A REPORT

ON

IMPLEMENTATION OF INDUSTRIAL ROBOTICS IN MANUFACTURING AUTOMATION

BY

Mohammed Emaan 2022A7PS0036U

AT

UNIQUE WORLD ROBOTICS, UAE

A Practice School – I station of

BITS Pilani, Dubai Campus
Dubai International Academic City, Dubai
UAE

(JUNE 2024 – AUGUST 2024)

A REPORT

ON

IMPLEMENTATION OF INDUSTRIAL ROBOTICS IN MANUFACTURING AUTOMATION

BY

Mohammed Emaan 2022A7PS0036U Computer Science

Prepared in Partial Fulfillment of the
Practice School – I Course

AT

UNIQUE WORLD ROBOTICS, UAE

A Practice School – I station of

BITS Pilani, Dubai Campus
Dubai International Academic City, Dubai
UAE

(JUNE 2024-AUGUST 2024)

BITS Pilani, Dubai Campus
Dubai International Academic City, Dubai
UAE

Station: UNIQUE WORLD ROBOTICS **Center:** DUBAI

Date of Start: 10th June 2024 **Date of Submission:** 29th July 2024

Title of the Project: Implementation of Industrial Robotics in Manufacturing Automation.

ID No. / Name of the student: 2022A7PS0036U / Mohammed Emaan

Discipline of Student: Computer Science

Name(s) and Designation(s) of the Expert(s):

1. Mr. Mohammed Mukhtar – Technical Lead
2. Mr. Ali Abdurrahman – Robotics Engineer

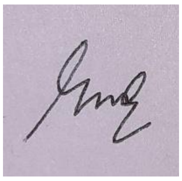
Name of the PS Faculty: Dr. Vijaya Ilango

Key Words: Industrial, robotics, robots, implementation, manufacturing, automation

Project Area(s): Industrial Robotics, manufacturing processes, manufacturing automation,

Abstract:

Unique World Robotics, established in 2019, is a dynamic leader in STEM education, headquartered in Dubai, UAE. Driven by passion for excellence, a comprehensive range of programs are offered to empower and inspire learners of all ages. Industrial robotics can be understood as robotic arms that have sensors and controllers and can perform various operations and functions in the manufacturing processes in industries. This report discusses the implementation of Industrial Robotics in manufacturing automation in industries and highlights the revolutionary influence of industrial robotics research on contemporary production methodologies, stressing the continuous endeavors to surmount obstacles concerning scalability, cost-efficiency, and regulatory conformance. In the final section, a summary of the report along with the future scope is provided.



Signature of the Student
Date: 29.07.2024

Signature of PS Faculty
Date: 29.07.2024

ACKNOWLEDGEMENTS

Firstly, I would like to express my heartfelt gratitude to Prof. Srinivasan Madapusi, Director BPDC who has given us an opportunity to understand and apply our engineering concepts in a practical atmosphere.

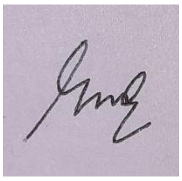
I am truly grateful to Mr. Mohammed Mukhtar, Technical Lead at Unique World Robotics for coordination and assisting me by providing the required information about the organization.

I would also like to thank Mr. Ali Abdurrahman, Robotics Engineer at Unique World Robotics, for helping and guiding me throughout my project.

I would like to thank Dr. Vijaya Ilango, the faculty for my PS station for providing me with all the assistance required for the successful completion of the report.

My sincere gratitude to Dr. A Somasundaram, Dean – Practice School and Placement Division, for giving us this opportunity to work and apply our knowledge in the technical field and gain firsthand experience.

Lastly, I would like to thank my parents, without whose support and guidance, the successful completion of this report would not have been possible.



Mohammed Emaan
2022A7PS0036U

LIST OF FIGURES

LIST OF TABLES

CONTENTS

CHAPTER 1: INTRODUCTION

1.1. OVERVIEW OF THE COMPANY:

Unique World Robotics was established in 2019 with a vision to revolutionize learning with innovation. “Unique world robotics is a dynamic leader in STEM education headquartered in Dubai, UAE” [1].

Unique World Robotics is an educational technology company, offering a wide range of programs integrated to empower and inspire learners of all age groups. As a forward-thinking organization, Unique World Robotics is committed to making a meaningful impact on society as their programs not only foster technical expertise but also align with the UN Sustainable Development Goals (SDGs) to create positive change in the environment.

With the right exposure and guidance to real-world robots, Unique World Robotics believes that anyone from a young primary student to a working official, could build a completely functional robot.

At Unique World Robotics, we may explore Robotics and its complete spectrum which include Machine Learning (ML), Artificial Intelligence (AI), Swarm Robotics, Automated Navigation System, Robot Operating System (ROS), Iot, IIot 3D Printing, Augmented Reality (AR), Virtual Reality (VR), and the list goes on. The facility also consists of the most modern electrical and mechanical tools, a dedicated coding laboratory, an extensive private library, experimental zones for AR and VR and a fully equipped Robotics Academy where we can interact with real robots, namely, Industrial Robots, Humanoid Robots, and drones, and a lot more.

Unique World Robotics provides several certified courses, services to schools and universities involving Project Assistance, School Futuristic Workshops, Robotic Exhibitions, and Robotics Innovation Lab Set Up, and training to corporate banks and teachers as well. They also provide programs such as weekend workshops, vacation camps and online courses. They also undertake students to participate in many prestigious competitions around the world namely, First Lego League, First Tech Challenge, World Robot Olympiad, Robofest, and the FIRA world Championship.

Unique World Robotics additionally offer products such as Humanoid Robots, 3D Printers and Industrial Robotic Arms. Sanbot Max and Sanbot Elf (as shown below in figure 1.1) are the two Humanoid Robots which are offered as products. The Sanbot Max Robot is designed for implementation into various kinds of business situations, providing staff members and customers with efficient and intelligent services. A couple of its features include 75KG load handling capacity and top velocity of 5 m/s, and voice interaction and facial recognition. The Sanbot Elf is a natural blend of machine and human. Some of its features include voice localization, facial recognition, video chat, voice interaction and healthcare management.

Under 3D printers, the Dobot Mooz, an industrialized grade changeable metallic 3D printer, which takes interchangeable heads and all in one design for CNC craving, laser engraving, and 3D printing is available.

Figure 1.1 The Sanbot Max and the Sanbot Elf

The Dobot Magician, which is a multitasking desktop robotic arm compiled with different end-tools, can recognize interesting functions such as writing and drawing, laser engraving, and 3D printing is a part of their products offered. It supports secondary development by over 20 programming languages and 13 extensible interfaces. Some of its features include low cost, small size and easy operation, multi robot collaboration, 3D printing, laser engraving, multiple extension ports and so on. The Dobot CR5 (6 – axis robot) and the Dobot M1 are also among the notable products offered.

Figure 1.2 The Dobot Magician

In Conclusion, Unique World Robotics Began their journey in April 2019, aiming to provide exceptional educational experience in robotics, driven by their desire to inspire young minds. They started with the Alton Robot as their inaugural project, although less complex initially, their projects have since progressed significantly. Their commitment remains dedicated to fostering excellence and innovation, with the aim of empowering the next generation through unparalleled educational opportunities.

1.2. LITERATURE REVIEW:

In the first article "Industrial Robotics" the author defines Industrial Robotics as "Robot Systems used for Manufacturing" [2]. The author proceeds to give us a brief on the history of robotics, then proceeds to elaborate on the features namely serial architecture and parallel architecture of industrial robots and the different types such as articulated, autonomous, SCARA, delta robots, spherical coordinate, cylindrical coordinate, and cartesian coordinate. He then proceeds to brief on the autonomy, technical description, the market structure and finally talks about the health and safety regarding robotics in the Industrial field.

In the next paper reviewed, "Robotic Automation in Manufacturing", the author first gives a brief introduction on robotics and an overview on automation. The author defines three statements to monitor the characteristics of robots, "Robots must never harm human beings; Robots must follow instructions from humans without violating rule 1; Robots must protect themselves without violating the other rules" [3]. In the next section, a brief elaboration on the different types of robotics used in manufacturing is given, manufacturing applications, the benefits, the challenges and global adoption of robotic automation is also stated in detail.

In the final paper reviewed, "Robotics is Manufacturing", the author first gives us a brief on the motivation factors and the justification for the use of robotics in manufacturing automation. In the paper the author gives us information on the advances in the industry 4.0 and how this has affected robotics automation in manufacturing. Some of the main areas of advances include sensors and the advanced sensor technologies, machine vision and the types of vision, computer vision and machine intelligence which includes image transformation, image analysis, thresholding and image understanding, application of robotic visual systems, grippers, types of grippers, robot accuracy and repeatability.

CHAPTER 2: INDUSTRIAL ROBOTICS

2.1. INTRODUCTION:

"Industrial Robotics is a robot system used for manufacturing. Industrial robots are automated, programmable and can move on three or more axes" [4].

Common applications of robotics in manufacturing processes are assembly, disassembly, pick and place for printed circuit boards, painting, welding, labeling, and palletizing, packaging, result testing and inspection all of which is completed with high precision, stamina and velocity/speed.

In the year 2022, as per IFR (International Federation of Robotics), an estimated 3,903,366 industrialized robots were in global operation.

2.2. HISTORY:

As per the ISO standard, "Bill" Griffith P. Taylor constructed the first industrial robot in 1937, and it was featured in Meccan Magazine in March 1928. Almost all the Meccano parts used to construct the crane-like apparatus came from a single electronic motor. There were five axes of motion available, which include rotation and grasp.

Figure 2.1 George Devol

The robot was able to arrange wooden blocks in predetermined configurations. First, a graph paper was used to plot the amount of motor rotations needed for each needed leverage. The paper tape, which was likewise powered by the robot's lone motor, received this data after that. In 1997, Chris Shute constructed an exact copy of the robot.

The first robotics patents were applied for and obtained in 1954 by George Devol. Joseph F. Engelberger and Devol launched Unimation in 1956, and it was the first business to manufacture a robot.

Since moving things less than a dozen feet apart was the primary function of unimation robots at first, they were also known as programmable transfer machines. A 6-axis articulated robot, all electric, The Stanford Arm created by Stanford University's Victor Scheinman in 1969, was intended to enable an arm solution. Due to this, the robot was able to precisely follow any path in space, opening new and advanced applications for it, such as welding and assembly.

The late 1970s saw a surge in interest in robotics, leading numerous US corporations to enter the sector, notably General Motors and General Electric (along with FANUC LTD of Japan founded the joint venture FANUC Robotics). Adept Technology, Inc. and Automatix were two American startups.

In the end, only a few non-Japanese businesses survived in this sector; the most notable ones were The Germans firms, the Swedish-Swiss company, ABB Brown Boveri, KUKA Robotics, The Italian Company Comau, Adept Technology, and Stäubli.

2.3. TYPES OF INDUSTRIAL ROBOTS:

Industrialized Robots are mainly of six types [5] -

2.3.1. ARTICULATED ROBOTS:

The most common kind of industrial robots are articulated ones, which are also called robotic arms or manipulator arms because of their resemblance to human arms. Because of their multiple degrees of freedom articulations, articulated arms can move in a variety of ways.

2.3.2. AUTONOMOUS ROBOTS:

A robot that carries out its functions without the supervision of a human is said to be autonomous. Built by W. Grey Walter in the late 1940s, The first automotive robots in the environment were Elmer and Elsie. They were the first robots in history to be designed with free will and trained to "think" in the same way as human brains. Because of their shape and movement, Elsie and Elmer were frequently referred to as tortoises. They were able to move in response to light stimulation, a phenomenon known as phototaxis.

2.3.3. CARTESIAN COORDINATE ROBOTS:

Known by several names such as gantry, rectilinear, and x-y-z robots, cartesian robots consist of three flashy joints for tool leverage and three rotational joints for the tool's arrangement in space.

These robots require six axes, or degrees of freedom, to relocate and arrange the effector organ in any direction. Three axes are enough in a 2-dimensional surrounding: two for displacement and one for position.

Figure 2.2 A Six-Axis Robot

2.3.4. CYLINDRICAL COORDINATE ROBOTS:

Cylindrical coordinate essential robots are categorized by having a prismatic joint linking at least one of their links and a rotary joint at the base. They may slide to move both horizontally and vertically. The robot can navigate confined locations without sacrificing speed thanks to its effector design's tiny size.

2.3.5. SPHERICAL COORDINATE ROBOTS:

Robots with spherical coordinates only possess rotary section points/joints. Among the earliest robots to be employed in an industrial setting are these ones. They are frequently employed in plastic injection and extrusion, welding, and machine tending in die-casting.

2.3.6. SCARA ROBOTS:

The term Selective Compliance Assembly Robot Arm is abbreviated as SCARA. Two parallel intersection points/joints that allow leverage in the X-Y two-dimensional plane identify SCARA robots. At the effector, rotating shafts are arranged vertically. Applications requiring accurate lateral motions are performed by SCARA robots. They work well in applications involving assembly.

2.3.7. DELTA ROBOTS:

Delta robots are also known as Parallel Link Robots. They are made up of parallel linkages that are joined to a single base. When it comes to high maneuverability activities and direct control applications (such fast pick-and-place jobs), delta robots are especially helpful. Utilizing parallelogram linkage or four bar systems is advantageous for delta robots.

2.4. FEATURES OF INDUSTRIAL ROBOTS:

Industrialized robots either have a parallel or a serial architecture –

2.4.1. SERIAL ARCHITECTURE:

Integrated as a succession of links attached by motor-actuated intersection points/joints that stretch from an end-effector to a base, serial architecture robots are highly frequent industrial robots. Typical examples of this category are Stanford manipulators and SCARA.

2.4.2. PARALLEL ARCHITECTURE:

A serial architecture robot, a parallel architecture robot, is built so that every chain is typically small, straightforward, and able to be tight against undesired leverage. Positioning errors in one chain are not cumulative; instead, they are averaged with the others. As with a serial robot, every actuator should still move in its own degrees of freedom; but, in a parallel robot, the influence of the other chains also limits a joint's off-axis flexibility. Unlike the serial chain, which gets less rigid as more components are included, the total parallel architecture robot is stiff in relation to its components due to its closed-loop rigidness.

2.5. AUTONOMY:

Different robots have different levels of autonomy. Certain robots have been trained to do precise tasks repeatedly (repetitive actions) with great levels of accuracy and consistency. The velocity, acceleration, deceleration, distance of a sequence of coordinate motions, and direction are specified by preprogrammed routines that govern these operations.

Other robots can operate on objects that are considerably more oriented to their liking, or they can even be programmed to conduct tasks on the object itself, including identification. “Robots, for instance, frequently include machine vision subsystems that serve as their visual sensors and are connected to strong computers or controllers to provide more accurate guidance” [6]. The role of artificial intelligence in contemporary industrial robots is growing.

A robot that carries out its functions without the supervision of a human is said to be autonomous. Historical instances include Space Probes. Examples from today's world include vacuums and self-driving automobiles.

The autonomy of industrial robot arms operating on assembly lines within factories may likewise be deemed independent, even though their mobility is limited, and they operate in a highly regulated environment.

2.6. TECHNICAL DESCRIPTION:

2.6.1. DEFINING PARAMETERS:

- Number of axes – To access a particular point in a plane, you need two axes, and to reach a particular point in space, you need three axes. There are three more axes (pitch, yaw, and roll) that are needed to properly coordinate the orientation of the arm's end, or wrist. Certain designs, like the SCARA robot, compromise motion possibilities to save costs and improve accuracy and speed.

- Degrees of Freedom – This typically corresponds to the number of axes.

- Working Envelope – The area of space that a robot can access.

- Kinematics – The real configuration of the robot's joints and stiff parts, which establishes its range of motion. Robot kinematics can be classified into four classes: parallel, cartesian, articulated, and SCARA.

- Payload or Carrying Capacity – The capacity of a robot to lift weights.

- Speed/Velocity – How quickly the robot could move its arm's end into place. This can be expressed as a compound speed, which is the arm's end speed when all axes are moving, or as the linear or angular speed of each axis.

- Acceleration – The speed at which an axis can accelerate. Due to this constraint, a robot might not be able to move over short distances or along complicated paths that need frequent direction changes at its designated maximum speed.

- Accuracy – The robot's proximity to a predetermined location. The mistake represents a symbolism of accuracy when the robot's absolute position is compared and measured to the required location. External sensing, such as an Infra-Red or vision system, can increase accuracy. Refer to the robot's calibration. Accuracy can change depending on the payload, speed/velocity, and location enclosed in the workspace.

- Repeatability – The robot's ability to return to a position that has been programmed. Accuracy and this are not the same thing. It's possible that it only moves one millimeter toward the designated X, Y, and Z location when instructed to do so. This is its accuracy, which could be increased through calibration. However, the repeatability will be within 0.2mm only if the location is stored into the memory of the controller and it comes back to within 0.2mm of the stored location each time it is sent there.

- Motion control – In certain scenarios, including basic pick-and-place tasks, the robot only needs to consistently return to a small set of previously learned locations. More complex applications require motion to be continually regulated to follow a way in space with given direction and speed, such as finishing (spray painting) and welding.

- Power source – While some robots utilize hydraulic actuators, others employ electric motors. While the latter are more robust and useful in situations like spray painting, when a spark might cause an explosion, the former are quicker. On the other hand, the arm's low internal air pressure can stop the entry of other impurities and flammable vapors. It is very doubtful that any hydraulic robots will be available on the market today. Spark-proof shielding, brushless electric motors, and more sealings made it easier to build equipment that can operate in explosive environments.

- Drive – While few robots use gears to interconnect electric motors to joints, while others use direct drives—that is, connecting the motor directly to the joint. When gears are used, there is quantifiable "backlash," or axis-free movement. Due to backlash, mini robot arms usually use low torque high speed DC motors, which typically call for large gearing ratios. The harmonic drive is typically utilized in these situations.

- Complaisance – Which is a measurement of the degrees or displacement that a robotic axis will experience upon applying pressure. When a robot reaches its maximum payload position, compliance causes it to be somewhat lesser than when it is not holding any workload. When transporting large weights, compliance may also be the cause of overshooting, in which case acceleration would need to be decreased.

2.6.2. ROBOT PROGRAMMING AND INTERFACES:

An industrialized robot's sequences and motions are usually programmed or set up by interconnecting the robot remote controller to a desktop, laptop, or (internal or external) connections.

A work cell, or cell, consists of a robot and several other devices or peripherals. A robot, a molding machine, and a components feeder could be in a typical cell. One computer or PLC controls and integrates all the machines. Programming is required for the robot's communication with other machines in the network/cell, including synchronization and positioning with/along them.

Operating System:

Software for the matching interface is downloaded on the computer. The process of programming is made much simpler when a computer is used. Based on the system architecture, specialized robot software could be operated by the computer, the robotic controller, or both.

Procedure and location data are the two basic elements that must be learned or programmed. For instance, the locations of the hole and the feeder must first be coded or taught to transfer a nail from one another. Second, any I/O required—such as an indication to let know the exact point in time when the screw is in the feeder and is ready to be found—must be coded into the process of getting the screw located in the feeder to the available hole. Both programming chores are made easier by robot software.

Familiarizing the robot with its locations can be achieved by several methods:

- Locational Commands - A GUI or text-related command that allows the compulsory X-Y-Z locations to be supplied and modified can be used to guide the robot to the desired location.

- Teach Pendant – A teach pendant may be used to instruct robot postures. This is a coding and control unit that is portable. These machines usually include the capability to physically move the pre-coded robot to a desired place, to "jog" to "inch" to change a location. They even feature the ability to adjust the velocity, which is useful when testing out a new or modified routine or when cautious positioning calls for a slower pace. Additionally, a sizable emergency stop button is usually present. Usually, the teach pendant is no longer useful after the robot has been programmed. Every teach pendant has a three-position Deadman switch. The robot can only move in the manual mode when located in the center position, or not completely pressed. The robot stops once it is either fully pressed in or released. It is possible to leverage natural reactions to boost safety thanks to this method of operation.

Figure 2.3 A Typical Teach Pendant

After programming, the robot typically disconnects the teach pendant or PC and starts using the software that was loaded onto its controller. On the other hand, a microprocessor is frequently utilized to either 'control' the robot and its accessories or to offer extra storage capacity for free access to a multitude of intricate pathways and procedures.

- Lead-by-the-nose – A lot of robot producers offer this technology. Using this method, a user grasps the manipulator of the robot as another simultaneously enters a prompt that dis-energizes the machine and makes it unable to move properly. The robot is hence physically moved to the needed locations and/or along the needed path by the user, and the software records these places in memory. The robot can be programmed to follow the taught course or reach these spots later. This method is well-liked for applications like paint spraying.

- Offline coding – is the graphic mapping of the robot, the entire cell, and every machine or instrument in the center/workspace. The procedure may then be mimicked by moving the robot around the screen. Using a robotics simulator, embedded applications for robots can be developed independently of the end effectors and the arm's physical functionality. Robotic simulation has the benefit of saving time when designing robotics applications. Because many "what if" situations can be tested and tried before the workspace/system is engaged, it may also raise the safety levels connected with robot equipment. Software for simulating robots offers a framework for teaching, testing, executing, and debugging programs written in different programming languages.

  Robotics programs can be designed and debugged off-line with the help of robot simulation tools, and the last version of the code can be experimented on a real robot/robot. Before being implemented in a "real world" system, a range of algorithms, equipment, controllers, and configurations can be attempted and experimented in a virtual environment that mimics the characteristics of a robot system. With the use of both geometric and kinematic modeling, robotics simulators can compute the pre executed motion of an industrialized robot in real time.

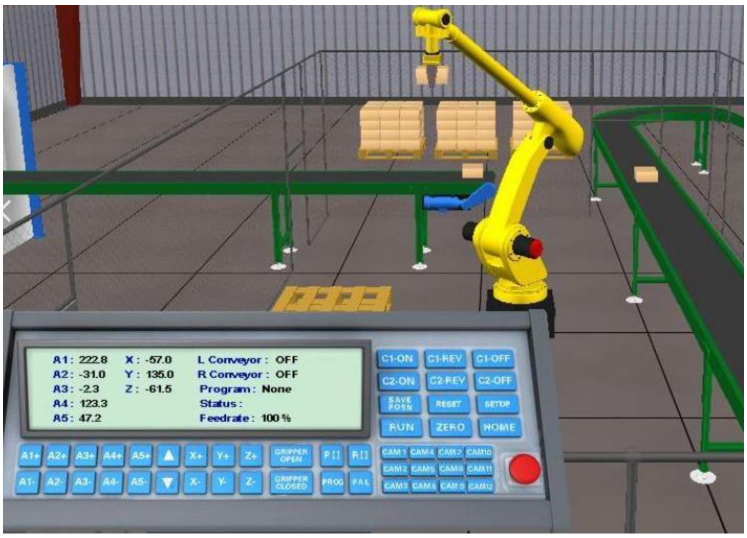


Figure 2.4 A Robotic Simulator

- Independent Manufacturing robotic coding tools – are a flexible, comparatively new method of programming robot applications. Coding is done via drop and drag of already defined building/template elements using a graphical user interface. They frequently include offline programming in addition to the running of simulations to assess viability. The user will no longer need to become familiar with the proprietary languages of each manufacturer if the system can upload the native robot code to the robotic controller. Consequently, this strategy may be a crucial step toward standardizing programming techniques.

- Others – Additionally, user interfacing devices—typically touchscreen units—are frequently used by machine operators as a control panel of the operator. The operator/operators can control a variety of peripheral applications that can be designed into the same robot system, as well as flip between programs and make changes within programs. These include barcode printers, end effectors, safety interlock systems, emergency stop controls, conveyor belts, machine vision systems, feeders that supply the robot with parts, and a virtually limitless number of other industrialized devices that can be taken control and managed through the control panel of the operator.

2.6.3. END-OF-ARM TOOLING

The most important and crucial robot peripheral is the end effector, often referred to as end-of-arm/arms tooling (EOAT). Typical end effectors are spray guns, grinders and deburrers (burrs, belt grinders or pneumatic disk, etc.), grippers (electromechanical or pneumatic devices that can hold/grab an object), and welding devices (e.g., spot welders, MIG-welding guns, etc.). Using magnets or a vacuum to pick up items is another popular method. End effectors are often extremely intricate, custom-built to fit the product being handled, and able to take up multiple products at once. To assist the robot systems in finding, positioning, and handling objects, they might make use of a variety of sensors.

2.6.4. CONTROLLING MOVEMENT

The degrees of each joint or the position of the horizontal axes (or joining of the two for robot formats are the only characteristics required for a specific robot to fully recognize the end effector (welding torch, gripper, etc.). On the other hand, there are numerous approaches to defining the locations. The most popular and practical method of establishing a point is to give it a Cartesian/XY coordinate, which is the "end effector" position in millimeters in the X, Y, and Z axes with respect to the robot's origination. The orientation of the extreme effector in yaw, roll, and pitch as well as the location of the tools point in relation to the robot faceplate must also be described, depending on the kinds of joints that a specific robot may have. The robot controller must execute what is called Cartesian Transformation to convert these coordinates to joint angles for a joined arm. For a multiple axis robot, these conversions may need to be carried out recursively or repeatedly.

When positioning a robot using Cartesian coordinates, two options are available: either input the coordinate directly into the systems or use a tech pendant to move the robots in X, Y, and Z directions. A human operator/operator can envisage motions like right/left, up/down, etc. far more easily than they can move each joint individually. Once the intended position is attained, it is further described according to the robot software that is being used, such as P1 through P5 below.

Explain set of points (P1–P5):

- Cautiously above the workpiece point - P1
- 8 inches above bin A, or P2, like it is defined
- At the ready to participate from until bin A (designated as P3)
- Ten centimeters above/beyond bin B, or P4.
- Positioned to participate from bin B. (expressed as P5)

2.6.5. TYPICAL PROGRAMMING

To function, most articulated robots store a list of locations in their memory and move at different points during their programming performing sequence. A robot that is transporting objects from bin A up to bin B, for instance, may have a basic "pick and place" algorithm like this one:

Set program:

- Proceed until P1.
- Proceed until P2 and then until P3.
- Tighten the gripper
- Proceed until P2 Proceed until P4
- Proceed until P5.
- Grip openly
- Proceed until P4
- Proceed until P1 and complete it.

Table 2.1 Different Languages of Programming in Industrial Robots

Robotic Brand	**Language Title**
ABB	RAPID
Comeau	PDL1
Fanuce	Karil
Kawasaki	AS
Kuka	KRL
Stabil	VAL2
Yaskawe	Inform

2.6.6. SINGULARITIES

According to ANSI/RIA R16.06-1999, the ANS (American National Standard) for Robot Systems and Industrialized Robots — Safety Requirements, define singularity as "a condition caused by the collinear alignment of two or more robot axes resulting in unpredictable robot motion and velocities." Robotic arms that mostly use a "triple-roll wrist" have it. The three wrist axes that regulate roll, pitch, and yaw all travel through a single point on this wrist. Robot makers are required by ANSI/RIA to notify the user of any singularities that arise when the system is being manually operated.

In six-axis robots that are vertically articulated, and wrist partitioned, a second kind of singularity arises for when the center of the wrist is located on a sphere with radius simialr to the separation between axes 4 and 1. This is known as shoulder singularity. Aside from singularities due to alignment, when axes 6 and 1 meet, several robot manufacturers also refer to them. This is only a shoulder singularity sub-case. Joint 1 rotates rapidly as the robot approaches a shoulder singularity.

When the center of the wrist is in the same plane as axes 3 and 2, vertically articulated wrist partitioned six-axis robots experience the third and final sort of singularity.

2.7. MARKET STRUCTURE:

By the end of 2022, there were approximately 3,903,366 operational industrial robots, as per to the IFR (International Federation of Robots) study World Robotics 2023. The IFR projects that global industrial robot sales will reach US$16.8 billion in 2018. According to estimates, the yearly turnover for robot systems in 2018 was US$48.0 billion, considering the cost of systems engineering, peripherals and software.

In 2017, China emerged as the leading industrialized robot market, with 154,662 sold units. As of the end of 2018, China possessed the greatest number of industrial robots in operation (649,447). In 2018, US industrial robot manufacturers sold 35,880 robots to US firms, a 7% increase over 2017.

With 30% of the market, the automobile sector is the largest user of industrial robots. It is followed by the electrical and electronics industries with 26%, the machinery and metal industries with 16%, the plastics and rubbers industries with 8%, and the food industry at 6%. In the garment, leather, and textile industries, 1,588 units are in operation.

2.8. HEALTH AND SAFETY:

The usage of industrialized robots is predicted to rise globally, with the International Federation of Robotics projecting that by 2020, 8 million new robot installations will be completed in factories around the globe [IFR 2017]. Wayback Machine, 2017-02-11 Archived. “Fast advancements in automation technology (such as exoskeletons, collaborative and mobile robots, and fixed robots) have the potential to both improve working conditions and create new risks in production environments” [7]. Therefore, NIOSH researchers have found 61 robot associated deaths between 1992 and 2015 by conducting a BLS CFI key word search. This is so given that there is no occupational surveillance data on injuries resulting specifically from robots. Below Fatality Judgement and Control Evaluation Code, NIOSH along with its state associates have considered four robot-related fatalities which used data from the BLS (Bureau of Labor Statistics). An overview of the numerous robot-related fatalities and injuries that the OSHA, which stands for Occupational Safety and Health Administration had investigated, is available on the OSHA Accident Search internet site. As more collective and already existing robots, exoskeletons (powered), and vehicles (autonomous) are introduced in the workstation, the rate of injuries and casualties may rise over time.

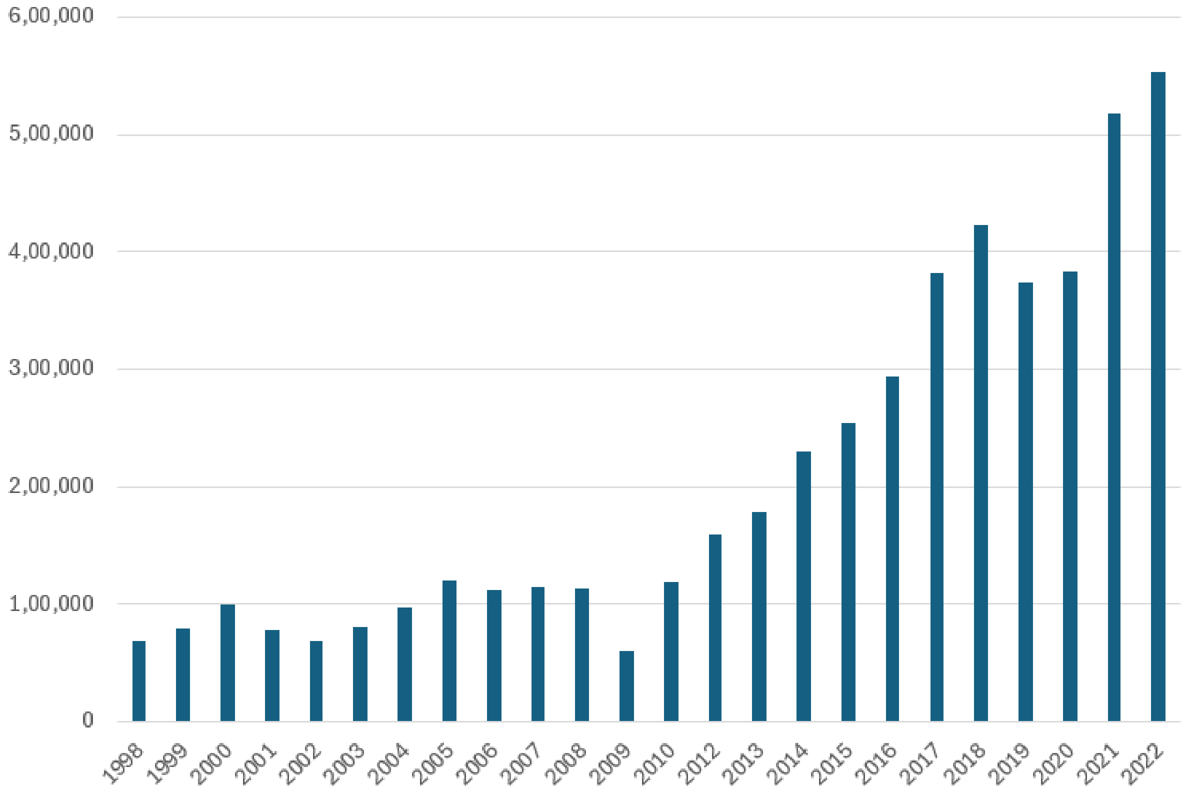


Figure 2.5 Annual Supply of Robots Estimated Worldwide (in units)

American National Standards Institute (ANSI) and the Automated Industries Association (RIA) are operating collectively to produce safety specifications. NIOSH, RIA, and OSHA endorsed an accord on October 5, 2017, to collaborate on improving technical know-how, identifying and mitigating potential workplace hazards related to industrialized robots and every new automation of homo sapiens-robot association accession and connections, and supporting in the affinity of necessary research to lower workshop hazards. The goal of the Center of Industrial Robotics Analysis, which was recognized alongside NIOSH on October 16, is to "provide scientific leadership to guide the development and use of occupational robots that enhance worker safety, health, and wellbeing." The pursuing and stoppage of damage and mortalities, interference and hatred action to advertise secure machine switch and ailment algorithms, and the conversion of positive clue supported mediation into workplace habit are among the exploration needs that NIOSH along with its partners have identified thus far.

CHAPTER 3: ROBOTIC AUTOMATION IN MANUFACTURING

3.1. INTRODUCTION:

Manufacturing businesses use cutting-edge technologies like robotic automation to increase productivity. Any technology that lessens the need for human help is referred to as automation. According to several economists, automation is a technological revolution that has the potential to cause a fundamental shift in the labor market and increase job polarization. Routine occupations have seen a fall in employment.

Manufacturing is one of the key industries where automation is used. “Robotics has seen a sharp rise in its application in manufacturing in recent years” [8]. Many good changes have occurred in production because of robots. The concept of robot automation presents the use of robots or machines to reduce costs and enhance production.

From stationary robots to collaborative robots, mobile robots, rehabilitation robots, personal robots, service robots, social robots, space robots, military robots, officer robots, police robots, industrialized robots, robotics has evolved and taken on various forms. Robots are becoming more and more common in practically every sector of the economy, including manufacturing and healthcare.

“Despite the wide variety of robots available, each with a unique purpose or application, four fundamental characteristics unify them all” [9]:

- Every robot has a mechanical structure that is intended to accomplish a specific task.
- Electronic parts power and regulate the machine components.
- Every robot needs to be able to sense its environment; examples of this include light and stress detectors for hands, chemical detectors for the nose, listening and sonar detectors for ears, etc.
- Computer programming code is present in every robot to some extent.

Robots are fundamentally made up of programs since they are intelligent. Robotic systems come in three ideas: fusion, artificial intelligence, and remote management. Certain robots have been trained to do precise tasks repeatedly (repetitive actions) with great levels of accuracy and consistency. The robots' benefits and drawbacks are illustrated in Figure 3.1 below.

Table 3.1 Some Pros and Cons of Robots

Pros	**Cons**
Savings	Expertise
Quality	ROI
Production	Expense
Safety	Employment

3.2. OVERVIEW ON AUTOMATION:

A broad variety of applied sciences that lessen biological interaction in procedures are referred to as automation. Numerous methods, including pneumatic, electronic, electrical, mechanical, hydraulic, and computer-based equipment, have been used to do it. Automation can take several forms, such as robotics, human-machine interaction, supervisory control and data acquisition (SCADA), robotics, robotic process automation, and programmable logic controllers (PLCs). Additional categories for automation include:

- Fixed,
- Programmable
- Adaptable

The principal benefits of automation include [10]:

- Enhanced productivity or throughput
- Higher caliber
- More predictability
- Enhanced process or product robustness (consistency)
- Enhanced output consistency
- Lower direct labor costs and expenditures
- Shorter cycle time
- Enhanced precision
- Releasing people from boring, repetitive labor
- Work that is necessary for the creation, implementation, upkeep, and functioning of automated processes; frequently organized as tasks
- Increased capacity for human action

The following are automation's primary drawbacks [10]:

- High starting price
- Increased output without human involvement may translate into increased uncontrolled development of flaws.
- Increased capacity may result in increased issues when systems malfunction.
- Automation initiators frequently have a limited understanding of human adaptability.
- Others using automation may cause significant disruptions to people who are expecting money from their jobs.
- Not all tasks can be automated with current technology.
- Because many automated activities need significant capital investments and generate enormous quantities of products, faults can be exceedingly dangerous and expensive.
- Quality upgrade and less labor to save to be obtained as a process is more computerized.
- Availability of less un-automated procedures left as more and more processes get automated.

3.3. ROBOTICS IN MANUFACTURING:

"The following five robotic technology categories have altered and will continue to alter the manufacturing sector" [11]:

- Collaborative Robots: A type of robotic automation known as collaborative robots is designed to operate securely next to human employees in a shared workspace. In most cases, a human worker completes more sophisticated and cerebral activities while a collaborative robot handles repetitive, mundane tasks. Collaborative robots are meant to supplement human workers' intelligence and problem-solving abilities with their accuracy, uptime, and reproducibility.

  The integration of collaborative robots varies highly from those of industrial robots. Safety is the primary consideration in the design of collaborative robots, which include softened edges, force constraints, and light weights. Most collaborative robots are equipped with various sensors and safety measures that initiate an automatic shutdown in the event of any inadvertent interaction, preventing collisions with human workers. The potential uses of robotic automation are substantially expanded when it can operate in conjunction with humans. As more and more sectors come to understand the financial benefits of this technology, the marketplace for combined robots is predicted to rise exponentially.

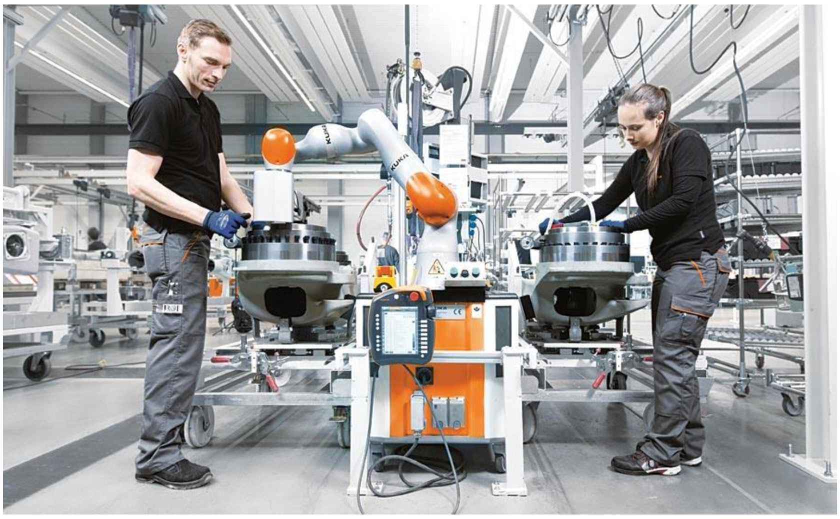


Figure 3.1 Industrial Collaborative Robot

  Collective robots will be interesting machinery to watch as they become a common kind of robotic automation, with significant market potential in several industries both within and outside of the factory setting robots.

- Autonomous Mobile Robots: Advanced transport robots called Autonomous Mobile Robots (AMRs) are made to move loads on their own in a variety of industries, including consumer products, automotive, logistics, and other industrial activities. Leading the way into the future in the automation sector are ABB Robotics' intelligent

AMR/AGV robots, which are outfitted with cutting-edge software tools and a strong safety architecture to facilitate safe and effective interactions with both humans and other machines. Our solutions are adaptable and unmatched, helping our clients boost their productivity and competitiveness across a broad spectrum of industrial applications.

- Industrial Robots: Industrial robots are manufacture-line automated systems. These versatile tools typically comprise a manipulator, which is a robotic arm including at least one axis of working that can be designed to work on three or more. Industrial robots are amazingly fast, accurate, and don't get tired whilst doing repetitive tasks, which makes them standard for usage in warehouses and factory assembly lines.

  With over 3.4 million industrial robots in use worldwide, the manufacturing industry's global robot-to-human ratio stands at one to 71. Additionally, a McKinsey survey indicates that over the next five years, industrial enterprises intend to allocate 25% of their capital to robots, an industry that is expected to generate $43 billion in sales by 2027.

- Robots with Machine Vision: Robot vision is the process of giving robots eyes so they can see and comprehend their environment. It uses a combination of cameras, sensors, and software to take and process images, assisting robots in precise task execution, object identification, and space navigation. Imagine a robot in a factory that, like you are spotting your friend in a crowd, can identify the correct part by simply looking at it on a conveyor belt full of various products.

  Automation of processes such as product assembly, quality assurance, and even the control of self-driving cars depends heavily on this technology. Robot vision improves a robot's capacity to engage with the real environment by using 2D and 3D vision systems, respectively, to identify forms and patterns and to perceive distance and depth. It all comes down to increasing the intelligence and adaptability of robots, increasing their productivity, and decreasing errors across a range of uses.

Figure 3.2 Robotic Vision

- Robotic Blacksmithing: Metamorphic Manufacturing, commonly referred to as Robotic Blacksmithing, is a completely new method of producing components that makes use of both contemporary automation and sensing technologies and the knowledge bases of traditional blacksmiths. In the vein of additive manufacturing, but with the capacity to change the geometry of a piece of material through deformation processing instead of building it up, it allows unique component geometries with the quality and dependability of contemporary mass production procedures. Taking advantage of the performance boost while also enabling custom geometries and small-batch production has the worth to be revolutionary in the production industry because deformation processing is known to produce materials with microstructures that frequently outperform other processes, such as casting or additive manufacturing.

The following are the reasons why manufacturing uses robots [12]:

- To increase productivity from the handling of raw materials to the packaging of completed goods.
- They can be configured to run continuously for uninterrupted production even in the event of a power outage.
- Robotic equipment is incredibly adaptable and may be made to carry out extremely complicated tasks.
- To increase efficiency and maintain their competitiveness, manufacturers must increasingly embrace robotic automation.
- Almost all business sizes can benefit greatly from robotic automation in terms of cost.
- Robotic manufacturing can be used for any repetitive operation. Workers are shielded from hazardous, boring, and repetitive duties by robots.
- Robots handle minute components that are too small for human vision and are error-free.
- By freeing up labor, robots enable businesses to optimize employees' abilities in other business domains. They produce better-paying positions in programming, engineering, management, and maintenance, among other fields.
- Domestic businesses may now compete on pricing with overseas businesses thanks to robotic automation.
- Robots swiftly recoup their initial investment, usually in less than two years.

Several tasks are carried out by robots in the manufacturing industry. The following are the most typical locations where robots are used in the production process:

- Material Handling: When handling items requiring hazardous products that could contaminate humans if in touch, robots are utilized.
- Welding: This risky and very precise method of attaching metal parts is called welding. Welding tasks are increasingly being performed by robots. Figure 3.1 shows welding robots.
- Assembly: Assembling product pieces is a labor-intensive, repetitive task. Reduction in error occurs when a robot replaces such a network.

- Dispensing robots are positioned strategically close to the product's path in operations that are needed for glue, paint, or sprays.
- Processing: Before being made available for sale, some products need to go through a particular kind of processing, such sawing, polishing, or carving. Automata performing this task range in level of autonomy.

Figure 3.3 Welding Robots

3.4. MANUFACTURING APPLICATIONS:

Numerous manufacturing domains can benefit from the implementation of robotic automation. Below are the most common applications of robotic computerization in manufacturing:

Automation industry: It is the one that uses robots the most in developed countries worldwide. It is, specifically, the biggest user of industrial robots. On production lines, robots are more dependable, accurate, versatile, and efficient. The automobile sector continues to have the most automated chain of supply in the world because of robotic automation. In several aspects, such as internal logistics, materials removal, component transfer and machine tending, robotic vision, spot and arc welding, sealing and coating, painting robots are assisting automakers in streamlining their automation processes. Figure 3.2 depicts a typical car production facility [13].

Electronics manufacture: As circuits and component sizes continue to decrease, the manufacture of electronics becomes more intricate. Robotic automation holds significant promise for producing today's high-tech electronic goods and devices. It covers practically every phase of the electronics manufacturing cycle. It offers numerous advantages in terms of safety, quality, cost and flexibility. Component fabrication, pick and place, handling materials and components, inspections, assembly lines, etching, soldering, physical and visial testing, placing tiny components on PCBs, applying adhesives, inspecting, and packing are typical tasks. By reducing the number of workers while boosting production speeds, decreasing errors and waste, and improving production times, robots can drastically save labor expenses. Robots equipped with cameras on their arms can visually inspect electronic assemblies. A robot's usage in electrical manufacturing is depicted in Figure 3.3.

Figure 3.4 A Typical Automotive Manufacturing [13]

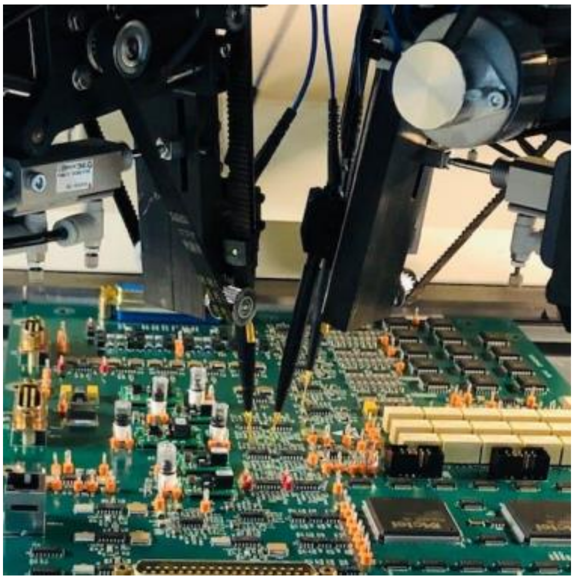


Figure 3.5 Robots used in Electronics Manufacturing

Lights-out Manufacturing: This is a labor-saving production method in which all tasks are completed by machines rather than by humans. The reason behind the name "lights out manufacturing" is that robots can operate in environments devoid of lights, air conditioning, coffee breaks, vacation days, and other necessities for human labor. Robots can operate without any disruptions thanks to lights-out production. It gained popularity in 1982 when General Motors used automation and robots to replace risk-averse bureaucracy. Preventive maintenance, personnel dedication, and dependable equipment are necessary for lights out manufacturing to grow. Businesses that use this production method can benefit from increased energy efficiency.

Automated Production Lines: To move parts between the stations, a transfer system connects several workstations. As these lines are usually configured for extended production runs, this is an illustration of fixed automation. For an automated transfer line to function well, all the many processes and other activities involved must be correctly sequenced and coordinated. Many sectors employ automated manufacturing lines, but the automotive sector is one of them [14].

Robotic Processing Automation: As robotic process automation (RPA) becomes more common, the industrial industry is setting the standard. Manufacturers can cut down on time spent on expensive manual operations by automating some work processes with RPA. It is an essential Industry 4.0 innovation. Numerous repetitive, rule-based procedures can be automated by it, which reduces the time spent on human labor, boosts productivity, spurs creativity, and lowers expenses. Unfortunately, due to several additional issues, exchanging RPA systems has justified to be costly and challenging to implement thus far. RPA portfolios of the manufacturers are expected to grow at a rapid rate as RPA technology advances. Businesses concentrate on achieving more stability and fewer errors in their RPA operations.

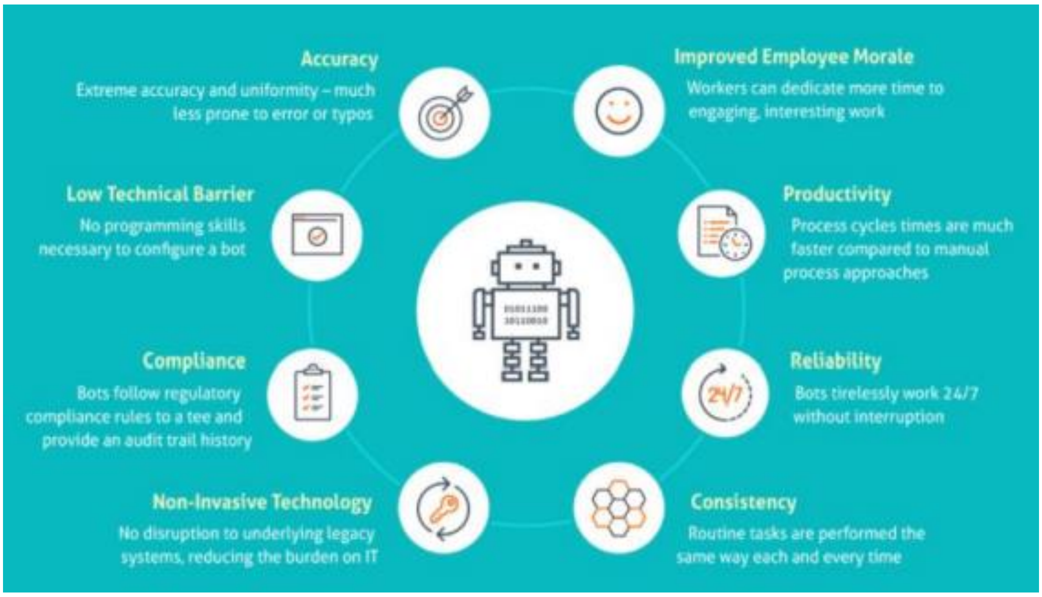


Figure 3.6 RPA in the Production Industry

Figure 3.4 shows some of the advantages of Robotic Process Automation (RPA) in the manufacturing sector and explains them as follows [15]:

- Error-free and reliable outcomes
- The ability to use workers for higher-value tasks
- A rise in job satisfaction because of avoiding time-consuming, low-value activities
- Quicker and more accurate delivery schedule

- A trail of recorded effort completed
- Recognizing irregularities or other warning signs
- A 40% or more decrease in operating expenses
- Better oversight and insight into the entire process
- Resources freed up to concentrate on more fruitful work
- Notably reduced downtime and improved quality

The forging, robotic welding, reshoring, and food industries are among the other production sectors that use robotic automation.

3.5. BENEFITS:

Robots are developing in ways that many global production managers and corporate executives could only imagine. Increasing flexibility, lowering costs, raising quality, and improving worker safety are the main goals of robotic automation. Using robotic autonomous operation, smart manufacturing objectives can be met. Robotics' advantages include important tasks that are completed accurately and consistently. A robot speeds up manufacturing operations by working around the clock to maximize output and decrease downtime.

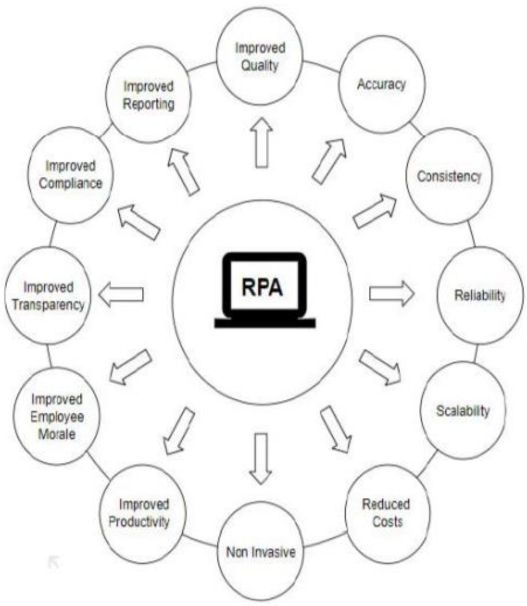


Figure 3.7 Advantages of Robots in Process Automation

Additional advantages of robotic automation consist of [16]:

- Improved Quality and Consistency: Robots can deliver more accurate, dependable procedures as well as improved manufacturing quality. They can boost output, effectiveness, and security while a process is in operation.
- Maximum Productivity: The two main economic benefits of automation that are most frequently mentioned are higher production and increased productivity. The ratio of

output units to labor input units is the conventional definition of productivity in a process.

- Increased Safety: Repetitive tasks performed by robots reduce the possibility of worker damage.
- Lower Direct Labor Costs: When some workers are replaced by robots, workers have more time to employ their talents and knowledge elsewhere. Labor reduction boosts profit, which is always a crucial corporate objective.
- Overcoming Obstacles: Manufacturers are using robots to assist them overcome several significant obstacles, such as limited labor supply, competition in the global market, and safety.
- Reduce Cost: As robotic automation grows more sophisticated and adaptable, the cost per unit is being reduced.

3.6. CHALLENGES:

Like everything, robots have advantages and disadvantages. Among the difficulties robotic automation faces are [17]:

- High initial cost: Purchasing a robot usually entails a sizable upfront cost.
- Skillset can be limited: Industrial robot deployment requires industrial robot training and experience from an automation business. Industrial robots require complex programming, upkeep, and operation. There aren't many people with these abilities now.
- Current costs: Industrialized robots have their own current costs, like maintenance, although they may lower labor costs related to manufacturing.
- Competitive Competition: Due to their inability to compete with low-cost foreign labor, several manufacturers were forced to offshore their employment.
- Labor: Robotic automation refers to the substitution of an automated system for human labor. Automation has in fact resulted in job losses for workers.
- Stress: An employee experiences emotional stress when their job is replaced by robots. The employee might have to move.
- Robotics' limitations: Industrial robots are still a desirable substitute for human work, but they are still unable to complete some tasks. For completing the tasks, robots rely on the environment networks consisting of PLCs, conveyors, grippers and vision systems.

Despite these problems, humans will always be better than machines at a few tasks. The pros of imagination, governing, resilience and versatility.

3.7. GLOBAL ADOPTION OF ROBOTIC AUTOMATION:

Globally, the use of robots has increased. When it comes to the use of robot technology in manufacturing, Germany and Italy have advanced beyond the United States. Data are available from the International Federation of Robotics (IFR) for six major non-manufacturing sectors and 13 manufacturing-related industries. IFR estimates that about 2,499,543 industrialized robots will be in use by the close of 2017. We examined the application of robotic automation across numerous nations.

- United States: There were 136 robots employed for every thousand workers in the US car industry, compared to just 8.6 for all other manufacturing sectors. The biggest of the country's private industrial sectors is the production sector, which is also essential to the country's economy. As fascination in robotics improved in the late 1970s, several US firms, including General Electric and General Motors, jumped on the bandwagon. The US is experiencing a severe social problem with unemployment because of the rapid advancement of technology and automation.

- China: In 2018, the Chinese market, which is a manufacturing hub due to cheap labor, had 154,032 sales of industrial robots, making it the largest in the world. Most factories have replaced 50% of their personnel with robots.

- Japan: The 22-factory workspace in Oshino, Japan, FANUC, a well-established robot producer, as to construct their goods, uses the lights-out production concept. Robots can cut the time needed to harvest strawberries by up to 40%, according to trials conducted in Japan.

- Canada: 3D printing, robots, and ICT technologies are all part of the country's sophisticated manufacturing industry. Canada makes it easier for Industry 4.0 innovations to be seamlessly integrated into manufacturing processes.

CHAPTER 4: ADVANCES IN INDUSTRIAL ROBOTICS WITH INDUSTRY 4.0

4.1. MOTIVATIONAL FACTORS/ECONOMIC JUSTIFICATION FOR USE:

Following are a few factors or justifications for the use of robotics in the Industrial Field:

• Hazardous work for humans -

An industrialized robot must be taken into consideration for a task when both the work and the surroundings in which it is conducted are dangerous, unsafe, unhealthy, unpleasant, or otherwise uncomfortable for people [18]. Apart from die casting, numerous other occupations involve risks or uncomfortable conditions for workers, such as spot welding, arc welding, and spray painting. Throughout each of these procedures, industrial robots are used.

Figure 4.1 Occupational and Health Hazards

• Repetitive work cycle -

A repetitive work cycle is another feature that tends to encourage the usage of robotics. A robot can typically complete a work cycle more consistently and reliably than a human worker if the motion parts in the cycle are the same, or very similar.

• Difficult handling for humans -

Industrial robots could be able to do the work if it requires handling heavy or otherwise challenging-to-manipulate parts or tools.

• Multi-shift operation –

The financial payback of replacing a manual process with a robot occurs much faster than with a single shift in physical operations needing more shifts. The robot replaces two or three workers instead of only one.

• Infrequent changeovers -

The majority of batch or job shop processes demand a physical workspace transition from one task to the next. Since no parts are being created during the transition, the time needed to complete it is not productive time. As a result, during relatively lengthy production runs with few changeovers, robots have historically been easier to justify.

4.2. SENSORS IN ROBOTICS:

A large range of sensors can be used to gather manufacturing process data for feedback control. A transducer, or application that changes a manual variable from one form to another that is more appropriate for a particular use, is what is known as a sensor [19]. Specifically, a sensor is an apparatus that, to measure a variable of interest or physical stimulus (such pressure, force, temperature, or movement), transforms it into another accessible arrangement (often an electric quantity like voltage).

There are two types of sensors used in industrial robotics: external and internal.

• Internal sensors -

Robot internal detectors are parts of the machine that regulate the joints' locations and velocities. Together with the robot controller, these devices make up a feedback regulator loop. Optical encoders and potentiometers are common sensors used to regulate the robot arm's position. The robot arm's speed is managed via a variety of tachometer types.

• External sensors -

The purpose of the robot's external sensors is to synchronize its actions with those of the other devices within the cell. They serve as locks. These outward sensors are frequently basic gadgets, such as limit switches that detect when a part is prepared for retrieval from a conveyor or has been correctly positioned in a fixture.

4.2.1. ADVANCED SENSOR TECHNOLOGIES:

Some of the advanced sensor techniques that are used in the industrial robotics field are described below:

• Tactile sensors -

These are employed to ascertain whether the sensor and another object have made touch. Touch sensors and force sensors are the two categories of tactile sensors used in robot applications [20]. Touch sensors just show that there has been touch with the item. Force sensors show how much force is applied to an object. This could be helpful in a gripper to gauge and regulate the force used to hold onto a small object.

• Proximity sensors -

These show the proximity of an object to the sensor. This kind of sensor is referred to as a range sensor when it is utilized to show the object's real distance.

• Optical sensors -

In addition to being frequently employed for proximity detection, photoelectric cell and other photometric applications can be used to perceive the absence or presence of items.

Figure 4.2 Optical Sensors

4.3. MACHINE VISION:

Robotics employs machine vision for guiding, inspection, and part identification, among other things. Vision-guided robot (VGR) systems can now be programmed more easily and quickly, and machine vision is becoming a standard element in an increasing number of robot installations, particularly in the automotive sector [21].

4.3.1. TYPES OF VISION SYSTEMS:

There are three varieties of vision systems:

• 1D Robotic Vision (Minimal level vision) -

One-dimensional cameras are used in 1D vision systems to analyze the numerical signal of a single line collection at a time and compare changes among line groups that came before and ones that are currently present. Typically, 1D camera-equipped robots are used to examine the surface of parts that are produced continuously. The least popular kind of robotics systems are 1D vision systems since most manufacturers want to program more intricate tasks.

• 2D Robotic Vision (Intermediate level vision) -

Robotic vision classifications most commonly use two-dimensional vision systems. Both X and Y plane views of an object are possible with 2D systems. Two different kinds of 2D vision procedures exist: line scans and area images. Area scans are useful for acquiring two-dimensional images of objects, although they are not as effective at capturing rounded edges. Like how a document scanner operates, line scan vision creates a 2D image by depicting each line of a part and stitching them together to make it. Line scans are frequently used to capture constantly moving objects in high resolution, for cylindrical parts, and in cramped spaces.

• 3D Robotic Vision (High-level level vision) -

In recent years, 3D visions systems have become more and more common in the robotics industry [22]. Robots may observe objects in three dimensions and receive picture feedback via 3D systems that simulate real-world object sight in all six degrees of freedom. The breadth of robot applications has expanded thanks to robotic 3D vision. Robots can autonomously detect and adapt to changes in part types, positions, orientation, environments, and applications while they're in use thanks to 3D vision systems. Applications for these vision systems include palletizing, pick and, assembly, part transfer, and even welding. The ABB IRB 2600 can automate complex assemblies thanks to improved visual guiding when 3D vision is integrated.

4.4. COMPUTER VISION AND MACHINE INTELLIGENCE:

• Robot vision definition: The method of obtaining, interpreting and characterizing data from pictures of a 3-dimensional environment is known as robot vision. Three basic tasks comprise robotic vision: image understanding, image analysis, and image transformation.
• Robotic vision, sometimes referred to as processor vision or machinery vision, is a significant sensor technology that has potential uses in a wide range of industrial processes.
• A key component of an "intelligent" robotics system nowadays is computer vision.
• A robot's vision system gives it an advanced sensory mechanism that enables it to react to its surroundings in a flexible and intelligent way.
• The ongoing desire to expand the versatility and range of applications of robotics systems drives the usage of vision and other sensing technologies [23].
• While force, touch, and proximity sensors are important for enhancing robotic performance, vision is acknowledged as the highest potent robot sensory capacity.

Table 4.1 Computer Vision vs Machine Intelligence

Computer Vision	**Machine Intelligence**
Detection	Classification
Recognition	Prediction
Perception	Training

4.4.1. IMAGE TRANSFORMATION:

• The method of automatically digitizing visual images with image applications is known as image transformation [24].
• The forward end of a vision system, or image device, functions as a visual image transducer to transform light energy into electrical energy.
• In contrast, the eye serves as the image device in humans.
• A photodiode array, camera, charge-coupled device (CCD) array, or charge-injection device (CID) array can be used as the image device in a vision system.
• The continuous analog signal that an image device produce is proportionate to the content of light reflected from the image.
• The correspondent signals need to be translated and saved in digital form before they can be used to analyze an image on a computer.
• To do this, pixels, or tiny areas known as picture elements, are separated into a rectangular image array.

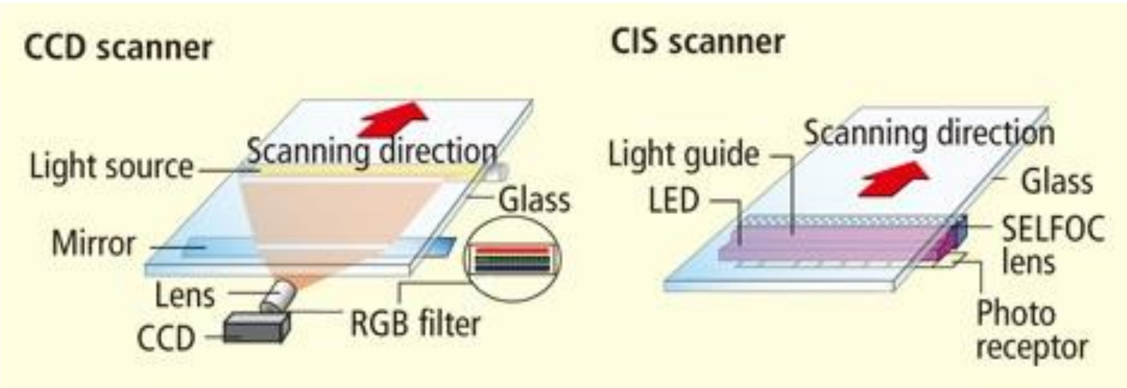


Figure 4.3 A CCD and CID Scanner

• When using CCD arrays or photodiodes, the number of pixels is equal to the number of CCD devices or photodiodes.
• An analog-to-digital (A/D) converter's sampling grid is provided by the pixel configuration.
• The corresponding gray-level values of the transformed pixels are recorded in a memory matrix, also known as a picture visual matrix.

4.4.2. IMAGE ANALYSIS:

• The line markings serve as a foundation for picture understanding since they specify the forms of the items that make up a scene.
• A computer must locate an object's edges to generate drawings of the object inside a scene. Therefore, the fundamental idea behind edge uncover is that edges result in line markings, which result in forms, which result in the comprehension of images [25].
• The ability to recognize edges
• In a smoothed picture matrix, the points with the biggest difference in grey-level values are often used to represent the edges.

• It should be understood from calculus that a step edge's slope tends toward infinity. With this concept, all we need to do is figure out the first derivative—also known as the gradient—between two neighboring greyscale values.
• Pixel differentiation is the name of the technology.

4.4.3. THRESHOLDING:

• Following that, lines may be found from the thresholded binary matrix.
• Model matching, tracking, and template matching are a few common methods for locating lines from an edge-point matrix.
• Limiting
• After that, lines may be found in the thresholded binary matrix. Model matching, tracking, and template matching are some of the frequently used methods for locating lines from an edge-point matrix.

4.4.4. IMAGE UNDERSTANDING:

• Picture understanding, also known as machine perception, is the last step in robot vision, wherein the data gathered during picture analysis is interpreted.
• Much of the study on image understanding is focused on the "blocks world."
• The blocks world operates under the assumption that 2-D rectangle and triangular solids can be used to analyze and characterize real-world images.
• Under this blocks-world assumption, various A} based image recognizing programs that can analyze real-world imageries have been effectively constructed.

4.5. APPLICATION OF ROBOT VISION SYSTEM:

Three categories exist for the use of machine vision in robotics applications [26]:
• Inspection
• Identification
• Navigation

4.5.1. INSPECTION:

• The robot serves as an application's secondary support system, with the vision system handling the inspection process.
• Checking for surface flaws, confirming the occurrence of mechanisms in an assembly, assessing dimensional precision, and partially verifying the incidence of holes and other features are among the goals of visual inspection.

4.5.2. IDENTIFICATION:

• Applications where the goal is to identify and categorize an object instead of inspecting it fall under the category of identification.

• Inspection suggests that one must decide whether to accept or reject the part.

4.5.3. NAVIGATION:

• The goal of navigation control is to use visual information to guide the movements of the machine and additional components within the robot unit.
• Controlling the robot's end effector's course toward a workspace object is one example.

4.6. GRIPPERS:

Grippers are end effectors, which are used to grip and move things throughout a work cycle. An end effector is often ascribed to the robot's wrist. Typically, the objects are creation components that are relocated throughout the cell [27]. This grouping includes functions for loading and unloading systems.

4.6.1. TYPES OF GRIPPERS:

Following are a few categories of grippers that are employed in manufacturing automation:

• Mechanical grippers, which have two or more portions and can be released and finished on the job part by the robot controller (a two-finger gripper is shown in Figure 8.10)
• Vacuum grippers, which utilize suction cups to grab flat objects.
• Magnetized devices to retain iron machinery
• Adhesive devices, which attach a flexible material, like fabric, using an adhesive substance
• Basic mechanical tools, such scoops and hooks.

4.6.2. MECHANICAL GRIPPERS:

The most widespread kind of gripper is the mechanical gripper.

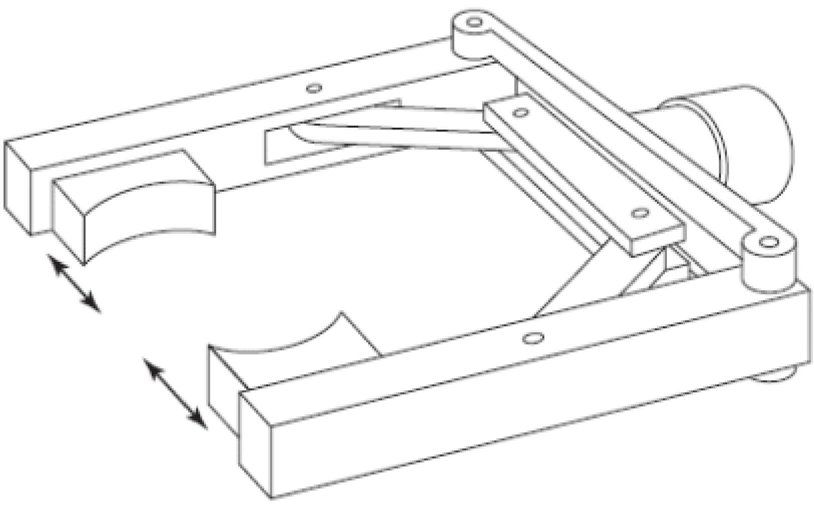


Figure 4.4 A Robot Mechanical Gripper

The following are a few advances and innovations in mechanical gripper technology:

• Machines are filled and discharged using dual grippers. They comprise a single end effector that has two gripper devices. With a single gripper, the robot must reach within the production machine twice: once to unload the finished item and deposit it outside, and once more to gather up the next part and load it inside. As the machine examines the previous task, the robot uses a dual gripper to pick up the next work element. The robot only enters the machine once throughout a machine cycle to eliminate the completed part and load the next one. This lowers the cycle time for each component.

• Changing fingers that work with a single gripper mechanism. The gripper has different fingers attached to it to accommodate different pieces.

• Sensory input in the fingers that gives the gripper the ability to sense the part's presence or, in the case of delicate work parts, apply a predetermined, limited force to the part while gripping [28].

• Grippers with several fingers that resemble human hands in general structure.

• Commercially available standard gripper products, which eliminate the need to create a gripper specifically for each unique robot application.

4.7. ROBOT ACCURACY AND REPEATABILITY:

The robot's accuracy is defined as its wrist's ability to be positioned at a desired place inside the work volume [29].

The robot's repeatability is determined by how well it can position its end-of-wrist at a previously learned location within the work volume. The robot will reposition itself slightly each time it tries to reach the preprogrammed location. The previously described mechanical flaws are the main cause of variances in repeatability.

4.8. CONCLUSION:

Industrial robotics is undergoing a revolution because of advances in Industry 4.0, which are enabling production processes to operate with never-before-seen efficiency and flexibility. Artificial Intelligence (AI), the Internet of Things (IoT), and big data analytics are integrating to improve robotic capabilities, allowing for autonomous decision-making and predictive maintenance. Robotics are becoming a crucial component of smart, agile factories that can react quickly to market demands as the industry adjusts to new advances. Looking ahead, additional funding for Industry 4.0 technologies will hasten the development of industrial robotics and open the door to worldwide production settings that are safer, more efficient, and more adaptable.

CHAPTER 5: CONCLUSION

5.1. CONCLUSION:

In conclusion, by accelerating and improving accuracy of operations, robots are changing the production landscape. As technology advances, more companies of all sizes will be able to purchase robots, increasing their competitiveness in international marketplaces. They assist businesses satisfy client requests effectively while maintaining high quality by streamlining processes, lowering errors, and reducing errors.

In the future, robots will develop further to collaborate with humans more closely. AI is making them smarter, and they can change swiftly to meet shifting demands for manufacturing. Humans and robots working together to create safer workplaces and more adaptable operations will spur innovation and long-term growth in the manufacturing sector.

Robots are essential to updating manufacturing processes because they provide a route to increased productivity and competitiveness. Businesses that adopt these innovations will be better prepared to handle upcoming obstacles and take advantage of opportunities in a world economy that is changing quickly.

5.2. FUTURE SCOPE:

Future robotics applications in manufacturing have the potential to completely alter operational dynamics and industry standards. As artificial intelligence, machine learning, and sensor integration continue to progress, robotics will be able to perform tasks with greater autonomy, adaptability, and precision. This progression has the potential to boost industrial firms' competitiveness internationally by increasing productivity and lowering operating costs.

Furthermore, collaborative robotics will be essential in changing work settings and promoting safer and more effective human-machine interactions. Cobots, or collaborative robots, will simplify processes while freeing up employees to concentrate on more difficult jobs that call for human judgment and creativity. Robotics is predicted to be applied in a wide range of industries outside of manufacturing, including logistics, healthcare, and agriculture. This will spur innovation and boost economic growth in previously unanticipated ways. Businesses looking to remain ahead of the curve in a fast-changing industrial landscape will need to adopt these technological improvements to position themselves to take advantage of the opportunities that the intelligent automation revolution presents.

REFERENCES

[1] uniqueworldrobotics.com. (n.d.). "Robotic process automation courses" -robotics academy in dubai-Uniques World Robotics. [online] Available at: https://uniqueworldrobotics.com/about.html

[2] Wikipedia Contributors (2019). "Industrial robot". [online] Wikipedia. Available at: https://en.wikipedia.org/wiki/Industrial_robot

[3] Sadiku, M., Chukwu, U., Ajayi-Majebi, A. and Musa, S. (n.d.). "Robotic Automation in Manufacturing". Journal of Scientific and Engineering Research, [online] 2021(4), pp.140–149. Available at: https://jsaer.com/download/vol-8-iss-4-2021/JSAER2021-8-4-140-149.pdf

[4] Iso.org. (2021). Available at: https://www.iso.org/obp/ui/#iso:std:iso:8373:ed-3:v1:en

[5] Guarana-DIY (2020). "The Top Six Types of Industrial Robots in 2020 "| DIY-Robotics Blog. [online] DIY-Robotics. Available at: https://diy-robotics.com/blog/top-six-types-industrial-robots-2020/

[6] web.archive.org. (2012). "*Machine Vision Fundamentals: How to Make Robots 'See'": Nasa Tech Briefs*. [online] Available at: https://web.archive.org/web/20120127043340/http://www.techbriefs.com/privacy-footer-69/10531

[7] National Academies of Sciences, E. (2017). *Information Technology and the U.S. Workforce: Where Are We and Where Do We Go from Here?* [online] *nap.nationalacademies.org*. Available at: https://nap.nationalacademies.org/catalog/24649/information-technology-and-the-us-workforce-where-are-we-and

[8] www.stlouisfed.org. (n.d.). "*The Rise of Automation: How Robots May Impact the U.S. Labor Market" | St. Louis Fed*. [online] Available at: https://www.stlouisfed.org/publications/regional-economist/second-quarter-2019/rise-automation-robots

[9] Wikipedia Contributors (2019). "*Robotics"*. [online] Wikipedia. Available at: https://en.wikipedia.org/wiki/Robotics

[10] Wikipedia Contributors (2019). "*Automation*". [online] Wikipedia. Available at: https://en.wikipedia.org/wiki/Automation

[11] Robot Shop Community. (2020). "*5 Robots Changing Manufacturing Forever*". [online] Available at: https://community.robotshop.com/blog/show/5-robots-changing-manufacturing-forever

[12] Acieta. (n.d.). "*Manufacturing Robots, Industrial Robot Manufacturing*". [online] Available at: https://www.acieta.com/robotic-automation/automation-for-every-industry/general-manufacturing/

[13] Genesis Systems. (2018). "*6 Common Applications for Robots in Automotive Manufacturing*". [online] Available at: https://www.genesis-systems.com/blog/robots-automotive-manufacturing-top-6-applications

[14] Groover, M.P. (2019). "Automation - Manufacturing applications of automation and robotics". In: *Encyclopædia Britannica*. [online] Available at: https://www.britannica.com/technology/automation/Manufacturing-applications-of-automation-and-robotics

[15] BDO. (2018). "*An Introduction to Robotic Process Automation for Manufacturers*". [online] Available at: https://www.bdo.com/insights/industries/manufacturing/an-introduction-to-robotic-process-automation-for-manufacturers#:~:text=RPA%20is%20the%20use%20of

[16] Manufacturing.net. (2021). "*How Robotic Processing Automation Will Change in 2021*". [online] Available at: https://www.manufacturing.net/automation/blog/21319201/how-robotic-processing-automation-will-change-in-2021

[17] Stevens, M. (2021). "*Pros and cons of using industrial robots in manufacturing*". [online] www.wipfli.com. Available at: https://www.wipfli.com/insights/articles/mad-pros-and-cons-of-using-industrial-robots-in-manufacturing

[18] Hogg, S. (2018). 7 Industrial Robotics Hazards and How to Avoid Them | Bastian Solutions. [online] Bastiansolutions.com. Available at: https://www.bastiansolutions.com/blog/7-industrial-robotics-hazards-and-how-to-avoid-them/

[19] Basic Electronics Tutorials. (2018). Sensors and Transducers and Introduction. [online] Available at: https://www.electronics-tutorials.ws/io/io_1.html

[20] www.sciencedirect.com. (n.d.). tactile sensor - an overview | ScienceDirect Topics. [online] Available at: https://www.sciencedirect.com/topics/computer-science/tactile-sensor

[21] www.cognex.com. (n.d.). Vision Guided Robotics | Cognex. [online] Available at: https://www.cognex.com/industries/vision-guided-robotics

[22] www.inbolt.com. (n.d.). Inbolt - On 3D Machine Vision in the Manufacturing Industry. [online] Available at: https://www.inbolt.com/resources/on-3d-machine-vision-in-the-manufacturing-industry

[23] Licardo, J.T., Domjan, M. and Orehovački, T. (2024). Intelligent Robotics—A Systematic Review of Emerging Technologies and Trends. Electronics, [online] 13(3), p.542. Doi: HTTPs://doi.org/10.3390/electronics13030542

[24] Hanna, K.T. (2022). What is digitization? - Definition from WhatIs.com. [online] WhatIs.com. Available at: https://www.techtarget.com/whatis/definition/digitization

[25] Roboflow Blog. (2024). Edge Detection in Image Processing: An Introduction. [online] Available at: https://blog.roboflow.com/edge-detection/

[26] www.superannotate.com. (n.d.). Computer vision applications in robotics | SuperAnnotate. [online] Available at: https://www.superannotate.com/blog/computer-vision-robotics

[27] SlideShare. (2023). Unit 3.pptx. [online] Available at: https://www.slideshare.net/slideshow/unit-3pptx-256358882/256358882

[28] Morin, A. (n.d.). Sensory Seeking vs. Sensory Avoiding in Children. [online] www.understood.org. Available at: https://www.understood.org/en/articles/sensory-seeking-and-sensory-avoiding-what-you-need-to-know

[29] evs (2023). Accuracy VS Repeatability VS Resolution: What’s Their Difference in Industrial Robotics? [online] EVS Robot. Available at: https://www.evsint.com/difference-in-accuracy-repeatability-and-resolutio