Robotics in Indian Industry

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Abstract— **The word "robot" was coined by the Czech playwright Karel Capek in 1921. In 1961, the first manufacturing robot, Unimate, hit the assembly line for GM. This welding robot, which received its commands from a magnetic drum, continued a century's old interest in mechanizing tools to move automatically. Future of robotics lies in meeting the demands of today's manufacturing environment, reducing the human labour exponentially, where different industry specific jobs like cutting, grinding, polishing, painting, spraying and assembly are done by articulated robots.**

With the development in robotics over the past, application of a robot is fundamental to the design of the automation system. R & D has become an integral part of machine design particularly in the field of robotics. In this paper, some interesting facts about robotics and its future in industrial applications has been discussed, like Object picking robotics using 3-D object recognition by sensors, extra-heavy payload handling and state of the art technology which have replaced expensive sensors and controls by advanced industrial robots.

***Keywords*— Robots; payload; degree of freedom; humanoid Introduction**

I.INTRODUCTION

As robots migrated out of the fixed automation, fully structured factory assembly lines into the unstructured and unpredictable worlds of space, underwater, in the air and on the ground, where many of the future applications could be imagined, it became clear that a complementary range of sensors and considerable artificial intelligence would be needed to achieve autonomy. This striving for autonomy in complex, unstructured and unpredictable environments, sometimes cohabited by humans became and still is the holy grail of robotics and has given rise to the field of 'intelligent robotics' where perception, reasoning and actuation are highly coupled to achieve useful tasks with little human guidance Fig 1. Pursuit of this goal whilst promising practical outcomes, is also laced with no small measure of romance, in the idea of fabricating a human like 'creature' of intelligence and grace which can be a human helper and companion. For many people it is a machine that imitates a human like the androids in Star Wars, Terminator and Star Trek: The Next Generation. The type of robots that we encounter most frequently is robots that do work that are too dangerous, boring, onerous, or just plain nasty. Most of the robots in the world are of this type. They can be found in auto, medical, manufacturing and space industries. In fact, there are over a million of these types of robots working for us today. Some robots like the Mars Rover Sojourner and the upcoming Mars Exploration Rover, or the underwater robot Caribou help us learn about places that are too dangerous for us to go.

According to International Federation of Robotics president Arturo Baroncelli, "In 2013, about 179,000 industrial robots were sold worldwide, again an all-time high and 12 percent more than in 2012." He also predicts that the trend will continue for years to come.

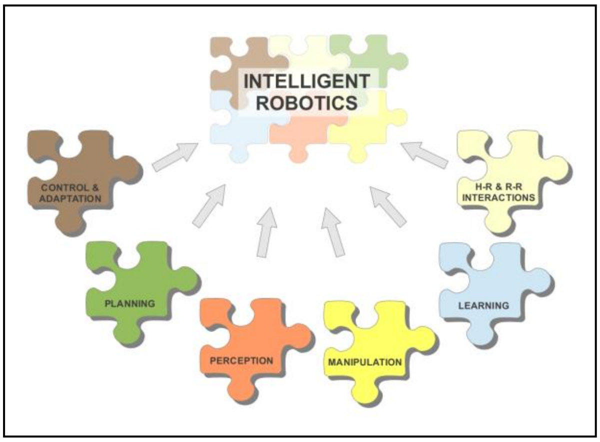

Fig 1. Intelligent Robotics

II. HISTORY OF INDUSTRIAL ROBOTS

In 1956, George Devol and Joe Engelberger, established a company called Unimation, a shortened form of the words Universal Animation. Inspired by the short stories and novels of Isaac Asimov, Devol and Engelberger Brain stormed to derive Unimate Fig 2. The first industrial robot arm based upon Devol's patent, Programmed Article Transfer became the seminal industrial robot patent which was ultimately sub-licensed around the world.

The Japanese Robot Association (JIRA, later JARA) was established, this was the first national robot association. The Japan Robot Association was formed in 1971 as the Industrial Robot Conversazione, a voluntary organization. The Conversazione was reorganized into the Japan Industrial Robot Association (JIRA) in 1972, and the Association was formally incorporated in 1973

The first fully electric, microprocessor-controlled industrial robot, IRB 6 from ASEA, Sweden, was delivered to a small mechanical engineering company in southern Sweden in 1974 with anthropomorphic design; its arm movement mimicked that of a human arm, with a 6kg payload and 5 axes. The S1 controller was the first to use an intel 8 bit microprocessor. The memory capacity was 16KB. The controller had 16 digital I/O and was programmed through 16 keys and a four digit LED display.

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Fig 2. Unimate

Hiroshi Makino, University of Yamanashi, Japan, developed the SCARA-Robot (Selective Compliance Assembly Robot Arm) in 1981

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, hence the term: Selective Compliant. The second attribute of the SCARA is the jointed two-link arm layout similar to our human arms, hence the often-used term, Articulated. This feature allows the arm to extend into confined areas and then retract or "fold up" out of the way. In 1981, SCARA robots were launched by Sankyo Seiki, Japan and Hirata, Japan.

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. The new configuration saved floor space in manufacturing settings.

Invention and Entrepreneurship in Robotics and Automation Award: In 2005 the IEEE Robotics and Automation Society (IEEE/RAS) and the International Federation of Robotics (IFR) agreed to jointly sponsor the Invention and Entrepreneurship in Robotics and Automation (IERA) Award. The purpose of this award is to highlight and honor the achievements of the inventors with value creating ideas and entrepreneurs who propel those ideas into world-class products

KUKA, Germany, presents the first "Light Weight Robot" in 2006. Developed in cooperation with DLR, Institute of Robotics and Mechatronics, Germany, the outer structure of the KUKA lightweight robot is made of aluminium. It has a payload capacity of 7 kg and, thanks to its integrated sensors, is highly sensitive. This makes it ideally suited to handling and assembly tasks. Due to its low weight of just 16 kg, the robot is energy-efficient and portable and can perform a wide range of different 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.

III. CLASSIFICATION OF ROBOTS

A. Classification by Degrees of Freedom:

A manipulator should have degrees of freedom to manipulate an object freely in three dimensional spaces. From this point of view a robot may be a

General purpose robot: if it possesses 6 degrees of freedom.

Redundant robot: if it possesses more than 6 degrees of freedom. It provides more freedom to move around obstacles and operate in a tightly confined work space.

Deficient robot: if it possesses less than 6 degrees of freedom.

B. Classification by Kinematic Structure:

According to kinematic structure robots can be classified as

Serial Robot or Open- loop Manipulator: A robot is said to be a serial robot or an open-loop manipulator if its kinematic structure takes the form of an open-loop chain. Example: Adept-One Robot.

Parallel Manipulator: if it is made up of a closed-loop chain. In general, a parallel manipulator has the advantages of higher stiffness, higher payload capacity, and lower inertia to the manipulation problem than a comparable serial manipulator, at the price of a smaller workspace and more complex mechanism

Hybrid Manipulator: if it consists of both open and closed loop chains. Example: Fanuc S-900 W. Many industrial robots employ this type of robot construction.

C. Classification by Drive Technology:

Manipulators can also be classified by their drive technology. The three popular drive technologies are

Electric: Most manipulators use either electric DC servomotor or stepper motors because they are clean and relatively easy to control.

Hydraulic: used for high speed and/or high-load-carrying capabilities. A major disadvantage associated with this is the possibility of leaking oils. A hydraulic drive is inherently flexible, due to bulk modulus of oil.

Pneumatic: Also used for high speed and/or high-load-carrying capabilities. A pneumatic drive is clean and fast but it is difficult to control because air is a compressible fluid.

D. Classification by Workspace Geometry:

Workspace of a manipulator can be defined as the volume of space the end of effecter can reach. The workspace can be of two types: A reachable workspace is the volume of space within which every point can be reached by the end effecter in at least one orientation. A dextrous workspace is the volume of space within which every point can be reached by the end effecter in all possible orientation.

Cartesian robot: In this the kinematic structure of a robot arm is made of three mutually perpendicular prismatic joints. The wrist centre position of a Cartesian robot can be conveniently described by three Cartesian co-ordinates associated with the three prismatic joints. The regional work-space of a Cartesian robot is a rectangular box Fig 3. When a Cartesian robot is mounted on rails above its workspace, it is called a gantry robot.

Fig 3. Cartesian robot

Cylindrical Robot: A robot arm is called cylindrical robot if either the first or second joint of a Cartesian robot is replaced by a revolute join. The wrist centre position of a cylindrical robot can be described by a set of cylindrical coordinate system associated with the three joint variables. The workspace of a cylindrical robot is confined by two concentric cylinders of finite length.

Spherical Robot: A robot arm is called a spherical robot if either the first or second joint of a Cartesian robot is replaced by a revolute joint. The wrist centre position of a spherical robot can be described by a set of spherical coordinate system associated with the three joint variables. The workspace of cylindrical robot is confined by two concentric spheres.

Articulated Robot: A robot arm is said to be an articulated, if all three joints are revolute. The workspace of an articulated robot is very complex, typically a crescent shaped cross section. Puma robot is an articulated robot.

The SCARA (selective compliance assembly robot arm) Robot: it is a special type of robot consisting of two revolute joints followed by a prismatic joint. All three joint axes are parallel to each other and usually point along the direction of gravity. The wrist has one degree of freedom and hence the entire robot has 4 degrees of freedom. This type of robot is useful for assembling parts on a plane Fig 4.

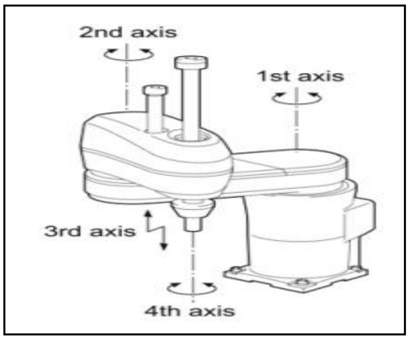

Fig 4. SCARA robot

IV. APPLICATION OF INDUSTRIAL ROBOTS

During 2015, the material handling robots segment accounted for nearly 47% of the global industrial robotics market in heavy industries owing to high demand for the handling of heavy components under harsh working environment. Material handling robots can handle heavy payloads and are highly useful in certain production lines, which involve huge machine parts that cannot be lifted manually.

As globalization occurs, steel mills have the opportunity to re-evaluate their methods of production. No longer are paper and pencils necessary to calculate the right mix of iron ore. After a wave of globalization in the 1980s, an international steel market was created, which strained less-profitable mills causing them to close. Industrial robots are applied to (1) picking work, (2) medium payload handling work, (3) assembly work, etc

a) Steel mills tag steel billets as they come off the caster in order to have information about the steel's characteristics when it is later used to make specific products. In typical manual tagging processes, the chance of human error in affixing the tags to the proper billets adds potentially serious quality control problems. Additionally, the area where tagging takes place is a dangerous spot, with workers exposed to hot steel, overhead crane traffic and repetitive-stress tasks.

Nucor Steel plant has developed a robotic tagging system that eliminates the risk of losing track of billets in the manufacturing process. The automated system welds an identification tag, integrates a 3D laser scanner, a six-axis robot, an SQL database and other components. It is designed to operate mostly unattended, reliably and accurately welding a tag to each billet of steel – and verify that it was done correctly.

b) At production sites, parts in bins are arranged and transferred by workers. Parts such as bolts are stored in bins, and it is easy for humans to handle several types of parts at a time. However, it is extremely difficult for robots to measure parts in bins with a sensor, recognize individual parts, and take them out. Bin picking robotics being developed using 3D object recognition technology. The main feature of the system is that unlike conventional systems that use cameras (2.5-dimensional or stereo vision), this system is not affected by ambient light because it adopts lasers as the three-dimensional measurement method. In addition, this system is highly compatible with 3D CAD systems and facilitates switching product types when used with 3D CAD data, providing enhanced usability.

c) As a persistent economic slump trims global demand, nimble, cost-competitive foundry operators across the developing world have increased competitive pressure for ferrous and non-ferrous metal castings. For manufacturers in the developed world, this supports the business case for the adoption of robust, heat-resistant robots that can withstand the hostile environments and heavy work pieces of modern foundries, provide the flexibility needed to produce quality castings that meet each client's specifications, and reduce production costs. Heavy-duty foundry robots can handle payloads of up to 1,500 kg and feature ultra high-torque wrists that effectively, safely manipulate bulky payloads at every step of the manufacturing process. These robots use an advanced link design to eliminate the need for an unwieldy counterweight that reduces turning radiuses and shrinks side-to-side clearance. These heat-resistant pieces of equipment can operate in hostile environments while executing delicate handling of moulds, casting extraction operations, core assembly and setting, ladling of molten and cooling metal, and additional material removal tasks such as de burring, grinding and polishing.

d) Robotic automation solutions not only allow them to significantly increase production in less time and at less cost, but also to actually manufacture better quality products. Getting to market faster with better quality products gives metal product manufacturers the competitive advantage they need. Now robots can execute targeted welds – including arc, spot and friction spot joining – on multiple metal plates, sheets, and various metal pipes and tubes, helping operators exceed production and quality goals. Robots excel at bulk and heavy material handling of components for the assembly of agricultural machinery, earth moving and construction equipment, recreation vehicles, utility trucks, and rolling stock, to name a few. Precise, application-specific software makes possible, tasks like grinding, plasma cutting, laser cutting and laser cladding of die-cast fixtures, plates, sheets, pipes and other metal components.

V. PRESENT OF INDUSTRIAL ROBOTICS

Now we have access to very rich set of sophisticated sensors Fig. 5, computing platforms and all variety of agile mechatronic devices, it would seem that nothing should hold us back in achieving the dream of a autonomous robot agent which could carry out a variety of complex tasks in unstructured environments and at the same time be able to interact cooperatively with humans. However this is still far from being achieved. Considerable advances have nevertheless been made. Flexure, backlash, and pay-load variations do, however, add error but this is usually manageable, perhaps with the addition of special devices such as lasers and cameras. Attempts of carry out similar evaluations on a free roaming mobile robot using only odometry have not been satisfactory since wheel slippage, load distribution; support surface undulations and wheel shape imperfections introduce errors which are accumulative and unrecoverable from. Mismatches can have serious localisation consequences but continuity and velocity constraints can be used to detect inconsistency and ambiguity level [1], [2], [3].

Fig. 5 Industrial Bar code detector

VI. FUTURE OF ROBOTICS

Leaving science fiction aside, the expectations concerning intelligent robotic technology development over the next decade or so are quite modest. The practical application domains where robotics technology is most likely to be used are Transport (Public and private), Exploration (ocean, space, dessert etc), Mining (dangerous environment), Civil Defence (Search and rescue, fire fighting etc), Security / Surveillance (patrol, observation and intervention). , Domestic services (Cleaning etc), Entertainment (robotic toys etc), Assistive technologies (support for the fragile), War machines, Scientific Instrumentation (Synchrotron sample preparation, chemical screening etc) [4], [5].

VII. CHALLENGES IN INDUSTRIAL ROBOTICS

1. Software development

We require a team that understands electronics, circuits and wiring. We also need software developers that understand firmware, people who are experts in machine vision, machine learning, security; wireless networking… the list goes on. All of this effort gets people to the point where they have a functional robot to start building on. Despite open-source libraries like ROS, Open CV, Eigen and others, there's a still lot of extra work required to get an actual robot working.

2. Connectivity

Wireless connectivity is always a bolt-on addition. People just think they can stick Wi-Fi on these devices and everything will just work. That's how we all access the Internet with our laptops. Well, what happens when the robot moves outside? What happens when two robots connected together move farther than a couple hundred feet apart? So in new era robots we bolt-on an LTE modem. Data plans are expensive. For connected machines, cell-phone companies often only provide around 1Mb per month for a reasonable price.

For that price, connected robot might be able to send a few crappy images per month to other robots, or back to us. This isn't very useful for robots that need to make quick decisions in tandem with each other, or if we are a company using robots collecting data to make decisions (for example natural resource discovery).

3. Interoperability

The biggest challenge of all is interoperability. None of the products we see today, or in the near future, are built to work with one another. None of the drones we buy are built to easily work with our automated lawn mower, or our autonomous car, or our fridge. The list goes on. We might be sceptical that these things need to work together. There certainly may be some advantage to it - for example, an idle autonomous car could pick up our groceries. But it's more about the ability that they can work together. If they can talk to each other, and fundamentally work in the same way, the creators can spend less time just getting up to speed and more time working on the hard problems. Imagine if we had to design a circuit board, program the operating system, touch screen, wireless connectivity and case just to build an app for a phone - that is the current state of robotics today.

4. From Lab to shop floor

This research investment is largely languishing in labs in part because the limited software architectures of current industrial robots present a barrier to the transition of research products. As a result, it simply costs too much to apply these advanced capabilities to improve industrial productivity. Robots are flexible enough to accomplish a wide variety of automation tasks, but until the return on investment to integrate and program robots for agile processing becomes attractive, robots will continue to be deployed in only limited applications, and opportunities for greater productivity will be lost. Advances in robotics research require economical pathways to application to realize their full potential. ROS-Industrial seeks to provide this pathway.

VIII. TRENDS IN INDUSTRIAL ROBOTICS

1. Usability

The automotive industry has had a long history of using robots, but for industries that are relatively new to automation, programming robots can be a challenge. We need to find ways to make robots easier to use so that they do not require such a highly skilled workforce to deploy, operate and maintain. In fact, this question is one of the largest technical challenges the industry is currently grappling with. As more and more companies find that robots are within their affordability range, it is clear that one of the final barriers to adoption is the perceived complexity of programming and designing robotic systems.

2. Human robot collaboration

Close collaboration between humans and robots, working as colleagues on assembly lines and in other applications, will be a large part of the future of industrial robotics. In fact, there may come a time when the line between what is made by a human and what is made by a robot is blurred to the point of becoming indistinct. This will be especially pronounced during a transition phase in which robots are still incapable of perfectly reproducing human dexterity, but have enough dexterity and ability to work with delicate objects that they can take over some but not all of the jobs that currently require a human touch.

3. Remote monitoring

Futuristic companies that depend on robots will be such that they may manage the robots and the teams that rely on them from any device, anywhere with an Internet connection to simplify all stages of robot interaction (design, sales, installation, commissioning, operation, oversight, and service). Future of robotics is closely tied to the aspects of connectivity that the entire industry is focusing on. This relates to the application of connectivity to remotely monitor robots.

4. Improved sensing Technical challenge with robot application involves the tools that allow robots to interact with the world around them, including advanced sensing and advanced gripping. In order to allow robots to do all the jobs that they are well suited for, they will need to develop more "human-like" Fig. 6. abilities to find, identify and manipulate objects.

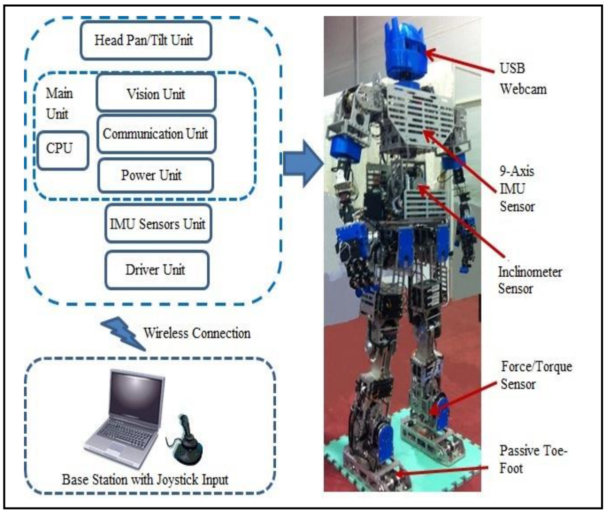

Fig 6. Humaniod robot with sensors

When combined with powerful processing capability, tools like force control and advanced 2D and 3D vision will create a kind of robotic "independence" and allow the robot to make "decisions" about what to do when it encounters the inevitable hiccups that arise in everyday operation. Already some manufacturers have a new generation of Integrated Force Control and Integrated Vision to help make these advanced technologies available to more and more end-users.

5. Trained workforce

Industrial robots have created a whole new ecosystem of high-paying and rewarding jobs. Designing, building, marketing, selling, installing, operating and maintaining robots creates jobs that didn't exist before robots. The jobs this "robot ecosystem" creates are typically high paying, rewarding and come with good levels of benefits. Robots allow companies to remain cost competitive even while maintaining production in a high cost country as opposed to moving operations to a low cost country. This preserves jobs in the high cost countries that would otherwise be entirely shifted to the low cost countries. This concept, known as reshoring in the industry, helps to balance out employment around the world.

CONCLUSION

Today industrial robots and robotic systems are key components of automation. More than 1.1 million industrial robots are operating in the factories all over the world:

- Improving quality of work for employees
- Increasing production output rates

- Improving product quality and consistency
- Increasing flexibility in product manufacturing
- Reducing operating costs

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 Analysts forecast global industrial robotics market in electronic and electrical industry to grow at a CAGR of 5.43% over the period 2014-2019. Key players in the global industrial robotics market in electrical and electronics industry: ABB Ltd., Adept Pvt. Ltd., KUKA AG, Shanghai-Fanuc Corp. and Yaskawa Electric Corp. Other prominent vendors in the market are: Apex Automation and Robotics, Aurotek, Axium, Baumann, Daihen, Finsar and Kawasaki Robotics.

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