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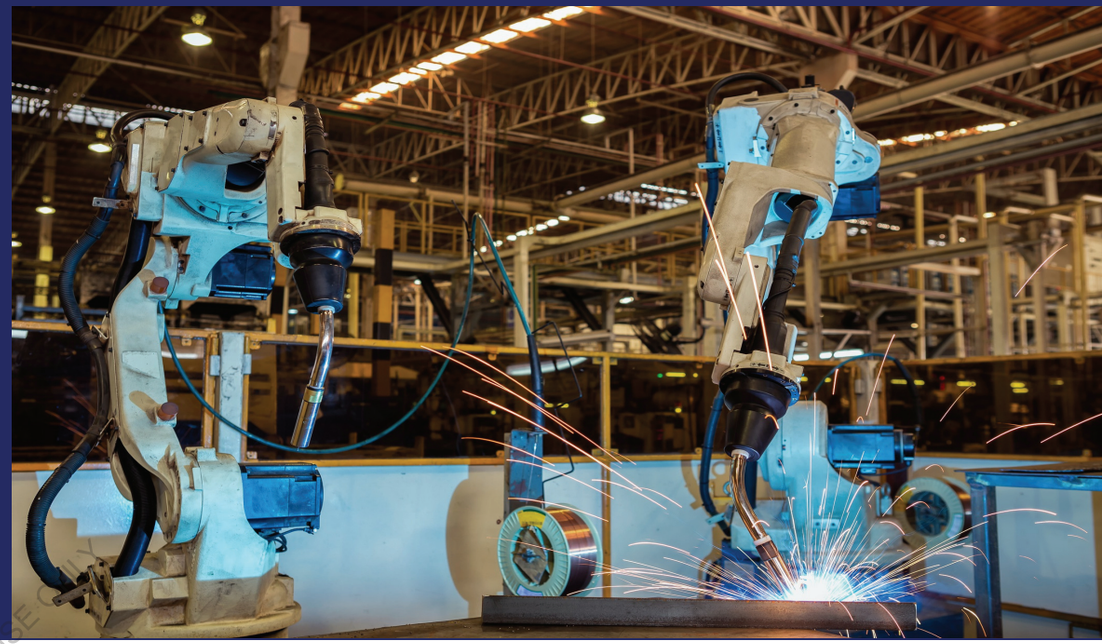

Dr. Aadarsh Malviya is currently working as Associate Professor in the department of Computer Science and Engineering ,Dronacharya Group of Institutions, Greater Noida.
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ROBOTICS & AUTOMATION

ROBOTICS & AUTOMATION

Written By-

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About The Author's

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PREFACE

The objective of this book is to deliver exactly what is on the cover – **Robotics & Automation**. The emphasis is on Robotics techniques applied to ground mobile robots. The book starts with professional robot design principles that have been scaled down for smaller robot projects. The AI section begins with convolution neural networks for object recognition and continues with reinforcement learning and genetic algorithms. The robot gets a voice and learns to tell jokes using AI-based voice recognition that can discern user intent. The book introduces a novel way to navigate without a map using a literal divide and conquer program that uses the upper part of the room to remember paths, and the lower part of avoid

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Thanks to all my friends for sharing my happiness when starting this project and following with encouragement when it seemed too difficult to be completed. I would have probably give up without their support and example on what to do when you really want something

Last and not least: I beg forgiveness of all those who have been with me over the course of the years and whose names I have failed to mention.

INDEX

Contents

CHAPTER -1

1.0 Robotics

Robotics is the term used in artificial intelligence that deals with a study of creating intelligent and efficient robots.

Robotics is a branch of engineering and computer science that involves the conception, design, manufacture and operation of robots. The objective of the robotics field is to create intelligent machines that can assist humans in a variety of ways.

Robotics can take on a number of forms. A robot might resemble a human or be in the form of a robotic application, such as robotic process automation, which simulates how humans engage with software to perform repetitive, rules-based tasks

To function, a combination of computer programming and algorithms, a remotely controlled manipulator, actuators, control systems -- action, processing and perception -- real-time sensors and an element of automation help to inform what a robot or robotic system does.

Some additional applications for robotics include the following:

- **Home electronics.** Vacuum cleaners and lawnmowers can be programmed to automatically perform tasks without human intervention.
- **Home monitoring.** This includes specific types of robots that can monitor home energy usage or provide home security monitoring services, such as Amazon Astro.
- **Artificial intelligence (AI).** Robotics is widely used in AI and machine learning (ML) processes, specifically for object recognition, natural language processing, predictive maintenance and process automation.
- **Data science.** The field of data science relies on robotics to perform tasks including data cleaning, data automation, data analytics and anomaly detection.
- **Law enforcement and military.** Both law enforcement and the military rely heavily on robotics, as it can be used for surveillance and reconnaissance missions. Robotics is also used to improve soldier mobility on the battlefield.
- **Mechanical engineering.** Robotics is widely used in manufacturing operations, such as the inspection of pipelines for corrosion and testing the structural integrity of buildings.
- **Mechatronics.** Robotics aids in the development of smart factories, robotics-assisted surgery devices and autonomous vehicles.
- **Nanotechnology.** Robotics is extensively used in the manufacturing of micro electromechanical systems, which is a process used to create tiny integrated systems.
- **Bioengineering and healthcare.** Surgical robots, assistive robots, lab robots and telemedicine robots are all examples of robotics used in the fields of healthcare and bioengineering.
- **Aerospace**. Robotics can be used for drilling, painting, coating, inspection and maintenance of aircraft components.

1.1 TYPES OF ROBOTICS

Robots are designed to perform specific tasks and operate in different environments. The following are some common types of robots used across various industries:

- **Industrial robots.** Frequently used in manufacturing and warehouse settings, these large programmable robots are transforming the supply chain by performing tasks such as welding, painting, assembling and material handling.
- **Service robots.** These robots are used in a variety of fields in different scenarios, such as domestic chores, hospitality, retail and healthcare. Examples include cleaning robots, entertainment robots and personal assistance robots.
- **Medical robots.** These robots help with surgical procedures, rehabilitation and diagnostics in healthcare settings. Robotic surgery systems, exoskeletons and artificial limbs are a few examples of medical robots.
- **Autonomous vehicles**. These robots are mainly used for transportation purposes and can include self-driving cars, drones and autonomous delivery robots. They navigate and make decisions using advanced sensors and AI algorithms.
- **Humanoid robots.** These robots are programmed to imitate and mimic human movements and actions. They look humanlike and are employed in research, entertainment and human-robot interactions.
- **Cobots.** Contrary to the majority of other types of robots, which do their tasks alone or in entirely separated work environments, cobots can share

workplaces with human employees, enabling them to work more productively. They're typically used to remove costly, dangerous or time-consuming tasks from routine workflows. Cobots can occasionally recognize and respond to human movement.

- **Agricultural robots.** These robots are used in farming and agricultural applications. They can plant, harvest, apply pesticides and check crop health.
- **Exploration and space robots.** These robots are used in missions to explore space as well as in harsh regions on Earth. Examples include underwater exploration robots and rovers used on Mars expeditions.
- **Defense and military robots.** These robots aid military tasks and operations including surveillance, bomb disposal and search-and-rescue missions. They're specifically designed to operate in unknown terrains.
- **Educational robots.** These robots are created to instruct and educate kids about robotics, programming and problem-solving. Kits and platforms for hands-on learning in academia are frequent examples of educational robots.
- **Entertainment robots.** Created for entertainment purposes, these robots come in the form of robotic pets, humanoid companions and interactive toys.

1.2 THE PROS AND CONS OF ROBOTICS

Robotic systems are coveted in many industries because they can increase accuracy, reduce costs and increase safety for human beings.

Advantages of robotics include the following:

- **Safety.** Safety is arguably one of robotics' greatest benefits, as many dangerous or unhealthy environments no longer require the human element. Examples include the nuclear industry, space, defense and maintenance. With robots or robotic systems, workers can avoid exposure to hazardous chemicals and even limit psychosocial and ergonomic health risks.

- **Increased productivity**. Robots don't readily become tired or worn out as humans do. They can work continuously without breaks while performing repetitive jobs, which boosts productivity.
- **Accuracy.** Robots can perform precise tasks with greater consistency and accuracy than humans can. This eliminates the risk of errors and inconsistencies.
- **Flexibility.** Robots can be programmed to carry out a variety of tasks and are easily adaptable to new use cases.
- **Cost savings.** By automating repetitive tasks, robots can reduce labor costs.

However, despite these benefits, robotics also comes with the following drawbacks:

- **Task suitability.** Certain tasks are simply better suited for humans -- for example, those jobs that require creativity, adaptability and critical decision-making skills.
- **Economic problems.** Since robots can perform most jobs that humans do with more precision, speed and accuracy, there's always a potential risk that they could eventually replace human jobs.
- **Cost**. Most robotic systems have a high initial cost. It can also cost a lot to repair and maintain robots.
- **Increased dependency**. Overreliance on robots can result in a decrease in human talents and problem-solving abilities as well as an increase in technological dependence.
- **Security risks.** There's always a risk of robotic devices getting hacked or hijacked, especially if they're being used for defense and security purposes.
- **Power requirements.** Robots consume a lot of energy and constant power to operate. Regular upkeep and maintenance are also needed to keep them in good working condition.

1.3 Robotics History

First use of the word "Robotics":

The word robot was firstly introduced to public by Czech writer Karel Capek in his play Rossum's Universal Robots (R.U.R), published in 1920. The play begins with a factory that makes artificial people known as robots.

The word "Robotics", was coined accidentally by the Russian-born, American scientist, Issac Asimov in 1940s .

1.4 The three laws of Robotics:

Issac Asimov also proposed his three "Laws of Robotics", and he later added a "zeroth law"

Zeroth Law - A robot is not allowed to injured humanity, or, through inaction it allows humanity to come to harm.

First Law - A robot can not injure a human being, or, through inaction it allows a human being to come to harm, unless it would violate the higher order law.

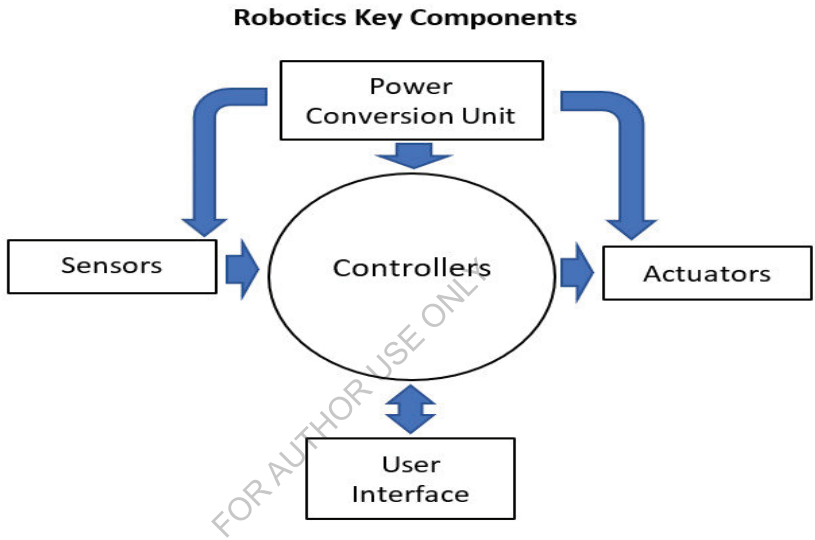
Second Law - A robot should follow the orders given it by human beings, except when such orders give by humans would conflict with a higher order law.

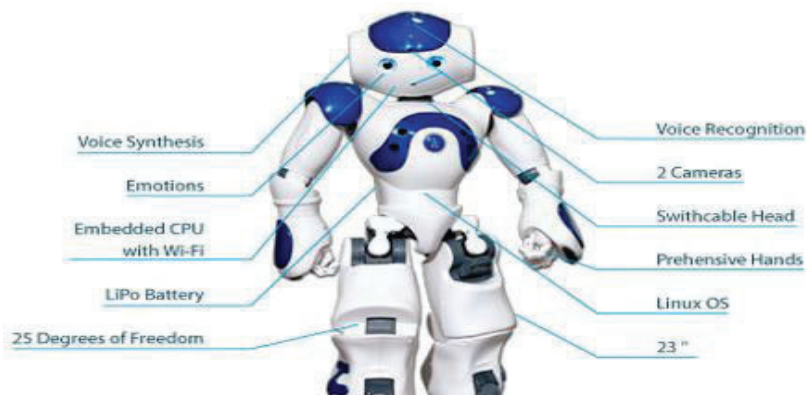
Third Law - A robot is allowed to protect its own existence as long as such protection would not conflict with a higher order law.

The first industrial robot: UNIMATE

In 1954 first programmable robot is designed by George Devol, who coins the term Universal Automation. He later shortens this term to Unimation, which become the name of the first robot company in 1962.

1.5 COMPONENTS OF ROBOT





- **Power Supply -** The working power to the robot is provided by batteries, hydraulic, solar power, or pneumatic power sources.
- **Actuators -** Actuators are the energy conversion device used inside a robot. The major function of actuators is to convert energy into movement.
- **Electric motors (DC/AC)-** Motors are electromechanical component used for converting electrical energy into its equivalent mechanical energy. In robots motors are used for providing rotational movement.
- **Sensors -** Sensors provide real time information on the task environment. Robots are equipped with tactile sensor it imitates the mechanical properties of touch receptors of human fingerprints and a vision sensor is used for computing the depth in the environment.
- **Controller -** Controller is a part of robot that coordinates all motion of the mechanical system. It also receives an input from immediate environment through various sensors. The heart of robot's controller is a microprocessor linked with the input/output and monitoring device. The command issued by the controller activates the motion control mechanism, consisting of various controller, actuators and amplifier.

1.6 Robot Locomotion

Locomotion is the method of moving from one place to another. The mechanism that makes a robot capable of moving in its environment is called as robot locomotion.

There are many types of locomotion's:-

- Wheeled
- Legged
- Tracked slip/skid
- Combination of legged and wheeled locomotion

Legged locomotion

- It comes up with the variety of one, two, four, and six legs. If a robot has multiple legs then leg coordination is required for locomotion.
- Legged locomotion consumes more power while demonstrating jump, hop, walk, trot, climb up or down etc.
- It requires more number of motors for accomplish a movement. It is suited for rough as well as smooth terrain where irregular or too smooth surface makes it consume more operational power. It is little difficult to implement because of stability issues.

The total number of possible gaits (a periodic sequence of release and lift events for each of the total legs) a robot can travel depending upon the number of robot legs.

If a robot has K legs, then the number of possible events is,

$$N = (2K-1)!$$

In case of a two-legged robot (K=2), therefore the number of possible events is

$$N = (2K-1)!$$
$$N = (2\times 2-1)!$$
$$N = 3!$$
$$N = 6$$

Hence, there are six possible different events:-

- Lifting the Right leg
- Lifting the Left leg
- Releasing the right leg
- Releasing the left leg
- Releasing both the legs together
- Lifting both the legs together

In case of K=4 legs, there are 5040 possible events. Hence the complexity of robots is dependent on number of legs of robots. On increasing legs of a robot the complexity of robotic system increases.

Wheeled Locomotion

It requires less number of motors for accomplishing a movement. It is little easy to implement as there are lesser stability issues in case of more number of wheels. It is more power efficient as compared to legged locomotion.

- **Castor wheel -** It rotates around the offset steering joint and wheel axle.
- **Standard wheel -** It rotates around the contact and the wheel axle.
- **Ball or spherical wheel -** This wheel is technically difficult to implement due to architectural complexity. It is an Omni directional wheel with only one directional movement is allowed.
- **Swedish 45 and Swedish 90 wheels -** It is an Omni-wheel, which rotates around the contact point, around the wheel axle, and around the rollers.

Slip/Skid Locomotion

In Slip/Skid locomotion the vehicles use tracks as available in a tank. The robot is steered by moving tracks with different speeds in the same or opposite direction. It offers stability because of large contact area of ground and track.

CHAPTER -2

2.0 Artificial Intelligence in Robotics

With the invention of machines or computers, their capability to perform different tasks went on increasing exponentially. Humans have developed the power of computer systems in terms of diverse working domains, with increasing speed, and reducing size with respect to time.

What is Artificial Intelligence

According to the founder of Artificial Intelligence, John McCarthy, it is "The engineering and science developed intelligent machine, especially an intelligent computer programs".

It is a way of developing a computer, a computer-controlled robot, or software that think intelligently, in a similar manner the intelligent humans think.

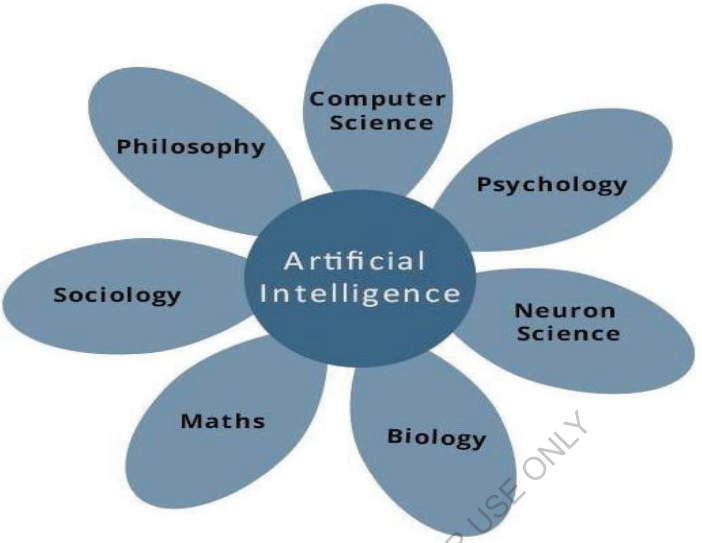
Artificial Intelligence is implemented by studying how human brain thinks and how humans decide, learn, and work while trying to solve a problem, and then using the result of this study as a basis of developing intelligent systems and software.

Goals of Artificial Intelligence

- ✓ **For Implementing Human Intelligence in Machines** - Creating systems that understand, learn, think and behave like humans.
- ✓ **For Developing Expert Systems** - The systems which exhibit intelligent behavior, learn, explain, demonstrate, and advice its users.

2.1 Contributes to Artificial Intelligence

Artificial intelligence is a technology and science based on disciplines such as Psychology, Computer Science, Biology, Mathematics, Linguistics, and Engineering. A major thrust to artificial intelligence is the development of computer functions associated with human intelligence, such as learning, reasoning and problem solving.

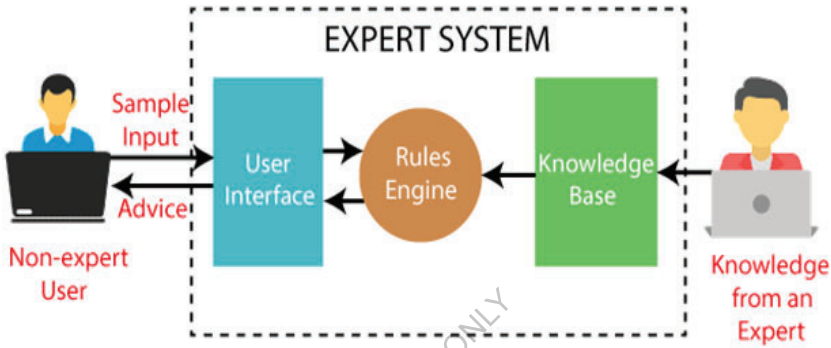


2.2 Programming with and without Artificial Intelligence (AI)

Programming with AI	Programming without AI
AI programs can absorb new modifications by using highly independent pieces of information together. Therefore you can modify even a minute piece of information in a program without affecting its structure.	Modification in a program leads to change in its structure.
A computer program with AI can answer the **generic** questions it is meant to solve.	A computer program without AI can answer the **specific** questions it is meant to solve.
Easy and quick program modification.	Modification is not quick and easy. It may result in affecting the program adversely.

2.3 Application of Artificial Intelligence (AI)

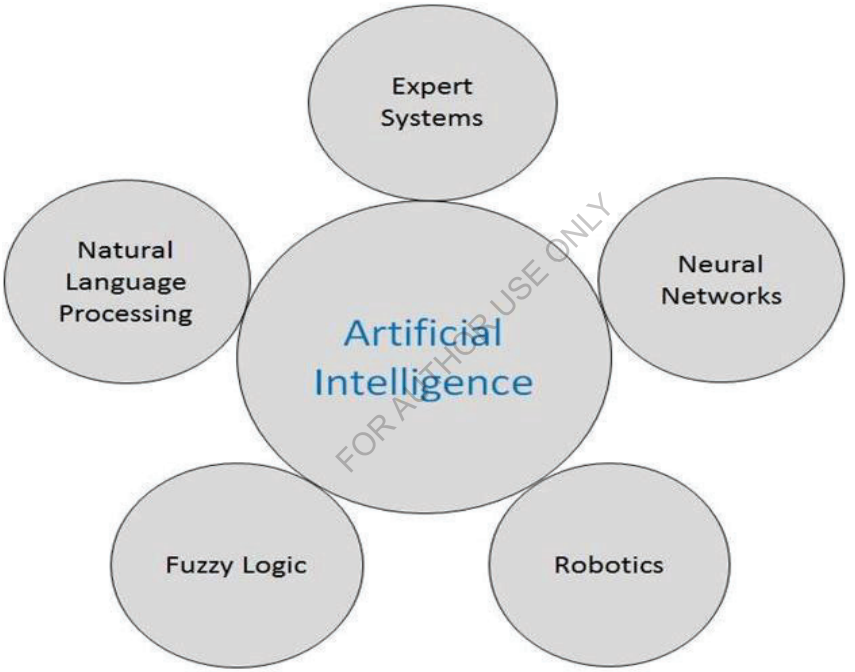
- **Expert Systems -** There are various applications which integrate machine, special information and software to impart advising and reasoning. These systems provide explanation and advice to the users.



- **Gaming -** AI plays major role in strategic games such as poker, chess, tic-tac-toe, etc. Using artificial intelligence the machine can think of large number of possible moves based on general knowledge.
- **Natural Language Processing -** Using natural language processing it is possible to interact with a computer that can understand natural language spoken by humans.
- **Vision systems -** These systems interpret, understand, and comprehend a visual input on the computer.
- **Intelligent Robots -** Robots are designed for performing the tasks given by a human. They have sensors embedded to detect physical data from the outside environment such as heat, light, sound, pressure, etc. They have multiple sensors, efficient processors and large memory, to exhibit intelligence. In addition, they are capable to learn from their mistakes and they can easily adapt to the new environment.

2.4 Artificial Intelligence Research Areas

The working domain of artificial intelligence is huge in width and breadth. Therefore before proceeding further considers the prospering and common research areas in the domain of artificial intelligence are:-



- **Expert System** - In artificial intelligence, an expert system are used for solving complex problems by reasoning about knowledge, represented primarily by if-then rules rather than by conventional procedural code. In general, an expert system is a computer system that uses the decision-making capability of a human expert.
- **Neural Networks -** Neural networks are system of interconnected ?neurons? which exchange messages between each other. In machine learning artificial

neural networks (ANNs) belongs to a family of model inspired by biological neural networks (the nervous system of animals, present inside a brain) and are used for approximate functions or estimate a large number of inputs which are generally unknown.

- **Robotics** - Robotics is a branch of Artificial Intelligence (AI), it is mainly composed of electrical engineering, mechanical engineering and computer science engineering for construction, designing and application of robots. Robotics is science of building or designing an application of robots. The aim of robotics is to design an efficient robot.
- **Fuzzy logic** - Fuzzy logic was introduced in 1965 as a proposal of fuzzy set theory. It is applied to various fields, from artificial intelligence to control theory. Fuzzy logic is a form of many-valued logic in which truth table values of variable may be real number between 0 and 1.
- **Natural Language Processing** - Natural language processing (NLP) is a method of communicating with an intelligent system by using a natural language such as English. The input and output of NLP system is speech and written text.

2.5 Voice and Speech Recognition

Voice and Speech both terms are common in expert systems, natural language processing and robotics. As these terms are used interchangeably, their objectives are different.

The differences between voice and speech recognition are given below:

Voice Recognition	Speech Recognition
The aim of voice recognition is to recognize WHO is speaking.	The aim of speech recognition is to understand and comprehend **WHAT** was spoken.
This recognition system requires training as it is person oriented.	This recognition system does not require training as it is not speaker dependent.
It is used for identifying a person by	It is used for hand-free computing, menu

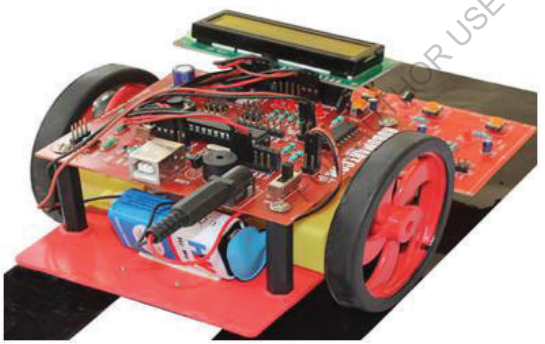
analyzing its voice, tone, pitch, etc	navigation, or map.
Speaker dependent Voice Recognition systems are easy to develop.	Speaker independent Speech Recognition systems are difficult to develop.

2.6 Types of Robots

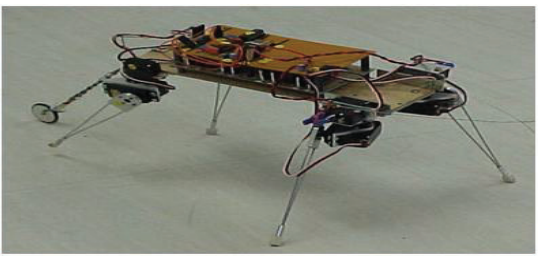
1) Mobile Robots

Mobile robots are able to move from one location to another location using locomotion. It is an automatic machine that is capable of navigating an uncontrolled environment without any requirement of physical and electromechanical guidance devices. Mobile Robots are of two types:

(a) Rolling robots - Rolling robots require wheels to move around. They can easily and quickly search. But they are only useful in flat areas.



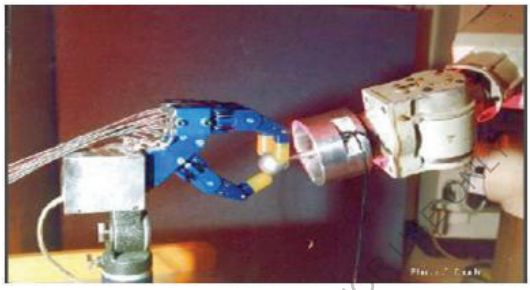
(b) **Walking robots** - Robots with legs are usually used in condition where the terrain is rocky. Most walking robots have at least 4 legs.



2) Industrial Robots

Industrial robots perform same tasks repeatedly without ever moving. These robots are working in industries in which there is requirement of performing dull and repeated tasks suitable for robot.

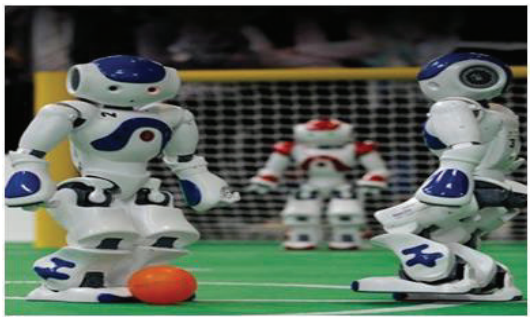
An industrial robot never tired, it will perform their works day and night without ever complaining.



3) Autonomous Robots

Autonomous robots are self-supported. They use a program that provides them the opportunity to decide the action to perform depending on their surroundings.

Using artificial intelligence these robots often learn new behavior. They start with a short routine and adapt this routine to be more successful in a task they perform. Hence, the most successful routine will be repeated.

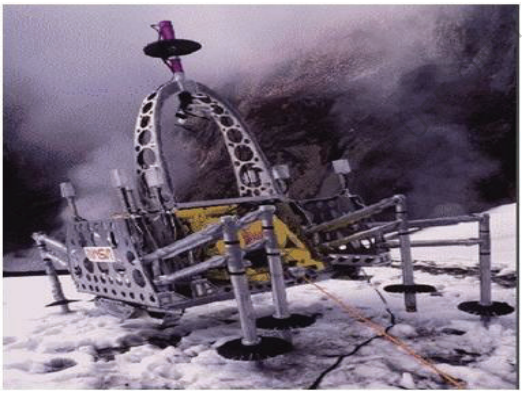


4) Remote Controlled Robots

Remote controlled robot used for performing complicated and undetermined tasks that autonomous robot cannot perform due to uncertainty of operation.

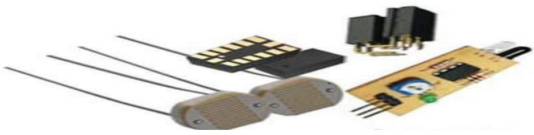
Complicated tasks are best performed by human beings with real brainpower. Therefore a person can guide a robot by using remote. Using remote controlled operation human can perform dangerous tasks without being at the spot where the tasks are performed.

Let's see a NASA robot designed to explore volcanoes via remote control.



2.7 Types of Robot Sensors

There are different type of sensors are available to choose from and the characteristics of sensors are used for determining the type of sensor to be used for particular application.



1) Light Sensor

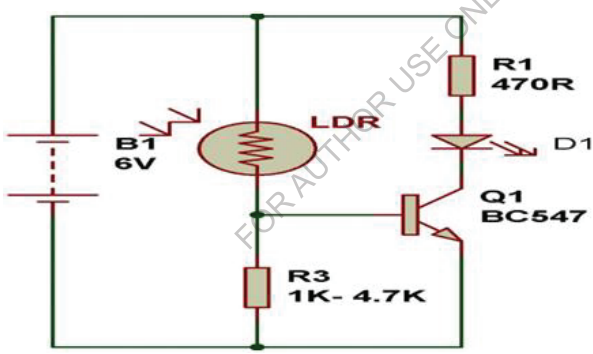
Light sensor is a transducer used for detecting light and creates a voltage difference equivalent to the light intensity fall on a light sensor.

The two main light sensors used in robots are **Photovoltaic cells and Photo resistor.** Other kind of light sensors like phototransistors, phototubes are rarely used.

The type of light sensors used in robotics are:

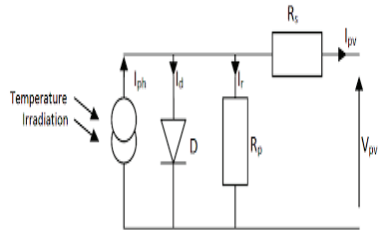
Photo resistor - It is a type of resistor used for detecting the light. In photo resistor resistance varies with change in light intensity. The light falls on photo resistor is inversely proportional to the resistance of the photo resistor. In general photo resistor is also called as Light Dependent Resistor (LDR).

circuit diagram of Photo resistor sensor:



Photovoltaic Cells - Photovoltaic cells are energy conversion device used to convert solar radiation into electrical electric energy. It is used if we are planning to build a solar robot. Individually photovoltaic cells are considered as an energy source, an implementation combined with capacitors and transistors can convert this into a sensor.

circuit diagram of photovoltaic cell :



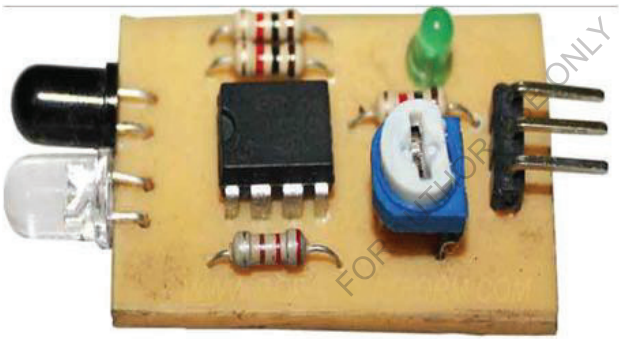
2) Proximity Sensor

Proximity sensor can detect the presence of nearby object without any physical contact. The working of a proximity sensor is simple. In proximity sensor transmitter transmits an electromagnetic radiation and receiver receives and analyzes the return signal for interruptions. Therefore the amount of light receiver receives by surrounding can be used for detecting the presence of nearby object.

Consider the types of proximity sensors used in robotics are:-

Infrared (IR) Transceivers - In IR sensor LED transmit the beam of IR light and if it find an obstacle then the light is reflected back which is captured by an IR receiver.

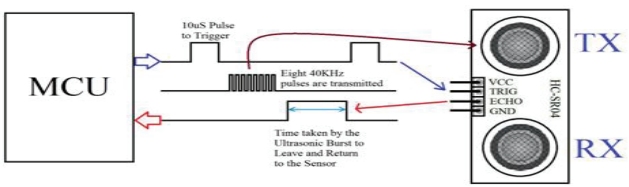
PCB board layout of IR Transceiver circuit:



Ultrasonic Sensor - In ultrasonic sensors high frequency sound waves is generated by transmitter, the received echo pulse suggests an object interruption.

In general ultrasonic sensors are used for distance measurement in robotic system.

interfacing of ultrasonic sensor with Microcontroller unit:

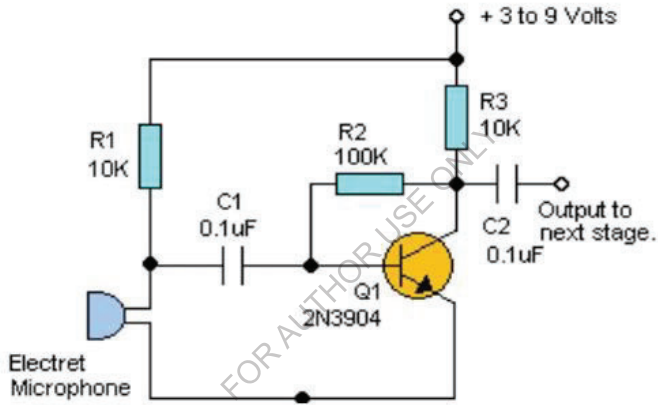


3) Sound Sensor

Sound sensors are generally a microphone used to detect sound and return a voltage equivalent to the sound level. Using sound sensor a simple robot can be designed to navigate based on the sound receives.

Implementation of sound sensors is not easy as light sensors because it generates a very small voltage difference which will be amplified to generate measurable voltage change.

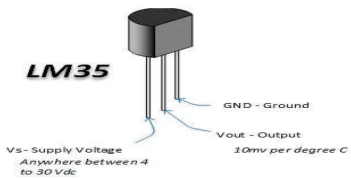
sound sensor based switching circuit:



4) Temperature Sensor

Temperature sensors are used for sensing the change in temperature of the surrounding. It is based on the principle of change in voltage difference for a change in temperature this change in voltage will provide the equivalent temperature value of the surrounding.

Few generally used temperature sensors IC?s are TMP35, TMP37, LM34, LM35, etc.



temperature sensor pin diagram

5) Acceleration Sensor

Acceleration sensor is used for measuring acceleration and tilt. An accelerometer is a device used for measuring acceleration.

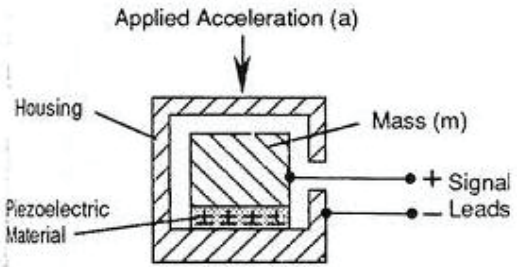
The two kinds of forces which affect an accelerometer is:-

- **Static Force** - It is the frictional force between any two objects. By measuring this gravitational force we can determine the how much robot is tilting. This measurement is useful in balancing robot, or for determining whether robot is driving on a flat surface or uphill.
- **Dynamic Force** - It is the amount of acceleration required to move an object. Measurement of dynamic force using an accelerometer tells about the velocity/speed at which robot is moving.

Accelerometer is comes in different configuration. Always use the one which is most appropriate for your robot. Some factors need to be considered before selecting accelerometer is:

1. Sensitivity
2. Bandwidth
3. Output type: Analog or Digital
4. Number of Axis: 1,2 or 3

Schematic diagram of basic accelerometer:



Basic Accelerometer

CHAPTER -3

3.0 Robotics hardware designing using Eagle Software

This software is Easily Applicable Graphical Layout Editor (EAGLE) used for PCB designing. To design an electronic circuit schematic and layout on Printed Circuit Board (PCB) eagle software is used.

Eagle is a PCB design software package consists of a PCB editor, a schematic editor and an auto router module. This software also provides wide variety of library components, but library editor is also provided for design new parts or modify the existing one.

Why use Eagle:

Eagle is PCB CAD software used for designing hardware of the system. Consider the few reasons why Eagle is preferred over other hardware designing tools:-

- **Lightweight -** It is lightweight software which requires anywhere from 50-200MB of disk space. The installer package is about 25MB. So you can download to install to run for making a PCB very quick.
- **Cross-platform -** Eagle can run on Windows, LINUX, MAC. This is a feature not too many other PCB design software provide.
- **Free/Low-Cost -** The free version of EAGLE provides enough utilization for designing of any PCB using toolbar of software.

Drawing the Schematic:

Using this software we can draw the schematics of Power Supply, an Atmel AtMega16 Microcontroller, LCD, Motor Driver IC (L293D) and remaining I/O-pins connected to headers.

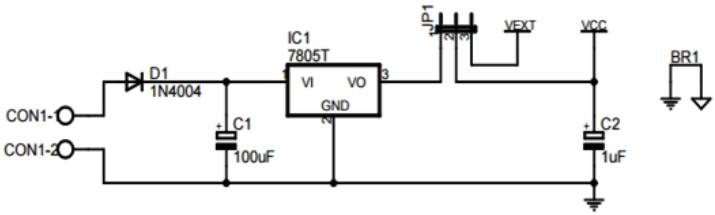
Consider the Eagle Toolbar for editing the schematic of the circuit is,

Using the above tools the desired operation can be performed for drawing schematic structure of the circuit. When adding the components you will notice a small black cross on each device. It is the origin or handle of the device used for manipulate the device with various tools.

Power supply

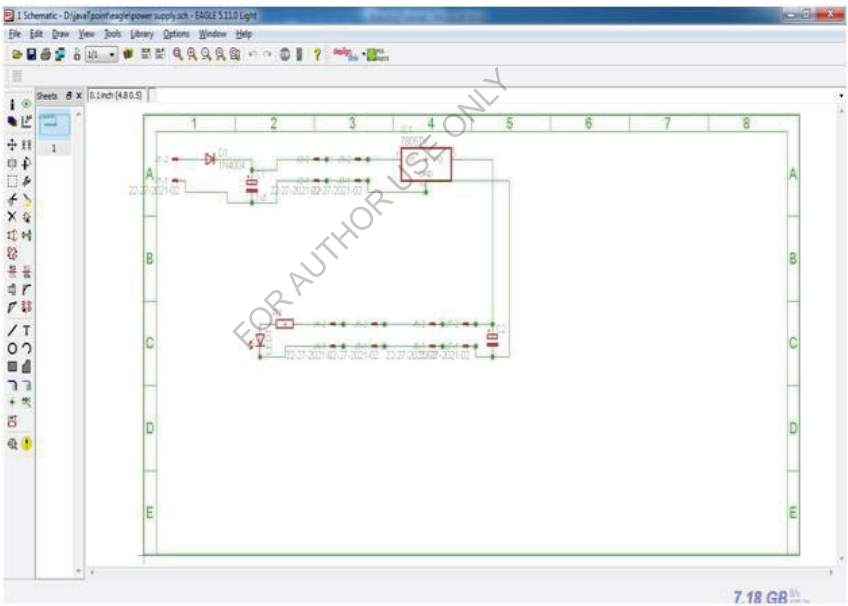
Power supply is the circuit used for converting 220V AC signal to 5V or 10V DC signal required for operation of robot electronic circuit.

Start drawing the power supply in upper left corner of the frame in Eagle software. According to below circuit diagram,



Then use add-command to **add** the components and use the **net**-command to draw the connections.

Consider the schematic representation of power supply circuit on eagle software is,

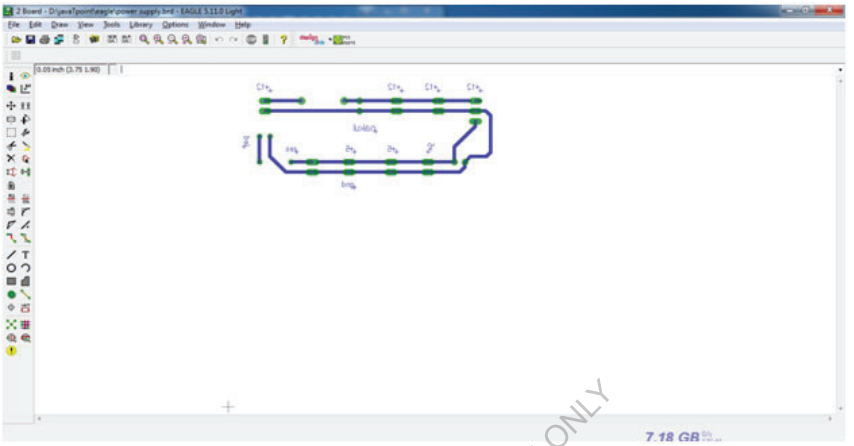


Use **name** command to rename the components.

Use **smash** command to detach the name and value texts from component and it allow them to be positioned with the **move**-command

Use **value** command to change the value of a component.

Consider the PCB board layout after completing the routing between the terminals is,

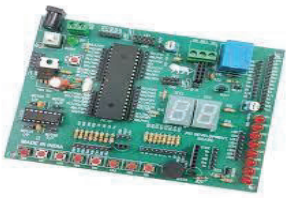


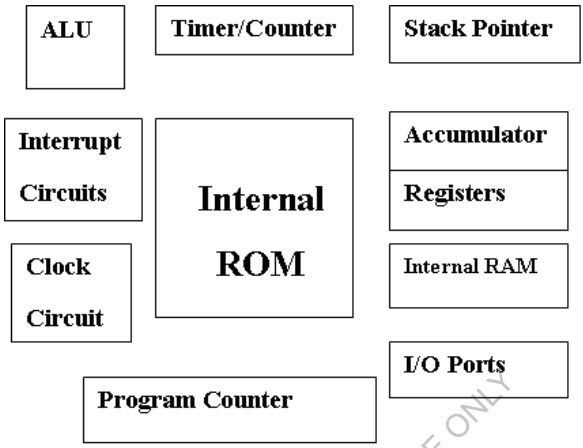
After completion of board layout it is run to generate PDF. The PDF generated is used for taking the printout of above layout on Over Head Projector sheet (known as OHP sheets) or a wax paper for designing a PCB board.

3.1 Microcontroller in Robotics

Microcontroller is the advanced version of microprocessors. It contain on chip central processing unit (CPU), Read only memory (ROM), Random access memory (RAM), input/output unit, interrupts controller etc.

Therefore a microcontroller is used for high speed signal processing operation inside an embedded system. It acts as major component used in designing of an embedded system.



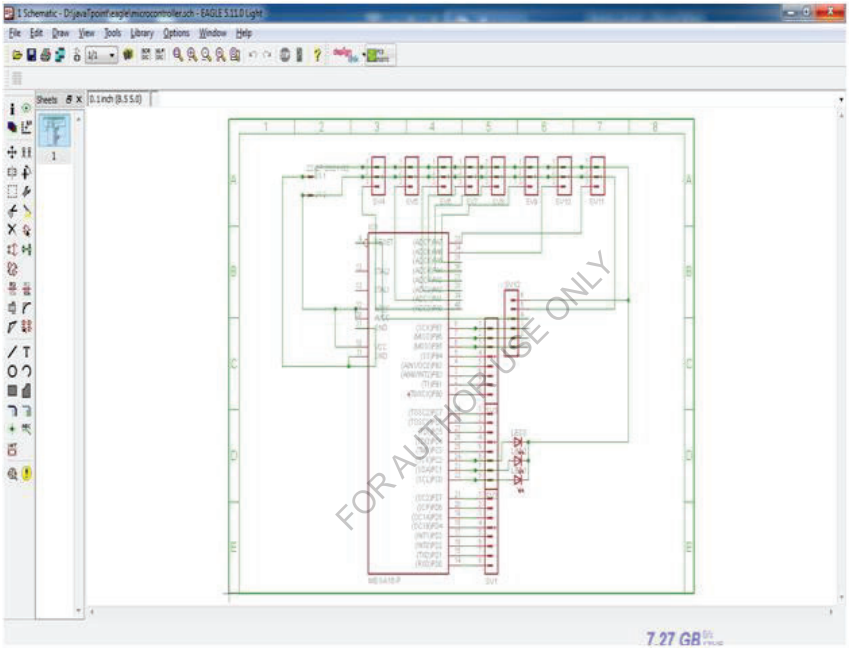


Basic components of Microcontroller

- **Arithmetic and Logic unit (ALU) -** ALU inside a microcontroller used to perform the arithmetic and logic operation. It performs the logic operation on the data stored inside a register.
- **Accumulator -**Accumulator is the register inside which the intermediate arithmetic and logical operation data is stored.
- **Working registers -** Registers are the storage device used to store the data inside a microcontroller in different address location.
- **Program counter -** Program counter is used for counting the number of program executed inside a microcontroller.
- **Stack pointer -** Stack pointer act as a pointer to the certain address. It is a register used to store the address of the last program request made by the processor inside a stack.
- **Clock circuit -** Clock circuit is used for generate the clock pulse required as a reference signal for the microcontroller.
- **Interrupt circuit -** Interrupt circuit is used for generating the interrupt signal when the higher priority process required to be served first on basis of priority by microcontroller.
- **Internal ROM -** Internal ROM is read only memory used to store the information in embedded system. It acts as a main memory for storing the instruction and data inside a microcontroller.

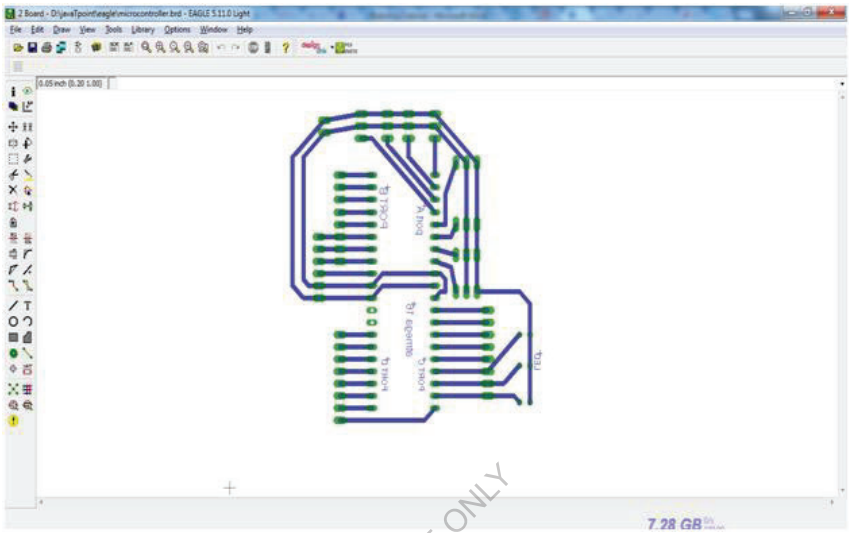
- **I/O ports -** I/O ports are used for connecting input devices like sensor, keyboard etc with input ports and output devices like LCD, buzzer etc with output ports available in microcontroller.

Consider the schematic representation of Atmega-16 Microcontroller circuit on eagle software is,



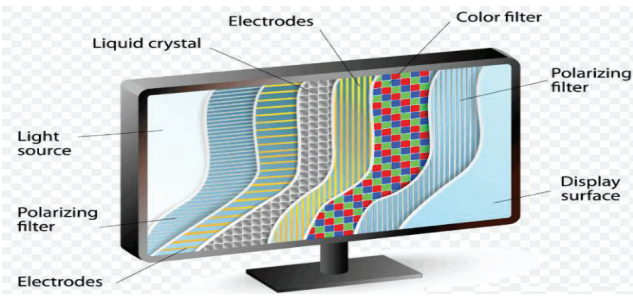
Consider the PCB board layout after completing the routing between the terminals of microcontroller and header is,

After completion of board layout it is run to generate PDF. The PDF generated is used for taking the printout of above layout on Over Head Projector sheet (known as OHP sheets) or a wax paper for designing a PCB board.

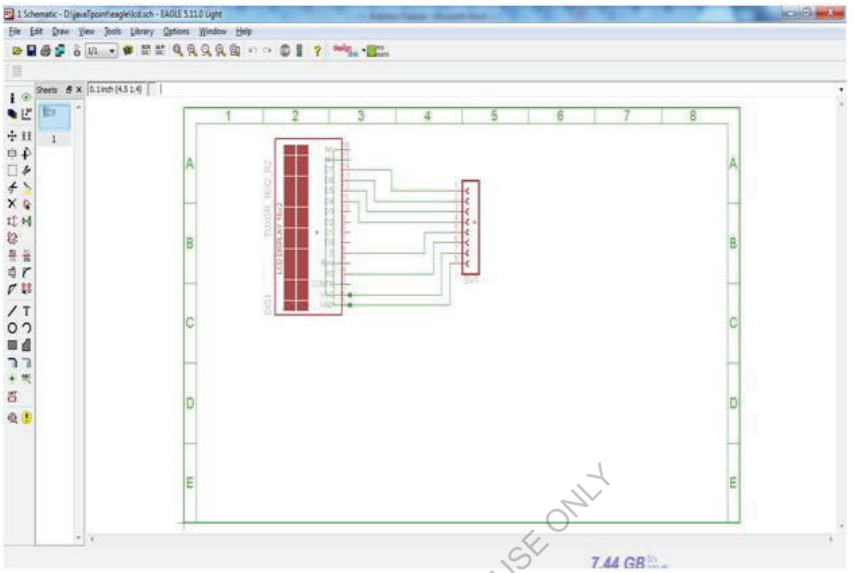


3.2 Liquid Crystal Display (LCD)

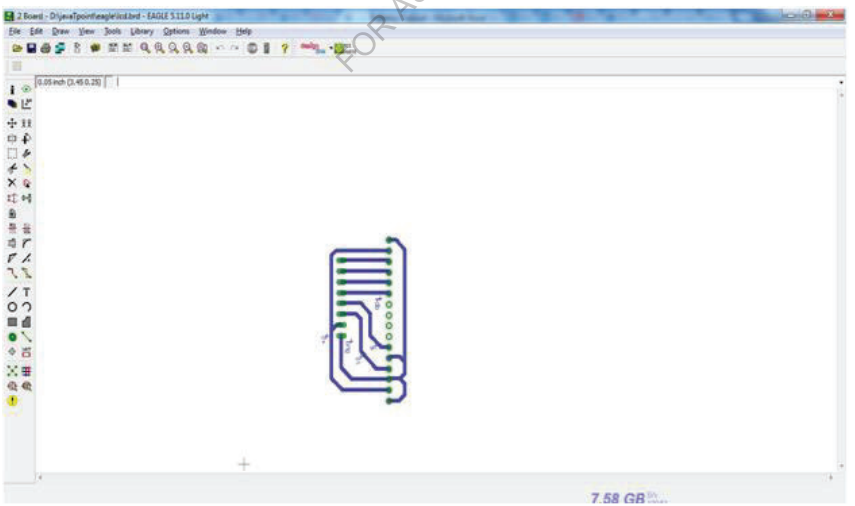
Liquid Crystal Display (LCD) is an electronic device, which is frequently used in many applications for displaying the information in a text or image format. The LCD is used for displaying the alphanumeric character on its screen. The LCD display is consists of 8-data lines and 3-control lines which are used for interfacing the LCD display with 8051 microcontroller.



Consider the schematic representation of LCD on eagle software is,



Consider the PCB board layout after completing the routing between the terminals of LCD and header is.

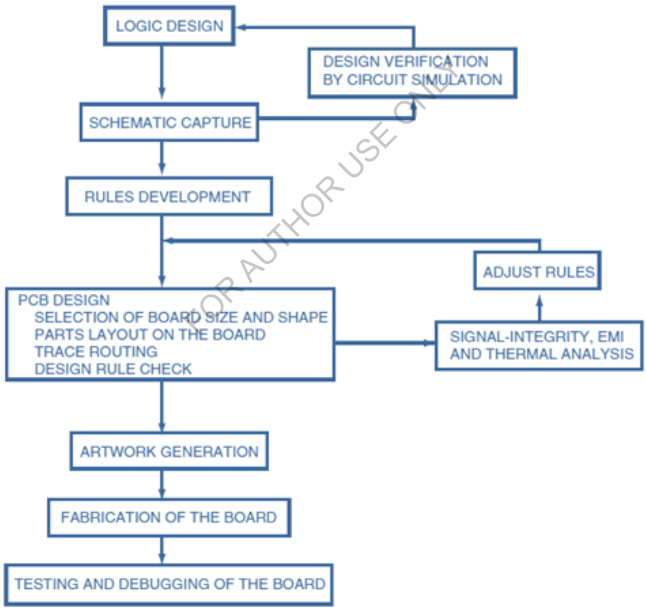


After completion of board layout it is run to generate PDF. The PDF generated is used for taking the printout of above layout on Over Head Projector sheet (known as OHP sheets) or a wax paper for designing a PCB board.

3.3 Designing of PCB (Printed Circuit Board)

Printed circuit board connects electrical components using etched copper pathways and it also provides mechanical strength to the robotic circuit. PCBs are composed of organic and inorganic dielectric materials with many layers.

The overall PCB design flow summarized into the flowchart is as shown below:-



The eagle software is used for generating the layout of the circuit. In PCB copper tracks are used on a conducting sheet. The pre-defined tracks reduce the wiring therefore reduce the faults arising due to lose connections.

Materials required in PCB designing:

- Laser Printer
- Over Head Projector (OHP) sheets or a wax paper.
- Electric Iron
- Two Plastic Trays
- Steel wool
- PCB/ Copper board
- Black permanent marker
- Drill machine
- Etching solution (Ferric Chloride)

So by using above material combination the electronic Hardware required for robots is designed.

3.4 PROJECT: Obstacle Avoider Robot

Obstacle avoider robot is the important part of mobile robotics. Obstacle avoidance is task which is used for detecting the presence of object in a path of robot or any vehicle.

Obstacle avoiding robot is an intelligence device, which is used to protect the robot from any physical damages. It automatically sense and overcome the obstacles on its path.

Working:

In this project, we will study how to design and simulate an obstacle avoider robot using AVR ATmega16 microcontroller and Analog IR Sensor. This robot designed is an automatic robot i.e. no manual control is required for the operation of robot.

In obstacle avoider robot we use ADC of the ATmega16 microcontroller to convert analog signals to digital values. After converting the IR sensors signal into digital equivalent signal i.e. threshold value (3V in our project case). According to the output of above comparison, the microcontroller send the control signal to the DC motor driver Integrated Circuit (L293D) of robot to move the robot in forward, left or right direction. The above operation of sensors output comparison, ADC conversions and robot control continues till the power source is applied.

Hardware Required:

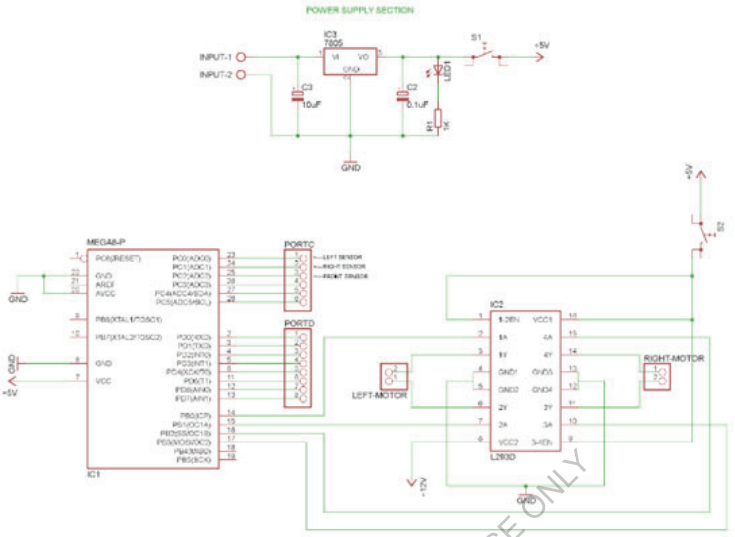
- 12V, 1A DC Adapter-1 piece
- Analog IR Sensor-3 piece
- AVR Microcontroller Board-1 piece
- DC Motor Driver-1 piece
- AVR USB Programmer-1 piece
- 1 to 1 Connector-15 piece
- 10 to 10 FRC Female Connector-2 piece
- Robot-1 piece

Software Required:

- BASCOM-AVR Integrated Development Environment (IDE)
- AVRDUDE-GUI
- WinAVR-2010
- USBasp Driver

Circuit diagram:

Consider the eagle software based circuit diagram of obstacle avoider robot is:-

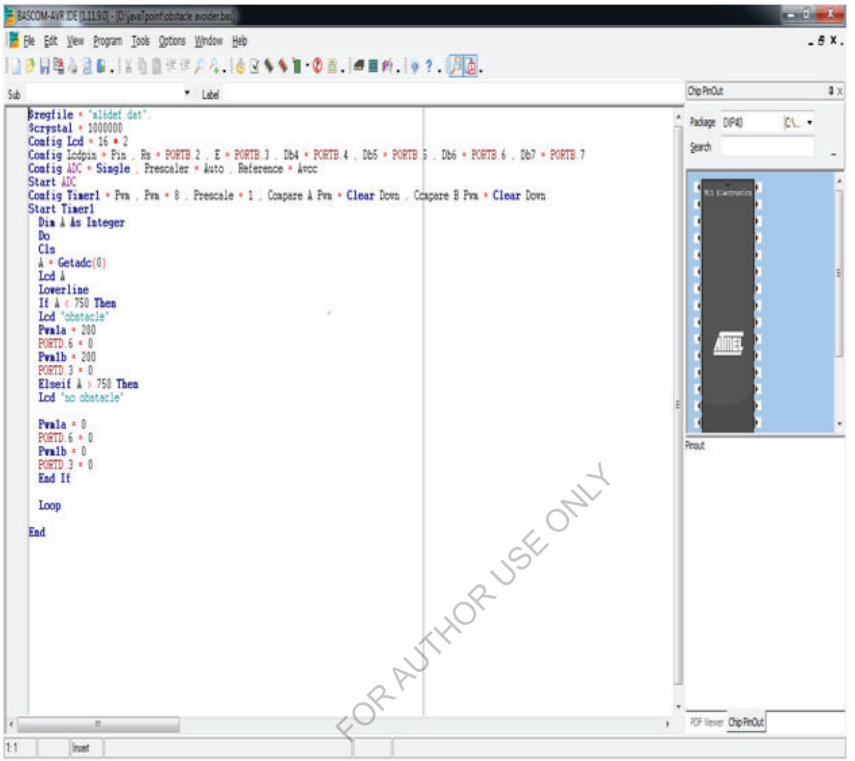


Source Code:

```
1.      $regfile = "m16def.dat".
2.      $crystal = 1000000
3.      Config Lcd = 16 * 2
4.      Config Lcdpin = Pin , Rs = Portb.2 , E = Portb.3 , Db4 = Portb.4 , Db5 = Por
        tb.5 , Db6 = Portb.6 , Db7 = Portb.7
5.      Config Adc = Single , Prescaler = Auto , Reference = Avcc
6.      Start Adc
7.      Config Timer1 = Pwm , Pwm = 8 , Prescale = 1 , Compare A Pwm = Clear
        Down , Compare B Pwm = Clear Down
8.      Start Timer1
9.        Dim A As Integer
10.       Do
11.       Cls
12.       A = Getadc(0)
13.       Lcd A
14.       Lowerline
15.       If A < 750 Then
```

```
16.         Lcd "obstacle"                          '
17.         Pwm1a = 200
18.         Portd.6 = 0
19.         Pwm1b = 200
20.         Portd.3 = 0
21.         Elseif A > 750 Then
22.         Lcd "no obstacle"
23.         Pwm1a = 0
24.         Portd.6 = 0
25.         Pwm1b = 0
26.         Portd.3 = 0
27.         End If
28.         Loop
29.       End
```

Consider the screenshot of source code used in obstacle avoider robot using BASCOM-AVR Integrated Development Environment (IDE) is:-



3.5 Line Follower Robot

What is line follower:

Line follower robot is an autonomous machine that can follow a path. The path can be seen like a white line on a black surface (or vice-versa) or it can be invisible as magnetic field.

Requirement of line follower robot:

Sensing a line and maneuvering the robot to stay on path, while constantly correcting wrong moves by using feedback mechanism forms a simple and effective closed loop system. As a programmer we get an opportunity to ?teach?

the robot how to follow the line therefore it gives robot human like property of responding to stimuli.

Consider the practical application of line follower robot is:

- Guidance system for industrial robots moving on shop floor
- Automated cars running on road with embedded magnet.

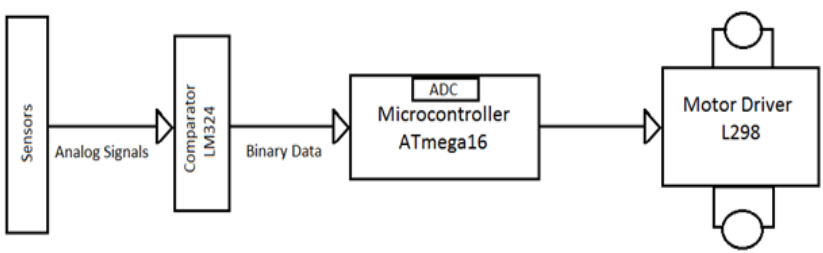
Hardware Required:

- 12V, 1A DC Adapter-1 piece
- Analog IR Sensor-3 piece
- AVR Microcontroller Board-1 piece
- DC Motor Driver-1 piece
- AVR USB Programmer-1 piece
- 1 to 1 Connector-15 piece
- 10 to 10 FRC Female Connector-2 piece
- Robot-1 piece

Software Required:

- BASCOM-AVR Integrated Development Environment (IDE)
- AVRDUDE-GUI
- WinAVR-2010
- USBasp Driver

Block Diagram:



Algorithm:

1. R=rightmost sensor which reads 0, L=leftmost sensor which reads 0. If no sensor on right (or Left) is 0 than L (or R) equals to 0.
2. If all sensor read 1 then go to step 3,

   Else,

   If L<R Move Right

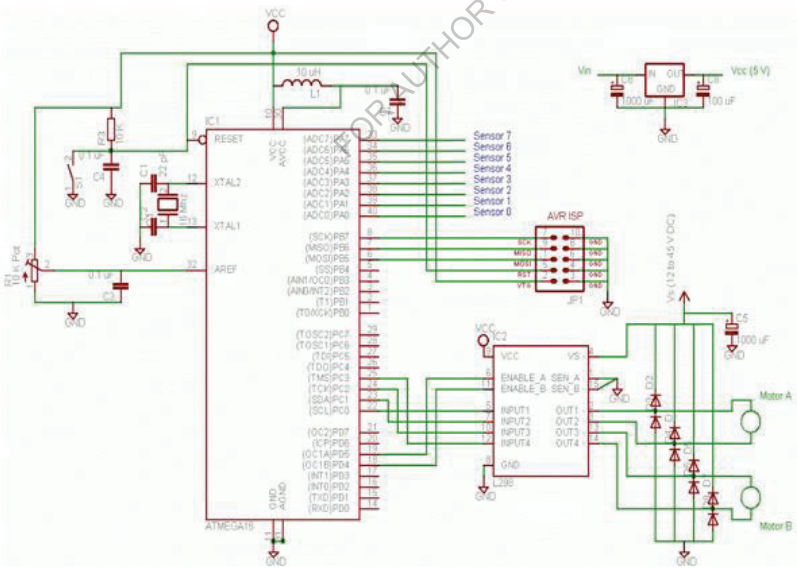
   If L>R Move Left

   If L=R Move Forward

3. Move anticlockwise if line was last seen on Left, Move clockwise if line was last seen on Right. Repeat step 3 till line is found.

Circuit Diagram:

Consider the eagle software based schematic circuit of line follower robot is:-

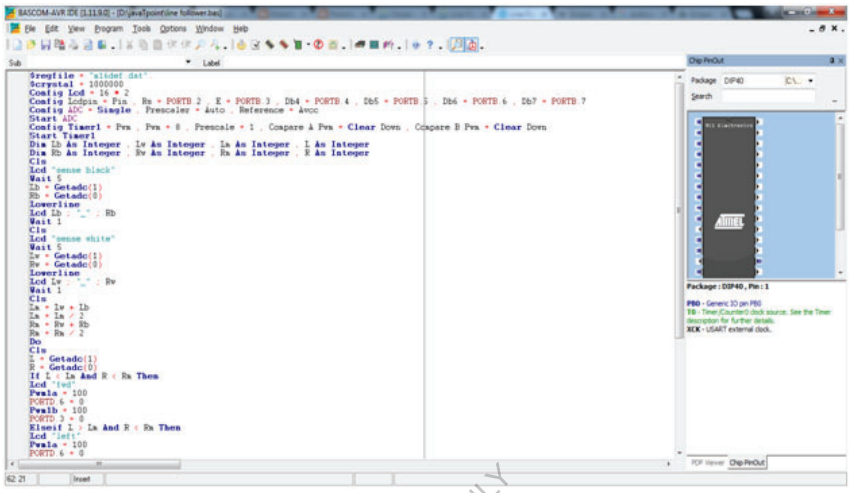


Source Code:

```
1.      $regfile = "m16def.dat".
2.      $crystal = 1000000
3.      Config Lcd = 16 * 2
4.      Config Lcdpin = Pin , Rs = Portb.2 , E = Portb.3 , Db4 = Portb.4 , Db5 = Por
    tb.5 , Db6 = Portb.6 , Db7 = Portb.7
5.      Config Adc = Single , Prescaler = Auto , Reference = Avcc
6.      Start Adc
7.      Config Timer1 = Pwm , Pwm = 8 , Prescale = 1 , Compare A Pwm = Clear
    Down , Compare B Pwm = Clear Down
8.      Start Timer1
9.      Dim Lb As Integer , Lw As Integer , Lm As Integer , L As Integer
10.     Dim Rb As Integer , Rw As Integer , Rm As Integer , R As Integer
11.     Cls
12.     Lcd "sense black"
13.     Wait 5
14.     Lb = Getadc(1)
15.     Rb = Getadc(0)
16.     Lowerline
17.     Lcd Lb ; "_" ; Rb
18.     Wait 1
19.     Cls
20.     Lcd "sense white"
21.     Wait 5
22.     Lw = Getadc(1)
23.     Rw = Getadc(0)
24.     Lowerline
25.     Lcd Lw ; "_" ; Rw
26.     Wait 1
27.     Cls
28.     Lm = Lw + Lb
29.     LmLm = Lm / 2
30.     Rm = Rw + Rb
31.     RmRm = Rm / 2
```

```
32.     Do
33.     Cls
34.     L = Getadc(1)
35.     R = Getadc(0)
36.     If L < Lm And R < Rm Then
37.     Lcd "fwd"
38.     Pwm1a = 100
39.     Portd.6 = 0
40.     Pwm1b = 100
41.     Portd.3 = 0
42.     Elseif L > Lm And R < Rm Then
43.     Lcd "left"
44.     Pwm1a = 100
45.     Portd.6 = 0
46.     Pwm1b = 0
47.     Portd.3 = 0
48.     Elseif L < Lm And R > Rm Then
49.     Lcd "right"
50.     Pwm1a = 0
51.     Portd.6 = 0
52.     Pwm1b = 100
53.     Portd.3 = 0
54.     Elseif L > Lm And R > Rm Then
55.     Lcd "stop"
56.     Pwm1a = 0
57.     Portd.6 = 0
58.     Pwm1b = 0
59.     Portd.3 = 0
60.     End If
61.     Loop
62.     End
```

Consider the screenshot of source code used in Line Follower robot using BASCOM-AVR Integrated Development Environment (IDE) is:-



CHAPTER - 4

4.0 Robotics and Artificial Intelligence

Robotics is a separate entity in Artificial Intelligence that helps study the creation of intelligent robots or machines. Robotics combines electrical engineering, mechanical engineering and computer science & engineering as they have mechanical construction, electrical component and programmed with programming language. Although, Robotics and Artificial Intelligence both have different objectives and applications, but most people treat robotics as a subset of Artificial Intelligence (AI). Robot machines look very similar to humans, and also, they can perform like humans, if enabled with AI.

In earlier days, robotic applications were very limited, but now they have become smarter and more efficient by combining with Artificial Intelligence. AI has played a crucial role in the industrial sector by replacing humans in terms of productivity and quality. In this article, 'Robotics and Artificial Intelligence, we will discuss Robots & Artificial Intelligence and their various applications, advantages, differences, etc. Let's start with the definition of Artificial Intelligence (AI) and Robots.

What is Artificial Intelligence?

Artificial Intelligence is defined as the branch of Computer Science & Engineering, which deals with creating intelligent machines that perform like humans. Artificial Intelligence helps to enable machines to sense, comprehend, act and learn human like activities. There are mainly 4 types of Artificial Intelligence: **reactive machines, limited memory, theory of mind, and self-awareness.**

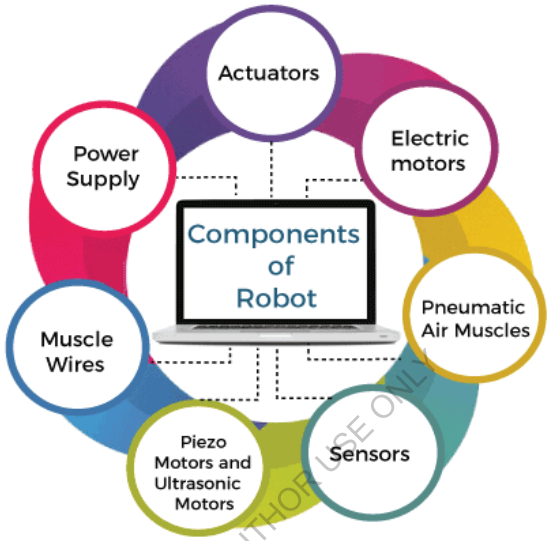
What is a robot?

“A robot is a machine that looks like a human, and is capable of performing out of box actions and replicating certain human movements automatically by means of commands given to it using programming”

. Examples: Drug Compounding Robot, Automotive Industry Robots, Order Picking Robots, Industrial Floor Scrubbers and Sage Automation Gantry Robots, etc.

4.1 Components of Robot

Several components construct a robot, these components are as follows:



- **Actuators:** Actuators are the devices that are responsible for moving and controlling a system or machine. It helps to achieve physical movements by converting energy like electrical, hydraulic and air, etc. Actuators can create linear as well as rotary motion.
- **Power Supply:** It is an electrical device that supplies electrical power to an electrical load. The primary function of the power supply is to convert electrical current to power the load.
- **Electric Motors:** These are the devices that convert electrical energy into mechanical energy and are required for the rotational motion of the machines.
- **Pneumatic Air Muscles:** Air Muscles are soft pneumatic devices that are ideally best fitted for robotics. They can contract and extend and operate by pressurized air filling a pneumatic bladder. Whenever air is introduced, it can contract up to 40%.
- **Muscles wire:** These are made up of nickel-titanium alloy called Nitinol and are very thin in shape. It can also extend and contract when a specific

amount of heat and electric current is supplied into it. Also, it can be formed and bent into different shapes when it is in its martensitic form. They can contract by 5% when electrical current passes through them.

- **Piezo Motors and Ultrasonic Motors:** Piezoelectric motors or Piezo motors are the electrical devices that receive an electric signal and apply a directional force to an opposing ceramic plate. It helps a robot to move in the desired direction. These are the best suited electrical motors for industrial robots.
- **Sensor:** They provide the ability like see, hear, touch and movement like humans. Sensors are the devices or machines which help to detect the events or changes in the environment and send data to the computer processor. These devices are usually equipped with other electronic devices. Similar to human organs, the electrical sensor also plays a crucial role in Artificial Intelligence & robotics. AI algorithms control robots by sensing the environment, and it provides real-time information to computer processors.

4.2 AI technology used in Robotics

Computer Vision

Robots can also see, and this is possible by one of the popular Artificial Intelligence technologies named Computer vision. Computer Vision plays a crucial role in all industries like health, entertainment, medical, military, mining, etc.

Computer Vision is an important domain of Artificial Intelligence that helps in extracting meaningful information from images, videos and visual inputs and take action accordingly.

Natural Language Processing

NLP (Natural Languages Processing) can be used to give voice commands to AI robots. It creates a strong human-robot interaction. NLP is a specific area of Artificial Intelligence that enables the communication between humans and robots. Through the NLP technique, the robot can understand and reproduce human language. Some robots are equipped with NLP so that we can't differentiate between humans and robots.

Similarly, in the health care sector, robots powered by Natural Language Processing may help physicians to observe the decease details and automatically fill in EHR. Besides recognizing human language, it can learn common uses, such as learn the accent, and predict how humans speak.

Edge Computing

Edge computing in robots is defined as a service provider of robot integration, testing, design and simulation. Edge computing in robotics provides better data management, lower connectivity cost, better security practices, more reliable and uninterrupted connection.

Complex Event Process

Complex event processing (CEP) is a concept that helps us to understand the processing of multiple events in real time. An event is described as a Change of State, and one or more events combine to define a Complex event. The complex event process is most widely used term in various industries such as healthcare, finance, security, marketing, etc. It is primarily used in credit card fraud detection and also in stock marketing field.

For example, the deployment of an airbag in a car is a complex event based on the data from multiple sensors in real-time. This idea is used in Robotics, for example, Event-Processing in Autonomous Robot Programming.

Transfer Learning and AI

This is the technique used to solve a problem with the help of another problem that is already solved. In Transfer learning technique, knowledge gained from solving one problem can be implement to solve related problem. We can understand it with an example such as the model used for identifying a circle shape can also be used to identify a square shape.

Transfer learning reuses the pre-trained model for a related problem, and only the last layer of the model is trained, which is relatively less time consuming and cheaper. In robotics, transfer learning can be used to train one machine with the help of other machines.

Reinforcement Learning

Reinforcement learning is a feedback-based learning method in machine learning that enables an AI agent to learn and explore the environment, perform actions and learn automatically from experience or feedback for each action. Further, it is also

having feature of autonomously learn to behave optimally through hit-and-trail action while interacting with the environment. It is primarily used to develop the sequence of decisions and achieve the goals in uncertain and potentially complex environment. In robotics, robots explore the environment and learn about it through hit and trial. For each action, he gets rewarded (positive or negative). Reinforcement learning provides Robotics with a framework to design and simulate sophisticated and hard-to-engineer behaviours.

Affective computing

Affective computing is a field of study that deals with developing systems that can identify, interpret, process, and simulate human emotions. Affective computing aims to endow robots with emotional intelligence to hope that robots can be endowed with human-like capabilities of observation, interpretation, and emotion expression.

Mixed Reality

Mixed Reality is also an emerging domain. It is mainly used in the field of programming by demonstration (PbD). PbD creates a prototyping mechanism for algorithms using a combination of physical and virtual objects.

4.3 What are Artificially Intelligent Robots

Artificial intelligent robots connect AI with robotics. AI robots are controlled by AI programs and use different AI technologies, such as Machine learning, computer vision, RL learning, etc. Usually, most robots are not AI robots, these robots are programmed to perform repetitive series of movements, and they don't need any AI to perform their task. However, these robots are limited in functionality.

AI algorithms are necessary when you want to allow the robot to perform more complex tasks.

A warehousing robot might use a path-finding algorithm to navigate around the warehouse. A drone might use autonomous navigation to return home when it is about to run out of battery. A self-driving car might use a combination of AI algorithms to detect and avoid potential hazards on the road. All these are the examples of artificially intelligent robots.

Advantages of integrating Artificial Intelligence into robotics

- The major advantages of artificially intelligent robots are social care. They can guide people, especially come to aid for older people, with chatbot like social skills and advanced processors.
- Robotics also helps in Agricultural industry with the help of developing AI based robots. These robots reduce the farmer's workload.
- In Military industry, Military bots can spy through speech and vision detectors, along with saving lives by replacing infantry
- Robotics also employed in volcanoes, deep oceans, extremely cold places, or even in space where normally humans can't survive.
- Robotics is also used in medical and healthcare industry as it can also perform complex surgeries that have a higher risk of a mistake by humans, but with a pre-set of instructions and added Intelligence. AI integrated robotics could reduce the number of casualties greatly.

4.4 Difference in Robot System and AI Programs

Here is the difference between Artificial Intelligence and Robots:

1. AI Programs

Usually, we use to operate them in computer-simulated worlds.

Generally, input is given in the form of symbols and rules.

To operate this, we need general-purpose/Special-purpose computers.

2. Robots

Generally, we use robots to operate in the real physical world.

Inputs are given in the form of the analogue signal or in the form of the speech waveform.

Also, to operate this, special hardware with sensors and effectors are needed.

4.5 Future of Artificial Intelligence

Undoubtedly, Artificial Intelligence (AI) is a revolutionary field of computer science, which is ready to become the main component of various emerging technologies like big data, robotics, and IoT. It will continue to act as a technological innovator in the coming years. In just a few years, AI has become a reality from fantasy. Machines that help humans with intelligence are not just in sci-fi movies but also in the real world. At this time, we live in a world of Artificial Intelligence that was just a story though for some years.

Artificial Intelligence (AI) at Present

Before going deep dive into AI in future, first, let's understand what is Artificial Intelligence and at what stage it is at present. We can define AI as, "**It is the ability of machines or computer-controlled robot to perform task that are associated with intelligence.**" So, AI is computer science, which aims to develop intelligent machines that can mimic human behavior.

Based on capabilities, AI can be divided into three types that are:

- **Narrow AI**: It is capable of completing dedicated tasks with intelligence. The **current stage of AI is narrow AI.**
- **General AI**: Artificial General Intelligence or AGI defines the machines that can show human intelligence.
- **Super AI**: Super AI refers to self-aware AI with cognitive abilities that surpass that of humans. It is a level where machines can do any task that a human can do with cognitive properties.
- **At the current stage, AI is known as Narrow AI or Weak AI, which can only perform dedicated tasks**. For example, **self-driving cars, speech recognition, etc.**

4.5 Myths about Advanced Artificial Intelligence

1. Super intelligence by the year 2100 is not possible.

The reality about the possibility of super intelligence is that currently, we can't determine it. It may occur in decades, or centuries, or may never, but nothing is confirmed. There have been several surveys in which AI researchers have been asked how many years from now they think we will have human-scale AI with at least a 50% chance. All of these surveys have the same conclusion: The world's leading experts disagree, so we don't know. For example, in such a survey of AI researchers at the 2015 **Puerto Rico AI conference**, the (average) answer was by 2045, but some researchers estimated hundreds of years or more.

2. I will replace all human jobs.

It's certainly true that the advent of AI and automation has the potential to disrupt labour seriously - and in many situations, it is already doing just that. However, seeing this as a straightforward transfer of labour from humans to machines is a vast oversimplification.

With the development of AI, a revolution has come in industries of every sector, and people fear losing jobs with the increased development of AI. But in reality, AI has come up with more jobs and opportunities for people in every sector. Every machine needs a human being to operate it. However, AI has taken over some roles, but it reverts to producing more jobs for people.

3. Super-intelligent computers will become better than humans at doing anything we can do

As discussed above, AI can be divided into three types, **Weak AI**, which can perform specific tasks, such as weather Prediction. **General AI;** Capable of performing the task as a human can do, **Super AI**; AI capable of performing any task better than human.

At present, we are using weak AI that performs a particular task and improves its performance. On the other hand, general AI and Super AI are not yet developed, and researches are going on. They will be capable of doing different tasks similar to human intelligence. However, the development of such AI is far away, and it will take years or centuries to create such AI applications. Moreover, the efficiency of such AI, whether it will be better than humans, is not predictable at the current stage.

4. AI does not require human intervention.

People also have a misconception that AI does not need any human intervention. But the fact is that AI is not yet developed to take their own decisions. A machine learning engineer/specialist is required to pre-process the data, prepare the models, prepare a training dataset, identify the bias and variance and eliminate them, etc. Each AI model is still dependent on humans. However, once the model is prepared, it improves its performance on its own from the experiences.

How can Artificial Intelligence be risky?

Most of the researchers agree that super AI cannot show human emotions such as Love, hate or kindness. Moreover, we should not expect an AI to become

intentionally generous or spiteful. Further, if we talk about AI to be risky, there can be mainly two scenarios, which are:

1. AI is programmed to do something destructive:

Autonomous weapons are artificial intelligence systems that are programmed to kill. In the hands of the wrong person, these weapons could easily cause mass casualties. Moreover, an AI arms race could inadvertently lead to an AI war resulting in mass casualties. To avoid being dissatisfied with the enemy, these weapons would be designed to be extremely difficult to "turn off," so humans could plausibly lose control of such a situation. This risk is present even with narrow AI but grows as levels of AI intelligence and autonomy increase.

2. **Misalignment between our goals and machines:**

The second possibility of AI as a risky technology is that if intelligent AI is designed to do something beneficial, it develops destructive results. For example, Suppose we ask the self-driving car to "take us at our destination as fast as possible." The machine will immediately follow our instructions. It may be dangerous for human lives until we specify that traffic rules should also be followed and we value human life. It may break traffic rules or meet with an accident, which was not really what we wanted, but it did what we have asked to it. **So, super-intelligent machines can be destructive if they ask to accomplish a goal that doesn't meet our requirements.**

4.6 Future impact of AI in different sectors

Healthcare:

AI will play a vital role in the healthcare sector for diagnosing diseases quickly and more accurately. New drug discovery will be faster and cost-effective with the help of AI. It will also enhance the patient engagement in their care and also make **ease appointment scheduling, bill paying**, with fewer errors. However, apart from these beneficial uses, one great challenge of AI in healthcare is to ensure its adoption in daily clinical practices.

Cyber security:

Undoubtedly, cyber security is a priority of each organization to ensure data security. There are some predictions that cyber security with AI will have below changes:

- With AI tools, security incidents will be monitored.
- Identification of the origin of cyber-attacks with NLP.
- Automation of rule-based tasks and processes with the help of RPA bots.

However, being a great technology, it can also be used as a threat by attackers. They can use AI in a non-ethical way by using automated attacks that may be intangible to defend.

Transportation:

The fully autonomous vehicle is not yet developed in the transportation sector, but researchers are reaching in this field. AI and machine learning are being applied in the cockpit to help reduce workload, handle pilot stress and fatigue, and improve on-time performance. There are several challenges to the adoption of AI in transportation, especially in areas of public transportation. There's a great risk of over-dependence on automatic and autonomous systems.

E-commerce:

Artificial Intelligence will play a vital role in the e-commerce sector shortly. It will positively impact each aspect of the e-commerce sector, ranging from user experience to marketing and distribution of products. We can expect e-commerce with automated warehouse and inventory, shopper personalization, and the use of chatbots in future.

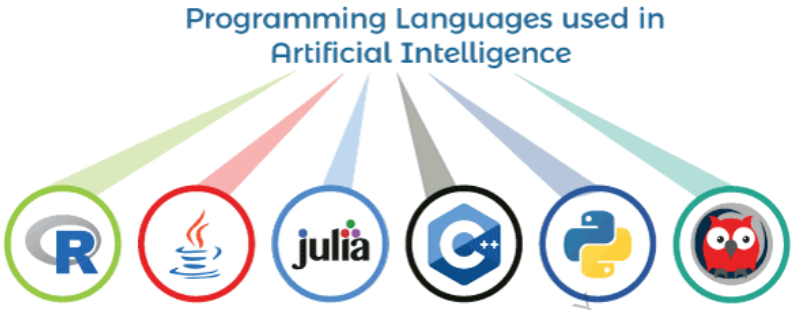
Employment:

Nowadays, employment has become easy for job seekers and simple for employers due to the use of Artificial Intelligence. AI has already been used in the job search market with strict rules and algorithms that automatically reject an employee's resume if it does not fulfil the requirement of the company. It is hoping that the employment process will be driven by most AI-enabled applications ranging from marking the written interviews to telephonic rounds in the future.

For jobseekers, various AI applications are helping build awesome resumes and find the best job as per your skills, such as **Rezi, Jobseeker,** etc.

4.7 Languages used in Artificial Intelligence

Artificial Intelligence has become an important part of human life as we are now highly dependent on machines. Artificial Intelligence is a very important technology to develop and build new computer programs and systems, which can be used to simulate various intelligence processes like learning, reasoning, etc.



- **Python**
- **R**
- **Lisp**
- **Java**
- **C++**
- **Julia**
- **Prolog**

1. Python

Python is one of the most powerful and easy programming languages that anyone can start to learn. Python is initially developed in the early stage of 1991. Most of the developers and programmers choose Python as their favourite programming language for developing Artificial Intelligence solutions. Python is worldwide popular among all developers and experts because it has more career opportunities than any other programming language.

Python also comes with some default sets of standards libraries and also provides better community support to its users. Further, Python is a platform-independent language and also provides an extensive framework for Deep Learning, Machine Learning, and Artificial Intelligence.

Python is also a portable language as it is used on various platforms such as **Linux, Windows, Mac OS, and UNIX.**

Features of Python

- It is easy to learn than any other programming language.
- It is also a dynamically-typed language.
- Python is an Object-oriented language.
- It provides extensive community support and a framework for ML and DL.
- Open-source.
- Large standard sets of libraries.
- Interpreted language.

Python is an ideal programming language used for Machine Language, Natural Processing Language (NLP), and Neural networks, etc. Due to the flexible nature of Python, it can be used for AI development. It contains various pre-existing libraries such as Pandas, SciPy and nltk, etc. Further, Python also contains simple syntax and easy coding, which makes Python the first choice of AI developers and programmers.

There are some standard Libraries in Python used for Artificial Intelligence as follows:

1. Tensor Flow Python
2. Keras Python
3. Theano Python
4. Scikit-Learn Python
5. PyTorch Python
6. NumPy Python
7. Python Pandas
8. Seaborn Python

2. Java

Java is also the most widely used programming language by all developers and programmers to develop machine learning solutions and enterprise development. Similar to Python, Java is also a platform-independent language as it can also be easily implemented on various platforms. Further, Java is an object-oriented and scalable programming language. Java allows virtual machine technology that helps to create a single version of the app and provides support to your business. The best thing about Java is once it is written and compiled on one platform, then you do not need to compile it again and again. This is known as WORA (Once Written Read/Run Anywhere) principle.

Features of Java

Java has so many features which make Java best in industry and to develop artificial intelligence applications:

- Portability
- Cross-platform.
- Easy to learn and use.
- Easy-to-code Algorithms.
- Built-in garbage collector.
- Swing and Standard Widget Toolkit.
- Simplified work with large-scale projects.
- Better user interaction.
- Easy to debug.

3. Prolog

Prolog is one of the oldest programming languages used for Artificial Intelligence solutions. Prolog stands for "**Programming in Logic**", which was developed by French scientist Alain Colmerauer in 1970.

For AI programming in Prolog, developers need to define the rules, facts, and the end goal. After defining these three, the prolog tries to discover the connection between them. Programming in AI using Prolog is different and has several advantages and disadvantages.

It may seem like a bizarre language to learn for those programmers who are from a C++ background.

Prolog may not be a great programming language to build something big, but it's a great language to study and think about problems in more logical ways rather than procedural.

Features of Prolog

- Supports basic mechanisms such as
- Pattern Matching,
- Tree-based data structuring, and
- Automatic backtracking.
- Prolog is a declarative language rather than imperative

4. Lisp

Lisp has been around for a very long time and has been widely used for scientific research in the fields of natural languages, theorem proofs, and to solve artificial intelligence problems. Lisp was originally created as a practical mathematical notation for programs but eventually became a top choice of developers in the field of AI.

Although Lisp programming language is the second oldest language after Fortran, it is still being used because of its crucial features. The inventor of LISP programming was **John McCarthy**, who coined the term Artificial Intelligence.

LISP is one of the most efficient programming languages for solving specific problems. Currently, it is mainly used for machine learning and inductive logic problems. It has also influenced the creation of other programming languages for AI, and some worth examples are **R** and **Julia.**

However, though being so flexible, it has various deficiencies, such as lack of well-known libraries, not so-human-friendly syntax, etc. Due to this reason, it is not preferred by the programmers.

Features of LISP

- The program can be easily modified, similar to data.
- Make use of recursion for control structure rather than iteration.
- Garbage Collection is necessary.
- We can easily execute data structures as programs.
- An object can be created dynamically.

5. R

R is one of the great languages for statistical processing in programming. However, R supports free, open-source programming language for data analysis purposes. It may not be the perfect language for AI, but it provides great performance while dealing with large numbers.

Some inbuilt features such as **built-in functional programming, object-oriented nature, and vectorial computation** make it a worthwhile programming language for AI.

R contains several packages that are specially designed for AI, which are:

- **gmodels** - This package provides different tools for the model fitting task.
- **TM** - It is a great framework that is used for text mining applications.
- **RODBC** - It is an ODBC interface.
- **OneR** - This package is used to implement the One Rule Machine Learning classification algorithm.

Features of R programming

- R is an open-source programming language, which is free of cost, and also you can add packages for other functionalities.
- R provides strong & interactive graphics capability to users.
- It enables you to perform complex statistical calculations.
- It is widely used in machine learning and AI due to its high-performance capabilities.

6. Julia

Julia is one of the newer languages on the list and was created to focus on performance computing in scientific and technical fields. Julia includes several features that directly apply to AI programming.

Julia is a comparatively new language, which is mainly suited for numerical analysis and computational science. It contains several features that can be very helpful in AI programming.

Features of Julia

- Common numeric data types.
- Arbitrary precision values.
- Robust mathematical functions.
- Tuples, dictionaries, and code introspection.
- Built-in package manager.
- Dynamic type system.
- Ability to work for both parallel and distributed computing.
- Macros and metaprogramming capabilities.
- Support for multiple dispatches.
- Support for C functions.

7. C++

C++ language has been present for so long around, but still being a top and popular programming language among developers. It provides better handling for AI models while developing.

Although C++ may not be the first choice of developers for AI programming, various machine learning and deep learning libraries are written in the C++ language.

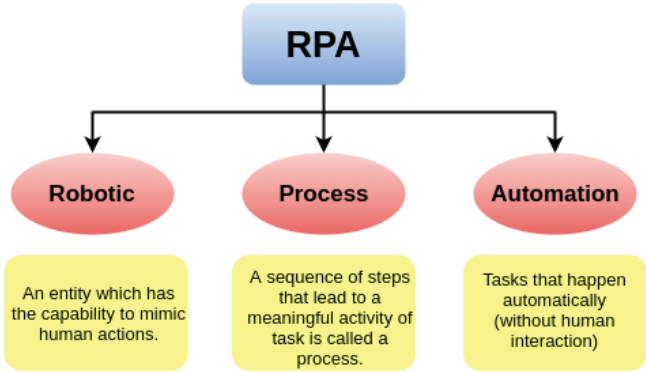
Features of C++

- C++ is one of the fastest languages, and it can be used in statistical techniques.
- It can be used with ML algorithms for fast execution.
- Most of the libraries and packages available for Machine learning and AI are written in C++.
- It is a user friendly and simple language.

CHAPTER -5

5.0 What is RPA

RPA stands for **Robotic Process Automation.** It is the technology used for software tools that automate human tasks, which are manual, rule-based, or repetitive. Typically, it is like a bot that performs such tasks at a much higher rate than a human alone. These RPA software bots never sleep and make zero mistakes, and can interact with in-house applications, websites, user portals, etc. They can log into applications, enter data, open emails and attachments, calculate and complete tasks, and then log out.



The term Robotic Process Automation creates a picture of physical robots doing some labor-intensive human physical tasks such as uploading or unloading heavy goods from a vehicle or cleaning the house etc. However, in reality, the picture is completely different. The word 'Robot' in 'RPA' is not a physical robot but a virtual system that helps in automating the repetitive manual computing or business process tasks.

RPA technologies can be divided into three categories:

Probots

These are the bots that follow simple, repeatable rules to process data.

Knowbots

These are the bots that search user-specified information from the internet and respond to the user.

Chatbots

These are the bots that act and respond as virtual agents. They reply to customer queries in real-time.

Why RPA?

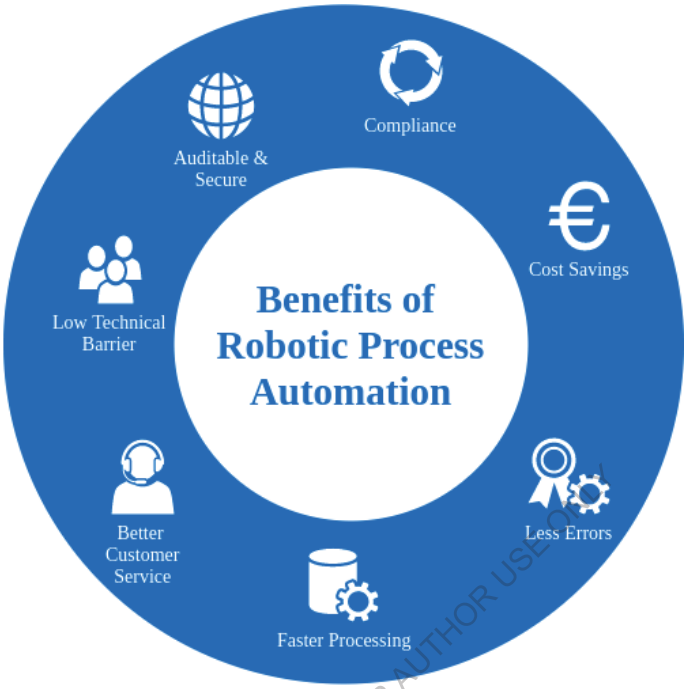
RPA is not part of an organization's IT infrastructure. Instead, it belongs to the top of the whole organization's IT infrastructure. In an IT environment, most of the business processes are not smart and intelligent. Many of them are dependent on

multiple IT systems, which rarely interact with each other. Such types of tasks are repetitive, time-consuming, and labor-intensive for human beings. With the Robotic Process Automation, it takes large IT transformation plans and implementation process to automate those types of repetitive, time-consuming, and rule-based tasks more quickly, accurately, and tirelessly, compared to a human being.

RPA technology uses bots that interact with web applications, web sites, excel worksheets, and emails to automate the tasks just like a human. RPA is currently the most efficient automation solution, and it helps human beings to focus on those tasks which require emotional intelligence, reasoning, judgment, and interactions with the customers, rather than just doing repetitive tasks.

5.1 Benefits of RPA

Robotic Process Automation technology provides the following benefits:



Cost Savings

RPA helps organizations to save a huge amount of cost as it is typically cheaper than hiring an employee to perform the same set of tasks.

Less Error

RPA works on standard logic and does not get bored, distracted, or tired. Hence, the probability of making errors reduces to a great extent, which means less re-work and an enhanced reputation for efficiency.

Faster Processing

RPA works faster than human employees as computer software does not need breaks, food, rest, etc., and can perform repetitive operations tirelessly. With RPA, processing time becomes predictable and consistent, which ensures high-quality customer service across the operations.

Prerequisite

There is no specific prerequisite for this tutorial. All you need is continuous learning and practicing with the tools. However, if you want to extend functionalities to match your requirements, then a basic knowledge of software coding and programming logic will be beneficial and put you at an advantage.

Problem

We assure you that you will not find any difficulty while learning through our RPA Tutorial. But if you find any mistake in this tutorial, we request you to kindly post the problem in the contact form so that we can improve it.

5.2 History of RPA (Robotic Process Automation)

RPA is the combination of several technologies, brought together under one toolkit for different automation purposes. Though the term **'RPA'** emerged in the early 2000s, the initial development was started after the 1990s.

'Machine Learning (ML)' is one of those technologies that helped towards innovation, which eventually lead to the creation of RPA. In 1959, **'Arthur Samuel'** developed Machine Learning. Machine Learning allowed computers to perform several critical tasks, such as translation and text summarization, etc. However, there were limits on how computers could process language. It led to the development of **'Natural Language Processing (NLP),'** which helped computers to understand and process human language more accurately. In 1960, NLP combined **'AI (Artificial Intelligence)'** for establishing the interactions between computers and human languages. Then, the technology progressed further towards the establishment of RPA, and there were few more developments in the 1990s.

Because of the continuous developments, there was an emergence of technology that most closely resembled RPA.

Screen Scraping

Screen Scraping technology is considered as a significant step towards the creation of RPA. This technology is used to extract data from web, programs, and documents, which is further displayed by another application.

While there were many benefits of screen scraping over manual labor, screen scraping was also limited to some extent. Due to limitations and lack of availability of source codes, programmers, and documentation, it became difficult to understand for the average business user.

Artificial Intelligence

Artificial intelligence is the ability of computer machines or robots to perform tasks that typically require human intelligence. AI programming is based on three techniques: learning, reasoning, and self-correction.

The applications for artificial intelligence are endless and can be applied to many different sectors and industries. Some of the commonly used technologies of AI are:

- **Image Recognition -** It is the technology that identifies and detects objects or attributes in images or videos.
- **Speech Recognition -** It is the technology that identifies words and phrases in spoken language and converts them into a machine-readable format.
- **Natural Language Generation -** It is the technology that transforms structured data into natural language.
- **Sentiment Analysis -** It is the technology that uses natural language processing, text analysis, and biometrics to identify, extract, quantify, and study subjective information.

5.3 Advantages and Disadvantages of RPA

Robotic Process Automation is a growing technology with several benefits. However, some people still are not convinced of it and make objections. In this article, we have addressed both sides (advantages and disadvantages) of RPA to give you a better understanding of this technology.

Advantages of RPA

Some of the significant advantages of Robotic Process Automation software are given below:

Code-Free

RPA doesn't require any coding or programming knowledge. The modern RPA tools are used to automate applications in any department where the clerical work is performed across an enterprise. Hence, Employees only need to be trained on how RPA works, and they can easily create bots, just through **GUI (Graphical User Interface)** and different intuitive wizards. It gives an advantage over the traditional methods of automation and enables accelerated delivery of business applications. Besides, this platform reduces the initial cost of installation, training, and deployment.

Non-Disruptive

One of the major challenges that IT deployment faces is the risky or complex transformation process, which prevents large organizations from redesigning, replacing, or enhancing the running system. However, the transformation process in RPA is very simple and straightforward. The RPA software robots follow the existing security, quality, and data integrity standards to access the end-user system in the same manner as human beings. These software robots also prevent disruption of any kind and maintain functionality and protections.

User-Friendly

RPA does not require a special kind of knowledge, such as coding, programming, or deep IT skills. RPA software is user-friendly, easy to understand, and easy to use. RPA tools allow users to create bots quickly and effortlessly by capturing mouse clicks and keystrokes with a built-in screen recorder component. Some of the RPA software includes the option to create and edit bots manually using the Task Editor.

Rich-Analytical Suite

RPA software contains an in-built analytical suite that evaluates the performance of the robot workflows. RPA analytical suite also helps in monitoring or managing the automated functions from a central console, which can be accessed from anywhere. It offers basic metrics on robots, workflows, and more. The analysis performed by the analytical suite helps users to track the operations and determine issues. There is no need for any integration since everything is inbuilt and set right out of the box.

Security

When an organization is running on automation, more users will demand access to RPA products. Therefore, it is important to have robust user access management features. RPA tools provide options to assign role-based security capabilities to ensure action specific permissions. Furthermore, the entire automated data, audits, and instructions which can be accessed by bots, are encrypted to avoid any malicious tampering. The enterprise RPA tools also offer detailed statistics of the logging of users, their actions, as well as each executed task. Thus, it ensures the internal security and maintains compliance with industry regulations.

Rule-based Exception Handling

RPA system allows users to deploy bots using rules-based exception handling. This feature proactively handles the exception. For example, RPA robot reports an exception, and then the actions given below are triggered:

- The same process is re-assigned to a different by the server.
- The current bot retries the same process and removes the previous bot from production.
- If retry is successful, the server maintains the reassignment and raises an alert to report exception & resolution.
- If retry is unsuccessful, it stops the current bot and raises an alert to report exception as well as failed resolution.

Hosting and Deployment Options

The RPA system provides deployment options across virtual machines, terminal services, and cloud. Cloud deployment is one of the best among all the other deployment options, which attracts most of the users due to its scalability and flexibility. Therefore, businesses can install RPA tools on desktops and deploy it on servers to access data for completing repetitive tasks. RPA systems can automatically deploy robots in a group of hundreds. Similarly, multiple bots can be used to run different tasks within a single process while processing a high volume of data.

Actionable Intelligence

This RPA feature refers to the ability to gain and apply knowledge as skills. Robots first obtain the data and then convert it into information and transform the information into actionable intelligence for the users. Artificial intelligence and

cognitive intelligence are the common features of RPA solutions that help bots to improve decision making over the period.

Debugging

One of the biggest advantages of RPA from a development perspective is debugging. Some RPA tools need to be stopped running while making changes and replicating the process. The rest of the RPA tools allow dynamic interaction while debugging. It allows developers to test different scenarios by changing the values of the variable without starting or stopping the running process. This dynamic approach allows easy developments and resolution in a production environment without requiring changes to the process.

Disadvantages of RPA

Some of the major drawbacks of Robotic Process Automation software are given below:

Potential Job Losses

If a robot can work faster with a more consistent rate, then it is assumed that there will be no need for human input. It is the main concern for the employees, and this results as a major threat to the labor market. However, this thinking is not accurate. Amazon has shown a great example of this limitation. The employment rate has grown rapidly during a period where they have increased the number of robots from 1000 to over 45000.

Initial Investment Costs

RPA is still in the stage of innovation, and so it can present challenges that may result in unwanted outcomes. Therefore, it isn't easy for organizations to decide whether they should invest in robotic automation or wait until its expansion. A comprehensive business case must be developed when considering the implementation of this technology; otherwise, it will be useless if returns are only marginal, which may not worth taking the risk.

Hiring Skilled Staff

Many organizations believe that to work with RPA, the staff must have significant technical knowledge of automation as robots may require programming skills and an awareness of how to operate them. It further forces organizations to either hire a skilled staff or train existing employees to expand their skills.

An automation company can be a little beneficial during initial installation and set-up. But the skilled staff can only adopt and manage the robots in the long-term.

Employee Resistance

People are usually habitual, and any change in the organization may cause stress to the employees. People who are involved in new technology will get new responsibilities, and they will have to learn new concepts of a specific technology. Because everyone may not have the same level of knowledge, it may lead existing employees to resign from their job.

Process Selection

It is always best to choose tasks that are repetitive, rules-based, and do not require human judgment. The non-standard processes are difficult to automate, and human interaction is required to complete such processes. So, there are limited tasks that you can automate with RPA.

5.4 RPA Use Cases/Applications

There are several examples of Robotic Process Automation in our day to day tasks. In the present time, many multinational companies are using this technology to automate their day to day tasks.

By implementing RPA, these companies are getting accurate, reliable, and consistent outputs with high productivity rates.

One of the most important tasks in the Robotic Process Automation program is the right selection of business processes and activities. It ensures positive results by automating the tasks that are repetitive and rule-based.

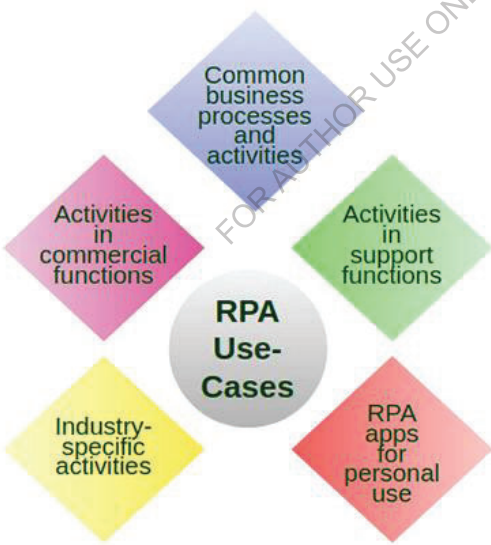
RPA Use Cases

The following list is categorized into five different sections that display the RPA use cases:

1. Common business processes and activities
2. Activities in commercial functions
    - Sales
    - Customer Relationship Management
3. Activities in support functions

- Tech Support
- Technology
- Finance
- HR
- Operations
- Procurement

4. Industry-specific activities
    - Banking
    - Insurance
    - Telecom
    - Retail
5. Robotic Process applications for personal use such as digital assistants



RPA Applications

There are several applications of RPA, but here, we are listing some of the common application areas:

Quote-to-Cash

It is considered as an important business process, which is responsible for increasing revenue for any organization. Organizations are usually dependant on selling. If there is any issue in the operations side of selling, then it can lead to customer's complaints.

Sometimes, organizations end up selling at reduced prices due to clerical errors. Automating such sales processes reduces errors and provides fast service to the customers.

Procure-to-Pay

It is the process that includes the extraction of invoices and payment data from various networks such as banks, vendors, logistics companies, etc. These networks usually do not provide easy integration methods. They generally involve manual labor to complete the tasks, which can be replaced by the RPA bots. It is the best way to fill integration gaps with a fully automated procure-to-pay.

Customer On boarding

Most of the B2C (Business-to-Consumer) organizations are following a customer on boarding process. They must maintain good relations with their customers so that customers start using their products. Using cognitive automation and OCR (Optical Character Reader), most of the customer on boarding tasks can be easily done. It can be applied even in companies that rely on legacy systems, which will help in improving the customer experience.

Employee On boarding

The process of setting up and onboarding new employees is labor-intensive and time-taking for HR and IT analysts. It includes a series of tasks such as creating new accounts, email addresses, access rights, etc. Because of the rule-based and repetitive nature of employee onboard activities, it can be automated to apply pre-defined workflow once the new user account is created. RPA bots can be assigned to send notifications and documents via email to new employees.

Data Migration and Data Entry

Most companies are still using legacy systems to perform critical functions. A legacy billing system is an example of such systems. It needs to interact with other systems that may not have the capability to get required data from APIs. In such cases, employees manually perform tasks to migrate the data using formats like

CSV. With the implementation of RPA, manual labor, and unexpected clerical errors, can be reduced to the minimum level. Organizations can also automate entire workflows of data entries, which can maximize productivity by reducing the time.

Data Validation

RPA is more suitable than any other tools to perform data validation tasks such as checking the accuracy and quality of source data before using, importing, or processing the data. The primary aim is to create data that is consistent, accurate, and complete, so there will not be any data loss and errors during a transfer.

Extracting Data from PDFs, Scanned Documents and other Formats

With technologies like Screen Scraping, OCR, and basic pattern recognition, data can be easily extracted from different formats, which will help to reduce the requirement of inputting the data manually.

Periodic Report Preparation

In every business, employees need to prepare regular reports to inform managers about their work and progress. Preparing such reports and sending them to the managers may distract employees. RPA solutions can be applied to auto-generate reports, analyze their contents, and further email them to relevant managers.

Generating Mass Emails

If there is a need for sending mass emails frequently, then RPA can be a great option to automate the process.

Creating and Developing Invoices

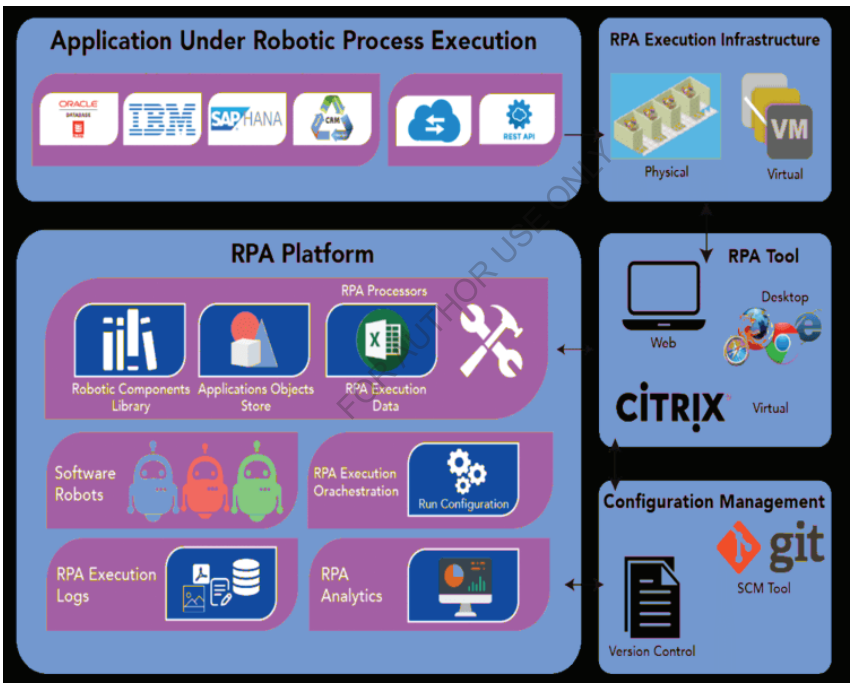
Since automation is faster than manual processes, customers will get the invoices earlier, including earlier payments and improved cash-flow. The process of generating invoices and sending it to the customers can also be automated.

Price Comparison

With the implementation of RPA, it is possible to keep track of the fluctuating prices. Software bots can easily create a summary of prices and also extract data for the best pricing.

5.5 RPA Architecture

The architecture of Robotic Process Automation (RPA) includes several different tools, platforms, and various infrastructure elements. They all together form a complete RPA tool. To understand this in detail, check out the following image that gives a brief description of a typical RPA solution and its architecture.



Application under Robotic Process Execution

RPA is considered as a well-suited technology for enterprises and enterprise applications. Enterprise applications may include SAP, Siebel, or other record

processing applications like Mainframes. Such types of applications are generally data-intensive, data-centric, and loaded with repetitive tasks.

5.6 RPA Tools

The capabilities that are usually seen in any RPA tool are described below:

- RPA tools allow automating a variety of applications in different environments (i.e., Desktop, Web, Citrix, etc.).
- RPA tools allow developing software bots that can be trained by recordings, configuring, and enhancing the programming logic such as loops and conditions, etc.
- RPA tools allow building reusable components that can be applied to multiple robots, which ensures the same time modularity, faster development, and easier maintenance.
- RPA tools allow the reading and writing of different data sources while executing the software robots.
- RPA tools allow building shared applications, user interface object stores, and object repositories containing object locators.

RPA Platform

RPA software bots in the cloud act like they are stored in a shared repository, which can be further shared across libraries of software robots. RPA platform helps in scheduling, distributing, and monitoring the execution of software robots. It also provides the ability to develop meaningful insights of software bots and their execution statistics.

RPA Execution Infrastructure

RPA execution infrastructure is defined as a bank containing physical or virtual lab machines that can be controlled on the basis of usage patterns. The process of scaling up or down the number of machines parallelly for automating the task can also be performed. This process does not require any further human interaction, so it can be left unattended for as long as needed.

Configuration Management

Configuration Management is used for stating the version of RPA assets as the underlying application. It helps in developing the software robots and also

updating them to newer versions. It also helps in branching and merging of RPA robots since they are reusable across the libraries.

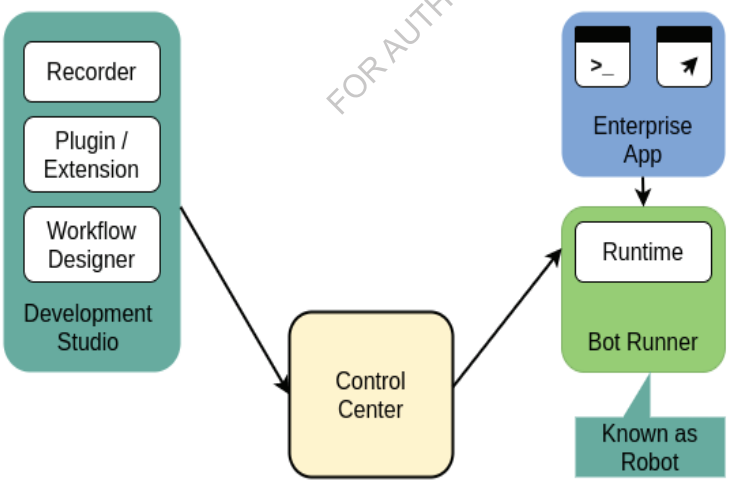
Therefore, RPA is a combination of several different layers of applications and tools that are combined to make it a complete system and the architecture.

5.7 Components of RPA

Robotic Process Automation includes some essential components that form the RPA platform. These components together help to automate repetitive and rule-based processes.

The core components of Robotic Process Automation are listed below:

- Recorder
- Development Studio
- Plugin/Extension
- Bot Runner
- Control Center



Components of RPA

Let's describe each of these components one by one:

Recorder

The recorder is one of the critical components of Robotic Process Automation. It adds an ability to automate web, desktop, and mainframe applications in a natural macro-like way without the need of any programming, coding or scripting.

Recorder in robotic automation uses an object recording approach as a primary mode. By default, RPA bots capture object properties, including their values of active elements throughout the recording. After the recording is complete, RPA bots find the same elements and repeat the process as they recorded. RPA robots perform actions such as click, hover, drag, or scroll, on the same elements during script execution. RPA Recorder also includes an option to modify the workflow and add the system actions manually. These actions may consist of opening applications, switching to a specific window, working with a clipboard, manipulating Excel files, etc.

Development Studio

Almost every RPA tool includes Development Studio in its core components. The Development Studio helps to design or develop intelligent process automation workflows. It allows you to get full control over the automation. It also allows you to install activities packages, wizards, recorders, and custom plugins.

Some typical features of RPA Developer Studio can be explained as below:

- Dashboard with **GUI (Graphical User Interface)**.
- Different types of Recorders.
- Logging and Exception Handling.
- Integration support with **OCR (Optical Character Reader)**.
- Collection of pre-built, drag-and-drop templates.
- Universal search option to search across all the automation resources such as libraries, activities, projects, etc.

Plugin/ Extension

Most of the RPA platforms consist of several plugins and extensions to perform easy development and execution. RPA plugins are the set of programs that can be installed along with the RPA tool. These plugins handle different types of tasks, such as extracting the data from invoices, manipulating the dates of different

databases, or transcribing speech, etc. RPA plugins are beneficial as they reduce the development efforts, error rates, and implementation time. They can be directly used after they are installed along with the RPA tool.

Bot Runner

Bot Runners are used for executing the developed software bots. They are the machines on which bots are run or executed. Multiple bots can be assembled parallelly for faster execution. The only requirement to run the bots is 'Run License'. The bots also report the execution status (i.e., execution logs, pass, or fail, etc.) back to the control center. Once a developer creates a software bot or task and further updates the status on the control room, the control room schedule and executes the bots on the bot runner. The serial of bot execution usually depends on the requirements or priorities.

Control Center

The control center is the most important component of any RPA tool. It is a web-based platform that is used to control the software bots created by the Bot Creator. It allows users to schedule, manage, control, and scale the activity of a vast amount of digital workforce. It also offers features such as centralized user management, automation deployment, source control, and a dashboard.

5.8 RPA Life Cycle

RPA Lifecycle does not have any particular defined structure. It includes different phases of the automation process, from the creation of bots to the execution of the bots. Check out the following diagram displaying all these phases:

RPA Life Cycle

Discovery Phase

The discovery phase is the initial phase of the RPA lifecycle. In this phase, the RPA process architect analyzes the requirements of the client. Then it is further decided whether the process can be automated or not. If the process can be automated, then the RPA analyst team might involve the RPA architect team and analyze the complexity of the process.

Solution Design Phase

Based on requirements, the steps to automate the task, are designed. The RPA technical architect, in collaboration with the process architect, develop a **Process Definition Document** (PDD), which includes information about the whole process. They follow the developmental methodology and develop a strategy to automate specific tasks to reduce manual work as much as they can.

Once all the requirements are matched, the next step is to decide the budget, number of people, time to be spent on the project, etc. Then, the analyst team creates a flowchart to understand the flow of processes, which helps in choosing the right processes for automation. After the selection of processes, the RPA tool is used to start the development of bots and automate tasks.

Development Phase

In this phase, the RPA developer creates scripts/bots to automate the tasks with the help of RPA tools. There are several RPA tools available in the market. Automation scripts/bots are generated by following the previously developed PDD. Generally, there is no requirement for coding. But it may change depending on the tasks to be automated.

UAT (User Acceptance Tests)

In this phase, the RPA development team tests the developed bots. These bots are tested in a pre-production environment to examine how the users can use them to automate specific tasks. If the testing phase gets passed successfully, then it is further transferred to the next stage. Besides, if the testing fails, then it is transferred back to the development phase, where RPA developers examine errors found in the testing phase and solve them.

Once the bots get successfully tested, then they are transferred to the deployment phase of the RPA Lifecycle.

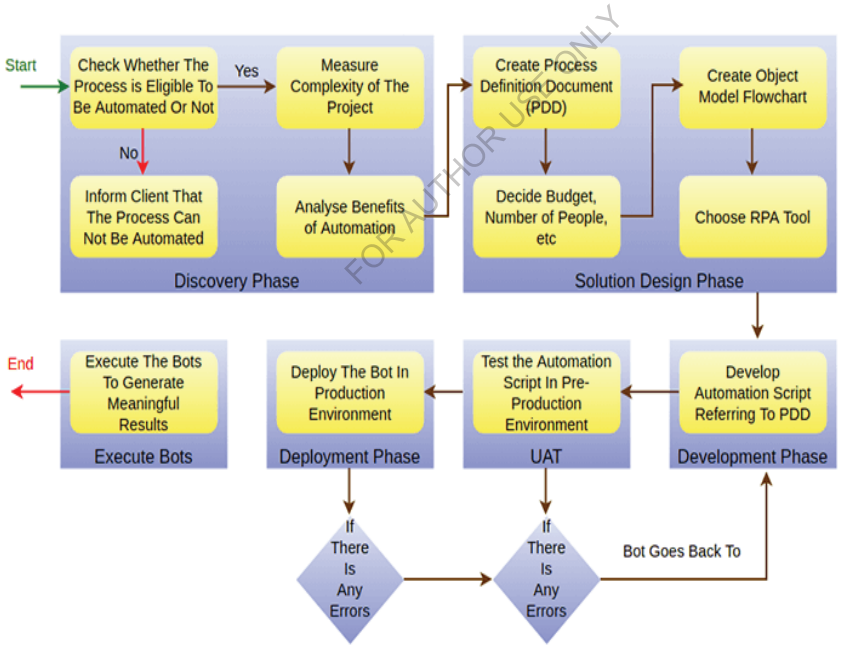
Deployment and Maintenance Phase

The bots are deployed into the production environment when only they have completed the development and testing phases. After the deployment process, users can use them to automate their tasks. If there is still a problem with the bots, like bots are not automating, then they are further transferred to the RPA development and testing team. The development team will again analyze the bots and resolve the problems.

Execute Bots

This phase includes the execution of the bots after deployment. Bots are also checked to ensure that the implementation is performed as per requirements.

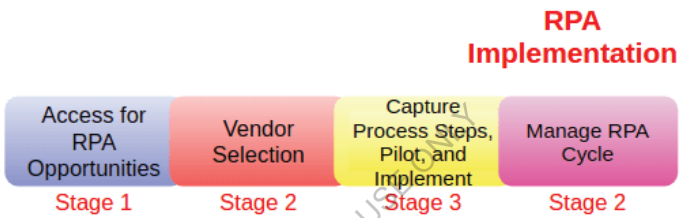
The following image explains the flow of building a bot:



5.9 RPA Implementation

RPA software has provided an excellent option for corporate and shared services. It is an efficient, cost-effective alternative to traditional process approaches. RPA implementations are increasing in popularity due to the money and resources according to time. Once the organizations make sure to implement RPA, they are required to move forward with a stage-wise implementation approach.

To implement RPA successfully in an organization, the organization must use time-tested and robust methodology. RPA implementation mainly depends on the requirements of the organization. It typically includes the following stages:



Stage 1 - Access for RPA Opportunities

Organizations should find the right business processes before the implementation of RPA technology. Implementation with the right processes can be beneficial for organizations. Every process in the business may not be suitable for the RPA implementation. Therefore, organizations should conduct a high-level assessment of the potential processes and select the right processes to be automated. It will help them to decide whether RPA is a good fit for their organization or not.

Once an organization has decided to implement this technology, they should set the objectives of the RPA initiative. It will be an excellent choice to get an agreement from executive stakeholders on project objectives.

This initial stage examines which areas will get the most benefit by switching to RPA technology. It also includes technology demonstrations by selected RPA vendors to serve as a POC (Proof of Concept) and platform for knowledge gathering.

Stage 2 - Select a Vendor

In this phase, organizations start finding RPA vendors based on the technical requirements of the organization. The selection process is an opportunity for RPA providers or vendors to show how they meet the requirements and criteria of the organization.

Organizations invite different RPA vendors to take part in the on-site presentation and show how RPA can help with the growth of the company. Many vendors agree to demonstrate the whole presentation by applying RPA technology to the selected processes as a proof of concept.

Then, organizations select a vendor that complies with their requirements and business objectives. There are two types of implementation that RPA vendors may present:

- RPA vendors will conduct the configuration and test for the organization.
- RPA vendors will sell bot licenses and teach how to implement them.

Most vendors provide both of these services. So, it depends on the requirements of the organization to choose any of these ways for the implementation. Many businesses opt for a vendor to code the initial pilot and develop an internal RPA center of expertise to handle future implementations.

Stage 3 - Capture Process Steps, Pilot, and Implement

During this stage, businesses ensure whether human resources are trained and ready to execute the selected RPA implementation plan. This stage also includes the activities required to support and test the IT environment. All the implementation activities are documented, tracked, and completed as per the defined criteria.

This stage also includes the facilitation of the pilot for the selected process areas or use cases. It allows businesses to observe the effectiveness and overall performance of the automation plan with an actual process in real-time.

As per the results of the pilot project, businesses may include scenarios that need to be automated, which showcase the full extent of the RPA technology. If there is any problem, then the RPA development team analyzes and resolves it. It further establishes the groundwork for upcoming state operational models.

Stage 4 - Manage the RPA Lifecycle

In this stage, the initial launch of RPA is processed. This stage also includes the planning for the ongoing success of RPA software through proactive maintenance. This strategy should combine governance, operating model, organizational structure, and change management plan of the RPA solution. There should be a good change management plan to estimate the impact of change in processes and systems. So, the businesses will be able to limit the margin of error as they proceed.

Keys to Successful Implementation

Before implementing RPA technology, organizations should consider the following keys which will help in successful implementation:

- Select the right project team for internal and external operations.
- Execute detailed work plans to ensure that no work is dropped.
- Form quick connections with IT, controls, and procurement.
- Estimate the impact of changes in people.

Working of RPA

With the name of RPA, many people may think about physical robots performing day to day tasks. However, RPA does not use physical robots to automate tasks. It does not replace humans with actual robots. The term 'robot' in Robotic Process Automation is a software running on physical or virtual machines. Such software help in configuring automation workflows to automate business operations.

How does RPA work?

Robotic Process Automation is operated by running a set of workflow tasks. It provides instructions to the software bots on what to do at each stage. Once this workflow has been programmed into the RPA, the software can then automatically run the program and complete the specified task multiple times as per the requirements.

One of the most common examples of RPA is the 'automated creation of invoices'. It is an essential function for any business, but sometimes, it can be a critical task. This task is usually repetitive, and so can be time-consuming for human employees as they have to deal with hundreds or thousands of such tasks every day.

Because of being repetitive and structured, these processes are ideal to be automated with the help of RPA. In a typical business, the workflow for this process may look like the following sequence:

- A customer requests for an invoice through mail.
- The operator checks the mail and opens the relevant billing software.
- Information is copied from the email into the billing software.
- The invoice is created using the given information and saved.
- The original sender is informed that the process is complete.

All these steps can be automated with the help of the RPA tool. As soon as the customer generates an email request, all these steps will be performed automatically by RPA bots, and there will be no need for human input. Preparing and cleansing data in a structured format helps the software bots to easily copy and paste data from one field to another without oversight.

In case of incomplete, inaccurate, or missing data, these software bots can send the acknowledgment to the original sender and request for the correct data. It prevents all kinds of mistakes that may arise as a result of user error.

How does RPA work with the existing systems?

RPA accesses the information from existing IT systems. Several ways can be used by RPA to integrate with the existing applications. It depends on the requirements of the organization to choose the appropriate way of integration.

There are usually two types of integration methods:

Back-end RPA Integrations

With the back-end integration, automation accesses systems and services under the control of a process automation server. It is generally used for unattended automation in which software bots carry out back-office tasks. These tasks may include processing of insurance claims at scale with minimal to no employee intervention.

Front-end RPA Integrations

Front-end integrations provide several different ways by which automation can connect with desktop applications such as SAP, PeopleSoft, and Sales force CRM, etc. A front-end automation can read/write data and capture events directly from the user interface of the host application, just like humans.

Working of AI-powered RPA

'AI-powered RPA' is a term used for advanced automation technology. It leverages several technologies like AI (Artificial Intelligence), OCR (Optical Character Recognition), Text Analytics, and Machine Learning, etc. Attended and unattended RPA is also a part of AI-powered RPA technology.

Machine learning adds abilities to the automation process, which helps in learning, expanding, and continually improving capabilities and certain aspects of its functionality.

Attended and unattended RPA can process information from structured databases, whereas cognitive automation can process it from unstructured data sources like scanned documents, emails, and letters. Artificial Intelligence also helps to train bots so that they can handle exceptions. AI uses the same methods that human employees use to handle exceptions in attended automation processes.

5.10 RPA Services

RPA services allow organizations to reduce the burden of repetitive tasks of employees. These services transform the business process framework into an automated and intelligent enterprise system. RPA services include assessment, strategy, design, implementation, and support to enhance productivity, reduce operational cost, and improve the scalability of an organization.

Some of the important RPA services are given below:

Business Readiness Analysis

Business Readiness Analysis is considered as the first and most critical step towards digital transformation. This service helps customers to identify such business processes and applications that are ideal for robotic process automation. Business readiness analysis services cover the following tasks:

- Process Assessment
- Scope and Compatibility
- Feasibility Study Report
- Effort and Benefit Estimation

Business Case Discovery

The RPA business case discovery service includes business and process maturity assessment to develop an optimization roadmap. The team of experienced consultants works together with the business team to identify efficient workload for automation. They also help in the selection of the right RPA platforms based on the existing IT environment and the requirement of RPA.

Proof of Concept (POC)

As soon as the identification of ideal use cases is made, RPA experts will set the objectives for the RPA proof of concept. They further build an internal RPA framework and avail appropriate IT access rights for the bots. They also compare various performance measures to ensure that the RPA POC execution showcases the full extent of the RPA value. The RPA proof of concept services covers the following tasks:

- Selection of POC Process
- Identification of suitable RPA platform
- Execution of Pilot Project
- Creation of Reference Architecture

Implementation

Most RPA vendors offer both attended (human-involved automation) and unattended automation (self-running automation). They also provide services like designing, development, and deployment of bots.

The automation developer creates software bots with the help of the RPA tool in the development stage. After the development and testing of the bots, they are deployed into the production environment.

The implementation service includes the following parts:

- Process Definition Documents (PDD)
- Solution Design Documents (SDD)
- Designing, Development, and Deployment of Bots
- Configuration and User Acceptance Testing (UAT)
- Release Notes

Legacy System Integration

Many organizations are still using outdated legacy systems, which slow down operational processes. Since legacy systems are the foundation for most of the organizations. Hence legacy modernization becomes a challenging task during data migration and data accessibility. However, RPA supports easy integration for legacy systems. With the help of this service, such systems can be easily upgraded and modernized for compatibility with the latest technology to achieve the desired performance. Therefore, this service helps in faster operations and subsequent business growth.

Web Extraction Service

Web extraction service allows users to access accurate, relevant, structured, and legitimate data in the preferred formats. It helps them with market research, sentiment analysis, price comparison, etc.

With a web extraction service, users can easily extract data from numerous pages within minutes. It saves precious time and resources so that they can prioritize making the right business decisions.

RPA Monitoring and Support

Although RPA robots are designed and deployed to automate the operational tasks that require human intervention, there is still a space for improvement. That's why most of the RPA vendors monitor and maintain the day-to-day tasks of bots. This type of routine analysis helps vendors to remove operational issues to ensure continuous improvement.

Benefits of RPA Services

- Increase in Deliverable Output
- Reduced Errors, so higher quality assurance and accuracy
- Reduced Operating Costs, Greater Performance, and Quality
- Maximum Flexibility - 24/7 Service Availability
- Higher Productivity, Accelerated Productivity Gains
- Increase in Customer Satisfaction

Why are RPA services Distinctive?

It is because the RPA services enhance the productivity of organizations after integration. These services help in the optimization of operational expenses, digital transformation, and support by eliminating repetitive and mundane manual tasks.

RPA Tools

RPA tools are the software that helps users to configure various tasks to get automated. Most of the organizations have periodic and repetitive tasks such as data entry, data extraction, report generation, etc. These tasks are manually performed on the software by the employees. Such repetitive tasks can be easily automated with the help of bots. The software that utilizes bots for performing automation is called the RPA Tool

Some popular RPA tools are described below:

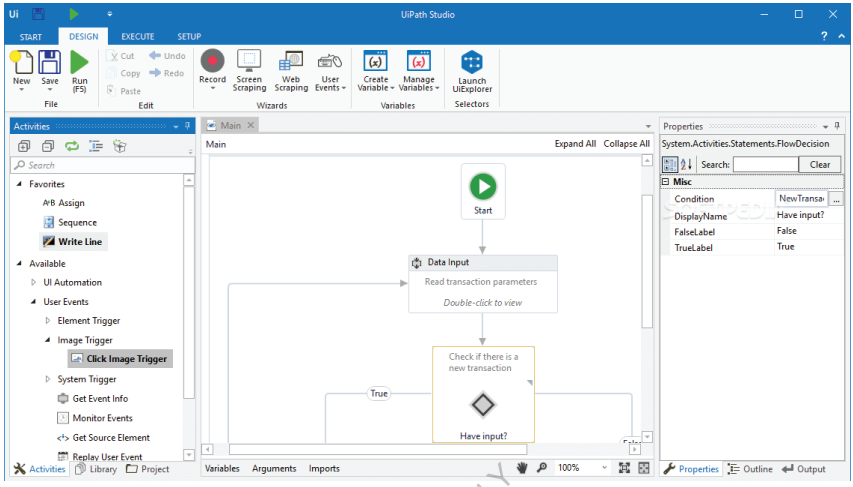
UiPath

UiPath is a highly extensible Robotic Process Automation tool that helps to automate desktop or web applications. It offers global enterprises to design and deploy a robotic workforce for their organizations.

The best thing about UiPath is that it includes a community edition that comes with drag and drop feature. So, the users do not need programming knowledge to automate the tasks using UiPath. The community edition is free for the people who want to learn, practice, and implement RPA.

Features

- It provides multiple hosting options, such as cloud environments, virtual machines, and terminal services.
- It supports a high range of web and desktop applications.
- It supports the auto-login feature to run bots.
- It includes scrapping solution which works with .Net, Java, Flash, PDF, Legacy, SAP, with maximum accuracy.

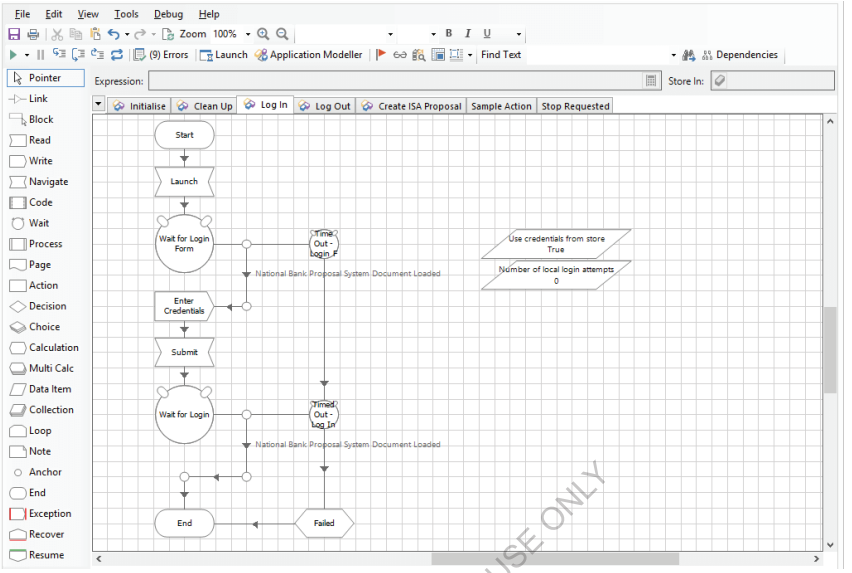


Blue Prism

Blue Prism is an RPA Tool that provides a virtual workforce to the organizations. It helps organizations to automate manual, repetitive, and rule-based business processes in an agile and cost-effective manner. It includes drag and drop support to automate the tasks.

Features

- It is platform-independent so that it can be used on any platform.
- It contains robust features like load balancing, data encryption, and end-to-end auditing. Thus, every change is audited.
- Blue Prism also supports automation of codes written in Mainframe, Java, Windows applications, and even web-based applications.
- It supports all major cloud platforms, like Microsoft Azure and Amazon AWS. So, users can manage most of the tasks centrally.



Automation Anywhere

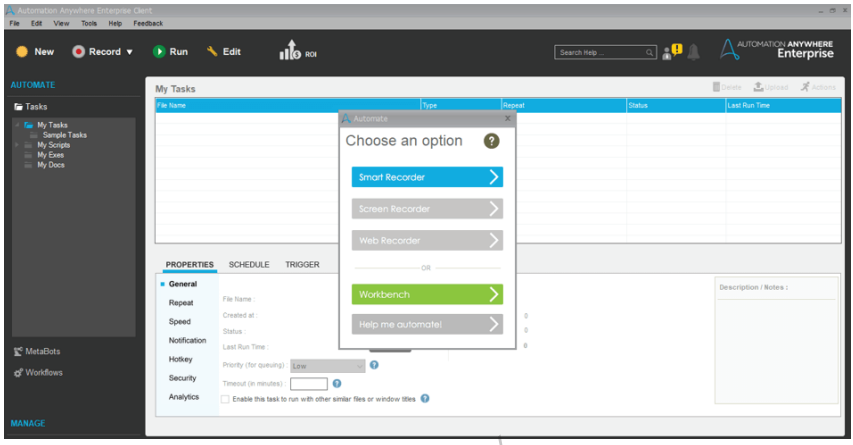
Automation Anywhere is one of the popular RPA vendors that offers powerful and user-friendly capabilities to automate any complex business process. This tool is a combination of all the core functions. It combines RPA with intellectual elements like language understanding and reading any unstructured data.

Automation Anywhere is a web-based administration system that provides control to run and manage end-to-end automated business tasks for companies. It allows automating a broad range of tasks, from basic windows configuration steps to the ultimate networking and remote database processes.

Features

- It provides easy integration with different platforms.
- It provides Bank-grade security through authentication, encryption, and credentials.
- It distributes tasks to multiple computers and rapidly automates complex and complicated tasks.

- It offers script less automation.

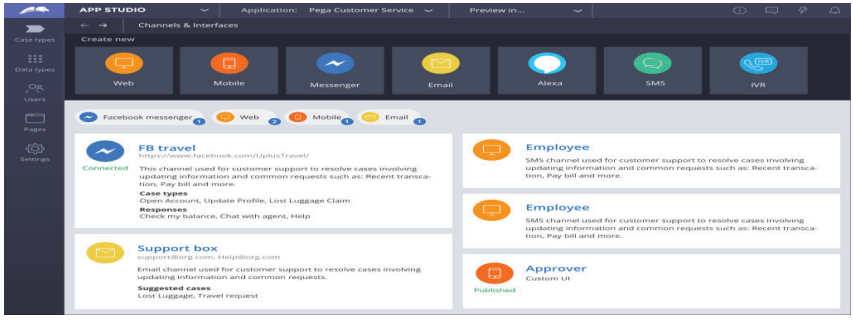


Pega

Pega is an RPA tool that can be used to automate the routine tasks which are repeated in a workflow. It adds the ability to automate tasks using the UI of existing applications. It can be beneficial to speed up manual tasks by automating user actions.

Features

- It provides a cloud-based solution.
- It helps in the deployment of the solutions to the customers.
- It captures insights at the desktop. It gets details of how work gets done.
- It does not store any execution data in a database. Everything gets stored in memory.



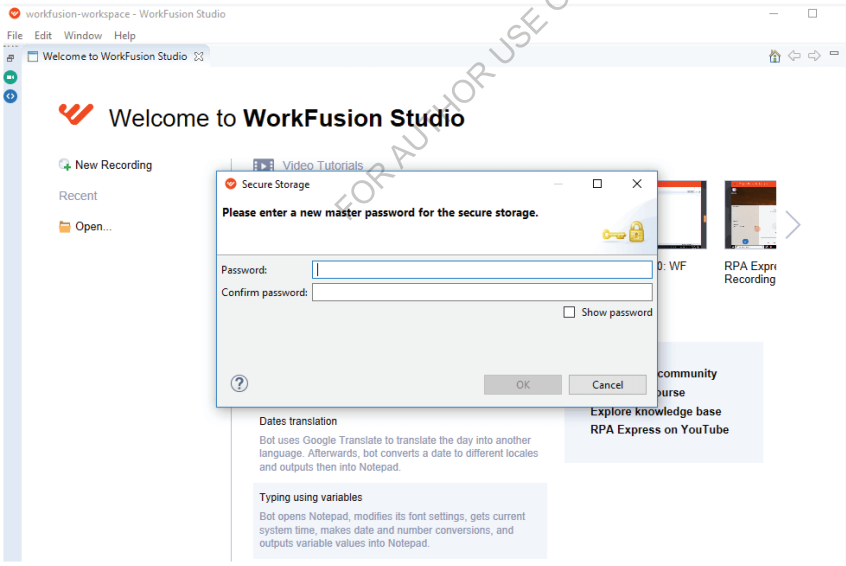
WorkFusion

WorkFusion is a **SaaS (Software-as-a-Service)** cloud computing platform. It automates the monitoring of data feed and helps you to manage crowd-sourced workers from global talent markets.

WorkFusion uses statistical quality control to ensure the accuracy of the work output.

Features

- It can collaborate with multiple users across different workstations.
- It supports quick start / stop automation, just by pressing a button.
- It also has a drag and drop feature.
- It allows organizations to digitize their operations and enhance productivity.



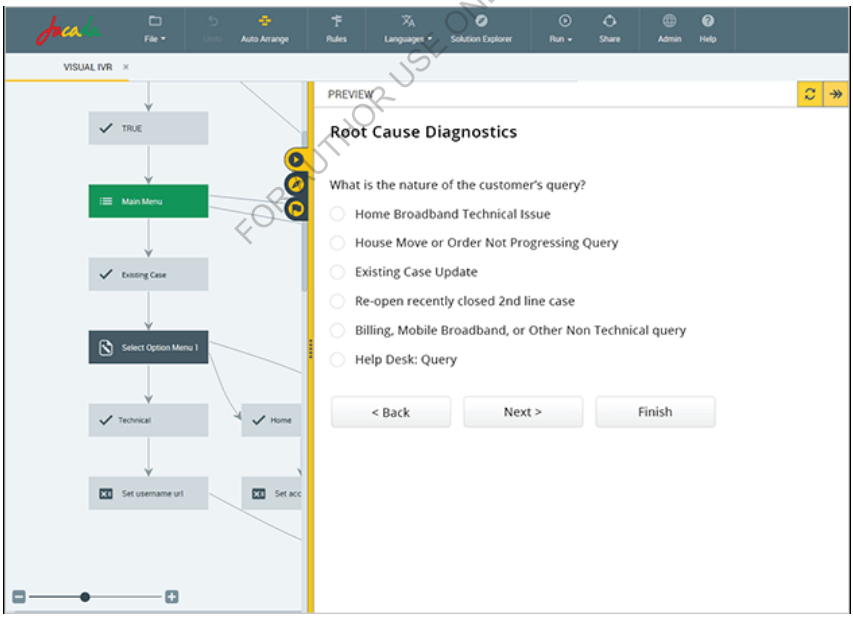
Jacada

Jacada is also one of the leading RPA tools. It helps in Desktop Automation and allows organizations to automate time-consuming, error-prone, and repetitive tasks. It supports in increasing accuracy, productivity, and customer satisfaction.

This tool is widely used for creating communication centers and customer services.

Features

- It includes hybrid RPA capabilities that combine attended and unattended bots.
- It provides an unparalleled level of flexibility for automated processes handling.
- It reduces the average handling time for organizations.
- It helps in increasing first call resolution (or instant resolution).



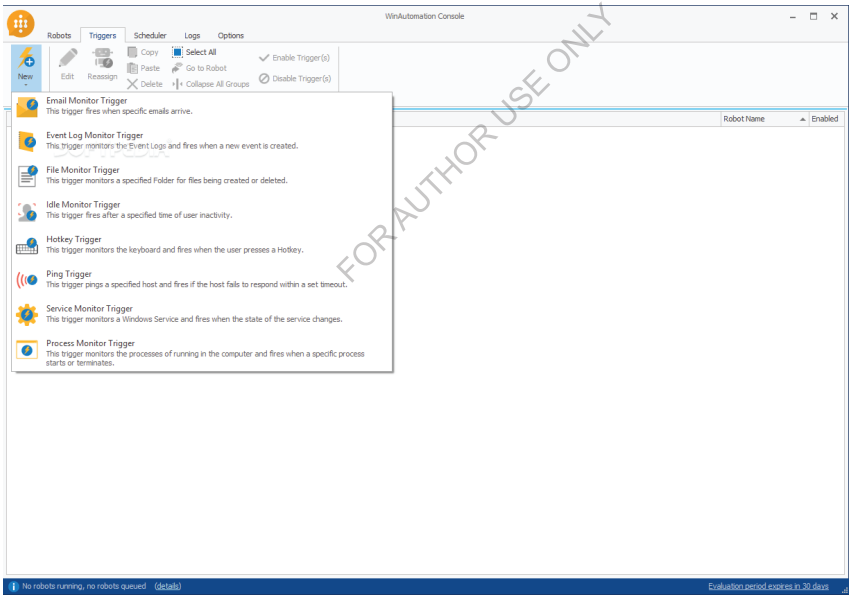
WinAutomation

WinAutomation is a powerful, robust, and easy to use windows-based desktop automation tool that allows the development of software robots. It provides enterprise-grade security and controls.

This tool can fill web forms, extract data, and transfer the same data from one application to another.

Features

- It provides easy integration with leading third-party applications.
- It supports parallel execution during testing.
- It includes image and optical character recognition.
- It requires minimal coding for the development of bots.



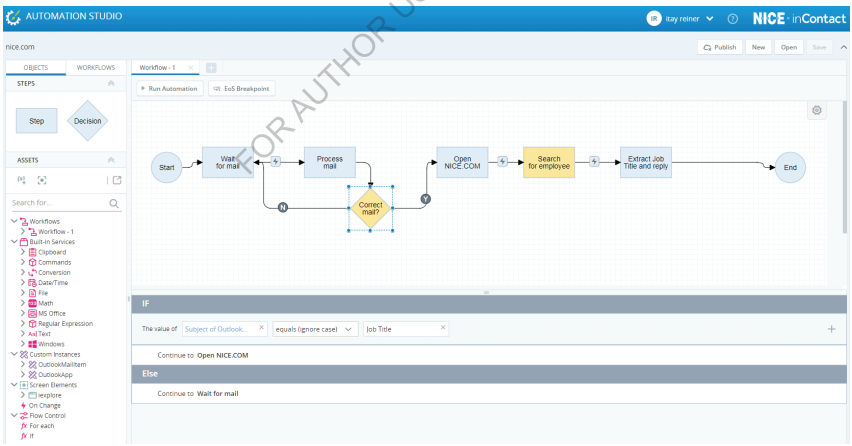
NICE Systems

The NICE system is an intelligent RPA tool which is also known as **NEVA (Nice Employee Virtual Attendant)**. It operates on both the cloud and on-premise business software. With the help of this tool, a variety of tasks can be executed independently without human intervention. It helps employees to perform repetitive tasks.

It allows businesses to make accurate inferences with the help of high-level analytics of structured and unstructured data.

Features

- It supports both attended and unattended automation.
- It is ideal for banks, Finance, HR, etc.
- It provides increased customer satisfaction and productivity.
- It automates ordinary tasks and ensures compliance adherence.



Contextor

Contextor is an integrated development environment used for a robotic automation process. It offers a complete customer view, online help, and exchange the data between two or more applications.

Features

- It helps in configuring robots through a drag & drop, and point & click approach.
- It can monitor the processes executed on the workstation.
- It can discover and recognize the target applications.
- It can maintain existing projects and add new features.

In the present time, there are many more vendors who are providing RPA Tools. However, the leading tools in the RPA market are **UiPath, Blue Prism,** and **Automation Anywhere**. These tools are most widely used in organizations for various purposes.

Core Functionalities of RPA Tools

Following core functionalities should be present in any RPA tool:

- A software robot should be able to interact with other systems either through Screen Scraping or API Integration.
- A software robot should be capable of making decisions and determine its actions based on inputs gathered from other systems.
- A software robot should have an interface to program the other robots.

Choosing the right RPA Tool

As we have seen, there are lots of RPA tools, but the question is which tool should we choose. Following are some parameters which should be considered before choosing the RPA tool:

Technology

The RPA tool must be platform-independent and should support all kinds of applications so that the organization will be able to perform their routine tasks outside the local desktops. There are some other important technologies (i.e.,

screen scraping, scalability, cognitive capabilities, etc.) that should be available in the RPA tool.

Scalability

One of the important parameters of the RPA tool is scalability. There should be an option to expand the robotic workforce as per the requirements. RPA tool should support expansion for either no extra or minimal cost.

Security

Security is an important parameter to be considered before the selection of the RPA tool. Since the software robots access and manage private data, the organization should check all the security features of the tool. They are required to measure all the security controls before the implementation of RPA. Otherwise, the system may become accessible to external malicious attacks. It can cause misuse of confidential data, privacy issues, and other security concerns.

Total Cost of Ownership

The total cost of ownership is considered as another important parameter that should be evaluated before choosing the RPA tool. It depends on different factors such as initial setup cost, vendor fees, repetitive license fees, cost of implementation, maintenance, and more. Because the organizations usually prefer to start small and then scale, that's why the evaluation of the cost of the RPA tool with the company's RPA roadmap in mind is necessary.

Ease of Implementation

The selection of the RPA tool must include easy and quick integration as per the business requirements. It is necessary to check the compatibility with existing legacy systems to enable smooth transition after the implementation.

Ease of Use & Control

The RPA tool should be flexible and easy to use for performing the automation process. There should be options that can be controlled easily. It is better to use such an RPA tool, which requires less training and can be operated by users who lack knowledge in programming.

Vendor Experience

Choosing an experienced vendor will drastically improve the speed of implementation and reduce the work required to implement RPA software.

Maintenance & Support

It's always good to choose such RPA providers who provide strong vendor support to their clients. A good vendor support helps in getting technological innovations, smoother deployments, better training, and certifications, etc.

Quick Deployment

The RPA tool should be able to help the user by interacting with applications which is available at the presentation layer. It also supports the user by validation, screens, and business rules, as they all are presented through a virtual desktop.

5.11 RPA Vs. AI

Without knowing the meaning of RPA and AI, it is hard to describe differences between them. Let's start with the definitions:

Robotic Process Automation (RPA) is a software robot that can mimic human actions. RPA tools are used to design and deploy these software robots. These tools utilize pre-defined activities and business rules to autonomously execute a combination of tasks, transactions, and processes across software systems. RPA can deliver the desired result without human interaction.

On the other side, Artificial Intelligence (AI) refers to machines that can simulate human intelligence. It combines cognitive automation with machine learning, hypothesis generation, language processing, and algorithm mutation to create insights and produce analytics at the same capability level as a human, or even higher.

Now, let's understand the differences between these two:

Robotic Process Automation	Artificial Intelligence
RPA is a software robot that can mimic human actions.	AI is the simulation of human intelligence in machines programmed to think like humans and mimic their actions.

RPA robots automate the tasks as per defined rules.	AI is based on 'thinking' and 'learning'.
RPA is a rule-based technology that has no intelligence. It just automates repetitive tasks.	AI includes technologies like **ML (Machine Learning) and NLP (Natural Language Processing)**, which help to do more than just creating rule-based engines to automate repetitive tasks.
RPA can make a huge impact on large businesses as they can process vast amount of data accurately without the need for manual inputting.	AI helps in decision making. It enables the automation of decision making without human involvement.
The main aim of RPA is to automate the repetitive and mundane business processes.	AI replaces human labor. In many companies, physical robots or machines are working in place of human workers.
RPA is easy to implement. Sometimes, an RPA can be complex with large networks of software robots exchanging information between each other, but it still will be a simpler proposition than AI.	AI needs a lot of work to set up and run.
RPA is said to be a process-centric technology because RPA is all about automating repetitive, and rule-based business processes. For example, RPA generates bills or process invoices, and so on.	AI is known as data-driven technology, which is all about providing good quality data. For example, AI helps in reading the bills and invoices and extracting their data to convert it into structured and intelligible information.

5.12 RPA Vs. Test Automation

The terms Test Automation and Robotic Process Automation look similar as they both contain 'Automation' and offer the same features of reducing manual labor. But these two are different. Let's get started with the definitions:

Robotic Process Automation (RPA) is a software robot that can mimic human actions. RPA tools are used to design and deploy these software robots. These tools utilize pre-defined activities and business rules to autonomously execute a combination of tasks, transactions, and processes across software systems. RPA can deliver the desired result without human interaction.

Test Automation is a method in software testing that makes use of specialized tools to control the execution of tests. It further compares the actual results with the predicted ones. Test Automation is performed automatically with little or no interaction from the test engineer. It is an important stage of a development process that is used to add additional testing that may be difficult to perform manually.

Now, let's understand the differences between these two:

Test Automation	**Robotic Process Automation**
Test automation automates repetitive test cases.	RPA automates repetitive business processes.
Test automation can be applied only to the product and its features.	RPA can be applied to the product as well as other business processes.
Programming or coding knowledge is required to perform Test automation.	RPA provides a drag and drop feature to automate the tasks. Therefore, programming knowledge is not compulsory.
Test automation is implemented across different environments (i.e., QA, Production, Performance, UAT).	RPA only needs a single production environment.
Test automation can be used only by a particular set of users (i.e., Developer and tester).	All the individuals across the team can use RPA.
Test automation can be used with limited software environments. For example, Selenium only works with	RPA can be used with a wide variety of software environments.

web applications.	
With the help of Test automation, only test cases can be automated.	RPA helps to automate tasks like data entry, loan processing, form-filling, etc.
Test automation helps in reducing the execution time.	RPA helps to minimise human workers.
Test automation works as a virtual assistant.	RPA works as a virtual workforce.
Test automation tools cannot be used for Robotic Process Automation.	RPA tools can be considered as testing tools at a basic level. However, these tools are not as good as test automation tools.
Test automation tools come with a constraint that they require software to run.	RPA can be applied to anything which is in a structured form. Hence, any testing tool exists in the market cannot be used as a RPA tool.
Test automation tools are intended to validate whether an IT application is performing as per the given specification.	RPA tools are expected to run on the business production environment to achieve business objectives.
Test automation can execute only what is coded in it.	Besides, many RPA tools have an AI engine that can process information like a human.
Some popular test automation tools are **"Selenium, HP - UFT/QTP, IBM -**	Some popular RPA tools are: **"Blueprism,**

5.13 RPA Vs. Traditional Automation

Without knowing the definitions of Robotic Process Automation and Traditional Automation, it is hard to understand the differences between them. Let's start with the definitions:

Robotic Process Automation (RPA) is a software that is used to automate a high volume of repetitive and rule-based tasks. RPA tools allow users to design and deploy software robots that can mimic human actions. These tools also utilize pre-defined activities and business rules to autonomously execute a combination of tasks, transactions, and processes across software systems. RPA can deliver the desired result without human interaction.

On the other side, Traditional Automation is the automation of any repeated tasks. It combines application integration at a database or infrastructure level. It requires minimal human intervention.

Robotic Process Automation	**Traditional Automation**
It does not require any modification in the existing systems or infrastructure.	It requires certain customizations in the existing IT infrastructure.
It can automate the repetitive, rule-based tasks. It mimics human actions to complete the tasks.	It does not include the ability to mimic human actions. It only executes the pre-defined programmatic instructions.
A user can start using RPA without knowing any programming. RPA allows automation with easy to use flowchart diagram. Therefore, users do not require to remember language syntax and scripting. They only need to focus on the functionalities given under automation.	Users are required to have the programming skills to use Traditional Automation for automating functionalities. Programming language requirement depends upon the type of automation tool. Users need to remember language syntax and scripting.
RPA provides the easy and quick implementation. It requires less amount of time as RPA software is process-driven.	Traditional Automation can take several months for implementation. Test designing and feasibility studies take a longer time.
RPA allows users to assign work to hundreds or thousands of virtual machines that can perform the allotted tasks without the requirement of physical machines.	On the other hand, Traditional Automation uses different programming techniques to achieve parallel execution or scalability. Physical machines are required to perform parallel execution. Those physical machines should have

	the capability of providing good processing speed.
RPA can be configured to meet the requirements of a particular user. It can be combined with several applications (e.g., calendar, e-mail, ERP, CRM, etc.) to synchronize information and create automated replies.	When it comes to customization, Traditional Automation is considered as a critical and complex technology compared to the RPA. The integration of different systems with Traditional Automation is a challenge due to the limitations of APIs.
RPA can be a little costly in the initial phase. But it saves a lot of time, money, and effort in the long run.	Traditional Automation is cheaper in the initial phase. However, it costs a lot more in the long run.
RPA is a more efficient option since it can make improvements instantly.	Traditional Automation requires more time, effort, and a considerable workforce.
With RPA, users can easily update any business flow due to its simplicity.	On the other hand, Traditional Automation may force users to change various scripts. Hence, maintenance and updating of thistechnology can be tough.

5.14 Examples of RPA

Automation is the requirement of several organizations to reduce the working time of repetitive manual tasks. Robotic Automation Process helps them to make use of RPA tools to complete all such repetitive, time-consuming work for improving customer satisfaction.

Robotic Automation is well suited for rule-based processes that are clearly defined and well documented. There are many examples of Robotic Process Automation in our day-to-day tasks. Here, we are listing some common examples below:

Web Site Scraping

Web scraping is the process that is used to extract vast amounts of data from websites. All the scraping tasks are performed by a piece of code, which is called a ' scraper'. Most web scrapers convert the data to a **CSV (Comma-Separated Values)** or Excel spreadsheet formats. However, some advanced scrapers also support formats such as JSON (JavaScript Object Notation) that can be used for an API **(Application Programming Interface)**.

Web Scraping is also termed as **Screen Scraping, Web Data Extraction, Web Harvesting**, etc.

Advantages of Web Scraping with RPA

- Low cost and minimal errors.
- Faster and Easy Setup.
- Customized scraping.
- Gathers social media data.
- Automates batch tasks.
- No need to build a team for scraping.

Order Processing

Nowadays, there are many e-commerce websites for online shopping. These sites allow customers to order various items from different categories (i.e., grocery, electronics, fashion, etc.).

Whenever a customer places an order from an e-commerce website, an item should be available on the actual repository. The process of placing orders through the actual repository is done on the back-end. It helps in maintaining the stock and also dispatching the item. The stock details are updated in the system accordingly. Such type of data entry tasks can be managed with RPA solutions as the entire process from order placement to stock updation will be automated. With the RPA implementation, there will be minimal chances of having any manual error that could be caused because of misunderstandings.

Advantages of Order Processing with RPA

- Better customer experience.
- Reduced costs.

- High flexibility and improved **ROI (Return of Investment)**.
- Improved data control.
- No requirement for manual data entry.

Data Management

In organizations, RPA can help employees to pull relevant information from legacy systems to make it available for the newer systems. RPA can also help organizations to manage their data for backups or restorations easily. These types of data management tasks can be fully automated with RPA solutions by giving them required information such as credentials, source, and destination details, etc.

With RPA, organizations can save time from managing the entire data manually. The whole process, including checking and monitoring the data, is performed with the help of the RPA tool. RPA can also help to generate the human task if there is a requirement of human intervention.

Advantages of Data Management with RPA

- Eliminates human errors.
- Saves administration hours.
- Reduces the delays that may occur in the manual process.
- Increases transparency and control with automated reporting.
- Streamlines the data management process and helps in conserving the resources.

Call Center Operations

Almost all organizations include call centers to solve customer queries. When the customer raises an issue, a call center executive will require to have all the information about a customer. They might need multiple systems or applications to get all the details.

With the help of RPA, it will be easy to consolidate all the details about a customer on a single screen. It will help the executive to have all the information required to provide the solutions for the specific queries.

Advantages of RPA Implementation with Call Center Operations

- Shorter call duration.
- Better communication.
- Optimal use of resources.
- Minimal chances of errors.
- Automated responses and triggers.

Forms Processing

Many organizations process forms for preparing the initial database in their system. It helps organizations to keep paper-based proof that can be served for further use in the investigation where paper-based proof is important. When these forms need to be transferred to digital, an RPA can be helpful.

RPA solution can read the forms and process further data entry tasks based on the data given in those forms.

Advantages of Forms Processing with RPA

- Reduced paper cost and storage memory.
- Remote access from anywhere.
- Checklist automation and enhanced auditing.
- Fast processing and improved productivity.

Credit Card Applications

RPA bots can be programmed to process the majority of credit card applications. They can handle several functionalities such as initiating a credit card application, collecting the required documents related to the individuals, performing necessary credit checks, carrying out required verifications, etc. RPA bots can automatically handle all these tasks.

Based on the details shared by an individual, RPA decides whether or not an individual is eligible for a card. If an individual is eligible for a new card, then the card will be issued. The entire process will be closed after the card is delivered successfully.

Advantages of Automating Credit Card Applications

- Improved employee productivity.

- Reduced process time.
- Better customer satisfaction.
- Access to online documents anytime, anywhere.
- Availability of useful methods to crosscheck operational metrics for process excellence.

Incoming Customer E-mail Query Processing

Many support organizations answer to thousands of e-mails daily. With RPA, such support tasks can be easily automated. RPA can handle the upcoming mails and separate them into defined groups. RPA can also provide automated responses to frequent issues or e-mails with the resolution. RPA categorizes the critical e-mails which are further assigned to respective personnel or executive.

Advantages of Automating E-mail Query Processing

- Increased scale and scope of e-mail campaigns.
- Increased average order value.
- Improved customer lifetime value.
- Increased **ROI (Return on Investment)** on staff costs.

Payroll Processing

Payroll processing is one of those tasks that require manual intervention every month in a year. RPA systems can be used to schedule and automate such repetitive tasks. These tasks may include data transfer and management, payslip generation, benefits disbursal, and others.

Advantages of Payroll Automation

- Generates accurate payslips.
- Calculates expenses, bounces, holiday pay, etc.
- Reduces the burden of compliance.
- Eliminates the requirement to understand complicated tax legislation.
- Saves and manages the data related to payslips and annual reports in an easily accessible and secure way.
- Payroll calculations and deductions at a faster rate.

Account Reconciliation

In banks and insurance sectors, requests for account reconciliation are very common and regular. An individual or an organization may perform account reconciliation to avoid overdrafts on cash accounts, fraudulent or overcharge on credit card transactions, etc. These types of tasks can be automated with the help of RPA software robots.

RPA helps in making such tasks easy by matching the payment details with the bank data and other records. The records are reconciled if the details are the same. During an unmatched or suspicious transaction, the software robot sends the records for further validation.

Advantages of Automating Account Reconciliation Process

- Reduces duplicate payments.
- Improved efficiency.
- Enhances the speed of the processes.
- Saves time in manually verifying bank statements and general ledger software.

Dispute Resolution

Dispute handling and management is another area of concern in the banking sector. RPA deployment in banks has drastically reduced the dispute resolution cycle and human errors. RPA helps in boosting operational efficiencies and overall customer experience.

Advantages of using RPA in Dispute Resolution

- Faster resolution to problems.
- Improved process.
- Prompt services.

Shipping Notifications

Many shipping and logistics companies are manually performing the operations like scheduling a delivery, tracking the information, estimating the time of arrival, etc. RPA can automate such manual processes and save time as well as costs. RPA can extract shipment details from incoming e-mails, log jobs from scheduling systems, and provide pick-up times in the customer's dashboard. The software bots

can also scan and capture carrier website data, track the delivery over GPS, and can also help in automating e-mail communications.

Advantages of Automating Shipping Notifications

- Reduces labor costs.
- Increases accuracy.
- Allows streamlining of several tasks into one process.
- Avoids dimensional weight surcharges.

On boarding Employees

When an organization hires employees, the offer letter is automatically generated and sent to the employees with the help of the RPA system. RPA system uses pre-defined rules to make decisions according to the new employee's profile. The details are also updated into the company's database. This type of on boarding system accesses the company's data system according to a specific job position.

Advantages of On boarding Automation

- Efficient Data Collection.
- No errors.
- Low cost.
- Time-saving.
- Enhanced security to store employee data.

Member Eligibility and Billing

RPA system can quickly check the eligibility criteria of individuals and organizations for various products provided by the banks and insurance companies. With the RPA implementation, these processes do not require human interaction to check eligibility. They are automated to process the data as per the eligibility criteria. Such processes can be made available online so that they can be used anytime from anywhere.

Advantages of automating Member Eligibility and Billing System

- Faster processing of applications.
- Automated verification system.
- Easy process.
- Higher customer engagement.

5.15 Myths of RPA

Robotic process automation (RPA) is one of the most popular technologies available for an organization that saves time, money, and resources. It is the best option to automate repetitive, high-volume, and rule-based processes that require human interaction. RPA uses software bots that mimic the tasks usually performed by humans. With RPA, an organization can surely improve the operational process and change the face of business.

Although several industries have deployed RPA with multiple benefits, there are still some myths about this technology. Here, we are discussing some common myths of RPA:

The Robots are Physical / Humanoid

The term robot in RPA creates a picture of a metal humanoid in our minds. It is one of the common myths about RPA that RPA uses physical robots or humanoids. But the fact is, there is no involvement of physical robots or industrial robots in RPA. Instead, a term robot refers to software robots or virtual robots that automate mundane and repetitive digital tasks.

Robots will replace humans

Another common myth about RPA is a concern that the human workforce will be replaced. In reality, RPA only decreases the requirement for repetitive human effort. Rather than replacing a human workforce, RPA will allow them to handle more value-added tasks that need human intelligence. In such a way, humans will achieve more time to innovate and seek out areas such as managerial or supervisory roles. There are continuously new roles being created in the automation environment. Organizations also need to manage roles for monitoring and training of software robots. There will be more opportunities in this field as the popularity of RPA is increasing day by day.

Apart from it, RPA is not yet intelligent to perform tasks like a human worker. RPA robots cannot make decisions on their own, as they do not include human intelligence or common-sense. Due to the lack of such features, RPA will not be

able to replace humans on its own. RPA can only handle rule-based tasks as per the logic it is coded or developed.

As a conclusion, we can say that there will be no mass unemployment with RPA.

Robots are completely accurate

RPA robots can eliminate human errors and can be completely accurate. But the main concept is that the software robots are only as accurate as they are developed or programmed. RPA bots do not contain any cognitive capabilities or intelligence. They simply execute the set of instructions they are programmed to execute.

So, if software robots are correctly set up, they will be completely accurate or error-free. If there are errors in the used logic of their code, they will continue to replicate those error hundreds or thousands of times until a human removes it. To eliminate this kind of error, it's important to ensure that processes are optimized and error-free before implementing the automation in any task. It is better to monitor the software robots in the initial stages of automation.

RPA is expensive

Many organizations have still not yet deployed the RPA, as they think that automation is expensive. But this is not true. The annual cost itself will be lower than the total wage of employees performing the same tasks. Apart from it, RPA robots can work 24/7 without any lunch break, or leave, etc. The most important fact is that one minute of work for the robot is roughly equivalent to approx. fifteen to twenty minutes of work for a human employee.

Therefore, hiring machines can create a huge cost-benefit for any organization. The other important thing for implementing RPA is that RPA does not require replacement for the existing systems. It can utilize existing systems to implement automation scripts to mimic human behavior. Thus, it will not cost anything more for adding new infrastructure and systems.

Robots can automate everything

Although RPA is emerging technology, it still does not allow automating all the processes. It only allows automating such processes that follow the criteria given below:

- Rule-based.
- High transaction volumes.

- Low exceptions.
- Stable and well-defined processes.
- Low system change.
- Structured data and readable electronic inputs.

It still does not guarantee that automating the processes satisfying the above terms will be beneficial. RPA analysts and process managers together find the best processes to be automated. RPA becomes more challenging where processes are non-standardized and need frequent human intervention to complete. For example- interacting with customers.

Robots are fully automated and can be left unattended 24/7

This is a big myth about RPA software bots. Humans are actually required for programming, running, scheduling, and monitoring the robots. There are some other processes, such as exception handling, tracking robot performance, and performing necessary support activities of production that need human intervention.

To use RPA software, one needs to have basic knowledge of programming

This is also a myth that a person should have the basic programming skills to use the RPA software. However, this is not true. There is no need for any programming knowledge to use the RPA system. To use RPA software, one should know how the software works on the front-end and how the tasks are assigned to the RPA worker for automation. Instead, RPA system developers require basic knowledge of coding, programming, and scripting.

Apart from it, many of the popular RPA software offers a "record-and-play" feature. This refers to the use of a desktop recorder that records the actions performed by a user. It further generates the script as per the performed actions. These types of scripts are usually not robust enough and cannot be trusted.

Nowadays, there are several platforms for developing RPA tools such as UIPath, BluePrism, Automation Anywhere, etc. They allow RPA developers to build RPA bots to perform automation without any hassle. These tools are also minimizing coding requirements.

5.16 Top RPA Vendors

In a digital marketplace, Robotic Process Automation (RPA) is known as one of the most innovative technology. It is growing very fast as enterprises are trying to do things easier and faster with the help of software. Such software can help to automate digital business processes with accurate decision making. RPA can streamline repetitive and rule-based business processes. It enables systems to take intelligent decisions with the help of RPA software robots.

Therefore, it is very important to choose the right vendor who can find the right business processes and provide the successful implementation of RPA solutions. Choosing the right vendor will help organizations to explore the full potential of robotic process automation.

Let's elaborate the top vendors of robotic process automation:

Blue Prism

Blue Prism is the registered name of the Blue Prism Limited, which is a UK based multinational software corporation. It was introduced in 2001. The primary aim of Blue Prism is to provide a technology that could help organizations to improve the accuracy and efficiency of their workflows.

Blue Prism is one of the top automation companies that invented the term 'Robotic Process Automation'. It uses business rules to automate the digital workforce in various ways. It plays a significant role in different sectors, such as investment firms, Banking Groups, E-commerce, etc.

In 2019, Blue Prism added three new software-as-a-service (SaaS) solutions:

- Blue Prism Cloud Hub
- Blue Prism Cloud Interact
- Blue Prism Cloud IADA

Cloud Hub is defined as a web-based management console that allows organizations to control their digital workforce. It also adds capabilities around the information cycle to manage the workforce easily.

The **interact** feature helps humans to interact with the software robots in the developed automated workflows as some processes may require manual intervention.

The term IADA stands for **Intelligent Automation Digital Assistant**. It is an AI-based orchestration tool that helps organizations to maximize the productiveness of their workers.

UiPath

It is a world-leading RPA company which provides solutions according to the particular industry, technology, and processes. It was introduced in 2005. The headquarter of Blue Prism was established in New York, United States.

UiPath provides an RPA platform to automate digital business processes across front-end and back-end office tasks. It includes products such as studio, software robots, and orchestrator. It provides solutions in various sectors such as Banking, Finance, BPO (Business Process Outsourcing), Insurance, Retail, Telecom, Manufacturing, Healthcare, Public Sector, etc. It allows users to perform Web Automation, Desktop Automation, GUI (Graphical User Interface) Automation, SAP Automation, Mainframe Automation, Citrix Automation, Excel Automation, Screen Scraping, and Screen Recorder, etc.

In October 2019, the firm added more products (i.e., UiPath Explorer, UiPath Apps, and UiPath Insights) to support Artificial Intelligence and end-to-end automation. These products helped the enterprise to interact with the software robots across both the front and back-office operations.

Automation Anywhere

It is a dedicated RPA company which is located in the United States. It was introduced in 2003. The company offers an enterprise platform that develops RPA software. It develops software bots that automate repetitive and rule-based tasks. It also includes cognitive machine learning and analytics technologies to allow organizations to manage their business processes faster. The company offers a wide range of products such as Robotic Process Automation, BotFarm, Bot Insight, IQ Bot, and Bot Store. It also uses technology that combines both Attended and Unattended RPA.

It gives solutions in different industries such as Finance, Banking, Healthcare, Science, Insurance, Public Sector, BPO, Telecom, Retail, and Manufacturing. The company serves customers in Europe and Asia.

Pega systems

It is one of the top vendors in the field of robotic process automation industry. It is a US-based robotic process automation company. It was introduced in 1983. It offers solutions in digital process automation, business process management, and customer relationship management.

Some of the top services of the Pega platform are application development, chatbots & virtual assistants, case management, decision management, workforce intelligence, DevOps & testing, mobility, and robotic automation. Pega provides everything that the organizations may require to transform the processes digitally.

There are three main types of Pega platforms:

- Pega Robotic Automation
- Pega Mobility
- Pega Cloud

Like other RPA vendors, Pegasystems also provides solutions in Banking, Insurance, Financial Services, Healthcare, Communication, Science, Government, Retail, Manufacturing, Media & Entertainment, Transportation, Hospitality, etc.

NICE

NICE is one of those RPA vendors that provide both attended and unattended automation solutions. It helps organizations to make smarter decisions with the help of RPA software bots to deliver better customer service, improved productivity, increased accuracy, and rapid return on investment.

The vendor officially acquired Eglue in 2011 and started working with robotic process automation. It further expanded across Europe and US to work with advanced robotic automation.

NICE offers products like RPA, Desktop Analysis, and **NEVA (Nice Employee Virtual Attendant)** Attended Automation. It also provides desktop automation that behaves like a digital assistant. Desktop automation helps organizations to automate repetitive desktop tasks with the help of software robots. They can also be configured to provide feedback to employees, which will help to complete the tasks more efficiently and accurately.

Contextor (acquired by SAP)

Contextor was also one of the top RPA vendors in the Robotic Process Automation industry. It was introduced in 2000. In 2018, the German-based company SAP

acquired Contextor to integrate robotic process automation capabilities into their products. SAP included RPA capabilities of Contextor tool with the SAP cloud platform, document processing, and conversational AI technology by SAP Leonardo Machine Learning. It helped SAP to deliver the intelligent RPA and accelerate the development of SAP Leonardo Machine Learning portfolio.

Contextor also includes solutions to monitor business activities and discover business processes. Business monitoring helps to measure business-related activities and generates reports based on such activities. Business Discovery helps to understand user activities and generates insights according to those activities.

Work Fusion

WorkFusion was founded in 2010. It provides rapid deployment that makes it different from its competitors. It can deploy RPA within twelve weeks. WorkFusion provides an intelligent automation cloud system that comes in business and enterprise tiers. The intelligent automation cloud system also comes in the free express version for personal automation projects.

The intelligent automation cloud is the business automation command center that is built on artificial intelligence. It is used to automate repetitive and rule-based digital business processes.

WorkFusion is referred to as a **software-as-a-service (SaaS)** cloud computing platform. It is the complete automation solution to automate the digital processes in the financial services, eCommerce, and retail industries, etc. It uses **statistical quality control (SQC)** to provide accuracy to the work output.

Softomotive

It is one of the widely used vendors of robotic process automation that can help organizations to put their repetitive tasks on autopilot. It was introduced in 2005. It is best known for providing Quadrant Knowledge Solutions. The primary aim of Softomotive is to offer the smoothest RPA experience. It is useful for small organizations.

Softomotive provides a Digital Transformation Research Report that is used for shared services. It allows Desktop and Enterprise Automation to utilize the benefits of RPA to the maximum extent. Organizations can choose between these automations, depending on their requirements.

Desktop Automation stands for the automation of desktop and web-based processes, and Enterprise Automation stands for the automation of digital enterprise processes. ProcessRobot is one of the top products of Softomotive that is broadly used in the RPA industry. Softomotive provides solutions in different sectors such as Banking, Finance, Insurance, BPO, Telecom, Retail, Manufacturing, Healthcare, Public Sector, etc.

Kofax Kapow

Kofax Kapow is another leader in the RPA market known for providing the most relevant and smoothest RPA tool. It can handle both small and big size businesses and empower their employees by automating repetitive processes. The Kofax tool is beneficial for automating the digital processes, whether they are in Information Technology or operations.

Like other RPA vendors, Kofax Kapow can also integrate data from various sources such as Microsoft Excel, MySql, and many other different databases. Furthermore, Kofax provides a flexible and open RPA platform that helps in the integration without changing or modifying the existing IT infrastructure. According to the 2018 report by The Forrester Wave Robotic Process Automation, Kofax Kapow was selected as the most reliable RPA performer in the world.

There are many more RPA vendors. Some others commonly used RPA vendors are tabulated below:

Vendor Name	Founded	Description
AntWorks	2015	AntWorks is an RPA platform that can understand any kind of data type. It provides Gen 2.0 Intelligent Automation technologies by developing human-like RPA robots in a low-code or no-code environment.
AutomationEdge	2015	AutomationEdge is one of the popular RPA solution providers. It is a unified platform that includes various capabilities like chatbots, intelligent automation bots, artificial

		intelligence, and machine learning. These capabilities help users to improve response time, grow a business, and reduce the overall costs.
Epiance	2001	The Epiance Robotic Process Automation (ERPA) improves the execution of a business process with a portfolio of software solutions. ERPA renders a portfolio of RPA solutions to facilitate on-demand process performance and data-driven process improvement.
Happiest Minds	2011	It deploys RPA to integrate technologies such as AI, Machine Learning, and other knowledge-based systems.
IGT Solutions	2010	It uses robotic automation to provide personalized solutions that require standard system access without the need of any modification in the existing IT infrastructure.
Kryon	2008	It is one of those RPA vendors which provides intelligent robotic process

		automation. It gives solutions for both digital and human workforces. It establishes an interaction between digital processes and human workflows to provide optimal process efficiency.
Lakson Technology	2006	Lakson Technology provides solutions for frictionless automation. It includes support for various business processes in IT sectors, banking, finance, healthcare, telecom, retail, and utilities, etc.
Nividous	2011	Nividous RPA platform allows the automation of digital, repetitive, high-volume processes with the help of AI-powered smarter bots. The platform provides both attended and unattended bots. While attended bots work along with the users to automate the front-end office tasks, unattended bots work in the background to automate back-end office tasks and other data processing.
Probotiq Solutions	2018	Probotiq Solutions provides solutions to

		enterprise clients using various technologies such as RPA, OCR (Optical Character Recognition), chatbots, artificial intelligence, machine learning, etc.
Protiviti	2002	Protiviti uses RPA techniques to identify suitable processes for automation. It also provides infrastructure validation and training management services.
SmartDocs	2010	SmartDocs is one of the leading solutions to implement digital transformation in any organization. It is a one-stop platform that provides quick application development, content collaboration, and automation of the digital business process.
HelpSystems	1982	HelpSystems uses state-of-the-art automation solution that helps organizations to develop comprehensive and intuitive software robots. These software bots use existing systems and applications to decrease the workload of the

		human employees.
Argos Lab	2016	It is one of the top-rated RPA vendors on the market. It provides easy access to robotic automation without the requirements of experienced developers.

RPA Failures

We have already discussed the brighter side of Robotic Process Automation and how it helps organizations to increase operational accuracy, efficiency, and achieve good ROI (Return of Investment) in a short period. All these profits are true, but it does not mean that RPA never fails. Many enterprises are still experimenting with this growing technology to achieve the scale according to their requirements. Apart from it, some survey reports found failures in around half of the RPA projects.

Many enterprises ignore this fact that there are plenty of RPA failure stories. They do not analyze the different cases and scenarios at the beginning of the RPA journey, which leads them into unacceptable or mixed results. Let's discuss the different reasons and causes why RPA can fail:

Shortage of Skilled Resources

The use of RPA is becoming an important factor in today's digital marketplace. But, there is a shortage of skilled resources in the market. Organizations are always afraid of managing the requirements of resources while starting or joining RPA technology. Instead, organizations implement this technology to achieve their goals. However, RPA professionals seak for lucrative packages that might not be suitable for some of the companies. In such cases, the shortage of resources often leads to the failures of RPA.

End-to-end Automation

There is a belief that organizations should automate most of the processes to get a good ROI (Return on Investment). However, it is not always possible to automate

all the steps of the process. In some processes, it may require the integration of machine learning and OCR technology. These new technologies will cost extra money. But, there is no assurity that it will produce the desired results. This is likely to lead to failure and disappointment in the RPA project.

Therefore, it is recommended to start with the simplest, basic functions that meet the requirements of RPA. It will help in finding quick wins and gains.

Lack of required support from Business

Sometimes, organizations do not provide required business rules, workflow diagrams, possible workarounds of failures, and other kinds of data due to security reasons. Such type of information is required to set up the Bot. If the organizations are not inclined to provide their support, then it will be a challenging task for the operation team. Therefore, organizations may not be able to achieve the desired results. It can be a cause of RPA failure.

Lack of proper team structure

There is a belief that RPA is used to automate all the digital processes, and there is no need for any human intervention. However. It is not true. Organizations are required to assign a team to monitor processes. The team should be capable of finding the problems in the processes and share them with the RPA providers. It will help them to achieve expected results. Lack of proper team structure might be another reason that can prevent organizations from achieving desired results.

Lack of support from the RPA platform vendor

There can be critical situations in any RPA project where there would not be an easy solution. In such cases, our team may not be able to automate a particular step. So, it is important to have vendor support as they know all the features of the RPA tool. They have expertise in using RPA tools and would also have seen many critical situations and solutions related to RPA.

Wrong selection of use cases for automation

It is very important to choose the correct use cases because it plays a crucial role in achieving good or bad ROI (Return on Investment). The selection of wrong use

cases will not produce the desired results. They will not improve the process efficiency or metrics proposed to the Business.

Failing to understand the complexity

When organizations are going to implement RPA, they should be focusing on simple, non-complex processes. However, the selection of non-complex and straightforward processes is not as easy as it sounds. It is better to analyze the selected processes and ensure that the processes are consistent and can be automated with repetitive rules.

Therefore, the complexity of processes identified for automation is also an important factor to get the desired ROI.

Lack of scheduled maintenance plans

It is a myth about RPA projects that there is a minimum to no maintenance required to manage or run an RPA project. However, the bots are deployed in such a way that there will be no requirement of any human intervention. But, the reality is that RPA requires scheduled checking and maintenance to ensure a smooth delivery. The maintenance is usually required in tasks like identification of new unhandled scenarios during Bot execution, issues faced in production environments, etc.

Pre-Implementation Assessment

Organizations must take a Proof of Concept (POC) test. It will help organizations to decide whether RPA is appropriate for them. It can be considered as a key part of a selection process.

Organizations should measure all the aspects of RPA with the help of POC. Because, if they implement RPA without a comprehensive understanding of profits and loss, then this can lead to RPA failure.

Post-Implementation Adoption

It is another factor that can be a reason of RPA failure. Most of the organizations think that they only need to implement RPA with a great approach. They only focus on measures required before the adoption of RPA. However, they fail to take care of circumstances that might come after the automation is deployed.

Learning from RPA Failures

Enterprises should always conduct pilots to understand how Robotic Process Automation works. It can take around two-three months. During this time, a robust RPA model must be developed. An RPA implementation requires advanced planning & training, project oversights, and a definition of success to overcome the reasons of failure:

Advanced Planning

Enterprises should have a proactive plan for successful RPA implementation. They should also focus on the future software of the company that might involve automation. Advanced planning includes the selection of the right processes to be automated and robust implementation of RPA technology. It is also important to get assurity about the expected time and budget before RPA implementation.

Project Oversight

Enterprises should monitor the automation project to ensure that RPA deployment is working as planned. In case of any change or upgrade, the automation should work as usual.

Defining Success

Companies should look for a broad implementation after getting a positive ROI. Instead of positive ROI, companies should also look at their journey to digital transformation and overcoming RPA challenges as additional measures of success.

There is another fact that most RPA projects fail due to human error. So, the organizations should re-analyze the processes and learn from their past mistakes. It is better to implement a different approach. Because, if an applied approach is not a good fit for RPA, then it doesn't mean the organizations should stop using the technology. These initial failures often lead to greater success.

RPA Jobs and Future

Robotic Process Automation has grown exponentially over the past few years. The demand for RPA is increasing in the RPA market as it promises to replace repetitive, rule-based, mundane, manual digital tasks with software robots. It also ensures organizations to make their operational processes error-free.

While RPA technology has grown significantly and essentially taken the automation technology, it begs one of the biggest questions: What are the future prospects and job options of RPA?

In this article, we will discuss the future scope and job options of RPA and understand why it is an important factor in automation marketing.

Scope of RPA

RPA has provided an excellent solution for organizations to replace repetitive, mundane, rule-based processes with software bots. It is now helping organizations who were looking to increase their workflow accuracy and efficiency. First, RPA was widely adopted in the IT sector. It amazed many big organizations as well as small and medium enterprises with outstanding results. Later, it was adopted in other sectors like Finance, Accounting, Banking, etc.

RPA tools are already being used in several organizations. This is going to be the most important thing in the upcoming years. Experts have predicted some points for the future of this technology, which are given below:

Wider Adoption

As it is getting older, more organizations are coming to know about this technology and its benefits. Many multinational organizations have already adopted this technology. Now, SMEs (Small and Medium Enterprises) and other mid-cap industries are moving to adopt this technology. The technology is expected to be used by most of the remaining organizations with the time.

Expansion

With the popularity of RPA, many use cases are also coming into the market. The use of RPA is expanding into various sectors such as accounting, banking, financial services, insurance, retail, manufacturing, law, oil, and gas, etc.

Added Intelligence

RPA is evolving to include artificial intelligence and machine learning. We can expect that RPA will support unstructured data processing and simple judgment based automation in upcoming days. This will help RPA to jump beyond just rule-based technology.

Integration of additional tools

Because companies are adopting RPA to automate their processes, it will become common to integrate it with other tools and software. It will be integrated with additional tools to enhance the features and make automation easier.

SPA will combine

SPA stands for Smart Process Automation. Nowadays, RPA is somehow struggling to automate the unstructured data process. With SPA, there will be a combination of different technologies such as machine learning, AI, and cloud technology that will help to automate the unstructured data process.

Bots as service

It is a belief that RPA bots will be used widely as cloud services. There is a possibility that RPA vendors would be combining Amazon AWS or Microsoft Azure to deliver their services on cloud with advanced AI capabilities.

According to the report by McKinsey & Company, it is predicted that RPA will have a significant economic impact of nearly $5.2 to $6.7 trillion by 2025.

RPA Career

Many large organizations have started investing in the RPA due to its popularity. They are focusing on career opportunities of RPA as it is growing very fast. RPA is facing some challenges in managing the resources required to run this technology. However, it is just temporary because it is spreading very fast in different sectors. It is common with every new technology that arrives in the market.

Since the RPA has grown within a short period, there are many opportunities to build a career in it. The technology is expanding with the combination of AI and machine learning, which will surely change the phase of future automation tasks. The expansion of this technology can also be seen in sectors other than IT. This is spreading in areas like banking, health, finance, accounting, development, etc.

A career in RPA can be beneficial as there is a shortage of resources. The emerging graduates can easily expect a major share of employment in this field. The salary packages for the professionals in this technology are relatively higher when compared to other fields. RPA is going to become the next trending technology, and you will have a great opportunity to find thousands of jobs in upcoming years.

Why choose a career in RPA?

Automation has provided a revolution to the business processes. It has amazed us with the use of software robots that we never imagined a decade back. But now it has changed the way of completing the tasks.

Robotic Automation is a combined workforce of human and software robots that allows us to automate rule-based, repetitive tasks. This innovation is expected to create a wider set of career opportunities for job seekers. Since it is emerging technology, therefore, it is the right time to start a career in RPA with proper training that will help you to have higher pay packages in the end.

RPA Jobs

It is just a myth that many people will lose their job with the arrival of RPA technology. The truth is that RPA has created plenty of job options for aspirants. However, it requires a particular skillset and knowledge. Therefore, it is clear that when the tasks are automated with the help of software robots, there will be new job opportunities. For example, we have already seen the replacement of horse carriage by cars and other transportation machines. It can be referred to as the automation of transportation. But, plenty of jobs were created in the automotive field with the automation of transportation.

In conclusion, advancement in technology only requires the unique creativity and cognitive skills of the human brain. So, RPA will help people to learn new things and reskill themselves.

People with RPA knowledge have lots of job options to choose from and get into employment in the new technology. An RPA developer can be usually assigned to perform three roles in the industry:

Process Designer

The Process Designer analyzes business requirements and processes. He further monitors the changes that occur after the implementation of bots during the development or testing phase.

Automation Architect

An Automation Architect is responsible for building an RPA project with the help of RPA tools to solve real-world problems.

Production Manager

Once the Automation Architect has built the project and rolled into the production, the Production Manager ensures that the processes are being triggered correctly. He also monitors whether all the exceptions are handled.

Technical Responsibilities

RPA developers are required to take the responsibilities given below:

- RPA developers design, develop, and deploy the RPA products to global clients with the help of global teams.
- RPA developers develop a project design to implement the software bots with the business processes.
- RPA developers create and manage the customization of automation.
- RPA developers provide required updates to support continuous improvement.
- RPA developers facilitate process design, validation rules, and generated reports.
- RPA developers configure process flows, control objects, exception handling, etc.

5.17 UiPath vs. Blue Prism vs. Automation Anywhere

The modern world is moving towards automation and artificial intelligence. RPA technology is going to set new heights in the upcoming days. RPA provides software robots to replace the human workforce. It can automate several repetitive tasks that are performed on computer systems.

Although there are several different RPA tools, the RPA market is mostly dominated by UiPath, Blue Prism, and Automation Anywhere. Each tool contains some specific features as well as its own positive and negative factors. Refer to the following table to know the differences between these tools:

Features	Blue Prism	Automation Anywhere	UiPath

Learning	Basic programming skills are beneficial. It can create business objects and manage them in the control centre.	This tool is good for the basic developer.	This tool is based on visual design. It provides a faster implementation.
Use	It is used for Desktop, Web and Citrix automation.	It is used to achieve fair efficiency across all mediums.	It is used for BPO automation. It shines in Citrix automation.
Software bots	RPA bots are only used for back-office automation.	RPA bots are used for both front-office and back-office automation.	RPA bots are used for the front-office as well as back-office automation.
Access	This tool has only application-based access.	This RPA tool has only application based entrance.	This tool has both browser and mobile access.
Cognitive Capability	It has a low level of cognitive capability.	It has a medium level of cognitive capability.	It also has a medium level of cognitive capability.
Recorders	Recorders are not available in this RPA tool.	Recorders are available. This tool allows you to record and modify your actions and supports smart record, web record, and screen record.	Recorders are available. The recorded actions can also be modified.

Architecture	It has client-server architecture.	It has client-server architecture.	It is a web-based (Cloud Based) orchestrator tool.
Technology	This tool is based on c-sharp.	This tool is based on Microsoft technologies.	This tool is based on numerous technologies such as SharePoint, cabana, and elastic search.
Operational Scalability	This RPA tool is good for operational scalability. The execution speed is very high.	This RPA tool provides limited deployment in a large scale robot deployment.	This RPA tool frequently fails or crashes in medium projects.
Process Designer	It includes a visual process designer.	It includes a script based process designer.	It includes a visual process designer.
Reliability	It includes very high reliability.	High reliability is one of the most important features of this tool.	It includes a moderate amount of reliability.
Pricing	This RPA tool has a high cost of acquisition. It provides restricted training.	This RPA tool has a higher cost of deployment.	This RPA tool has effective, entry-level pricing.
Certification	It includes three types of certifications. e.g., delivery provider, capability	It has recently launched several certifications programs.	It has free online training and certification programs.

	provider, and service provider.		
Coding/Programming	It allows the user to write codes. However, users can also use it without any knowledge of programming or coding.	Programming knowledge is not mandatory.	Programming knowledge is not mandatory.

Fluid Power

Fluid Power is the technology that deals with the generation, control, and transmission of power, using pressurized fluids. Fluid power is called hydraulics when the fluid is a liquid and is called pneumatics when the fluid is a gas. Hydraulic systems use liquids such as petroleum oils, synthetic oils, and water. Pneumatic systems use air as the gas medium because air is very abundant and can be readily exhausted into the atmosphere after completing its assigned task.

COMPONENTS OF A FLUID POWER SYSTEM:

Hydraulic System: There are six basic components required in a hydraulic system:

1) A tank (reservoir) to hold the hydraulic oil.

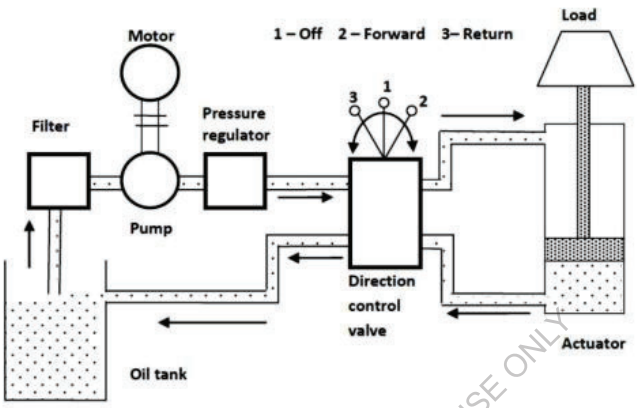
2) A pump to force the oil through the system.

3) An electric motor or other power source to drive the pump.

4) Valves to control oil direction, pressure, and flow rate.

5) An actuator to convert the pressure of the oil into mechanical force to do the useful work.

6) Piping to carry the oil from one location to the other



ADVANTAGES OF FLUID POWER SYSTEM:

The advantages of a fluid power system are as follows:

1) Fluid power systems are simple, easy to operate and can be controlled accurately: Fluid power gives flexibility to equipment without requiring a complex mechanism. Using fluid power, we can start, stop, accelerate, decelerate, reverse or position large forces/components with great accuracy using simple levers and push buttons.

2) Multiplication and variation of forces: Linear or rotary force can be multiplied by a fraction of a kilogram to several hundreds of tons.

3) Multifunction control: A single hydraulic pump or air compressor can provide power and control for numerous machines using valve manifolds and distribution systems.

4) Low-speed torque: Unlike electric motors, air or hydraulic motors can produce a large amount of torque while operating at low speeds.

5) Constant force or torque: Fluid power systems can deliver constant torque or force regardless of speed changes.

6) Economical: Not only reduction in required manpower but also the production or elimination of operator fatigue, as a production factor, is an important element in the use of fluid power.

7) Low weight to power ratio: The hydraulic system has a low weight to power ratio compared to electromechanical systems. Fluid power systems are compact.

8) Fluid power systems can be used where safety is of vital importance: Safety is of vital importance in air and space travel, in the production and operation of motor vehicles, in mining and manufacture of delicate products.

APPLICATIONS OF FLUID POWER:

1) **Agriculture:** Tractors and farm equipments like ploughs, movers, chemical sprayers, fertilizer spreaders.

2) **Aviation:** Fluid power equipments like landing wheels on aeroplane and helicopter, aircraft trolleys, aircraft engine test beds.

3) **Building Industry:** For metering and mixing of concrete ingredients from hopper.

4) **Construction Equipment:** Earthmoving equipments like excavators, bucket loaders, dozers, crawlers, and road graders.

5) **Defense:** Missile-launch systems and Navigation controls

6) **Entertainment:** Amusement park entertainment rides like roller coasters

7) **Fabrication Industry:** Hand tools like pneumatic drills, grinders, bores, riveting machines, nut runners

8) **Food and Beverage:** All types of food processing equipment, wrapping, bottling

9) **Foundry:** Full and semi-automatic moulding machines, tilting of furnaces, die casting machines

10) **Material Handling:** Jacks, Hosts, Cranes, Forklift, Conveyor system

CHAPTER -6

6.0 Pneumatics vs Hydraulics

What is Pneumatics?

Pneumatics is a branch of engineering that makes use of pressurized gas or air to affect mechanical motion based on the working principles of fluid dynamics and pressure. The field of pneumatics has changed from small handheld devices to large machines that serve different functions. Pneumatic systems are commonly

powered by compressed air or inert gases. The system consists of interconnected set of components including a gas compressor, transition lines, air tanks, hoses, standard cylinders, and gas (atmosphere). The compressed air is supplied by the compressor and transmitted through a series of hoses. The air flow is regulated by manual or automatic solenoid valves and the pneumatic cylinder transfers energy provided by the compressed gas to mechanical energy. A centrally located and electrically powered compressor powers cylinders, air motors, and other pneumatic devices. Pneumatic systems are controlled by a simple ON/OFF switch or valve.

Most industrial pneumatic applications use pressures of about 80 to 100 pounds per square inch (550 to 690 kPa). The compressed air is stored in receiver tanks before it is transmitted for use. The compressors ability to compress the gas is limited by the compression ratios.

Applications

Pneumatic systems are typically used in construction, robotics, food manufacturing and distribution, conveying of materials, medical applications (dentistry), pharmaceutical and biotech, mining, mills, in buildings, and tools in factories. Pneumatic systems are primarily used for shock absorption applications because gas is compressible and allows the equipment to be less susceptible to shock damage.

Applications of pneumatic systems include:

- Air compressors
- Vacuum pumps
- Compressed-air engines and vehicles
- HVAC control systems
- Conveyor systems in pharmaceutical and food industries
- Pressure sensor, switch and pump
- Precision drills used by dentists
- Air brakes used by buses, trucks, and trains
- Tampers used to pack down dirt and gravel
- Nail guns
- High pressure bank's drive-teller tubes
- Manufacturing and assembly lines

- Pneumatic motor, tire, and tools

Advantages and Disadvantages of Pneumatics

Pneumatic systems are selected above hydraulic systems because of the lower cost, flexibility, and higher safety levels of the system. Pneumatic systems are best suited for applications which require no risk of contamination because they offer a very clean environment for such industries as biotech, dentistry, pharmaceutical, and food suppliers. Since they use clean, dry, compressed air, the system can quickly convey items. The straight and simple design prevents clogging and reduces maintenance. Pneumatic systems are easy to install and portable. They are reliable and has an initial low setup cost because they operate on comparatively low pressure and inexpensive components that reduces operation costs.

What is Hydraulics?

Hydraulics is used for the generation, control, and transmission of power using pressurized liquids. It is a technology and applied science involving mechanical properties and use of liquids. Hydraulic systems require a pump and, like pneumatic systems, uses valves to control the force and velocity of the actuators. Industrial applications of hydraulics use 1 000 to 5 000 psi or more than 10 000 psi for specialized application. The word hydraulics originates from Greek words hydor – water and aulos – pipe. The following equipment is required for a hydraulic system: hydraulic fluid, cylinder, piston, pumps, and valves that control the direction of flow, which is always in one direction.

Hydraulic systems, unlike Pneumatic systems are often large and complex. The system requires more room because a container is required to hold fluid that flows through the system. Since the size of the system is larger, it requires more pressure; making it more expensive than Pneumatic systems. Due to their overall larger size and the incompressibility of oil, hydraulic systems can lift and move larger materials. Hydraulic systems are slower because oil is viscous and requires more energy to move through pipes. During configuration and planning, if the factory or plant has several hydraulic machines, it is ideal to have a central power unit to reduce noise levels.

Applications
Due to the risk of potential hydraulic oil leaks from faulty valves, seals or hoses – hydraulic applications do not apply to anything that would be ingested – such as food and medical applications. They are used in a variety of everyday machine applications:

- Elevators
- Dams
- Machine tools: hydraulic presses, hoppers, cylinders, and rams
- Amusement parks
- Turbines
- Dump truck lift
- Wheelchair lift
- Excavating arms for diggers
- Hydraulic presses for forging metal parts
- Wing flaps on aircraft
- Hydraulic braking system in cars
- Lift cars using a hydraulic lift
- Jaws of life

Advantages of Hydraulics

Hydraulic systems are more capable of moving heavier loads and providing higher forces due to the incompressibility of liquids. Hydraulic systems do many purposes at one time, including lubrication, cooling, and power transmission. Hydraulic powered machines operate at higher pressures (1 500 to 2 500 psi), generating higher force from small-scale actuators. To effectively use a hydraulic system, it is essential to pick an appropriately sized component to match the flow.

Hydraulic systems are larger and more complicated systems. Liquid, such as hydraulic oil is viscous and requires more energy to move. A tank is also required to store the oil from which the system can draw from when the oil is reduced. The initial costs are higher than Pneumatic systems because it requires power that needs to be incorporated into the machine.

6.1Programmable automation

One of the most important application areas for automation technology is manufacturing. To many people, automation means manufacturing automation. In this section, the types of automation are defined, and examples of automated systems used in manufacturing are described.

Three types of automation in production can be distinguished:

(1) fixed automation, (2) programmable automation, and (3) flexible automation.

Fixed automation, also known as "hard automation," refers to an automated production facility in which the sequence of processing operations is fixed by the equipment configuration. In effect, the programmed commands are contained in the machines in the form of cams, gears, wiring, and other hardware that is not easily changed over from one product style to another. This form of automation is characterized by high initial investment and high production rates. It is therefore suitable for products that are made in large volumes. Examples of fixed automation include machining transfer lines found in the automotive industry, automatic assembly machines, and certain chemical processes

Programmable automation is a form of automation for producing products in batches. The products are made in batch quantities ranging from several dozen to several thousand units at a time. For each new batch, the production equipment must be reprogrammed and changed over to accommodate the new product style. This reprogramming and changeover take time to accomplish, and there is a period of nonproductive time followed by a production run for each new batch. Production rates in programmable automation are generally lower than in fixed automation, because the equipment is designed to facilitate product changeover rather than for product specialization. A numerical-control machine tool is a good example of programmable automation. The program is coded in computer memory for each different product style, and the machine tool is controlled by the computer program. Industrial robots are another example.

Flexible automation is an extension of programmable automation. The disadvantage with programmable automation is the time required to reprogram and change over the production equipment for each batch of new product. This is lost production time, which is expensive. In flexible automation, the variety of products is sufficiently limited so that the changeover of the equipment can be done very quickly and automatically. The reprogramming of the equipment in flexible automation is done off-line; that is, the programming is accomplished at a computer terminal without using the production equipment itself. Accordingly, there is no need to group identical products into batches; instead, a mixture of different products can be produced one right after another.

6.2 CNC Machine Tool

CNC or "**computer numerical controlled"** machines are sophisticated metalworking tools that can create complicated parts required by modern technology. Growing rapidly with the advances in computers, CNCs can be found performing work as lathes, milling machines, laser cutters, abrasive jet cutters, punch presses, press brakes, and other industrial tools. The CNC term refers to a large group of these machines that utilize computer logic to control movements and perform the metalworking.

Robots as Precision Machine Tools

To remain competitive, high-end manufacturing companies are looking for accurate, reliable and maintenance-free machine tools offering fast change-over, programming and setup. Industrial robot technology could provide an excellent base for machining because it is flexible and affordable.

COMET (Plug-and-produce Components and Methods for adaptive control of industrial robots enabling cost effective, high precision manufacturing in factories of the future), co-funded by the EU, is creating a solution that enables the use of industrial robots for high-end machining. Robots of any brand fitted with the plug-and-produce controller unit can respond to manufacturing industry needs for cost effective, flexible and reliable manufacturing solutions.

Tasks for CNC Machines

In general, an individual CNC machine is only suited to one task. However, there is a range of different machines, each designed for a specific machining operation

- **Milling** — Controlling a rotary milling tool to progressively remove layers of material.
- **Drilling** — Positioning a spinning drill bit to create holes in a material.
- **Turning** — Controlling a static tool to remove material from a spinning workpiece.
- **Broaching** — Controlling a static broaching tool to cut polygonal shapes into a spinning or static workpiece.
- **Sawing** — Controlling a spinning saw tool to cut lines in a work piece.

Tasks for Robots

It would be impossible to give a complete list of all the possible tasks that a robot can be used for. The only limit is your imagination (and a few practical limitations of the technology).

- **Machining** — Many of the same tasks that CNC machines can do can also be done by a robot… but not all. This capability may be the reason that some people fail to recognize the differences between robots and CNC machines.
- **Pick and place** — Moving objects around the workspace.
- **Welding** — Spot welding, arc welding, resistance welding… all are achievable with robots.
- **Sorting** — A type of pick and place which requires added sensing to detect the type of object.
- **Painting** — Practically any process task which involves moving a tool along a path is suitable for robotics.

6.3 Differences between Robots and CNC Machines

Besides the tasks you can achieve with them, there are performance and quality differences between the two technologies.

1. **Workspace** — The workspace of a CNC machine can usually be defined as a small cube. Robots, by contrast, usually have a large, spherical workspace.
2. **Programming** — CNC machines are programmed using G-Code. These days, this is most often generated by a CAM software, not coded by hand. Robots are programmed using a manufacturer's programming language, but programs can be generated by many other programming methods (including G-Code) via a robot post-processor.
3. **Accuracy** — CNC machines are usually more accurate than robots with accuracies going down to fractions of a micron. Robot accuracies can be improved by calibration but are more likely to be 100s of microns.
4. **Stiffness** — CNC machines usually have high stiffness in all axes. The stiffness of robots is generally lower but it varies depending on the type of robot — e.g. a Scara robot has high stiffness in the Z axis.
5. **Singularities** — The position of a robot tool is usually calculated by an inverse kinematics algorithm. These can produce singularities — areas of the workspace which are basically "dead zones" caused by mathematics within the algorithm.

6.4 Robot Cycle Time: How to Calculate and Optimize Your Time

Robot cycle time is the time it takes a robot to complete one complete cycle of its programmed task. It includes both the value-added time — when the robot is moving or performing the operation — and any non-value-added wait time.

Research has shown that lower cycle times result in reduced costs per work piece. The longer your cycle time, the more it costs to create your products.

Because robots are very consistent, the cycle time has a powerful impact on the overall productivity of the robot. Any inefficiencies or wasted time will happen every single cycle. Thus, the inefficiency is multiplied.

Factors Affect the Robot Cycle Time

Various factors affect the cycle time of your robot. Some of these are under your control to change. Others are not.

Factors that affect it include:

- The robot model
- The controller model and configuration
- Specifics of the task you are performing
- The speed and acceleration of the robot

6.5 Calculate Robot Cycle Time with RoboDK

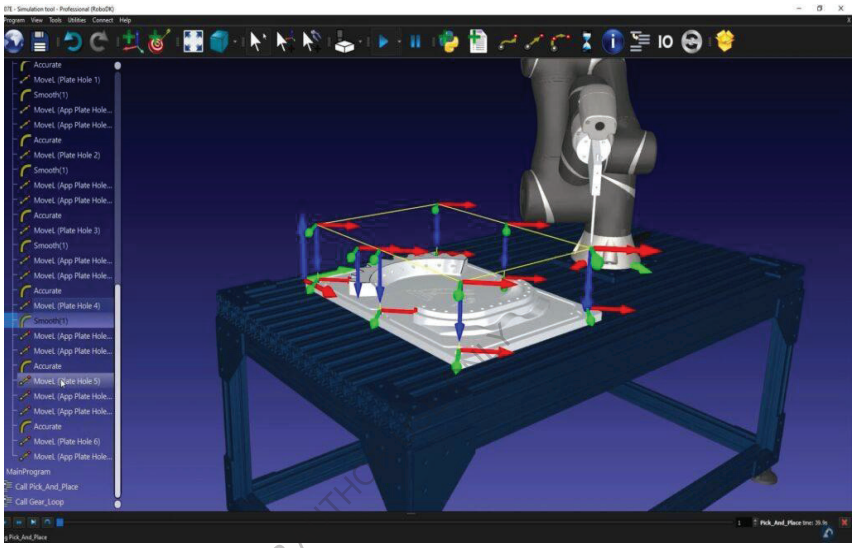
Before you can improve your cycle time, you first have to calculate it. This is where you can benefit from a good robot simulator.

RoboDK includes cycle time estimation as a core functionality of the software.

The steps to estimate your cycle time in RoboDK are:

- Set your robot's joint speed and acceleration as accurately as possible.
- Add rounding to any relevant robot movements (see below).
- Be aware of delays and pauses in the robot program. The software will also add these to the cycle time.

- Move your robot to the desired start position. This ensures RoboDK doesn't add an unnecessary movement to the start of the calculation.
- Run the robot program completely. When the program finishes, you will see the estimated cycle time in the bottom right-hand corner of the screen.



3 Ways to Optimize Robot Cycle Time

Now that you know your robot's cycle time, how can you optimize it?

Here are 3 great ways to optimize cycle time:

1. Add Rounding to Your Robot Moves

Rounding is a method to reduce this stop-start by making the robot move along a slight curve instead of going to the corner. This reduces the cycle time. You should only use it for paths where you don't need a highly accurate movement.

Every time your robot moves to a corner of a movement, it will have to stop and restart its motion. For example, for a robot following a square path, it will stop at each of the corners of the square.

2. Optimize the Robot's Speed and Acceleration

There is a delicate balance between the speed and acceleration of the robot. Changing one of them, or both, can have a significant impact on your cycle time.

The speed and accelerations are different for every robot model. Experiment with different speeds and accelerations to find the best configuration for your robot and task.

3. Track Metrics and Continuously Improve

The best way to optimize anything is to track it and continuously improve it over time. This requires you to choose the right metrics.

The first metric to track when optimizing your robot task is the "cycle time" itself. For each change you make to the robot's program, note down its effect on the cycle time. Over time, you can also track metrics like "number of cycles per day" or "cycles completed."

Geometric classification and Control classification of robotics

They can be further subdivided as:

Cartesian Robots: these are perhaps the most common types of robots. They have three axes which are linear i.e, they can only move in straight lines rather than rotating and are mounted at right angles to each other. Because of their rigid structure, this type of robots usually can offer good levels of precision and repeatability. Cartesian robots are mostly used in the industrial and the manufacturing sector.
Cylindrical robots: The body of this type of robot is such that the robotic arm can move up and down along a vertical member. The arm can rotate about that vertical axis and the arm can also extend or contract. This construction makes the manipulator able to work in a cylindrical space. They are used for assembly operations, spot welding and for die casting machines.

Spherical Robots: This type of robot works in a spherical system. It can move in a bi-angular and single linear direction. SCARA Robots: SCARA stands for Selective Compliance Arm for Robotic Assembly. This type of robot has two parallel revolute joints. They are used for assembly purposes all over the world.

Articulated Robots: These are robots with a wide range of movements that include forward, backward, upward and downward motion. Because of their large

work envelope, articulated robots can be used for several different applications like assembly, arc welding, material handling, machine tending, and packaging.

Parallel Robots: These are closed-loop systems to support a single platform where both accuracy and dynamic response are needed. An example of this kind of robot would be those used for drilling and milling.

Wheeled Robots and legged Robots: These are robots having wheels, and can be further be categorized as: single wheel robots, two-wheel robots, three and more wheel robots, bipedal robots (humanoid robots), tri-pedal robots, quadra-pedal robots and hexapod robots..

Airborne Robots: these robots can fly through the air. Drones are an extremely popular example of flying robots.

Aquatic Robots: These robots can work on or under water. They are mostly used for underwater exploration of oil, gas or minerals.

Isaac Asimov's "Three Laws of Robotics"

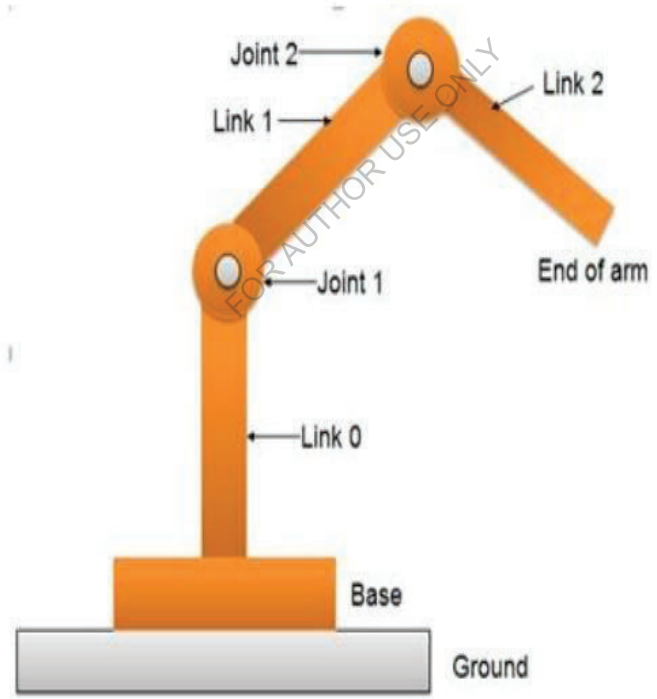
1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey orders given it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

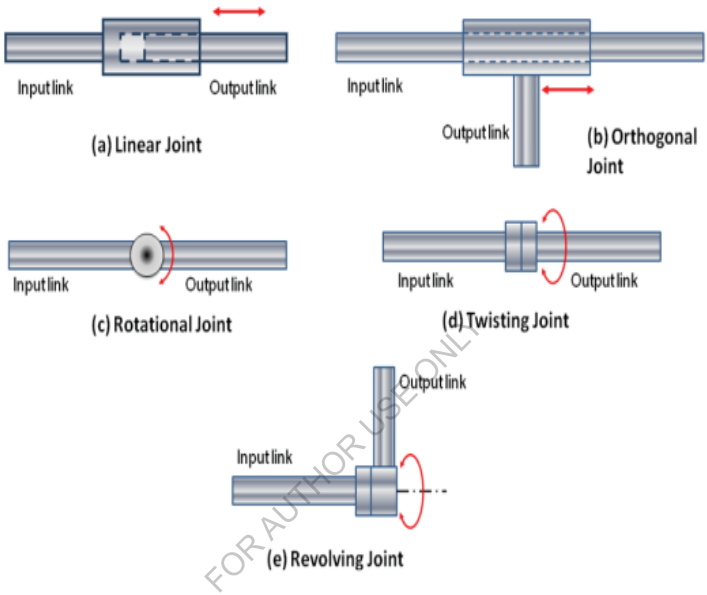
6.6 ROBOT ANATOMY

Joints and Links: The manipulator of an industrial robot consists of a series of joints and links. Robot anatomy deals with the study of different joints and links and other aspects of the manipulator's physical construction. A robotic joint provides relative motion between two links of the robot. Each joint, or axis, provides a certain degree-of-freedom (dof) of motion. In most of the cases, only one degree-offreedom is associated with each joint. Therefore the robot's complexity can be classified according to the total number of degrees-of-freedom they possess.

Each joint is connected to two links, an input link and an output link. Joint provides controlled relative movement between the input link and output link.

A robotic link is the rigid component of the robot manipulator. Most of the robots are mounted upon a stationary base, such as the floor. From this base, a joint-link numbering scheme may be recognized as shown in Figure 1. The robotic base and its connection to the first joint are termed as link-0. The first joint in the sequence is joint-1. Link-0 is the input link for joint-1, while the output link from joint-1 is link-1—which leads to joint-2. Thus link 1 is, simultaneously, the output link for joint-1 and the input link for joint-2. This joint-link-numbering scheme is further followed for all joints and links in the robotic systems.





a**) Linear joint (type L joint)** The relative movement between the input link and the output link is a translational sliding motion, with the axes of the two links being parallel.

b) **Orthogonal joint (type U joint)** This is also a translational sliding motion, but the input and output links are perpendicular to each other during the movement.

c) **Rotational joint (type R joint)** This type provides rotational relative motion, with the axis of rotation perpendicular to the axes of the input and output links.

d) **Twisting joint (type T joint)** This joint also involves rotary motion, but the axis or rotation is parallel to the axes of the two links.

e) **Revolving joint (type V-joint, V from the "v" in revolving)** In this type, axis of input link is parallel to the axis of rotation of the joint. However the axis of the

output link is perpendicular to the axis of rotation.

6.7 Joint Notation Scheme

A robot joint is a mechanism that permits relative movement between parts of a robot arm. The joints of a robot are designed to enable the robot to move its end-effector along a path from one position to another as desired.

The basic movements required for a desired motion of most industrial robots are:

Rotational movement: This enables the robot to place its arm in any direction on a horizontal plane.

Radial movement: This enables the robot to move its end-effector radially to reach distant points.

Vertical movement: This enables the robot to take its end-effector to different heights.

These degrees of freedom, independently or in combination with others, define the complete motion of the end-effectors

Revolute joints permit only angular motion between links. Their variations include:
Rotational joint (R)
Twisting joint (T)
Revolving joint (V)

In a prismatic joint, also known as a sliding or linear joint (L), the links are generally parallel to one another. In some cases, adjoining links are perpendicular but one link slides at the end of the other link.

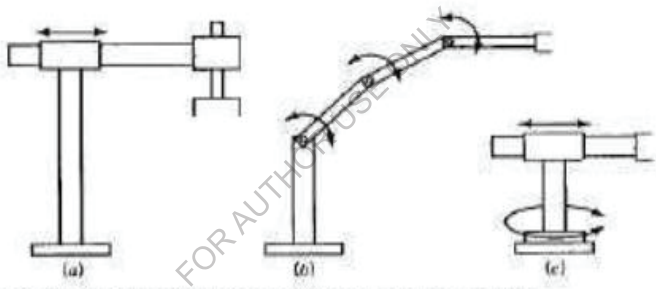
The joint motion is defined by sliding or translational movements of the links. The orientation of the links remains the same after the joint movement, but the lengths of the links are altered.

A rotational joint (R) is identified by its motion, rotation about an axis perpendicular to the adjoining links. Here, the lengths of adjoining links do not

change but the relative position of the links with respect to one another changes as the rotation takes place.

A twisting joint (T) is also a rotational joint, where the rotation takes place about an axis that is parallel to both adjoining links.

A revolving joint (V) is another rotational joint, where the rotation takes place about an axis that is parallel to one of the adjoining links. Usually, the links are aligned perpendicular to one another at this kind of joint. The rotation involves revolution of one link about another.



Robot configurations (a) LL Robot, (b) RRR robot, (c) TL robot

Manipulator Kinematics Kinematics is the study of motion without regard to the forces that create it. For example, Newtons equations for the motion of a point mass can be divided into kinematics and dynamics

$\dot{x} = v$, Kinematics $m\dot{v} = F$, Dynamics By ignoring the dynamics one obtains the system $\dot{x} = v$, where the velocity v is treated as an input to the system. Formally, the kinematic equations can be extended to second order equations (and higher) in the form

$\dot{x} = v$,

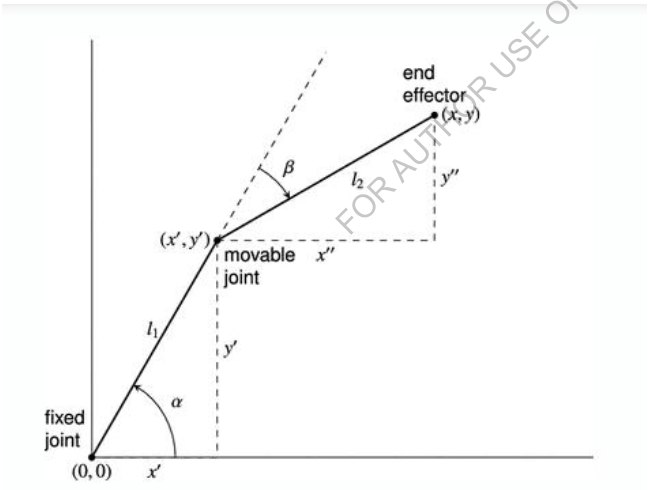
$v^{\cdot} = a$,

$a^{\cdot} = b$, etc.

where a is the acceleration, b is the rate of change of acceleration etc. In practice, the velocity kinematics are of particular interest and the higher order kinematic equations are rarely considered in robotic applications.

Forward kinematics

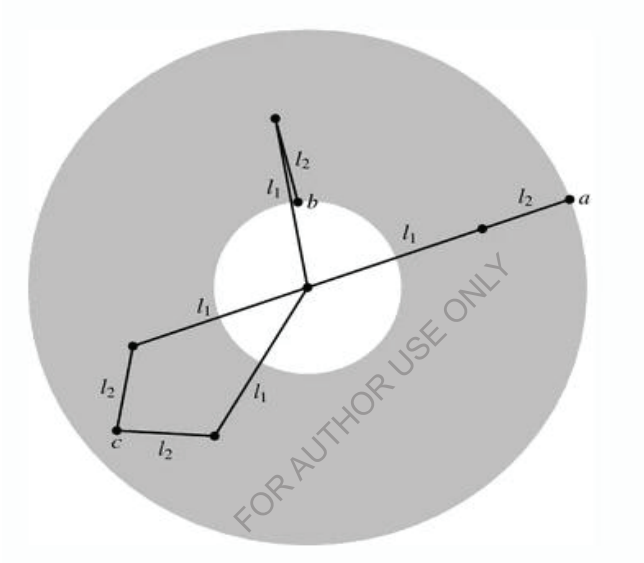
Forward kinematics specifies the joint parameters and computes the configuration of the chain. For serial manipulators this is achieved by direct substitution of the joint parameters into the forward kinematics equations for the serial chain. For parallel manipulators substitution of the joint parameters into the kinematics equations requires solution of the a set of polynomial constraints to determine the set of possible end-effectors locations.



Inverse kinematics

Inverse kinematics specifies the end-effectors location and computes the associated joint angles. For serial manipulators this requires solution of a set of polynomials

obtained from the kinematics equations and yields multiple configurations for the chain. The case of a general 6R serial manipulator (a serial chain with six revolute joints) yields sixteen different inverse kinematics solutions, which are solutions of a sixteenth degree polynomial. For parallel manipulators, the specification of the end-effectors location simplifies the kinematics equations, which yields formulas for the joint parameters.



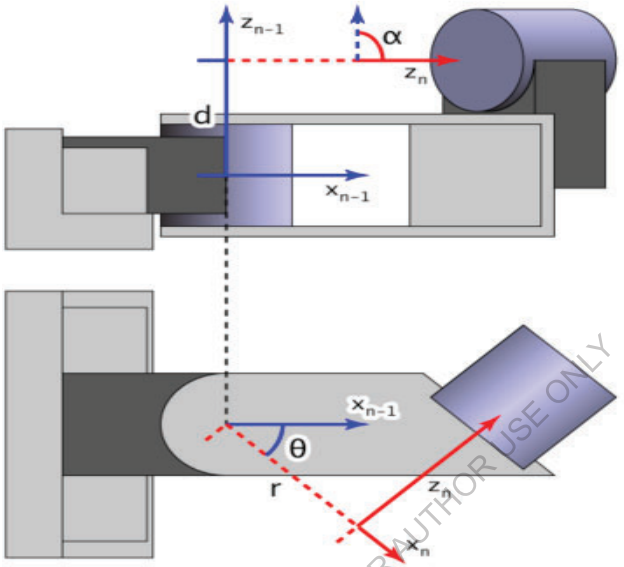
6.8 D-H notations

Denavit-Hartenberg (DH) parameters are often used in robotics to describe the robot properties like axis orientations and arm lenghts.

Denavit-Hartenberg is shortened to DH in the following document. The 4 DH parameters are called theta, d, alpha and a. DOF stands for degrees of freedom.
In mechanical engineering, the Denavit–Hartenberg parameters (also called DH parameters) are the four parameters associated with a particular convention for attaching reference frames to the links of a spatial kinematic chain, or robot manipulator.

Jacques Denavit and Richard Hartenberg introduced this convention in 1955 in order to standardize the coordinate frames for spatial linkages.

Richard Paul demonstrated its value for the kinematic analysis of robotic systems in 1981.[3] While many conventions for attaching reference frames have been developed, the Denavit–Hartenberg convention remains a popular approach.



A commonly used convention for selecting frames of reference in robotics applications is the Denavit and Hartenberg (D–H) convention which was introduced by Jacques Denavit and Richard S. Hartenberg. In this convention, coordinate frames are attached to the joints between two links such that one transformation is associated with the joint, [Z], and the second is associated with the link [X]. The coordinate transformations along a serial robot consisting of n links form the kinematics equations of the robot,

where [T] is the transformation locating the end-link.

In order to determine the coordinate transformations [Z] and [X], the joints connecting the links are modeled as either hinged or sliding joints, each of which have a unique line S in space that forms the joint axis and define the relative movement of the two links. A typical serial robot is characterized by a sequence of six lines Si, i = 1, 2, ..., 6, one for each joint in the robot. For each sequence of lines Si and Si+1, there is a common normal line Ai,i+1. The system of six joint

axes Si and five common normal lines Ai,i+1 form the kinematic skeleton of the typical six degree of freedom serial robot. Denavit and Hartenberg introduced the convention that z-coordinate axes are assigned to the joint axes Si and x-coordinate axes are assigned to the common normals Ai,i+1.

This convention allows the definition of the movement of links around a common joint axis Si by the screw displacement,

$$[Z_i] = \begin{bmatrix} \cos\theta_i & -\sin\theta_i & 0 & 0 \\ \sin\theta_i & \cos\theta_i & 0 & 0 \\ 0 & 0 & 1 & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

where θi is the rotation around and di is the slide along the z-axis—either of the parameters can be constants depending on the structure of the robot. Under this convention the dimensions of each link in the serial chain are defined by the screw displacement around the common normal Ai,i+1 from the joint Si to Si+1, which is given by

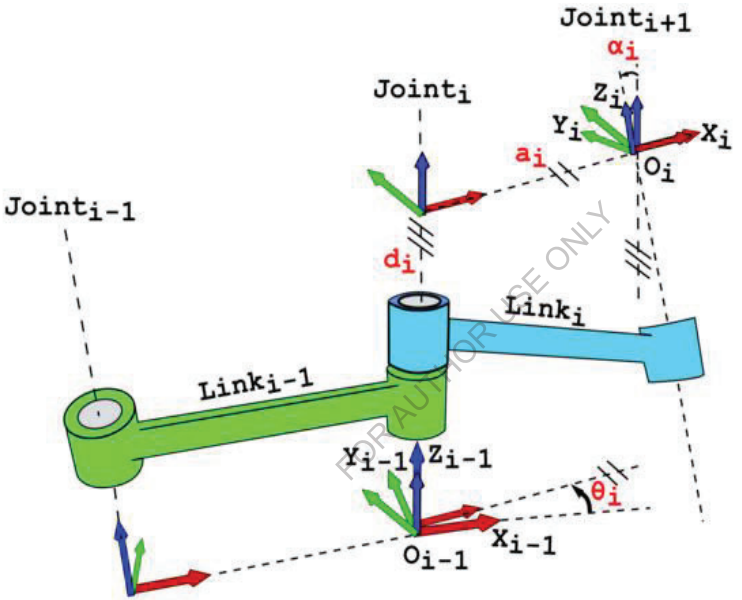
$$[X_i] = \begin{bmatrix} 1 & 0 & 0 & r_{i,i+1} \\ 0 & \cos\alpha_{i,i+1} & -\sin\alpha_{i,i+1} & 0 \\ 0 & \sin\alpha_{i,i+1} & \cos\alpha_{i,i+1} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

where αi,i+1 and ri,i+1 define the physical dimensions of the link in terms of the angle measured around and distance measured along the X axis.

Four parameters

The following four transformation parameters are known as D–H parameters:.[4]

- d: offset along previous z to the common normal
- θ: angle about previous z, from old x to new x
- r: length of the common normal (aka a, but if using this notation, do not confuse with α). Assuming a revolute joint, this is the radius about previous z.
- α: angle about common normal, from old z axis to new z axis



6.9 Denavit–Hartenberg matrix

It is common to separate a screw displacement into product of a pure translation along a line and a pure rotation about the line.

$$[Z_i] = \mathrm{Trans}_{Z_i}(d_i)\,\mathrm{Rot}_{Z_i}(\theta_i),$$

and

$$[X_i] = \mathrm{Trans}_{X_i}(r_{i,i+1})\,\mathrm{Rot}_{X_i}(\alpha_{i,i+1}).$$

$${}^{n-1}T_n = [Z_{n-1}] \cdot [X_n]$$

$$\mathbf{Trans}_{z_{n-1}}(d_n) = \left[\begin{array}{ccc|c} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d_n \\ \hline 0 & 0 & 0 & 1 \end{array}\right]$$

$$\mathbf{Rot}_{z_{n-1}}(\theta_n) = \left[\begin{array}{ccc|c} \cos\theta_n & -\sin\theta_n & 0 & 0 \\ \sin\theta_n & \cos\theta_n & 0 & 0 \\ 0 & 0 & 1 & 0 \\ \hline 0 & 0 & 0 & 1 \end{array}\right]$$

$$\mathbf{Trans}_{x_n}(r_n) = \left[\begin{array}{ccc|c} 1 & 0 & 0 & r_n \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ \hline 0 & 0 & 0 & 1 \end{array}\right]$$

$$\mathbf{Rot}_{x_n}(\alpha_n) = \left[\begin{array}{ccc|c} 1 & 0 & 0 & 0 \\ 0 & \cos\alpha_n & -\sin\alpha_n & 0 \\ 0 & \sin\alpha_n & \cos\alpha_n & 0 \\ \hline 0 & 0 & 0 & 1 \end{array}\right]$$

This gives:

$${}^{n-1}T_n = \left[\begin{array}{ccc|c} \cos\theta_n & -\sin\theta_n\cos\alpha_n & \sin\theta_n\sin\alpha_n & r_n\cos\theta_n \\ \sin\theta_n & \cos\theta_n\cos\alpha_n & -\cos\theta_n\sin\alpha_n & r_n\sin\theta_n \\ 0 & \sin\alpha_n & \cos\alpha_n & d_n \\ \hline 0 & 0 & 0 & 1 \end{array}\right] = \left[\begin{array}{ccc|c} & R & & T \\ \hline 0 & 0 & 0 & 1 \end{array}\right]$$

where *R* is the 3×3 submatrix describing rotation and *T* is the 3×1 submatrix describing translation.

$$\mathrm{Trans}_{z_{n-1}}(d_n) \cdot \mathrm{Rot}_{z_{n-1}}(\theta_n) = \mathrm{Rot}_{z_{n-1}}(\theta_n) \cdot \mathrm{Trans}_{z_{n-1}}(d_n).$$

6.10 Robot Drive Systems

The actions of the individual joints must be controlled in order for the manipulator to perform a desired move its body, arm, motion and wrist. The is provided by the drive system used to power the robot.

The joints are moved by actuators powered by a particular form of drive system.

Common drive systems used in robotics are electric drive, hydraulic drive, and pneumatic drive.

Types of Actuators

*Electric Motors, like: Servomotors, Stepper motors or Direct-drive electric motors

*Hydraulic actuators

*Pneumatic actuators

Mechanical Drive Systems

The drive system determines the speed of the arm movement, the strength of the robot, dynamic performance, and, to some extent, the kinds of application.

A robot will require a *drive system* for moving their arm, wrist, and body. A drive system is usually used to determine the capacity of a robot. For actuating the robot joints, there are **three different types** of drive systems available such as:

- Electric drive system,
- Hydraulic drive system, and
- Pneumatic drive system.

The most importantly used two types of drive systems are electric and hydraulic.

(i) Electric Drive System:

The electric drive systems are capable of moving robots with high power or speed. The actuation of this type of robot can be done by either DC servo motors or DC stepping motors. It can be well –suited for rotational joints and as well as linear joints. The electric drive system will be perfect for small robots and precise applications. Most importantly, it has got greater accuracy and repeatability. The one disadvantage of this system is that it is slightly costlier. An example for this type of drive system is Maker 110 robot.

(ii) Hydraulic Drive System:

The hydraulic drive systems are completely meant for the large –sized robots. It can deliver high power or speed than the electric drive systems. This drive system can be used for both linear and rotational joints. The rotary motions are provided by the rotary vane actuators, while the linear motions are produced by hydraulic pistons. The leakage of hydraulic oils is considered as the major disadvantage of this drive. An example for the hydraulic drive system is Unimate 2000 series robot.

(iii) Pneumatic Drive System:

The pneumatic drive systems are especially used for the small type robots, which have less than five degrees of freedom. It has the ability to offer fine accuracy and speed. This drive system can produce rotary movements by actuating the rotary actuators. The translational movements of sliding joints can also be provided by operating the piston. The price of this system is less when compared to the hydraulic drive. The drawback of this system is that it will not be a perfect selection for the faster operations.

What Are Actuators Used For?

Actuators are mechanical devices that convert energy into motion. This involves a control command that signals a change in a physical system which then generates

force to accomplish a task. The commanding signal can be human-operated or automatically controlled while the energy source varies.

The primary function of actuators is to control machines and allow parts to move. This motion can be any one of hundreds of operations such as lifting, clamping, blocking and ejecting. Typically, actuators are key parts in industrial and manufacturing operations where they activate valves, pumps, motors and switches.

Actuators usually control and direct mechanized motion. Movements can be linear, rotary or oscillatory. In other terms, that motion can be in one direction, circular or back and forth in regular intervals. No matter what end motion a mechanized system desires, it would impossible to achieve without actuator assistance.

Hydraulic Actuators

Hydraulic actuators remain the most popular energy conversion systems. They are common in heavy-duty work like large construction machinery, marine propulsion and cargo handling, military weapons and transportation systems and overall jobs where brute power rules.

How Hydraulic Actuators Work

Hydraulic actuators work on fluid compression and convert that pressure into motion under controlled circumstances. In almost all hydraulic systems, that fluid is some form of oil. Because oil is very difficult to compress, it easily transfers large amounts of energy by volume.

Pressurized hydraulic oil is used in cylinders, which are tubes containing rams. Hydraulic actuators use pressurized fluid energy to drive the ram and operate the device or machine that the actuator serves. Pressures used in a hydraulic actuator ranges between 1,000 to 5,000 pounds per square inch (psi). Large actuators can exceed 10,000 psi for specialized applications.

Hydraulic actuators provide the greatest overall force and power density you can get with any actuator design. They're relatively simple mechanisms with two main parts — a control device like a throttle and an actuation component such as a piston, slide or valve. Here are some pros and cons of hydraulic actuators.

Pros

If it's heavy-duty work you require, then there are far more pros to investing in hydraulic actuators than relying on air or electric power. Your return on investment is strength, efficiency and convenience among these other points:

- **Force:** Hydraulic actuator motors have a high horsepower-to-weight ratio. They are extremely forceful and produce a tremendous amount of power for their size. This makes them economical as well as highly efficient.
- **Safety:** Hydraulic power is easy to contain and control. Hydraulic systems are extremely dependable and their design has been long-proven to be safe and secure. Many hydraulic controls are automated, but it's simple to build manual overrides into hydraulics that let an operator directly control the actuator.

- **Mobility:** Here's where hydraulic actuators also excel. They are self-contained and portable without needing a cumbersome and complicated support system. Hydraulics are ideally suited for trucks and heavy equipment applications.

Cons

Although hydraulically controlled systems have considerable advantages over their rivals, they do have a few drawbacks. There are some applications where hydraulic power may not be compatible, in settings where there is any chance of contaminating product. Here are a few more cons you should know about if you're considering hydraulic actuators.

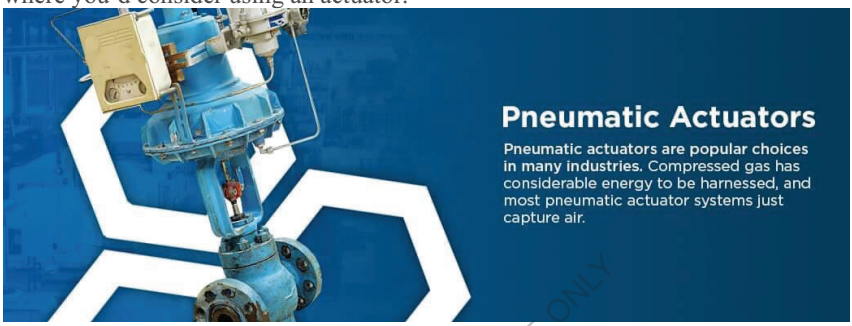
Initial investment: Because most hydraulic actuators are large and powerful, they can be relatively expensive as initial investments. However, like other investments, you have to consider your returns. An initial cash layout pays back over time, especially if you require the power and performance that a hydraulic actuator delivers.

Maintenance: Hydraulic equipment requires maintenance, and that can cost more time and money. But, you'll find that both pneumatic and electric actuators also need their share of maintaining, as does any industrial product.

Leakage: The biggest concern investors have about acquiring a hydraulic actuator is leakage. Hydraulic oil can leak and can be challenging to clean. It's also a serious contaminant. With proper maintenance, though, your risk of hydraulic leakage is significantly reduced.

Pneumatic Actuators

Pneumatic actuators are popular choices in many industries. Compressed gas has considerable energy to be harnessed, and most pneumatic actuator systems just capture air. Fortunately, there's a plentiful air supply in almost all applications where you'd consider using an actuator.



How Pneumatic Actuators Work

Compressing air is a technology that's been around a long time. It's simply intaking air at atmospheric pressure and then mechanically compressing it to a higher pressure. Most actuator systems that use pneumatic power have compression rates of about 80 to 100 psi.

This limited pressure rate makes pneumatic systems stable and safe. However, the low pressure rating makes them less powerful than higher capacity hydraulic actuators. Selecting a pneumatic system over a hydraulic or electric actuator is also a matter of application.

Pneumatic actuator systems have five main parts — a primary motor, a compressor unit, a storage tank, a delivery hose network and the actuator device. In the right situation, such as lighter duty applications, pneumatic systems are good choices. Here are some pros and cons of pneumatic actuators.

Pros

Speed is the biggest pro you'll find with pneumatic actuators. Compressed air allows for high-speed motion and energy released. If you have an application

where speed is more important than power, then you may consider a pneumatic actuator. Here are some more pros about pneumatics.

- **Fast:** Pneumatic actuators are the fastest on the market and that allows for high cycle times. Increased duty cycling allows for greater productivity. That transfers into profitability and a great investment return.
- **Economical:** On average, pneumatic actuators are less expensive to purchase than hydraulic or electric devices. That equates into less capital upfront and a quicker return coming back. Pneumatic actuators are an economical choice for light and medium-duty applications.
- **Simple:** Although there are five main components in pneumatic actuator systems, they're quite basic in design. Simplicity usually means there's less to go wrong and not as much to fix when it does.

Cons

The biggest negative you'll find about pneumatic actuators is their limited strength or work capacity. However, if this isn't a concern, don't overlook the value in pneumatic equipment. Here are three disadvantages to compressed air actuation:

- **Limited power:** This is only a negative if your application is big and bulky. Pressure means power, and there's only so much pressure to be made in pneumatics. When comparing pneumatic vs. hydraulic actuators, you're probably better off with a hydraulic system if you're after high energy.
- **Shorter life cycle:** Hydraulics have a better reputation for longevity than pneumatics. All things being equal, a hydraulic actuator will outlast one powered by compressed air. If you want long-term service, then this is a con to be aware of.
- **Temperature:** Compressed air contains water. Temperature is a big factor in determining the amount of air-water content you have at your facility. Pneumatic actuators are susceptible to water effects and have performance problems when the temperature is too high or too low.

Electric Actuators

Electric actuators have come a long way in a short time. At one point, actuators powered by electricity had their share of problems. They were weak, unreliable and only applicable to very light duty. That's not the case anymore, thanks to advances in technology.

How Electric Actuators Work

Electric activators work on alternating current that energizes an electric motor. Electric energy converts into torque which drives the actuator. This is a straightforward principle that's becoming far more accepted in the actuator industry.

Electric actuators use mechanical components like lead screws and gears to open and close their applications. The difference between pneumatic and electric actuators is that the electric motor is part of the actuator assembly rather than separate. Once applicable to light-duty work, that's now changing. Here are more pros and cons of electric actuators.

Pros

Like any type of actuator, electric actuators can be the right choice when matched with the right job. Here are a few pros that might make investing in electric actuators inviting.

- **Fast:** Electric actuators are directly driven. As such, they have excellent response times that make them fast performers. For quick and light work, electric actuators are great.
- **Precise:** Electric actuators are precise devices. Whereas hydraulic and pneumatic actuators have tolerances like slack, backlash and flex inherent in their design, that's not an issue with electrics. For precision control and performance, electric actuators are a good bet.
- **Clean:** Electricity is a clean energy source, meaning, there is no potential risk for leakage.

Cons

There are some cons to electric actuators, as there are with all mechanical devices. Here are three disadvantages to electric actuators:

- **Weak:** You can't get the same amount of strength and power with electrics that you can with hydraulics or pneumatics. Despite increased technology that adds strength to actuator designs, electrics still remain relatively weak.
- **Complicated:** Electric actuators tend to be complicated designs. Complications lead to a higher risk of breakdown and downtime. This is a con you'll want to remember when looking at actuation systems for your site.

- **Costly:** There is a significant cost attached to most electric actuation devices. On a cost-per-strength basis, electrics are considerably higher priced.

6.11 Robot Simulation:

Robotics simulation is a digital tool used to engineer robotics-based automated production systems. Functionally, robotics simulation uses digital representation – a digital twin – to enable dynamic interaction with robotics models in a virtual environment. The purpose of robotics and automation simulation systems is to bring automation systems online much faster and launch production with fewer errors than occurs with conventional automation engineering.

Automation simulation plays a key role in robotics because it permits experimentation that would be expensive and/or time-consuming if it had to be conducted with actual robots – and even more so when such experimentation must be conducted on the production floor. Robotics simulation permits engineers to try ideas and construct manufacturing scenarios in a dynamic virtual environment, collecting virtual response data that accurately represents the physical responses of the control system.

Robotics simulation has steadily evolved over time to keep up with the growing capabilities of industrial robots. Robots are being deployed into dynamic environments in which the robot's tasks may change frequently or involve human collaborators. Demand for advanced robotics of this kind continues to grow as manufacturers increase product complexity, variety and customization to meet customer demand. Advanced robotics incorporates runtime decision-making and reactive programming for unforeseen events, as well as the ability to adapt and improve based on data collected by the industrial internet of things (IIoT) processed with artificial intelligence (AI). The level of complexity in advanced robotics programming and deploying and operating advanced robots, as well as the high cost that would be incurred to debug a robotics system on the production floor, make advanced robotics simulation a critical component of manufacturing engineering.

Functionality of advanced robotics simulation software

Modern robotics and automation simulation software is designed to address single-robot stations all the way to complete production lines and zones. It begins with design and validation of automated manufacturing processes that include a variety of robotic and automation processes.

Once processes are designed and validated, the software supports detailed engineering of robotic paths and motions, helping engineers to ensure collision-free operation with optimized cycle times. Both time-based and event-based simulation methods may be employed. Advanced robotics simulation software also typically provides support for specific robotics applications:

- Resistance spot welding
- Arc welding
- Drilling and riveting
- Cutting
- Spraying
- Pick-and-place
- Safety operations

Because robotics simulation generates realistic and accurate behaviors and responses in the virtual realm to demonstrate what will happen in the physical realm, it enables manufacturers to design and optimize manufacturing processes without the time and cost penalties of tying up capital equipment or production floors.

Additional benefits:

- Faster product launch cycles
- Nearly cost-free testing of programming alternatives
- Virtual commissioning
- Minimized errors and debugging on the shop floor

6.12 Methods of robot programming

There are different ways in which robots can be programmed to perform their tasks. Each of the main methods are explained below:

Teach Method

This is by far the most popular standard method of programming a robot. The teach pendant is the interface between the operator / programmer and the robot, and the robot is manually driven to the required positions and paths in turn to create the program. To aid the ease of programming, the robot can be moved using different coordinate systems.

Some of the reasons why this method is preferred to others include:

- **Precision-** The operator can input very precise points or coordinates into the teaching pendant thus making it easier to ensure that the robot arm works as expected.
- **Safety**- As a result of the precision, it's easier to ensure that the robot arm and other moving parts will stay within a predefined space for safety purposes. This is especially important for robots that have safety stop or collision detection as a feature.
- **Intuitiveness-** Modern tablet-operated teaching systems are quite intuitive that robotics engineers may not be required to program or reprogram the industrial robots.

Advantages

- Most industrial robots come with a teach pendant, so technicians are already familiar with them.
- They allow precise positioning because the robot can be programmed using numerical coordinates in the world, robot, or other coordinate systems.
- Teach pendants are ideal for simple movements like painting a straight line or a large flat surface.

Disadvantages

- Requires more training and skilled robotics knowledge than more general-purpose, intuitive methods.
- It may be difficult for skilled craftspeople who are not familiar with programming. Programmers must learn a completely different programming language for each robot brand.
- It increases downtime as the robot must be stopped for programming.
-

Joint Co-ordinates

The robot joints are driven independently of each other in the required direction. This will require multiple moves of each axis / joint to achieve the position and orientation of the tool in relation to the work piece.

Global Co-ordinates

The tool centre point of the robot can be driven along the X, Y or Z axes of the robot's global axis system. Rotations of the tool around these axes can also be performed easily using this coordinate system. In this definition, the robot's global coordinate system is usually defined at the base of the robot.

Tool Co-ordinates

Similar to the global co-ordinate system but in this coordinate system, the axes of the robot are "attached" to the centre point of the tool (TCP) and therefore move with it. This system is especially useful when the robot is required to move at angles, which can easily be achieved by rotating the axis to the desired angle, and then initiating a straight line move along that axis

Work piece Co-ordinates

In many instances, it is also possible to define the coordinate system as a point in space within the working envelope of the robot. An example of where this would be beneficial might be where the robot is working between different work pieces and tools which may be moving such as a pallet conveyor or external manipulator. Other potential examples where this might be of use are where the robot is required to move in an arc of specific radius or where multiple work tools are available for use in the robot system.

The teach method of programming is often simple and relatively intuitive to use; however. for complex parts or operations, it can be a time-consuming process. In addition to programming the robots path and positions, the operator will also use the teach method to set specific logic actions at different points in the program, such as setting outputs or looking for input signals to confirm a part is present.

The traditional teach method may still be appropriate where robots are being programmed to perform the same task on just one or two part variants; however, other methods, such as off-line programming are becoming much more popular, especially where a wide range of different parts or tasks need to be processed.

Lead Through

This system of programming was initially popular with some early robot types; however, its use has declined over time, becoming the preserve of some painting applications in the main. In this scenario, the robot is programmed by being

physically moved through the task by an operator, defining points etc. along the way. The disadvantages of this method include the fact that any errors or inaccuracies introduced by the operator cannot be easily rectified. Although no longer a mainstream method of programming industrial robots, many collaborative robots or "Cobots" have this function available as a teaching option and it can be retrofitted to industrial robots where there is a need to do so.

Advantages

- It is quicker and removes the need for multiple button pressing, allowing the operator to simply move the robot to the desired position.
- It is more intuitive because the task is programmed like a human operator. This simplifies the learning process for operators.
- It requires no knowledge of programming concepts or familiarity with 3D CAD environments.

Disadvantages

- Since this method uses the physical robot for programming, it does not reduce downtime.
- It is more difficult to move the robot to precise coordinates.
  There is no way of entering a numerical value, and it is not so good for tasks that are "algorithmic" in nature.
- Moving the robot by hand would be difficult and inaccurate for such a task.

Off-line Programming

Offline programming allows robots or programmers to create program and path data directly from CAD models of the parts being processes. Typically, Off-line Programming methods are most beneficial in complex applications that would require extended periods of time for manual programming. These instances may include applications where parts are large or complex or in production environments where there are a high number of different part types and a low volume of each. Off-line Programming allows production to continue uninterrupted, and in most cases, only minor adjustments will be required to the program once downloaded to the robot, saving significant amounts of time when setting up to produce new part types. Various approaches to off-line programming

from simple path generation to full system design, programming and commissioning within a virtual environment.

Some of the advantages of offline programming include:

- Allows for more complexity
- Can lead to more efficient robot operation
- Supports precision
- Guarantees safety

Advantages

- Reduces the amount of time spent programming robots.
- Because programs are created offline, the robot only needs to be stopped while the new one is downloaded and tested.
- It can be intuitive, especially if the robot can be dragged and dropped around in a 3D CAD environment.
- It's simple to test various approaches to the same problem, which is inefficient for online programming methods.

Disadvantages

- Virtual models will almost certainly never be able to accurately represent the real world.
- After being applied to the real robot, the programs may still need to be tweaked.
- Overall, it may take longer. Although offline programming reduces the robot's downtime, it does require additional time to develop the simulation and test it on the robot.
- It can be time-consuming to resolve simulator issues instead of addressing production issues. This could be related to the simulator's quality.

6.13 ROBOTIC WELDING PROCESSES

Welding robots automate the process, which ensures higher accuracy, less waste, and faster operations. With the range of machinery available, robots can adapt to various welding processes, including arc welding, resistance welding, spot welding, TIG welding and more.

1. ARC WELDING

One of the most common types of robotic welding is the arc process. In this method, an electric arc generates extreme heat, up to 6,500 degrees Fahrenheit, which melts the metal. Molten metal joins parts together, solidifying into a stable connection after cooling. When a project requires a large volume of accurately conjoined metals, arc welding serves as an ideal application.

2. RESISTANCE WELDING

When projects need heat-treating or a way to lower costs, robots may use resistance welding. During this process, a current of electricity creates a pool of molten metal as it passes between the two metal bases. This molten metal joins the pieces of metal together.

3. SPOT WELDING

Some materials resist electrical currents, precluding them from other forms of welding. This situation frequently occurs in the automotive industry for piecing together parts of an automobile body. To overcome the issue, robotic welders use a variation of resistance welding to connect a pair of thin metal sheets in a single spot.

4. TIG WELDING

Robot welding applications requiring high levels of precision may require TIG welding. This method also goes by the term gas tungsten arc welding or GTAW. An electric arc passes between a tungsten electrode and the metal base.

5. MIG WELDING

Gas metal arc welding, also known as GMAW or MIG, is a fast and straightforward method that uses a high deposition level. The heated welder tip melts wire as it moves continuously to the tip. Molten metal can then drip onto a base, connecting the base to a different piece.

6. LASER WELDING

When welding projects require accuracy for a high volume of parts, laser welding is the preferred method of metal joining. Small parts, such as jewelry or medical components often use laser welding.

7. PLASMA WELDING

Plasma welding offers the most significant degree of flexibility because the operator can easily change both the speed of gas passing through the nozzle and the temperature.

6.14 ROBOTIC VS. MANUAL WELDING

Manual welding still has a place in modern manufacturing. For projects in which you need an expert to quickly change the styles of welding used, manual welding will be your best choice. A professional welder can promptly change what he's doing, but robots do not adapt as quickly to uncertain situations.

Because manual welding remains a process that many companies still need, professional welders will not disappear any time soon. In fact, with the shortage of expert welders mentioned above, those who hold certification will easily find work, even with multiple businesses investing in robots.

Replacing manual welders with robots will not put the AWS out of its certification business. Most robot welder operators need to hold certification in the robotics side of this field, for which the AWS also offers certifications. Having robotics experts who know about welding ensures the projects get properly programmed to finish as quickly and cost-effectively as possible.

PROS OF ROBOTIC WELDING

Robotic welding has many positive attributes that convince businesses to select this process for their projects. These benefits can boost productivity and the bottom line for both the welding company and the companies it delivers to.

1. INCREASED EFFICIENCY

Unlike human workers who require breaks and time off, a robot can operate on a 24-hour shift. Longer working hours and quicker speeds allow robotic welding machines to complete their projects much faster than people could. Thanks to the faster completion times, the output from robotic welders far surpasses anything possible from a human.

2. ENHANCED SAFETY

Robotic welders come equipped with a range of safety features to protect people from the welding arc, its temperature and its brightness. These safety features help keep the work area safe. When workers have a safer workplace, there will be more productive and have improved job satisfaction. Injuries and damaged equipment are also expensive for companies, so these safety features can also save them money.

3. BETTER ACCURACY

The ideal project for a robot involves repetitive motions applied to a large volume of parts. When engaged in this type of work, even the most experienced worker will eventually make errors. Robots will finish the project with a higher degree of accuracy because the machine will keep working with the same level of attentiveness until the project is complete.

4. LESS WASTE

Due to their increased precision, robots generate less waste due to mistakes. Manual welders may have to discard parts mistakenly welded together or those with weak junctions. Since robots operate with a higher degree of accuracy, they make fewer mistakes. Without as much material discarded from errors, a facility that uses robotic welders operates more efficiently and produces less waste.

5. LOWER DELIVERY COST

Once installed, robots can weld large numbers of parts together. Though upfront costs to the company using the robotic welder may be high, the high productivity of the machine will eventually recoup the loss. Since automatic

welders have high levels of production, projects done with them may cost less than those employing a team of human workers.

Robotic welders can also cut delivery costs. The company doing the welding can use one operator instead of a team of human welders to accomplish the same amount of work. By trimming overhead, the company you hire for welding work can offer lower prices or additional services.

CONS OF ROBOTIC WELDING

Robotic welding, while helpful, has some drawbacks that could outweigh the advantages in some situations.

1. HIGHER UPFRONT COST

Yes, your delivery costs will likely be lower when you use a company with robotic welders. However, if you were to invest in the machinery and trained operators yourself, you would probably find the investment a loss. Individual companies that don't professionally offer welding services may not use robotic welders enough to justify the high purchase price of the machinery.

If you want your business to take advantage of the benefits of robotic welding, outsourcing the job will be the most fiscally responsible option for your company. You'll get the fast turnaround for a high volume without having to dedicate a significant portion of your budget to machinery.

2. LESS FLEXIBILITY

The benefit of robots performing more accurately than people also comes with a downside. People can react to unexpected situations in a way that robots can't. When a robotic welder needs to make a change, the operator must stop its process and reprogram it. For complex projects, this increases the amount of time required.

3. NOT FEASIBLE FOR SMALL PROJECTS

For smaller projects, the time needed to program the robotic arm may be longer than the welding process. For smaller projects, a human welder could finish the task faster, but this timing depends on the project size and the operator's programming speed.

6.15 Robot Cell Layouts

Robot work cells can be organized into various arrangements or layouts.

These layouts can be classified into three basic type:

1. Robot-centered cell
2. In-line robot cell
3. Mobile robot cell

Robot-Centered Workcell

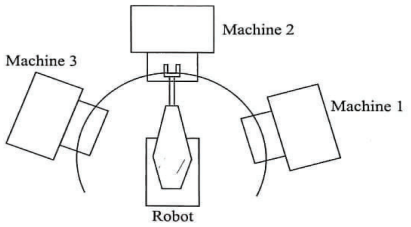
In the robot-centered cell, illustrated in fig, the robot is located at the approximate center of the cell and the equipment is arranged in a partial circle around it.

The most elementary case is where one robot performs a single operation, either servicing a single production machine, or performing a single production operation.

Initial installations of industrial robots in the 1960 s were illustrative of this case. Die casting, one of the very first applications for a robot, required the robot to unload the part from the die after each casting cycle and dip it into a quenching bath.

Other production machine applications required the robot to both load and unload the work part. For some of these applications, the cycle times of the machine were relatively long compared to the part-handling time of the robot.

Metal-machining operations are examples of this imbalance condition. This required the robot to be idle for a high proportion of cycle, causing low utilization of the robot.



Robot centered workcell layout

In-Line Robot Cell

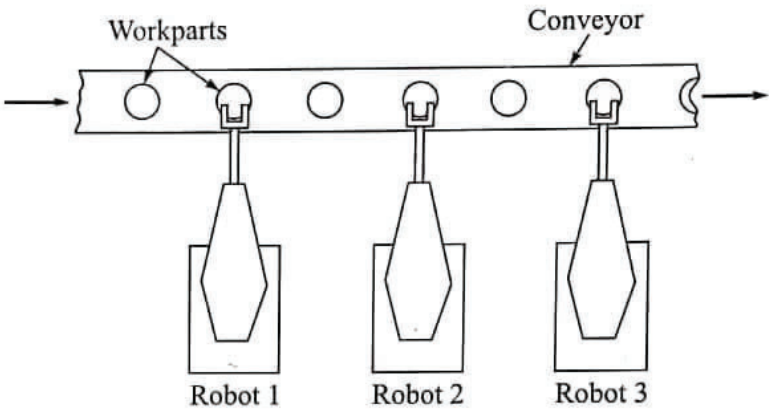
With the in-line cell arrangement, pictured in fig, the robot is located along a moving conveyor or other handling system and performs a task on the product as it travels past on the conveyor.

Many of the in-line cell layouts involve more than a single robot placed along the moving line.

A common example of this cell type is found in car body assembly plants in the automobile industry. Robots are positioned along the assembly line to spot, and weld the car body frames and panels.

The three categories of transfer systems that can be used with the in-line cell configuration are:

1. Intermittent transfer
2. Continuous transfer
3. Non-synchronous transfer



In Line Robot Workcell

Mobile Robot Cells

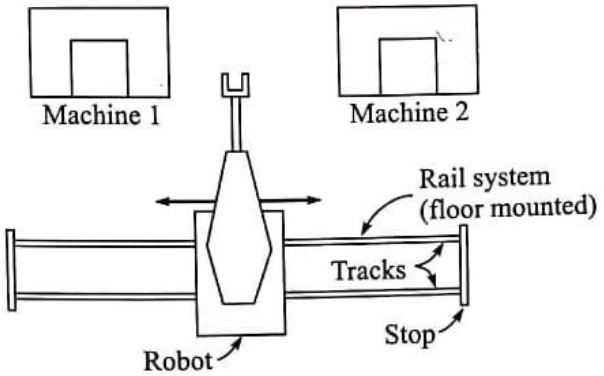
The third category of robot cell design is one in which the robot is capable of moving to the various pieces of equipment within the cell.

This is typically accomplished by mounting the robot on a mobile base which can be transported on a rail system.

The rail systems used in robot cells are either tracks fastened to the floor of the plant or overhead rail systems.

Figure illustrates the concept of the track-on-floor system, while the overhead rail system is shown in fig.

The advantage of the overhead rail system compared to the floor-mounted track system is that less floor space is required. The disadvantage is the increased cost of constructing the overhead system.



Mobile robot cell

Robotics Projects -1

In many application of controlling robots, it is quite difficult and complicated when there comes a part of controlling robot with remote or many different switches. In industrial robotics, medical application for surgery, military application in this field it is quite complicated to control the robot or machine with switches or remote. Therefore a new concept is introduced to control a machine with the movement of hand which will simultaneously control the position and movement of robot.

Working

For designing of an accelerometer based hand gesture controlled robot the AVR ATmega16 microcontroller is used. In this we use our hand gestures as input signals for driving the robot in various direction and the direction of movement of the robot is display on 16X2 alphanumeric LCD.

According to hand gesture, the ATmega16 microcontroller will send a required signal to DC motor driver (L293D) of the robot for driving the robot in desired direction.

The control hand gestures for the robot are right tilt, left tilt, forward tilt, backward tilt and no tilt to drive the robot in right, left, forward, backward direction and to stop it respectively. Now, tilt your hand in various directions and drive the robot as you want.

Robot Direction	Control Hand Gestures
Forward	Forward Tilt
Left	Left Tilt
Right	Right Tilt
Backward	Backward Tilt
Stop	no Tilt

Hardware Required

- 12V, 1A DC Adapter-1 piece
- 3-axis Accelerometer Sensor-1 piece
- AVR Microcontroller Board-1 piece
- DC Motor Driver-1 piece
- AVR USB Programmer-1 piece
- 16X2 Alphanumeric LCD-1 piece
- 1 to 1 Connector-15 piece
- 10 to 10 FRC Female Connector-3 piece
- Robot-1 piece

Software Required

- BASCOM-AVR Integrated Development Environment (IDE)
- AVRDUDE-GUI
- WinAVR-2010
- USBasp Driver

Accelerometer Sensor

Acceleration sensor is used for measuring acceleration and tilt. An accelerometer is a device used for measuring acceleration.

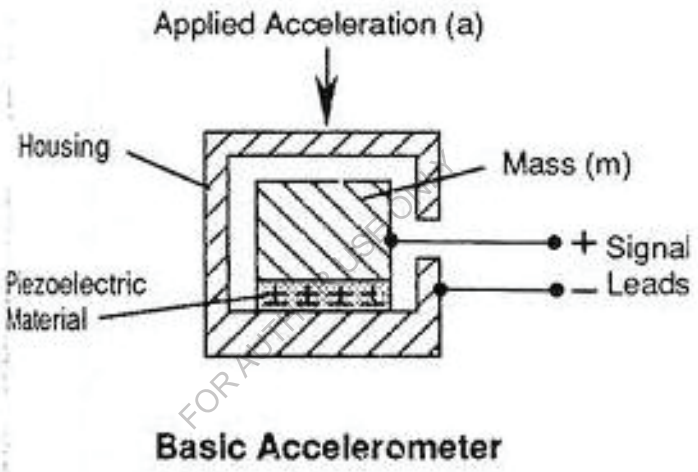
The two kinds of forces which affect an accelerometer are:

- **Static Force -** It is the frictional force between any two objects. By measuring this gravitational force we can determine the how much robot is tilting. This measurement is useful in balancing robot, or for determining whether robot is driving on a flat surface or uphill.
- **Dynamic Force -** It is the amount of acceleration required to move an object. Measurement of dynamic force using an accelerometer tells about the velocity/speed at which robot is moving.

Accelerometer is comes in different configuration. Always use the one which is most appropriate for your robot. Some factors need to be considered before selecting accelerometer is:-

- Sensitivity
- Bandwidth
- Output type: Analog or Digital
- Number of Axis: 1,2 or 3

Consider the schematic diagram of basic accelerometer:

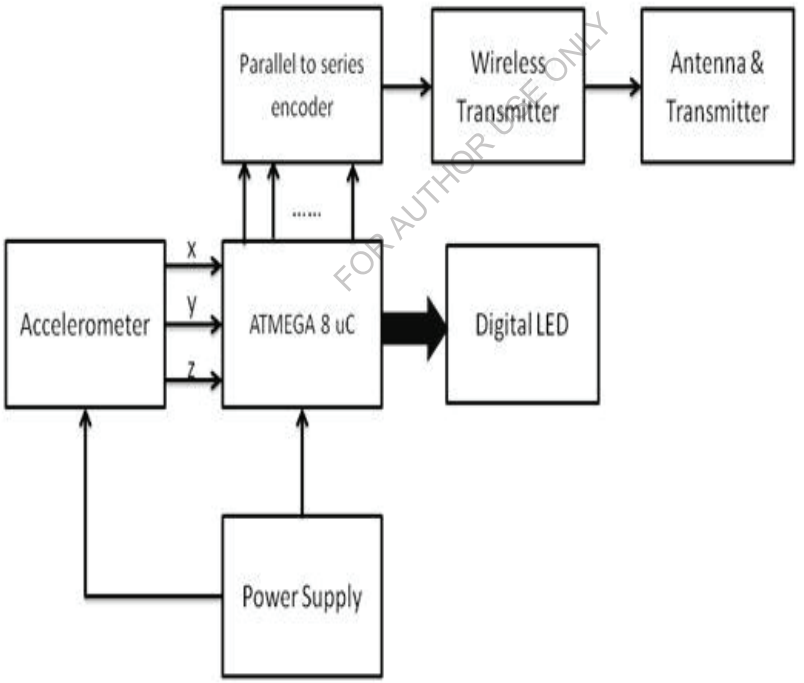


in accelerometer sensor there are 6 pin available in Integrated Circuit (IC):-

- X: On this pin we will receive analog data for x-direction movement.
- Y: On this pin we will receive analog data for y-direction movement.
- Z: On this pin we will receive analog data for z-direction movement.
- VDD: On this pin +5V is applied.
- GND: On this pin the ground is applied for biasing.
- ST: Using this pin sensitivity of accelerometer is set 1.5g/2g/3g/4g.

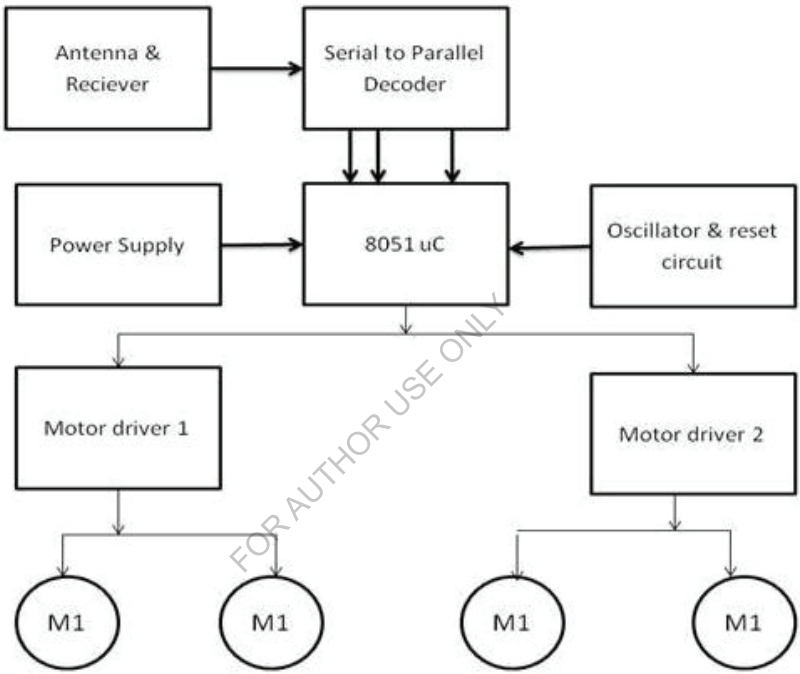
Transmitter Block Diagram

Consider the block diagram of transmitter circuit:



Receiver Block Diagram

Consider the block diagram of receiver circuit:



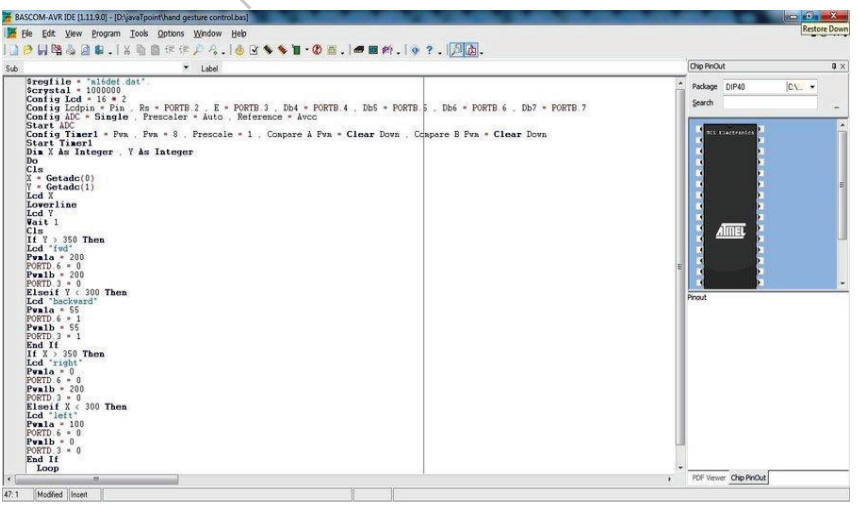
Construction

Source Code:

```
1.      $regfile = "m16def.dat".
2.      $crystal = 1000000
3.      Config Lcd = 16 * 2
4.      Config Lcdpin = Pin , Rs = Portb.2 , E = Portb.3 , Db4 = Portb.4 , Db5 = Por
    tb.5 , Db6 = Portb.6 , Db7 = Portb.7
5.      Config Adc = Single , Prescaler = Auto , Reference = Avcc
6.      Start Adc
7.      Config Timer1 = Pwm , Pwm = 8 , Prescale = 1 , Compare A Pwm = Clear
    Down , Compare B Pwm = Clear Down
8.      Start Timer1
9.      Dim X As Integer , Y As Integer
10.     Do
11.     Cls
12.     X = Getadc(0)
13.     Y = Getadc(1)
14.     Lcd X
15.     Lowerline
16.     Lcd Y
17.     Wait 1
18.     Cls
19.     If Y > 350 Then
20.     Lcd "fwd"
21.     Pwm1a = 200
22.     Portd.6 = 0
23.     Pwm1b = 200
24.     Portd.3 = 0
25.     Elseif Y < 300 Then
26.     Lcd "backward"
27.     Pwm1a = 55
28.     Portd.6 = 1
29.     Pwm1b = 55
30.     Portd.3 = 1
31.     End If
```

```
32.        If X > 350 Then
33.        Lcd "right"
34.        Pwm1a = 0
35.        Portd.6 = 0
36.        Pwm1b = 200
37.        Portd.3 = 0
38.        Elseif X < 300 Then
39.        Lcd "left"
40.        Pwm1a = 100
41.        Portd.6 = 0
42.        Pwm1b = 0
43.        Portd.3 = 0
44.        End If
45.          Loop
46.        End
```

The screenshot of source code used in hand gesture control robot using BASCOM-AVR Integrated Development Environment (IDE) is shown below:



Robotics Projects -2

DTMF based Mobile Controlled Robot

In general, wireless-controlled robots use RF circuits, which have the drawbacks of limited frequency range, limited working range and the limited control.

Use of mobile phone in robot control can overcome these limitations. It provides an advantage of working range as large as coverage area of the service provider, robust control, no interference with other controllers.

Working

In DTMF based mobile/cellphone controlled robot the AVR ATmega16 microcontroller is used with keypad as the input device to drive robot in various directions.

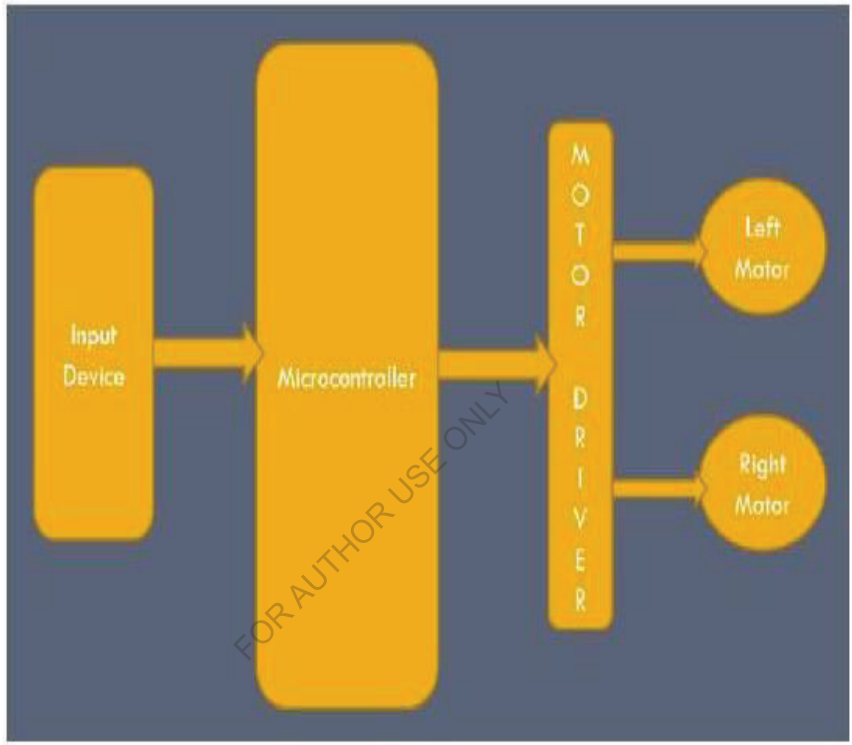
In this project two mobiles are used, one will be connected with the DTMF circuit and another will be used for calling the mobile attached with DTMF circuit.

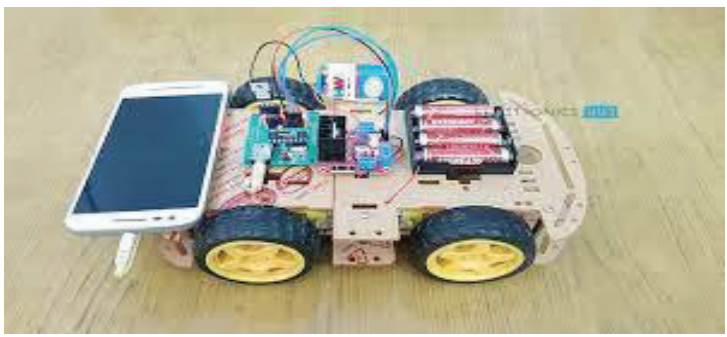
The ATmega16 microcontroller read the 4-bit output signal of DTMF decoder and it will process the signal for determining which key of mobile keypad is pressed, the ATmega16 microcontroller send the control signal to the DC motor driver (L293D) of the robot for driving the robot in desired direction.

The table showing different control keys with their equivalent robot direction is:-

Robot Direction	Control Keys
Forward	2
Left	4
Right	6
Backward	8
Stop	5

Block Diagram:





Consider the table showing Dual Tone Multiple Frequency (DTMF) for different keys of keypad are:-

Frequencies	1209 Hz	1336 Hz	1477 Hz	1633 Hz
697 Hz	1	2	3	A
770 Hz	4	5	6	B
852 Hz	7	8	9	C
941 Hz	*	0	#	D

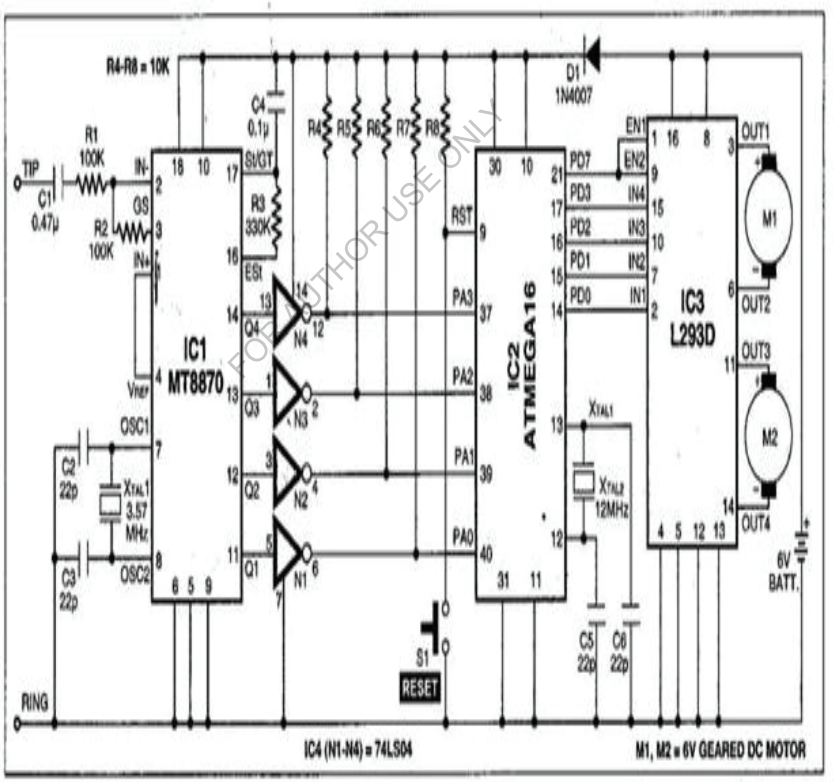
Hardware Required:

- 12V, 1A DC Adapter-1 piece
- DTMF Decoder-1 piece
- AVR Microcontroller Board-1 piece
- DC Motor Driver-1 piece
- AVR USB Programmer-1 piece
- Ear Phone with Connector-1 piece
- 1 to 1 Connector-15 piece
- 10 to 10 FRC Female Connector-3 piece
- Robot-1 piece

Software Required

- BASCOM-AVR Integrated Development Environment (IDE)
- AVRDUDE-GUI
- WinAVR-2010
- USBasp Driver

Circuit Diagram



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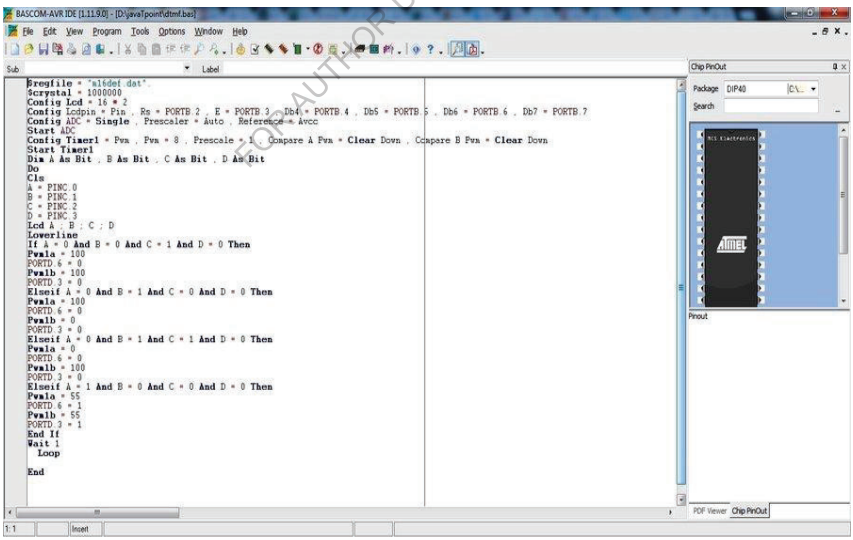
    tb.5 , Db6 = Portb.6 , Db7 = Portb.7
5.  Config Adc = Single , Prescaler = Auto , Reference = Avcc
6.  Start Adc
7.  Config Timer1 = Pwm , Pwm = 8 , Prescale = 1 , Compare A Pwm = Clear
    Down , Compare B Pwm = Clear Down
8.  Start Timer1
9.  Dim A As Bit , B As Bit , C As Bit , D As Bit
10. Do
11. Cls
12. A = Pinc.0
13. B = Pinc.1
14. C = Pinc.2
15. D = Pinc.3
16. Lcd A ; B ; C ; D
17. Lowerline
18. If A = 0 And B = 0 And C = 1 And D = 0 Then
19. Pwm1a = 100
20. Portd.6 = 0
21. Pwm1b = 100
22. Portd.3 = 0
23. Elseif A = 0 And B = 1 And C = 0 And D = 0 Then
24. Pwm1a = 100
25. Portd.6 = 0
26. Pwm1b = 0
27. Portd.3 = 0
28. Elseif A = 0 And B = 1 And C = 1 And D = 0 Then
29. Pwm1a = 0
30. Portd.6 = 0
```

```
31.         Pwm1b = 100
32.         Portd.3 = 0
33.         Elseif A = 1 And B = 0 And C = 0 And D = 0 Then
34.         Pwm1a = 55
35.         Portd.6 = 1
36.         Pwm1b = 55
37.         Portd.3 = 1
38.         End If
39.         Wait 1
40.          Loop
41.         End
```

The screenshot of source code used in hand gesture control robot using BASCOM-AVR Integrated Development Environment (IDE) is shown below:



Top Robotics Project Topics & Ideas for Beginners

1. Robotic Arm

The Robotic Arm project involves designing and building a robotic limb to perform various tasks, such as lifting and moving objects. This project covers the mechanical design of the robotic arm, motor control, and the principles of kinematics.

To work on this project, students should have a mechanics, electronics, and programming background. Familiarity with microcontrollers and actuators, such as servo motors, is essential for building the robotic arm.

Learning outcomes:

- Mechanical design of robotic limbs
- Motor control and kinematics
- Programming for precise and coordinated movements

2.Mobile-Controlled Robot

The Mobile-Controlled Robot project involves designing and programming a robot that can be controlled using a smartphone or tablet. This project teaches students how to integrate Bluetooth or Wi-Fi technology for wireless communication between the robot and the mobile device.

Before starting this project, students should have a basic understanding of electronics, microcontrollers, and programming. Familiarity with Bluetooth or Wi-Fi communication protocols is also beneficial.

Learning outcomes:

- Wireless communication using Bluetooth or Wi-Fi
- Robot control through a mobile device interface
- Integrating sensors and actuators for responsive movement

3. Solar-Powered Robot

The Solar-Powered Robot project focuses on designing and building a robot that can harness solar energy for its operation. This project introduces students to the concepts of renewable energy and energy-efficient design in robotics.

Students should have a foundation in electronics and programming to work on this project. Knowledge of solar panels and energy storage systems, such as batteries, is advantageous.

Learning outcomes:

- Understanding solar energy harvesting and storage
- Designing energy-efficient robotic systems
- Incorporating renewable energy sources in robotic

4. Maze Solver Robot

The Maze Solver Robot project challenges students to create a robot capable of navigating through a maze autonomously. This project involves developing algorithms for path finding and decision-making based on the robot's surroundings.

To undertake this project, students should have a programming, algorithms, and microcontrollers background. Experience with sensors, such as infrared or ultrasonic sensors, is beneficial.

Learning outcomes:

- Developing path finding algorithms
- Sensor integration for environment perception
- Implementing decision-making strategies for maze navigation

5. Voice-Controlled Robot

The Voice Controlled Robot project involves creating a robot that responds to voice commands. This project requires integrating speech recognition technology, natural language processing, and robot control systems.

Students working on this project should have prior experience with microcontrollers, programming and a basic understanding of artificial intelligence concepts. Familiarity with speech recognition libraries or APIs is a plus.

Learning outcomes:

- Integration of speech recognition technology
- Natural language processing for command interpretation
- Robot control based on voice commands

6. Swarm Robotics

Swarm Robotics is an advanced project that explores the coordination and cooperation of multiple robots working together to achieve a common goal. The project emphasizes the development of algorithms for de centralized control and communication between the robots

Students should have a strong foundation in programming, algorithms, and multi-agent systems to undertake this project. Experience with communication protocols and networking is beneficial.

Learning outcomes:

- Design and implementation of decentralized control algorithms
- Communication and coordination between multiple robots
- Understanding swarm intelligence principles

7. Autonomous Drone

The Autonomous Drone project involves designing, building, and programming a drone capable of autonomous flight and navigation. This project covers topics such as flight control systems, GPS integration, and obstacle detection.

Students interested in this project should have experience with electronics, programming, and control systems. Knowledge of aerodynamics and sensor integration is advantageous.

Learning outcomes:

- Design and assembly of drone components
- Integration of flight control systems and GPS
- Programming for autonomous flight and navigation

8. SLAM-Based Robot

The SLAM-Based Robot project involves creating a robot capable of Simultaneous Localization and Mapping (SLAM) for autonomous navigation in unknown environments. This project entails integrating various sensors, such as LiDAR or cameras, and developing algorithms for mapping and localization.

Learning outcomes:

- Sensor integration for environment perception

- Understanding and implementing SLAM algorithms
- Autonomous navigation in unknown environments

9. Robotic Exoskeleton

The Robotic Exoskeleton project focuses on designing and building a wearable robotic system to assist or augment human movement. To work on this project, students should have a mechanics, electronics, and programming background. Familiarity with force sensors and actuators, such as servo motors or linear actuators, is essential.

Learning outcomes:

- Understanding human biomechanics and movement
- Designing wearable robotic systems
- Integration of force sensing and actuator control

10.Humanoid Robot

The Humanoid Robot project involves designing, building, and programming a robot with human-like characteristics and capabilities, such as walking, talking, or facial expression recognition. This advanced project covers topics such as computer vision, natural language processing, and complex motor control.

Students interested in this project should have experience in electronics, programming, and control systems. Knowledge of artificial intelligence and computer vision is advantageous.

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