to 38 axes in 2004.

Comau, Italy, introduced the first Wireless Teach Pendant (WiTP) in 2006. All the traditional data communication/robot programming activities can be carried out without the restrictions caused by the cable connected to the Control Unit, but at the same time absolute safety is ensured.

KUKA, Germany, presents the first "Light Weight Robot" in 2006. It was developed in cooperation with DLR, Institute of Robotics and Mechatronics, Germany, the outer structure of the KUKA lightweight robot is made of aluminium. It ideally suited to handling and assembly tasks.

Fanuc, Japan, launched the first "Learning Control Robot" in 2010. FANUC's Learning Vibration Control (LVC) allows the robot to learn its vibration characteristics for higher accelerations and speeds. Learning control reduces the cycle time of the robot motion by suppressing the vibration of the robot arm [7].

Robotics has made several advancements throughout the years and one of those is the development of humanoid robots. Humanoid robots imitate human form through perception, processing, and action. Humanoid robotics was developed for the interaction with human beings among their environments and tools. These human robots can match the physical, cognitive, and social aspects of people, making them capable of the same tasks as humans. Today, robotics affects a broad sector of economic activities from automotive and electronics industries to food, recycling, logistics, etc.

IV. INDUSTRIAL ROBOT COMPONENTS

There are three basic components of industrial robot: Manipulator, Controller and Tooling.

Manipulator: It consists of the base and arm of the robot, including the power supply, which may be electrical, hydraulic or pneumatic. The manipulator is the device that provides movement in any number of degrees of freedom. The movement of manipulator can be described in relation to its coordinate system, which may be cylindrical, spherical, anthropomorphic or Cartesian. Depending on controller, movement can be point-to-point or continuous-path motion.

Controller: The versatility of a robot arises from its multi-axis mechanical configuration and the robot controller. The ability to reprogram the robot controller gives the flexibility to the robot to perform a wide range of actions. The controller contains various interfaces with both command devices and sensing units. The controller has to define the trajectory of the robot gripper with time and transform this trajectory, which is in Cartesian coordinates, into its base-frame coordinate system and finally into joint movements. Many of these tasks are to be performed in real time. Several easy-to-use robot programming languages such as VAL, MCL and APT are available.

Tooling: Tooling is what enables the robot to do a particular job. Tooling is sometimes used synonymously with end effectors, although the latter has a more restricted meaning to apply to end-of-arm fixturing to grasp, lift or turn. Tooling on the other hand, has a broader context which can apply to power tools for drilling and grinding, as well as for painting and welding guns. Typical end effectors include electromagnets, hooks, vacuum cups, adhesive fingers and bayonet sockets. There are six basic motions or degrees of freedom, which provide the robot the capability to move the end effectors through the required sequence of motions. The six motions consist of three arm and body motions and three gripper motions. The three arms and body motions consist of vertical traverse, radial traverse and rotational traverse. The gripper motions are yaw, pitch and roll [8].

V. INDUSTRIAL ROBOT APPLICATIONS

Industrial robots have a wide range of potential applications in manufacturing systems because they are flexible and programmable themselves. The use of sensors allows the robots to see, hear and smell the environment.

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The robot controllers can be generally integrated easily into the manufacturing system environment and are capable of communicating with other programmable controllers [9].

The first industrial robot was introduced to the U.S. in the 1960s, since then their technology has improved immensely creating many applications of robots. The advancement of robotics has also caused robots to become more widespread across various industries ranging from manufacturing to health care [10]. Many benefits of robots seem to be most noticeable in productivity, safety, and in saving time and money.

Productivity

- Robots produce more accurate and high quality work.
- Robots rarely make mistakes and are more precise than human workers.
- They can produce a greater quantity in a short amount of time.
- They can work at a constant speed with no breaks, days off, or holiday time.
- They can perform applications with more repeatability than humans.

Safety

- Robots save workers from performing dangerous tasks.
- They can work in hazardous conditions, such as poor lighting, toxic chemicals, or tight spaces.
- They are capable of lifting heavy loads without injury or tiring.
- Robots increase worker safety by preventing accidents since humans are not performing risky jobs.

Savings

- Robots save time by being able to produce a greater magnitude of products.
- They also reduce the amount of wasted material used due to their accuracy.
- Robots save companies money in the long run with quick ROIs (return on investment), fewer worker injuries (reducing or eliminating worker's comp), and with using less materials.

The list of the advantages of robots does not end there; they have also created jobs for workers. Many people believe the misconception that robots have taken away jobs from workers, but that is not necessarily true. Robots have created new jobs for those who were once on production lines with programming. They have pulled employees from repetitive, monotonous jobs and put them in better, more challenging ones.

Today robots are user-friendly, intelligent, and affordable. The benefits of robots continue to grow as more industries incorporate them [11].

VI. Uses Of Future Robots

Robots are already a part of our lives. Industrial robots widely used in manufacturing. Military and police organizations use robots to assist in dangerous situations. Robots already have a significant role in medicine. Robots are helping doctors achieve more precision in the operating room, performing safer, less invasive techniques. Future uses of robots are not limited to "operative" tasks in manufacturing. On the contrary, some of the most significant future uses of robots may be to provide feasible means of providing services or exploiting resources that cannot be provided or exploited at all at present. Handling dangerous radioactive wastes on a routine basis in a future disposal facility are one example [12]. The choice is between one kind of mechanization and another: human workers cannot be routinely exposed to these wastes. Mobile robots would offer a much greater degree of flexibility than teleoperators, or hard automation. Exploration, mining. construction or other routine activities in hazardous environments are other examples. Such tasks are difficult, dangerous and consequently inordinately expensive. Robots may find use in coal or other mines, simply because mines are such unpleasant and dangerous work environments for humans. Robots could drastically alter the economics of commercial utilization of space, for example [13].

In the long run, it is likely that if man succeeds in "industrializing" the moon, orbiting space colonies, asteroids or other planets, it will only be done with major assistance from robots. The Viking 2 Lander which touched down on the surface of Mars in September, 1976, is perhaps only the first of a line of "exploration" robots. Planned Mars surface rover missions will last 8-10 times longer than Viking and entail much greater complexity. The U.S. Navy and a number of other organizations are actively developing underwater robots or "unmanned submersibles" both for military and non-military purposes [14].

Finally, prosthetic robots and household robots exemplify service categories that are increasingly needed and difficult to obtain in any other way. Paraplegics, and especially quadriplegics, for instance, might be served full time by voice-activated robots capable of doing a variety of necessary tasks from feeding to page-turning. Such robots are being developed in Japan.

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In the U.S., the Veterans Administration has an ongoing program in Rehabilitative Robotics. The all purpose house hold "droid" robot is probably a rather visionary idea, at present, but robots could certainly be designed to perform some types of jobs, notably heavy cleaning. Joseph Engelberger, President of Unimation, has promised that he will soon have a robot (to be named Isaac, after Asimov) that will serve coffee in his office [15]. In fact, Nieman-Marcus Department Stores advertised a household robot (actually a remote controlled device) in their 1981 catalog. For every conceivable application of an industrial robot, there are at least ten applications for a household robot. It is impossible to believe that such a vast market will not be exploited at the earliest possible time. It is vitally important to recognize the potential importance of some of these applications and some of their adverse consequences in the picture as a whole [16]. It is entirely conceivable, for instance, that a century hence historians looking back might say, in effect, “the real significance of robotics development in the 1980's and 1990's is that they enabled mankind to expand his abode permanently beyond the earth's surface and thereby escape the trap of limited resources associated with that constraint".

Caterpillar has planned to develop remote controlled machines and expects to develop fully autonomous heavy robots by 2021. Some cranes already are remote controlled and it was demonstrated that a robot can perform a herding task. Robots are increasingly used in manufacturing (since 1960s). In auto industry they can amount for more than half of the "labour". There are even "lights off" factories such as an IBM keyboard manufacturing factory in Texas that are 100% automated. Robots such as HOSPI are used as couriers in hospitals, etc. Other hospital tasks performed by robots are receptionists, guides and porters helpers, (not to mention surgical robot helpers such as Da Vinci) Robots can serve as waiters and cooks. All of future history could be very different, depending on whether space is successfully "colonized" in the next century or not. On the other hand, discounted present value criteria might tend to put more weight on proven short-run applications that pay off because of displaced labour then on very large but very remote benefits. lt is too important to assess short-term benefits and costs, without unduly discounting long-term implications.

VII. CONCLUSION

This paper has introduced the concept of a system in which industrial robots were applied to picking work, medium payload handling work, assembly work, etc. by using advanced sensing technology, control technology, and mechanics technology with industrial robots.

It is becoming possible to apply industrial robots to tasks that cannot easily be automated and thus rely heavily on human workers. In addition, robots work long hours and handle heavy objects without getting tired or making mistakes, leading to improved quality. Robots help achieve higher production quality at a reduced operating cost compared to manual manufacturing. They help produce more parts with fewer defects using less equipment while maintaining their flexibility for future changes. Their capability is only increasing with time. Major robot manufacturers are regularly upgrading their robots with increased payload capacity, greater accuracy, increased reach and range of motion, speed and acceleration, faster communication with external equipment, better safety features, and lower operational cost. Modern industrial robots offer multiple advantages. They have single-handedly transformed products, facilities, and companies. Recent developments have made industrial robots more user-friendly, affordable, and intelligent than ever before.

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