Course Name with Code **:** 16MEE14 & Industrial Robotics

Unit **: I** **Date of Lecture:**

Topic of Lecture: Robot , Definition, Robot Anatomy,

Introduction : (Maximum 5 sentences)

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

Prerequisite knowledge for Complete understanding and learning of Topic:

- Different Joints
- Links
- DoF

Detailed content of the Lecture:

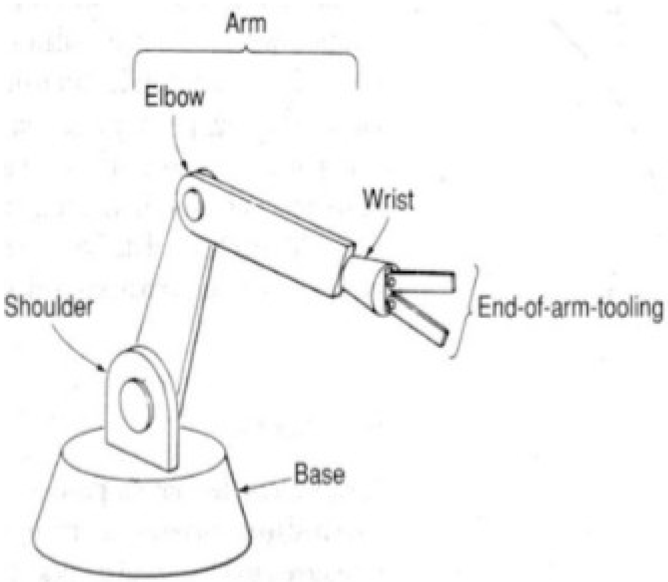
An industrial robot is a reprogrammable, multifunction manipulator designed to move materials, parts, tools and special devices through variable programmed motions for the performance of variety of tasks.

Laws of Robotics

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

Robot anatomy is concerned with the physical construction of the body, arm, and wrist of the machine. Most robots used in plants today are mounted on a base which is fastened to the floor. The body is attached to the base and the arm assembly is attached to the body. At the end of the arm is the wrist. The wrist consists of a number of components that allow it to be oriented in a variety of positions. Relative movements between the various components of the body, arm, and wrist are provided by a series of joints. These joint movements usually involve either rotating or sliding motions, which we will describe later in this section. The body, arm, and wrist assembly is sometimes called the manipulator. Attached to the robot's wrist is a hand. The technical name for the hand is "end effectors" .The end effector is not considered as part of the robot's anatomy. The arm and body joints of the manipulator are used to position the end effector, and the wrist joints of the manipulator are used to orient the end effector. The various parts of robots and their functions are as follows.

1. **Robot arm or Manipulator –** Provides a different work envelope
2. **End effector –** Grippers, Tools
3. **Power source –** Hydraulic, Pneumatic, Electrical
4. **Controller –** Control the robot Movements
5. **Sensor –** Transfers physical phenomenon into electrical signal
6. **Actuator –** Hydraulic or Electrical energy converted into Mechanical Energy



Video Content / Details of website for further learning (if any):
http://industrialrobot.info/robot-anatomy

Important Books/Journals for further learning including the page nos.:
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, Journal of Robotics and Automation, Page No-1-20

Course Name with Code : 16MEE14 & Industrial Robotics

Unit : **I** **Date of Lecture:**

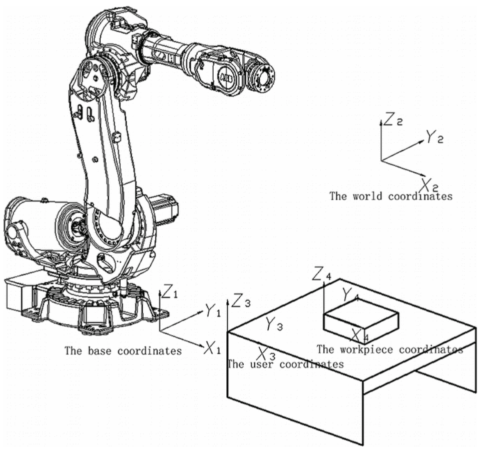
Topic of Lecture: Co-ordinate Systems

Introduction : (Maximum 5 sentences)
Although the robots have very good mechanical characteristics, their internal coordinate systems are complex. Therefore, the conversion of the internal coordinate systems of the robot, the coordinate system for optical design, and the coordinate system for actual processing are very important. It is also one of the key factors for industrial robots to be used in high-precision optical polishing.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Different Joints
- Links
- DoF

Detailed content of the Lecture:
An industrial robot, its internal coordinate systems include the base coordinates, the world coordinates, the user coordinates, the work-piece coordinates, and the tool coordinates. All these coordinate systems follow the right-hand law, as shown in the Fig



The base coordinates are defined on the main robot mounting-flange. Its origin O is the projection of the axis of rotation of the first axis onto the plane of the robot base, which defined as XOY.

For process-users, the coordinates of the worktable are used as a reference for programming. The coordinates of the worktable are named as the user coordinates. When the table is displaced or rotated, a corresponding change of the user coordinates would be sufficient, instead of reprogramming. This is the benefit of using the user coordinates.

If there are several work-pieces on the worktable in-process, individual coordinates for each work-piece maybe defined. The benefit for using individual coordinate system is that the controlling program could be modified easily if any work-piece needs to be relocated. The separate coordinates for each work-piece are named as work-piece coordinates. In the process, the user needs to define a coordinate that would be convenient toolpath according the placement and shape of the work-piece. Besides, the work-piece coordinates are useful when the robot is in “teach-mode.”

When the machining tool is mounted onto the end-flange of the robot, it is necessary to define its own coordinate system. Its origin coincides with the center of the tool [tool centre point (TCP)]. TCP describes the relationship of displacement and rotation between the machining point of the tool (it is assumed to be the geometric center of the polishing head in this article) and the center position of the robot end-flange. When a new tool is installed, a revised tool coordinate-system is needed, instead of reprogramming

Video Content / Details of website for further learning (if any):
https://www.spiedigitallibrary.org/journals/optical-engineering/volume-53/issue-5/055102/Coordinate-transformation-of-an-industrial-robot-and-its-application-in/10.1117/1.OE.53.5.055102.full?SSO=1

Important Books/Journals for further learning including the page nos.:
M.P.Groover, “Industrial Robotics – Technology, Programming and Applications”, McGraw-Hill, 2001, Journal of Robotics and Automation, Page No-1-20

Course Name with Code : 16MEE14 & Industrial Robotics

Unit : **I** **Date of Lecture:**

Topic of Lecture: Work Envelope

Introduction : (Maximum 5 sentences)
A robot's work envelope is its range of movement. It is the shape created when a manipulator reaches forward, backward, up and down. These distances are determined by the length of a robot's arm and the design of its axes. Each axis contributes its own range of motion.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Robot's Arm
- Range Of Motion
- Configuration

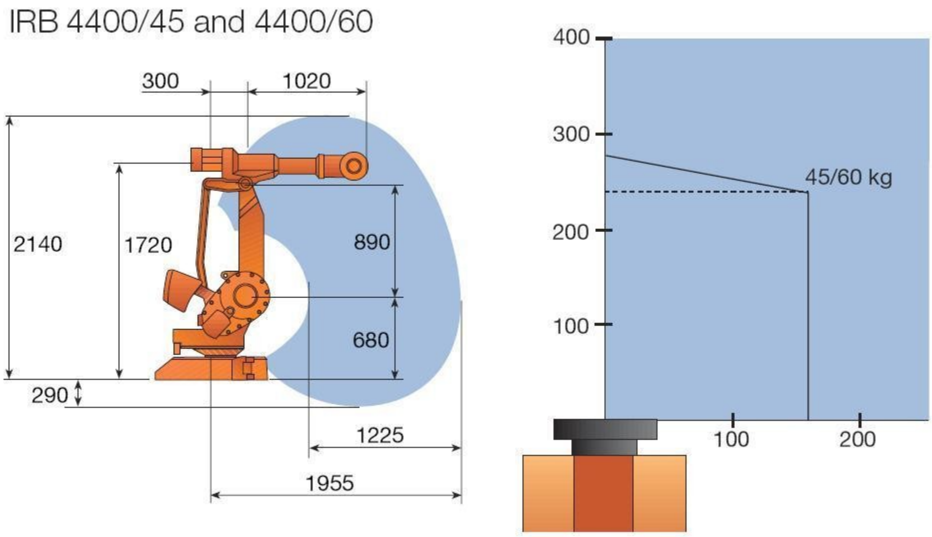
Detailed content of the Lecture:

WORK ENVELOPE

Work Envelope is defined as the envelope (or) space within which the robot can manipulate the end of the wrist.

A robot's work envelope is its range of movement. It is the shape created when a manipulator reaches forward, backward, up and down. These distances are determined by the length of a robot's arm and the design of its axes. Each axis contributes its own range of motion.

A robot can only perform within the confines of this work envelope. Still, many of the robots are designed with considerable flexibility. Some have the ability to reach behind themselves. Gantry robots defy traditional constraints of work envelopes. They move along track systems to create large work spaces.



It is important to take work envelope into consideration when choosing a robot. Try to make your work envelope match your application, setting, and part. Different work envelope capacities will suit different environments and needs.

Do you need a robot to handle a large part, or traverse a long distance? Then choose a model with a larger work envelope. Consider the advantages of a gantry system. Is your work in a contained space or with tiny objects? Then select a robot with a smaller work envelope.

Video Content / Details of website for further learning (if any):
http://thnet.co.uk/thnet/robots/25.htm

Important Books/Journals for further learning including the page nos.:
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001
International *Research Journal* of Engineering and Technology, Page No 29-33

Course Name with Code : 16MEE14 & Industrial Robotics

Unit : **I** **Date of Lecture:**

Topic of Lecture: Types and classification

Introduction : (Maximum 5 sentences)

The robot is a computer programmable machine that can carry out complex actions automatically. It can be guided and controlled either by an external control device or by the controller embedded within the machine. The classification of robots can be done on various criteria such as their power source, work envelope, size of the robot, type of drive system used etc.

Prerequisite knowledge for Complete understanding and learning of Topic:

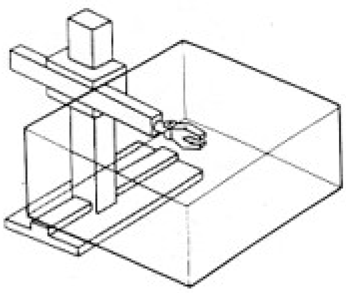
- Robot's Arm
- Range Of Motion
- Configuration

Detailed content of the Lecture:

On the basis of work envelope geometry, robots can be classified as Cartesian, Cylindrical, Spherical, Articulated, SCARA, and Delta

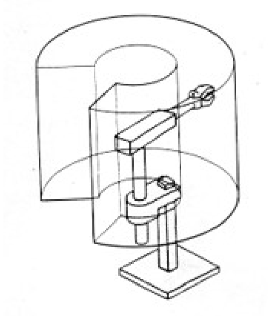
Cartesian configuration

The working envelope of the Cartesian configuration is a rectangular prism. There are no dead zones within the working envelope and the Robot can manipulate its maximum payload throughout the working volume

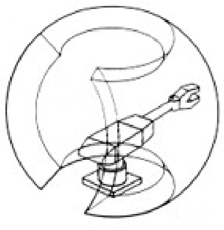


Cylindrical Configuration

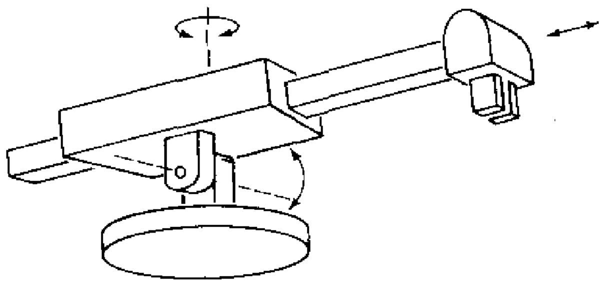
The working envelope of this configuration is as its name suggests a cylinder. The cylinder is hollow, since there is a limit to how far the arm can retract, this creates a cylindrical dead zone around the Robot structure



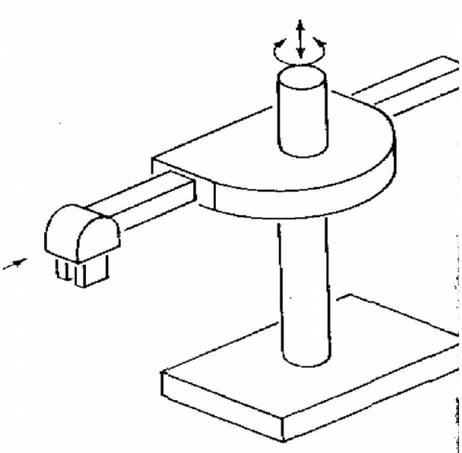
Polar Configuration
The working envelope of this configuration sweeps out a volume between two partial spheres. There are physical limits imposed by the design on the amount of angular movement in both the vertical and horizontal planes. These restrictions create conical dead zones both above and below the Robot structure.



ROBOT CONFIGURATIONS
Industrial robots are available in a wide variety of sizes, shapes, and physical configuration. The vast majority of today’s commercially available robots possess one of four basic configurations:
1. Polar configuration

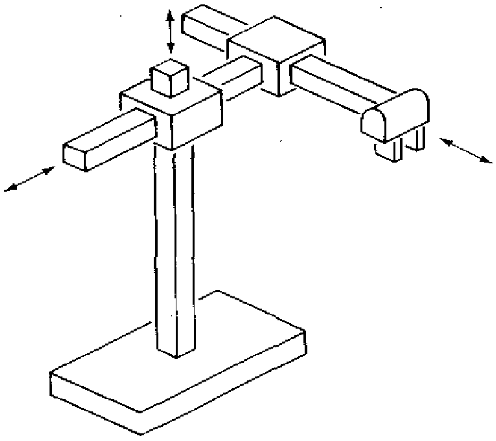


2. Cylindrical configuration



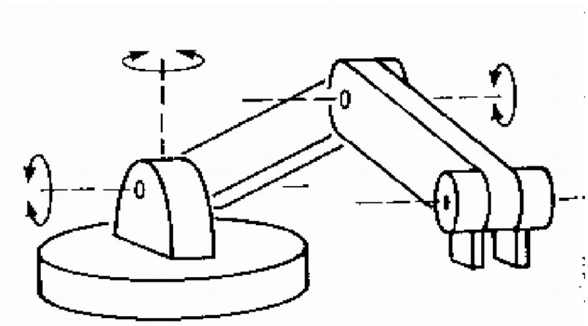
(b)

3. Cartesian coordinate configuration



(c)

4. Jointed-arm configuration



(d)

Video Content / Details of website for further learning (if any):
http://thnet.co.uk/thnet/robots/25.htm

Important Books/Journals for further learning including the page nos.:
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001
International *Research Journal* of Engineering and Technology, Page No 29-33

Course Name with Code **:** 16MEE14 & Industrial Robotics

Unit **: I** **Date of Lecture:**

Topic of Lecture: Specifications ,Pitch, Yaw, Roll, Joint Notations

Introduction : (Maximum 5 sentences)

Imagine three lines running through an airplane and intersecting at right angles at the airplane's center of gravity. Rotation around the front-to-back axis is called roll. Rotation around the side-to-side axis is called pitch. Rotation around the vertical axis is called yaw.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Center of gravity.
- Front-to-back axis
- Side-to-side axis

Detailed content of the Lecture:

Common Robot Specifications

Robot Size (kg): The physical dimensions and weight of an industrial robot arm need to be considered to ensure that the robot arm will fit with existing systems and equipment already on the shop floor.

Maximum Payload Capacity (kg): Industrial applications of robots and specifications often go hand-in-hand. Not only does the size and weight of the part need to be considered, but also the weight of the end-of-arm-tooling should be added into the equation.

Repeatability (mm): Repeatability refers to the ability of the robot arm to return to a previous point. Many current industrial robot arms feature repeatabilities of +/- 0.5 millimeters to +/- 0.02 millimeters. Factors such as number of axes, size, and reach affect repeatability.

Vertical and Horizontal Reach (mm): The reach capabilities of an industrial robot arm often play a major role in deciding whether the arm is right for the application. The robot arm needs to be able to reach all necessary areas of the part it is working on or system that it is working in.

Spatial resolution: The spatial resolution of a robot is the smallest increment of movement into which the robot can divide its work volume. Spatial resolution depends on two factors: the system's control resolution and the robot's mechanical inaccuracies. It is easiest to conceptualize these factors in terms of a robot with 1 degree of freedom.

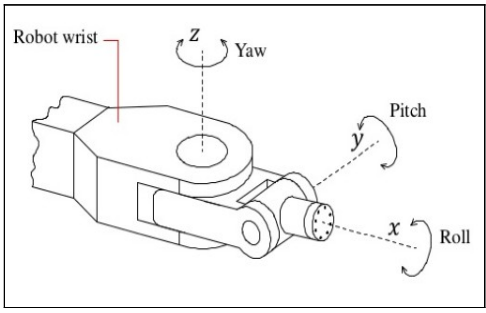
Accuracy: Accuracy refers to a robot's ability to position its wrist end at a desired target point within the work volume. The accuracy of a robot can be denned in terms of spatial resolution because the ability to achieve a given target point depends on how closely the robot can define the control increments for each of its joint motions.

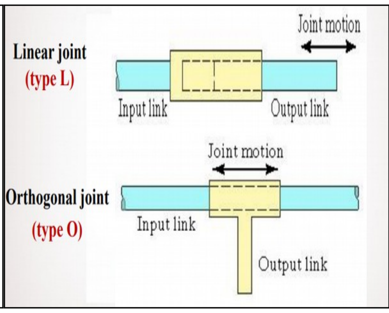
Wrist Motions

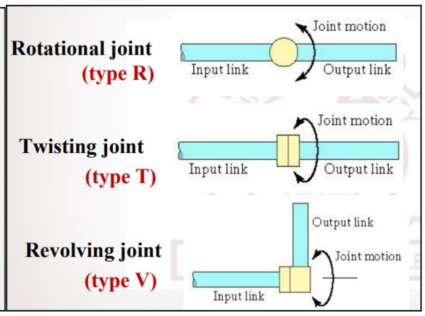
Pitch-Up and Down movement of the wrist

Yaw-Side to side movement of wrist

Roll- Rotation of wrist







Joint Notations

The five joint types are:

1. Linear joint (L). The relative movement between the input link and the output link is a linear sliding motion, with the axes of the two links being parallel.
2. Orthogonal joint (O). This is also a linear sliding motion, but the input and output links are perpendicular to each other during the move.
3. Rotational joint (R). This type provides a rotational relative motion of the joints, with the axis of rotation perpendicular to the axes of the input and output links.
4. Twisting joint (T). This joint also involves a rotary motion, but the axis of rotation is parallel to the axes of the two links.
5. Revolving joint (V). IN this joint type, the axis of the input link is parallel to the axis of rotation of the joint, and the axis of the output link is perpendicular to the axis of rotation.

Video Content / Details of website for further learning (if any):

https://robotacademy.net.au/lesson/denavit-hartenberg-notation

Important Books/Journals for further learning including the page nos.:

M.P.Groover, “Industrial Robotics – Technology, Programming and Applications”, McGraw-Hill, 2001, International *Journal* of Mechanisms and *Robotic* Systems, Page No - 27-29

Course Name with Code : 16MEE14 & Industrial Robotics

Unit : **I** **Date of Lecture:**

Topic of Lecture: Speed of Motion, Pay Load

Introduction : (Maximum 5 sentences)

Speed can be thought of as the rate at which an object covers distance. A fast-moving object has a high **speed** and covers a relatively large distance in a given amount of time, while a slow-moving object covers a relatively small amount of distance in the same amount of time.

Maximum **speed** of **robot's** endpoint is 4.4 meters per second, but this **speed** is achieved rarely by the **robot**. ... **Robot** maximum **speed** is under 1 meter per second in **motions**, where the trajectory is important. Algorithm analyzes and designs **speed** optimizing **motions** on high accuracy **motions**

Prerequisite knowledge for Complete understanding and learning of Topic:

- Designs speed
- Accuracy motions

Detailed content of the Lecture:

Speed of Motion

1. **Point-to-point (PTP) control robot:** is capable of moving from one point to another point. The locations are recorded in the control memory. PTP robots do not control the path to get from one point to the next point. Common applications include component insertion, spot welding, whole drilling, machine loading and unloading, and crude assembly operations.

2. **Continuous-path (CP) control robot:** with CP control, the robot can stop at any specified point along the controlled path. All the points along the path must be stored explicitly in the robot's control memory. Typical applications include spray painting, finishing, gluing, and arc welding operations.

3. **Controlled-path robot:** the control equipment can generate paths of different geometry such as straight lines, circles, and interpolated curves with a high degree of accuracy. All controlled path robots have a servo capability to correct their path.

Pay Load

Maximum payload is the weight of the robotic wrist, including the EOAT and work piece. It varies with different robot applications and models. Determining your payload requirements is one way to narrow down your robot search.

Robots are devices that are programmed to move parts, or to do work with a tool. Robotics is a multidisciplinary engineering field dedicated to the development of autonomous devices, including manipulators and mobile vehicles.

Roboticists develop man-made mechanical devices that can move by themselves, whose motion must be modelled, planned, sensed, actuated and controlled, and whose motion behavior can be influenced by nt”“programming”iftheys in moving in safe interaction with an unstructured environment, while autonomously achieving their specified tasks.

This definition implies that a device c movable mechanism, influenced by sensing, planning, actuation and control components. It does not imply that a minimum number of these components must be implemented in software, or be changeable by the “consumer” who uses can have been hard-wired into the device by the manufacturer.

Video Content / Details of website for further learning (if any):
http://www.brainkart.com/article/Speed-of-Robot-Motion_5123

Important Books/Journals for further learning including the page nos.:
M.P.Groover, “Industrial Robotics – Technology, Programming and Applications”, McGraw-Hill, 2001,
Journal of Industrial Engineering, Page No - 30-35

Course Name with Code : 16MEE14 & Industrial Robotics

Unit : **I** **Date of Lecture:**

Topic of Lecture: Robot Parts and Their Functions

Introduction : (Maximum 5 sentences)

The controller is the "brain" of the industrial robotic arm and allows the parts of the robot to operate together. It works as a computer and allows the robot to also be connected to other systems. The robotic arm controller runs a set of instructions written in code called a program. The program is inputted with a teach pendant. Many of today's industrial robot arms use an interface that resembles or is built on the Windows operating system.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Controller
- Arm
- Drive

Detailed content of the Lecture:

Robot Parts and Functions

Industrial robot arms can vary in size and shape. The industrial robot arm is the part that positions the end effector. With the robot arm, the shoulder, elbow, and wrist move and twist to position the end effector in the exact right spot. Each of these joints gives the robot another degree of freedom. A simple robot with three degrees of freedom can move in three ways: up & down, left & right, and forward & backward. Many industrial robots in factories today are six axis robots.

The end effector connects to the robot's arm and functions as a hand. This part comes in direct contact with the material the robot is manipulating. Some variations of an effector are a gripper, a vacuum pump, magnets, and welding torches. Some robots are capable of changing end effectors and can be programmed for different sets of tasks.

The drive is the engine or motor that moves the links into their designated positions. The links are the sections between the joints. Industrial robot arms generally use one of the following types of drives: hydraulic, electric, or pneumatic. Hydraulic drive systems give a robot great speed and strength. An electric system provides a robot with less speed and strength. Pneumatic drive systems are used for smaller robots that have fewer axes of movement. Drives should be periodically inspected for wear and replaced if necessary.

Sensors allow the industrial robotic arm to receive feedback about its environment. They can give the robot a limited sense of sight and sound. The sensor collects information and sends it electronically to the robot controlled. One use of these sensors is to keep two robots that work closely together from bumping into each other. Sensors can also assist end effectors by adjusting for part variances. Vision sensors allow a pick and place robot to differentiate between items to choose and items to ignore.

Every robot is connected to a computer, which keeps the pieces of the arm working together. This computer is known as the controller.

The controller functions as the "brain"of the robot. The controller also allows the robot to be networked to other systems, so that it may work together with other machines, processes, or robots.

Robots today have controllers that are run by programs - sets of instructions written in code. Almost all robots of today are entirely pre-programmed by people; they can do only what they are programmed to do at the time, and nothing else. In the future, controllers with artificial intelligence, or AI could allow robots to think on their own, even program themselves. This could make robots more self-reliant and independent.

Robot arms come in all shapes and sizes. The arm is the part of the robot that positions the end- effector and sensors to do their pre-programmed business. Many (but not all) resemble human arms, and have shoulders, elbows, wrists, even fingers.

The drive is the "engine" that drives the links (the sections between the joints into their desired position. Without a drive, a robot would just sit there, which is not often helpful. Most drives are powered by air, water pressure, or electricity.

The end-effector is the "hand" connected to the robot's arm. It is often different from a human hand - it could be a tool such as a gripper, a vacuum pump, tweezers, scalpel, blowtorch - just about anything that helps it do its job. Some robots can change end-effectors, and be reprogrammed for a different set of tasks.

Most robots of today are nearly deaf and blind. Sensors can provide some limited feedback to the robot so it can do its job.

Video Content / Details of website for further learning (if any):

http://www.brainkart.com/article/Robot-Parts-and-Functions_5124

Important Books/Journals for further learning including the page nos.:

M.P.Groover, “Industrial Robotics – Technology, Programming and Applications”, McGraw-Hill, 2001, Journal of Robotics, Page No-35-38

Course Name with Code **:** 16MEE14 & Industrial Robotics

Unit **: I** **Date of Lecture:**

Topic of Lecture: Need for Robots

Introduction : (Maximum 5 sentences)

Another really important role for **robots** today is managing assets, as a society we **have** a massive investment in assets in terms of power lines, water pipe lines, gas pipe lines and sewer systems. And in order to maintain the health of those assets, they **need** to be periodically inspected and that's very labor-intensive.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Complexity of humans
- Dirty or dangerous

Detailed content of the Lecture:

Need of Robot and its Application

Industrial Applications

Industrial robots are used to assemble the vehicle parts. As the assembly of the machine parts is a repetitive task to be performed, the robots are conveniently used instead of using mankind (which is more costly and less précised compared to robots.)

Auto Industry:

The auto industry is the largest users of robots, which automate the production of various components and then help, assemble them on the finished vehicle. Car production is the primary example of the employment of large and complex robots for producing products. Robots are used in that process for the painting, welding and assembly of the cars. Robots are good for such tasks because the tasks can be accurately defined and must be performed the same every time, with little need for feedback to control the exact process being performed.

Material Transfer , Machine Loading And Unloading

There are many robot applications in which the robot is required to move a work part or other material from one location to another. The most basic of these applications is where the robot picks the part up from one position and transfers it to another position. In other applications, the robot is used to load and/or unload a production machine of some type. Material transfer applications are defined as operations in which the primary objective is to move a part from one location to another location. They are usually considered to be among the most straightforward of robot applications to implement. The applications usually require a relatively unsophisticated robot, and interlocking requirements with other equipments are typically uncomplicated. These are the pick ad place operations. The machine loading and unloading applications are material handling operations in which the robot is used to service a production machine by transferring parts to and/or from the machine. Robots have been successfully applied to accomplish the loading and/or unloading function in the production operations.

. Die casting
· Plastic molding
· Forging and related operations
· Machining operations
· Stamping press operations

Video Content / Details of website for further learning (if any):
https://robotacademy.net.au/lesson/why-do-we-need-robots/

Important Books/Journals for further learning including the page nos.:
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, Journal of Robotics, page No- 38

Course Name with Code : 16MEE14 & Industrial Robotics

Unit : **I** **Date of Lecture:**

Topic of Lecture: Different Applications

Introduction : (Maximum 5 Sentences)

The First Robots Were Industrial Robots Because The Well-Defined Environment Simplified Their Design. Service Robots, On The Other Hand, Assist Humans In Their Tasks. These Include Chores At Home Like Vacuum Clears, Transportation Like Self-Driving Cars, And Defense Applications Such As Reconnaissance Drones.

Prerequisite Knowledge For Complete Understanding And Learning Of Topic:

- Humans Difficulty In Their Tasks
- Robot Configurations

Detailed Content Of The Lecture:

The Other Industrial Applications Of Robotics Include Processing Operations Such As Spot Welding, Continuous Arc Welding; Spray Coating, Also In Assembly Of Machine Parts And Their Inspection.

Robotic Arm

The Most Developed Robot In Practical Use Today Is The Robotic Arm And It Is Seen In Applications Throughout The World. We Use Robotic Arms To Carry Out Dangerous Work Such As When Dealing With Hazardous Materials. We Use Robotic Arms To Carry Out Work In Outer Space Where Man Cannot Survive And We Use Robotic Arms To Do Work In The Medical Field Such As Conducting Experiments Without Exposing The Research. Some Of The Most Advanced Robotic Arms Have Such Amenities As A Rotating Base, Pivoting Shoulder, Pivoting Elbow, Rotating Wrist And Gripper Fingers. All Of These Amenities Allow The Robotic Arm To Do Work That Closely Resembles What A Man Can Do Only Without The Risk.

Medical Applications

Medical Robotics Is A Growing Field And Regulatory Approval Has Been Granted For The Use Of Robots In Minimally Invasive Procedures. Robots Are Being Used In Performing Highly Delicate, Accurate Surgery, Or To Allow A Surgeon Who Is Located Remotely From Their Patient To Perform A Procedure Using A Robot Controlled Remotely. More Recently, Robots Can Be Used Autonomously In Surgery.

Future Applications

We Can Theorize A Likely Profile Of The Future Robot Based On The Various Research Activities That Are Currently Being Performed. The Features And Capabilities Of The Future Robot Will Include The Following (It Is Unlikely That All Future Robots Will Possess All Of The Features Listed).

•Intelligence: The Future Robot Will Be An Intelligent Robot, Capable Of Making Decisions About The Task It Performs Based On High-Level Programming Commands And Feedback Data From Its Environment.

•Sensor Capabilities: The Robot Will Have A Wide Array Of Sensor Capabilities Including Vision, Tactile Sensing, And Others. Progress Is Being Made In The Field Of Feedback And Tactile Sensors, Which Allow A Robot To Sense Their Actions And Adjust Their Behavior Accordingly. This Is Vital To Enable Robots To Perform Complex Physical Tasks That Require Some Active Control In Response To The Situation. Robotic Manipulators Can Be Very Precise, But Only When A Task Can Be Fully Described.

•Mobility And Navigation: Future Robots Will Be Mobile, Able To Move Under Their Own Power And Navigation Systems.

•Universal Gripper: Robot Gripper Design Will Be More Sophisticated, And Universal Hands Capable Of Multiple Tasks Will Be Available.

Future Manufacturing Applications

Robotic Welding Is One Of The Most Successful Applications Of Industrial Robot Manipulators. In Fact, A Huge Number Of Products Require Welding Operations In Their Assembly Processes. Welding Can In Most Cases Impose Extremely High Temperatures Concentrated In Small Zones. Physically, That Makes The Material Experience Extremely High And Localized Thermal Expansion And Contraction Cycles, Which Introduce Changes In The Materials That May Affect Its Mechanical Behavior Along With Plastic Deformation.

Hazardous And Inaccessible Nonmanufacturing Environments

Manual Operations In Manufacturing That Are Characterized As Unsafe, Hazardous, Uncomfortable, Or Unpleasant For The Human Workers Who Perform Them Have Traditionally Been Ideal Candidates For Robot Applications. Examples Include Die-Casting, Hot Forging, Spray-Painting, And Arc Welding. Potential Manufacturing Robot Applications That Are In Hazardous Or Inaccessible Environments Include The Following:

· Construction Trades

· Underground Coal Mining: The Sources Of Dangers In This Field For Humans Include Fires, Explosions, Poisonous Gases, Cave-Ins, And Underground Floods.

· Hazardous Utility Company Operations: The Robots Have A Large Scope Of Application In The Nuclear Wastage Cleaning In Nuclear Plants, In The Electrical Wiring, Which Are Dangerous And Hazardous To Humans.

· Military Applications

· Fire Fighting

Video Content / Details Of Website For Further Learning (If Any):

https://www.lacconveyors.co.uk/different-types-of-robots

Important Books/Journals For Further Learning Including The Page Nos.:

M.P.Groover, “Industrial Robotics – Technology, Programming And Applications”, Mcgraw-Hill, 2001,
International Journal of Intelligent Robotics and Applications, Page No- 533-539

Course Name with Code : Industrial Robotics / 16MEE14

Unit : II **Date of Lecture:**

Topic of Lecture: Pneumatic Drives, Hydraulic Drives

Introduction : (Maximum 5 sentences)
A Pneumatic actuator mainly consists of a piston or a diaphragm which develops the motive power. It keeps the air in the upper portion of the cylinder, allowing air pressure to force the diaphragm or piston to move the valve stem or rotate the valve control element.

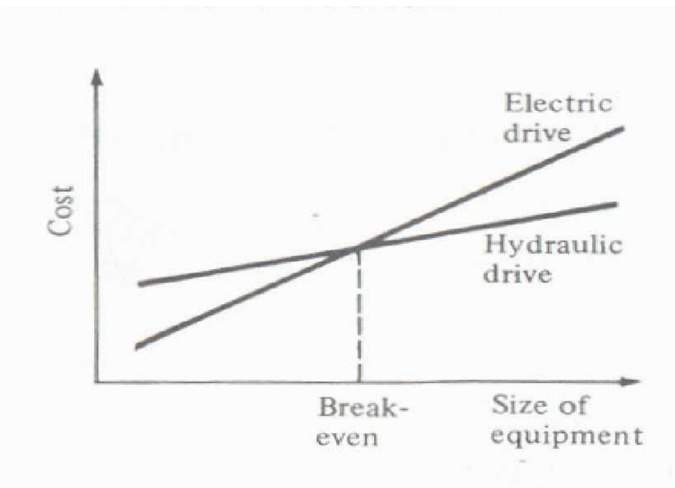
Prerequisite knowledge for Complete understanding and learning of Topic:

- Tie-rod cylinders
- Rotary actuators
- Grippers

Detailed content of the Lecture:

Pneumatic drive

- Pneumatic drive is generally reserved for smaller robots that possess fewer degrees of freedom (two- to four-joint motions).
- These robots are often limited to simple "pick-and-place"operations with fast cycles.
- Pneumatic power can be readily adapted to the actuation of piston devices to provide translational movement of sliding joints.
- It can also be used to operate rotary actuators for rotational joints.



Cost vs. size for electric drive and hydraulic drive

Hydraulic drive

- Hydraulic drive is generally associated with larger robots, such as the Unimate 2000 series.
- The usual advantages of the hydraulic drive system are that it provides the robot with greater speed and strength.
- The disadvantages of the hydraulic drive system are that it typically adds to the floor space required by the robot, and that a hydraulic system is inclined to leak oil which is a nuisance.
- Hydraulic drive systems can be designed to actuate either rotational joints or linear joints.
- Rotary vane actuators can be utilized to provide rotary motion and hydraulic pistons can he used to accomplish linear motion

Video Content / Details of website for further learning (if any):
https://en.wikipedia.org/wiki/Pneumatic_actuator

Important Books/Journals for further learning including the page nos.:
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, Journal of Fluid Power, Page No: 31-35

Course Name with Code : Industrial Robotics / 16MEE14

Unit : II Date of Lecture:

Topic of Lecture: Mechanical Drives , Electrical Drives
Introduction : (Maximum 5 sentences) When the various driving methods like hydraulic, pneumatic, electrical servo motors and stepping motors are used in robots, it is necessary to get the motion in linear or rotary fashion. When motors are used, rotary motion is converted to linear motion through rack and pinion gearing, lead screws, worm gearing or bail screws.
Prerequisite knowledge for Complete understanding and learning of Topic: • Drive System • Motors Principle • Types of Motors
Detailed content of the Lecture: Introduction Robot Drive Systems The actions of the individual joints must be controlled in order for the manipulator to perform a desired motion. The robot's capacity to move its body, arm, and wrist 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.

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.

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.

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.

Video Content / Details of website for further learning (if any):
http://www.brainkart.com/article/Mechanical-drives-system_5142/

Important Books/Journals for further learning including the page nos.:
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, Int. Journal of Robotics & Mechanical Engineering, Page No 31-35

Course Name with Code : Industrial Robotics / 16MEE14

Unit : II **Date of Lecture:**

Topic of Lecture: D.C. Servo Motors, Stepper Motor, A.C. Servo Motors

Introduction : (Maximum 5 sentences)

Electric motors are becoming more and more the actuator of choice in the design of robots. They provide excellent controllability with a minimum of maintenance required. There are a variety of types of motors in use in robots; the most common are dc servomotors, stepper motors, and ac servomotors.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Electric motors
- Motor Principle

Detailed content of the Lecture:

Electric Motors

- The main components of the dc servomotor are the rotor and the stator. Usually, the rotor includes the armature and the commutator assembly and the stator includes the permanent magnet and brush assemblies.
- When current flows through the windings of the armature it sets up a magnetic field opposite the field set up by the magnets.
- This produces a torque on the rotor. As the rotor rotates, the brush and commutator assemblies switch the current to the armature so that the field remains opposed to the one set up by the magnets.
- In this way the torque produced by the rotor is constant throughout the rotation. Since the field strength of the rotor is a function of the current through it, it can be shown that for a dc servomotor

$$T_m(t) = K_m I_a(t)$$

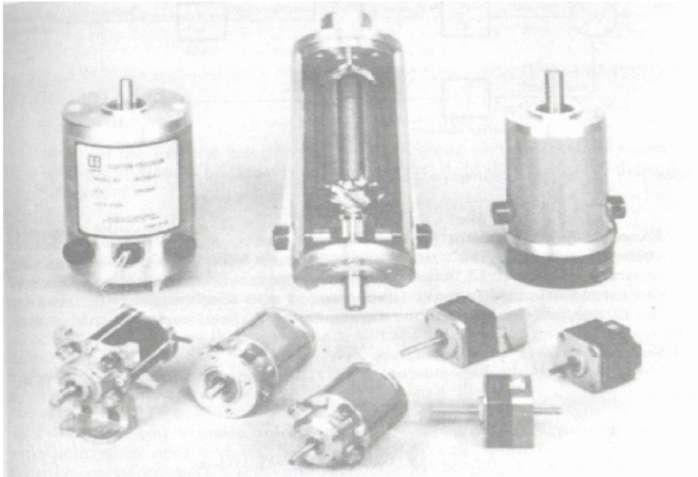
- Where T_m is the torque of the motor, I_a is the current flowing through the armature, and K_m is the motor's torque constant.Another effect associated with a dc servomotor is the back-emf. A dc motor is similar to a dc generator or tachometer. Spinning the armature in the presence of a magnetic field produces a voltage across the armature terminals. This voltage is proportional to the angular velocity of the rotor:

$$e_b(t)=K_b\square(t)$$

Where e_b is the back-emf (voltage), K_b is called the voltage constant of the motor, and w is the angular velocity. The effect of the hack-emf is to act as viscous damping for the motor: as the velocity increases the damping increases proportionately. If we were to supply a voltage across the motor terminals of V and the resistance of the armature were Ra, then the current through the armature would be V_{in}/R_a. This current produces a torque on the rotor and causes the motor to spin. As the armature spins it generates a back-emf equal to K_b(t) or e_b(t). This voltage must be subtracted from V_{in} in order to calculate the armature current.

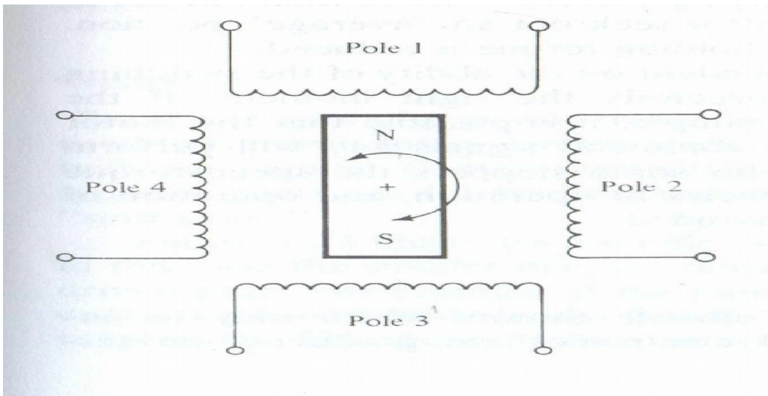
The actual armature current is therefore

$$I_a(t) = \frac{V_{\text{in}}(t) - e_b(t)}{R_a}$$



Stepper Motors

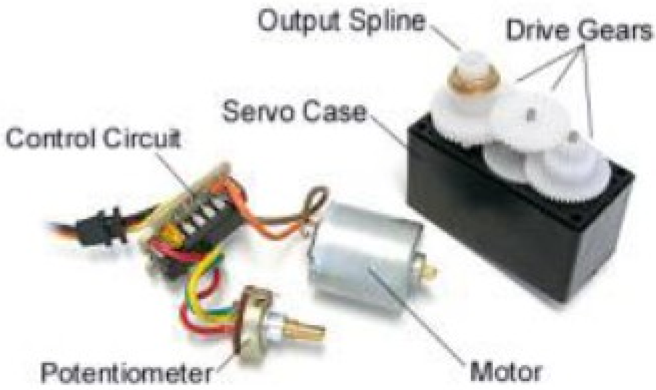
- Stepper motors (also called stepping motors) are a unique type of actuator and have been used mostly in computer peripherals.
- A stepper motor provides output in the form of discrete angular motion increments. It is actuated by a series of discrete electrical pulses.
- For every electrical impulse there is a single-step rotation of the motor shaft. In robotics, stepper motors are used for relatively light duty applications.
- Also, stepper motors are typically used in open-loop systems rather than the closed loop systems.
- Figure provides a schematic representation of one type of stepper motor.
- The stator is made up of four electromagnetic poles and the rotor is a two-pole permanent magnet.

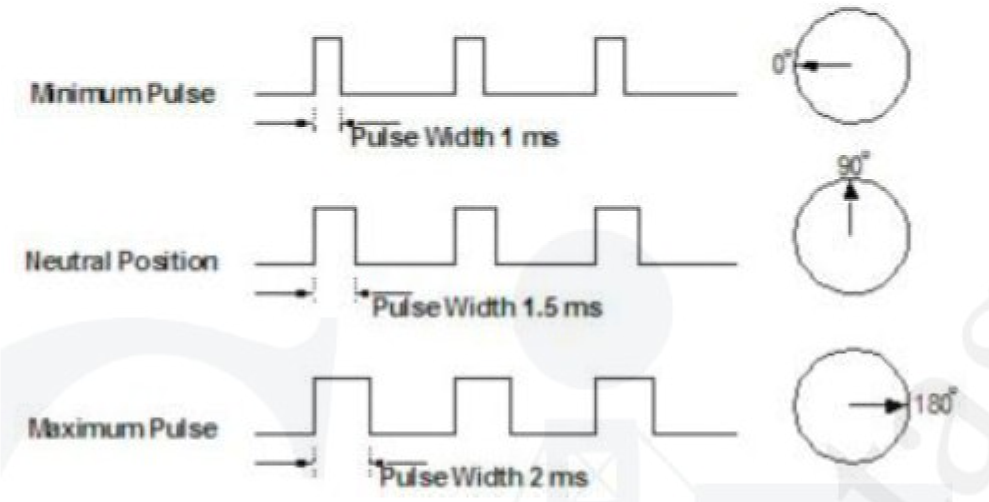


AC Servo Motor

Servos are controlled by sending an electrical pulse of variable width, or pulse width modulation (PWM), through the control wire. There is a minimum pulse, a maximum pulse and a repetition rate. A servo motor can usually only turn 90° in either direction for a total of 180° movement. The motor's neutral position is defined as the position where the servo has the same amount of potential rotation in the both the clockwise or counter-clockwise direction. The PWM sent to the motor determines position of the shaft, and based on the duration of the pulse sent via the control wire the rotor will turn to the desired position. The servo motor expects to see a pulse every 20 milliseconds (ms) and the length of the pulse will determine how far the motor turns. For example, a 1.5ms pulse will make the motor turn to the 90° position. Shorter than 1.5ms moves it to 0° and any longer than 1.5ms will turn the servo to 180°, as diagramed below.

When these servos are commanded to move, they will move to the position and hold that position. If an external force pushes against the servo while the servo is holding a position, the servo will resist from moving out of that position. The maximum amount of force the servo can exert is called the torque rating of the servo. Servos will not hold their position forever though; the position pulse must be repeated to instruct the servo to stay in position.





Video Content / Details of website for further learning (if any):
https://engineering.eckovation.com/servo-motor-types-working-principle-explained/

Important Books/Journals for further learning including the page nos.:
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001,
International Journal of Engineering Sciences &Management Research, Page No- 74-76

Course Name with Code : **Industrial Robotics / 16MEE14**

Unit : **II** **Date of Lecture:**

Topic of Lecture: Salient Features, Applications and Comparison of all these Drives

Introduction : (Maximum 5 sentences)
Difference between Pneumatic, Electrical & Hydraulic Actuators. Comparing features of Hydraulic, Pneumatic and Electrical Drives.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Payload
- Accuracy
- Range

Detailed content of the Lecture:
Difference between Pneumatic, Electrical & Hydraulic Actuators

SI. No.	Comparing Features	Hydraulic Drive	Electric Drive	Pneumatic Drive
1.	Power to weight-ratio	• Highest	• Moderate	• Lowest
2.	Payload carried by the robot	• Heavy	• Medium	• Low
3.	Controlling devices	• Needs a hydraulic power pack	• Control system is needed	•Pneumatic power like control devices needed
4.	Size and stiffness	• Very high.	• Low stiffness	• Very low
5.	Compliance of the system	• Low	• Better	• Good
6.	Leakage and cleanliness	• Worst	• Nil	• Better
7.	Reliability of the components	• Low	• High	• Higher
8.	Accuracy and response	• Good	• Higher	• Bad
9.	Need for maintenance	• Needed more	• Low	• Less
10.	Pressure, Torque and inertia on the actuator	• High	• Medium to high	• Low to medium
11.	Range of operational speeds	• Wide	• Comparatively less	• Very little
12.	Striking or generation of spark	• Not there	• Possible	• No sparks
13.	Path generation application	• Continuous path	• Both continuous pick and place	• Only in pick and place types

Actuator type	Pros	Cons
Pneumatic	Explosion proofing relatively simple Relatively in sensitive to corroding environments if control al is used Unsophisticated design Use of control gas possible Logic interlocking of signals can be realized easily Relative,/ low cost High stroking velocities can be realized Fail safe outages of the auxiliary energy do not prevent reaching of safe position (spring loaded actuator)	Distance to the source of energy is limited (dead time problems) Actuating force of spring backed units is limited Auxiliary energy must be generated and made available (cost implications) Auxiliary energy system requires considerable maintenance Small systems are normally not economical Sensitive to changing process pressure
Electric	Large distance to the source of energy is no problem Accessories and pans are standard supplies Easy inter locking of signals High regulation and control accuracy can be realized easily Large actuating force easy to achieve Remote control and monitoring functions can be implemented easily	Larger actuating forces difficult to achieve Limited stroking velocity Explosion proofing costlier in comparison to pneumatic or hydraulic actuators Reaching of safe position in case of auxiliary energy outages must be ensured by additional measures High maintenance costs
Hydraulic	High actuating forces High stroking velocities are possible Outages of the auxiliary energy do not prevent reaching of safe position (accumulator) High stability	Distance to the source of energy is knifed Tubing is required for transmission of the actuating power, implying additional leakage risks Costly control Considerable maintenance requirements

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=iuX5aGIJb3E

Important Books/Journals for further learning including the page nos.:
M.P.Groover, “Industrial Robotics – Technology, Programming and Applications”, McGraw-Hill, 2001, , Page No74-79

Course Name with Code : Industrial Robotics / 16MEE14

Unit : II **Date of Lecture:**

Topic of Lecture: End Effectors , Grippers

Introduction : (Maximum 5 sentences)
Grippers are end effectors used to grasp and hold objects. The objects are generally work parts that are to be moved by the robot. In robotics, an end effector is the device at the end of a robotic arm, designed to interact with the environment.

Prerequisite knowledge for Complete understanding and learning of Topic:
- Force
- Mechanics
- Tools

Detailed content of the Lecture:

END EFFECTORS
Attached to the robot's wrist is a hand. The technical name for the hand is "end effectors" .The end effector is not considered as part of the robot's anatomy. The arm and body joints of the manipulator are used to position the end effector, and the wrist joints of the manipulator are used to orient the end effector.

TYPES OF END EFFECTORS
There is a wide assortment of end effectors required to perform the variety of different work functions. The various types can he divided into two major categories:
1. Grippers
2. Tools
- Grippers are end effectors used to grasp and hold objects.
- The objects are generally work parts that are to be moved by the robot.
- These part-handling applications include machine loading and unloading, picking parts from a Conveyor and arranging parts onto a pallet.
- In addition to work parts, other Objects handled by robot grippers include cartons, bottles, raw materials, and tools. We tend to think of gripper as mechanical grasping devices, but there are alternative ways of holding objects involving the use of magnets, suction cups, or other means.
- Grippers can be classified as single grippers or double grippers although this classification applies best to mechanical grippers.
- The single gripper is distinguished by the fact that only one grasping device is mounted on the robot's wrist.
- A double gripper has two gripping devices attached to the wrist and is used to handle two separate objects.
- The two gripping devices can be actuated independently. The double gripper is especially useful in machine loading and. unloading applications.
- Suppose that a particular job calls for a raw work part to be loaded from a conveyor onto a machine

and the finished part to be unloaded onto another conveyor.

- With a single gripper, the robot would have to unload the finished part before picking up the raw part.
- This would consume valuable time in the production cycle because the machine would have to remain open during these handling motions.
- With a double gripper, the robot can pick the part from the incoming conveyor with one of the gripping devices and have it ready to exchange for the finished part.
- When the machine cycle is completed, the robot can reach in for the finished part with the available grasping device, and insert the raw part into the machine with the other grasping device.
- The amount of time that the machine is open is minimized.
- The term multiple gripper is applied in the case where two or more grasping mechanisms are fastened to the wrist.
- Double grippers are a subset of multiple grippers. The occasions when more than two grippers would be required are somewhat rare.
- There is also a cost and reliability penalty which accompanies an increasing number of gripper devices on one robot arm. Another way of classifying grippers depends on whether the part is grasped on its exterior surface or its internal surface, for example, a ring- shaped part. The first type is called an external gripper and the second type is referred to as an internal gripper.
- The tool-type end effector is attached to the robot's wrist. One of the most common applications of industrial robots is spot welding, in which the welding electrodes constitute the end effector of the robot.

Grippers

In robotics, an end effector is the device at the end of a robotic arm, designed to interact with the environment. The exact nature of this device depends on the application of the robot. In the strict definition, which originates from serial robotic manipulators, the end effector means the last link (or end) of the robot. At this endpoint the tools are attached. In a wider sense, an end effector can be seen as the part of a robot that interacts with the work environment. This does not refer to the wheels of a mobile robot or the feet of a humanoid robot which are also not end effectors—they are part of the robot's mobility.

Video Content / Details of website for further learning (if any):
https://www.rdergo.com/gripper-end-effectors/

Important Books/Journals for further learning including the page nos.:
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, Journal of Bionics Engineering, Page No. 116-121

Course Name with Code : Industrial Robotics / 16MEE14

Unit : II **Date of Lecture:**

Topic of Lecture: Mechanical Grippers, Pneumatic and Hydraulic Grippers

Introduction : (Maximum 5 sentences)

The function of the gripper mechanism is to translate some form of power input into the grasping action of the fingers against the part. The power input is supplied from the robot and can be pneumatic, electric, mechanical, or hydraulic.

Prerequisite knowledge for Complete understanding and learning of Topic:

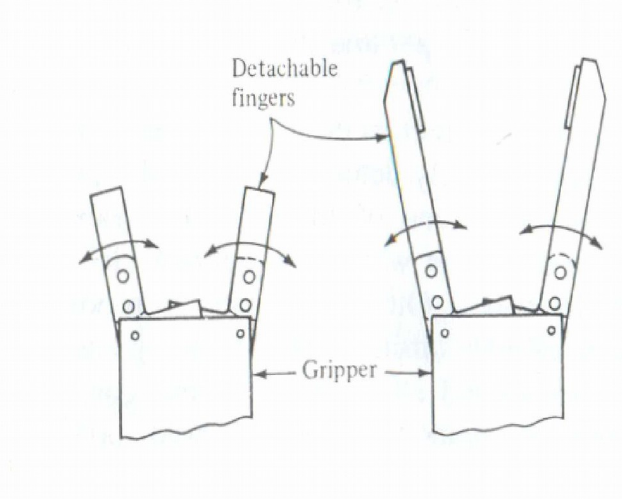
- Pressure
- Range
- Feedback Signals

Detailed content of the Lecture:

MECHANICAL GRIPPERS

Basic Definitions and Operation

- A mechanical gripper is an end effector that uses mechanical fingers actuated by a mechanism to grasp an object.
- The fingers, sometimes called jaws, are the appendages of the gripper that actually make contact with the object.
- The fingers are either attached to the mechanism or are an integral part of the mechanism. If the fingers are of the attachable type, then they can be detached and replaced.
- The use of replaceable fingers allows for wear and inters changeability different sets of fingers for use with the same gripper mechanism can be designed to accommodate different part models.
- An example of this interchangeability feature is illustrated in figure, in which the gripper is designed to accommodate fingers of varying sizes.
- In most applications, two fingers are sufficient to hold the work part or other object. Grippers with three or more fingers are less common.
- The function of the gripper mechanism is to translate some form of power input into the grasping action of the fingers against the part.
- The power input is supplied from the robot and can be pneumatic, electric, mechanical, or hydraulic.



End effectors require power to operate. They also require control signals to regulate their operation. The principal methods of transmitting power and control signals to the end effector are:

- Pneumatic
- Electric
- Hydraulic
- Mechanical

➢ The method of providing the power to the end effector must be compatible with the capabilities of the robot system.

For example, it makes sense to use a pneumatically operated gripper if the robot has incorporated into its arm design the facility to transmit air pressure to the end effector.

The control signals to regulate the end effector are often provided simply by controlling the transmission of the actuating power.

The operation of a pneumatic gripper is generally accomplished in this manner. Air pressure is supplied to either open the gripper or to close it.

In some applications, greater control is required to operate the end effector. For example, the gripper might possess a range of open/close positions and there is the need to exercise control over these positions.

In more complicated cases, feedback signals from sensors in the end effector are required to operate the device.

Video Content / Details of website for further learning (if any):
http://www.brainkart.com/article/Mechanical-Gripper_5137/

Important Books/Journals for further learning including the page nos.:
M.P.Groover, “Industrial Robotics – Technology, Programming and Applications”, McGraw-Hill, 2001,
Robotics and Autonomous Systems, Page No. 127-133

Course Name with Code : Industrial Robotics / 16MEE14

Unit : II Date of Lecture:

Topic of Lecture: Magnetic Grippers, Vacuum Grippers

Introduction : (Maximum 5 sentences)
The vacuum pump is a piston-operated or vane-driven device powered by an electric motor. It is capable of creating a relatively high vacuum. Magnetic grippers can be a very feasible means of handling ferrous materials.

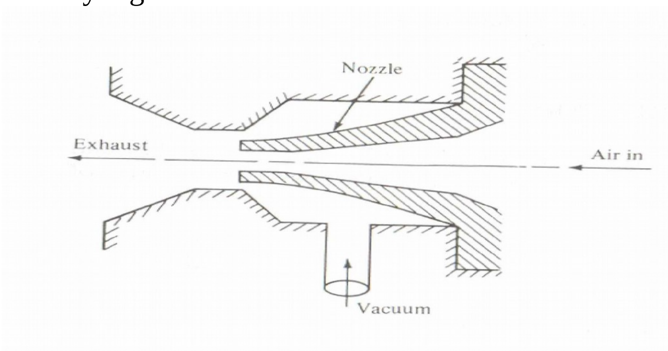
Prerequisite knowledge for Complete understanding and learning of Topic:

- Surface area
- Magnetic Flux
- Gripping Force

Detailed content of the Lecture:

Vacuum cups

- Vacuum cups, also called suction cups, can be used as gripper devices for handling certain types of objects.
- The usual requirements on the objects to be handled are that they be flat, smooth and clean, conditions necessary, form a satisfactory vacuum between the object and the suction cup. An example of a vacuum cup used to lift flat glass is pictured in figure.
- The suction cups used in this type of robot gripper are typically made of elastic material such as rubber or soft plastic.
- An exception would be when the object to be handled is composed of a soft material. In this ease, the suction cup would be made of a hard substance.
- The shape of the vacuum cup, as shown in the figure, is usually round.Some means of removing the air between the cup and the part surface to create the vacuum is required.
- The vacuum pump and the venturi are two common devices used for this purpose.
- The vacuum pump is a piston-operated or vane-driven device powered by an electric motor. It is capable of creating a relatively high vacuum.



Magnetic Grippers

- Magnetic grippers can be a very feasible means of handling ferrous materials.
- The stainless steel plate would not he an appropriate application for a magnetic gripper because 18-8 stainless steel is not attracted by a magnet.
- Other steels, however, including certain types of stainless steel, would be suitable candidates for this means of handling, especially when the materials are handled in or late form.
- In general, magnetic grippers offer the following advantages in robotic- handling applications:
- Pickup times are very fast. Variation in part size can be tolerated. The gripper does not have to be designed for one particular work part.
- They have the ability to handle metal parts with holes (not possible with vacuum grippers). They require only one surface for gripping.
- Disadvantages with magnetic grippers include the residual magnetism remaining in the work piece which may cause a problem in subsequent hand ling, and the possible side slippage and other errors which limit the precision of this means of handling.
- Another potential disadvantage of a magnetic gripper is the problem of picking up only one sheet from a stack. The magnetic attraction tends to penetrate beyond the top sheet in the stack. Resulting in the possibility that more than a single sheet will be lifted by the magnet.
- This problem can he confronted in several ways.
- First, magnetic grippers can he designed to limit the effective penetration to the desired depth, which would correspond to the thickness of the top sheet.
- Second, the stacking device used to hold the sheets can be designed to separate the sheets for pickup by the robot. One such type of stacking device is called "fanner" and it makes use of a magnetic field to induce a charge in the Ferrous sheets in the stack. Each sheet toward the top of the stack is given a magnetic charge.
- Causing them to possess the same polarity and repel each other. The sheet most affected is the one at the top of the stack.
- It tends to rise above the remainder of the stack, thus facilitating pickup by the robot gripper.

Video Content / Details of website for further learning (if any):
https://www.goudsmitmagnets.com/en/solutions/magnetic-handling/lifting-handling-magnets/magvacu-combi-grippers

Important Books/Journals for further learning including the page nos.:
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, IEEE Transactions on Robotics (TRO), Page No. 127-133

Course Name with Code : Industrial Robotics / 16MEE14

Unit : II **Date of Lecture:**

Topic of Lecture: Two Fingered and Three Fingered Grippers

Introduction : (Maximum 5 sentences)

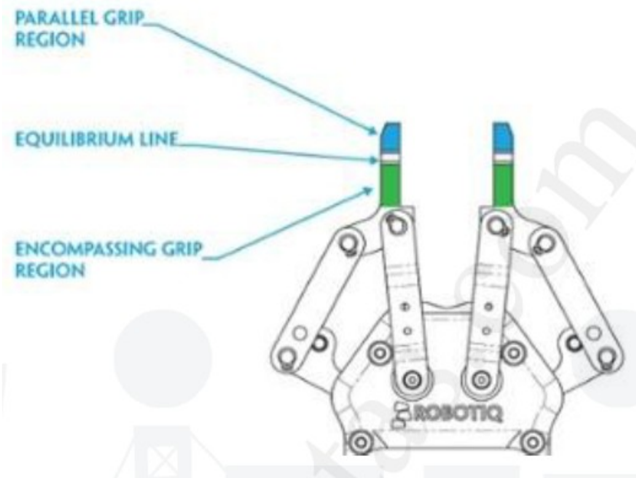
This unique feature allows the Gripper to pick up objects from the inside, which proves to be very useful in many situations. A three-fingered gripper that can securely hold a wide variety of shapes and parts. The device has three articulated fingers.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Parallel Grip
- Grip Region
- Equilibrium Line

Detailed content of the Lecture:

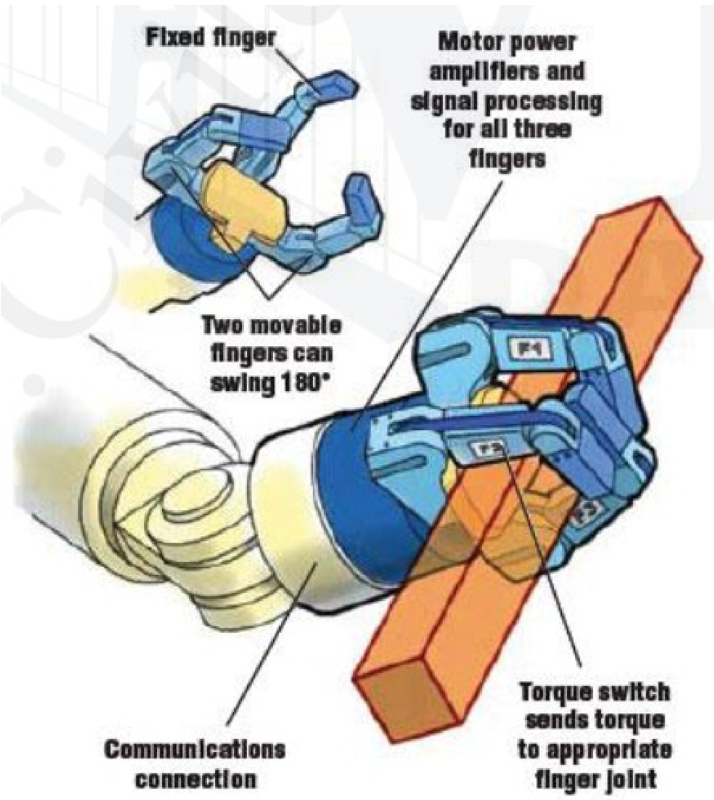
Two-fingered gripper



The mechanism driving the fingers of this Gripper is optimized to obtain two distinct contact regions. The first one, called the “encompassing grip region”, is located at the base of the fingers, while the second one, called the “pinch grip region”, is located at their end/tip. The boundary between these two adjacent regions is called the “equilibrium point”. When the contact of the finger with the object to be grasped occurs in the encompassing grip region, the finger automatically adapts to the shape of the object and curls around it. On the other hand, when the contact is made in the pinch grip region, the finger maintains its parallel motion and the object is pinched. Since the finger keeps its parallel motion when a contact is made above the equilibrium point during a pinch grip, the same is true for a contact made below the equilibrium point during an inside grip, i.e. for a force applied at the back of the finger. This unique feature allows the Gripper to pick up objects from the inside, which proves to be very useful in many situations

Three-fingered gripper

It's also costly to order custom-made handlers for special parts. To solve these problems, engineers at Barrett Technology Inc., Cambridge, Mass. (barrett.com), developed the Barrett Hand, a three-fingered gripper that can securely hold a wide variety of shapes and parts. The device has three articulated fingers. The center finger is fixed, and the other two rotate up to 180˚ around the outside of the hand's palm. This gives the hand a wide variety of grips and configurations. Each finger has two sections which act in concert to grab objects. When the first section touches an object, the second section continues retracting until it is also in contact. With all the fingers in play, and including the palm, the hand can have a seven-point grip on the object. This lets it deal with objects of unknown or inconsistent shapes. The hand can lift about 1.2 kg. The hand's eight joints are controlled by four brushless-dc motors, all in the wrist section. A torque switch lets four motors control eight axes of motion. The gripper's communications, five microprocessors, sensors, and signal processor are packed inside the palm body. A small umbilical cable connects the hand to an array of robotic arms from different manufacturers.



Video Content / Details of website for further learning (if any):
https://blog.robotiq.com/why-use-a-robot-gripper-with-3-fingers

Important Books/Journals for further learning including the page nos.:
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, International Journal of Robotics and Automation, Page No. 121-127.

Course Name with Code : Industrial Robotics / 16MEE14

Unit : II **Date of Lecture:**

Topic of Lecture: Internal grippers and external grippers, selection and design consideration.

Introduction : (Maximum 5 sentences)
In a wider sense, an end effector can be seen as the part of a robot that interacts with the work environment. This does not refer to the wheels of a mobile robot or the feet of a humanoid robot which are also not end effectors—they are part of the robot's mobility. End effectors may consist of a gripper or a tool.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Mobility
- Holding Point
- Environmental factor

Detailed content of the Lecture:

In robotics, an end effector is the device at the end of a robotic arm, designed to interact with the environment. The exact nature of this device depends on the application of the robot. In the strict definition, which originates from serial robotic manipulators, the end effector means the last link (or end) of the robot. At this endpoint the tools are attached. In a wider sense, an end effector can be seen as the part of a robot that interacts with the work environment. This does not refer to the wheels of a mobile robot or the feet of a humanoid robot which are also not end effectors—they are part of the robot's mobility.
End effectors may consist of a gripper or a tool. There are four general categories of robot grippers, these are:
1. Impactive – jaws or claws which physically grasp by direct impact upon the object.
2. Ingressive – pins, needles or hackles which physically penetrate the surface of the object
(used in textile, carbon and glass fibre handling).
3. Astrictive – suction[vague] forces applied to the objects surface (whether by vacuum,
magneto- or electroadhesion).
4. Contigutive – requiring direct contact for adhesion to take place (such as glue, surface
tension or freezing).

They are based on different physical effects used to guarantee a stable grasping between a gripper and the object to be grasped. Industrial grippers can be mechanical, the most diffused in industry, but also based on suction or on the magnetic force. Vacuum cups and electromagnets dominate the automotive field and in particular metal sheet handling. Bernoulli grippers exploit the airflow between the gripper and the part that causes a lifting force which brings the gripper and part close each other (i.e. the Bernoulli's principle). Bernoulli grippers are a type of contactless grippers, namely the object remains confined in the force filed generated by the gripper without coming into direct contact with it. Bernoulli gripper is adopted in Photovoltaic cell handling in silicon wafer handling but also in textile or leather industry. Other principles are less used at the macro scale (part size >5mm), but in the last ten years they demonstrated interesting applications in micro-handling.

A gripper is a motion device that mimics the movements of people, in the case of the gripper, it is the fingers. A gripper is a device that holds an object so it can be manipulated. It has the ability to hold and release an object while some action is being performed. The fingers are not part of the gripper, they are specialized custom tooling used to grip the object and are referred to as "jaws."

Two main types of action are performed by grippers:

External: This is the most popular method of holding objects, it is the most simplistic and it requires the shortest stroke length. When the gripper jaws close, the closing force of the gripper holds that object.

Internal: In some applications, the object geometry or the need to access the exterior of the object will require that the object is held from the center. In this case the opening force of the gripper will be holding the object

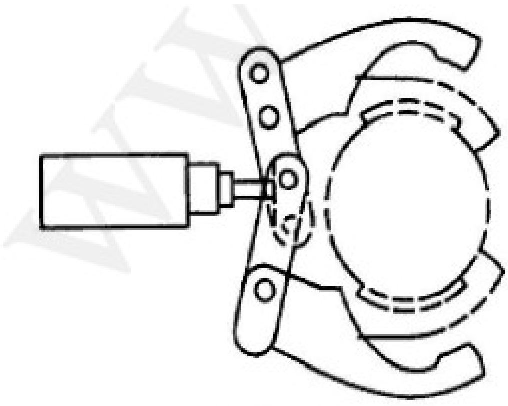


Figure 1 External gripper.

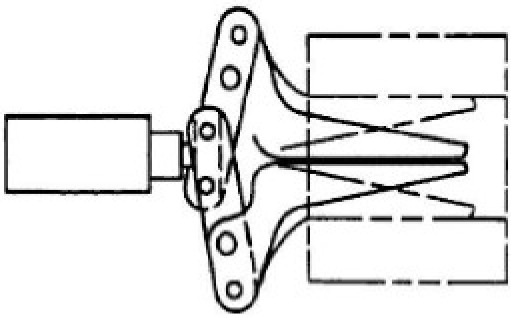


Figure 2 Internal gripper.

Video Content / Details of website for further learning (if any):
https://www.globalspec.com/learnmore/manufacturing_process_equipment/manufacturing_equipment_components/robots_robotic_accessories/grippers

Important Books/Journals for further learning including the page nos.:
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, International Journal of Advanced Robotic Systems, Page No. 121-140.

Course Name with Code : Industrial Robotics / 16MEE14

Unit : III Date of Lecture:

Topic of Lecture: Requirements of a sensor, Principles and Applications of the following types of sensors

Introduction : (Maximum 5 sentences)

Sensors used in robotics include a wide range of devices. Tactile sensors are devices which indicate contact between themselves and some other solid object. Proximity sensors are devices that indicate when one object is close to another Object. The miscellaneous category covers the remaining types of sensors and transducers that might be used for interlocks and other purposes in robotic Work cells.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Signal
- Tactile Sensor
- Proximity Sensor

Detailed content of the Lecture:

SENSORS IN ROBOTICS

Sensors used in robotics include a wide range of devices which can be into the following general categories:

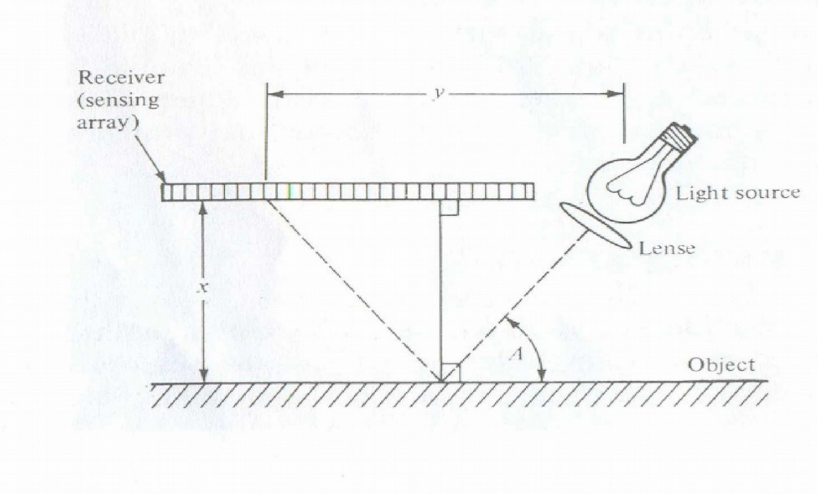
1 Tactile sensor
2 Proximity and range sensors
3 Miscellaneous sensors and sensor-based systems
4. Machine vision systems

TACTILE SENSORS

Tactile sensors are devices which indicate contact between themselves and some other solid object. Tactile sensing devices can be divided into two classes: touch sensors and force sensors. Touch sensors provide a binary output signal which indicates whether or not contact has been made with the object. Force sensors (also sometimes called stress sensors) indicate not only that contact has been made with the object but also the magnitude of the contact force between the two objects.

PROXIMITY AND RANGE SENSORS

Proximity sensors are devices that indicate when one object is close to another Object. How close the object must be in order to activate the sensor is dependent on the particular device. The distances can be anywhere between several millimeters and several feet. Some of these sensors can also be used to measure the distance between the object and the sensor, and these devices are called range sensors. Proximity and range sensors would typically be located on the wrist or end effectors since these are the moving parts of the robot. One practical use of a proximity sensor in robotics would be to detect the presence or absence of a work part or other object. Another important application is for sensing human beings in the robot work cell. Range sensors would be useful for determining the location of an object (e.g., the work part) in relation to the robot. A variety of technologies are available for designing proximity and range sensors. These technologies include optical devices, acoustics, electrical field techniques (e.g., eddy currents and magnetic fields), and others. We will survey only a few of the possibilities in the following paragraphs.



MISCELLANEOUS SENSORS AND SENSOR-BASED SYSTEMS

The miscellaneous category covers the remaining types of sensors and transducers that might be used for interlocks and other purposes in robotic Work cells. This category includes devices with the capability to sense variables such as temperature, pressure, fluid flow, and electrical properties An area of robotics research that might he included in this chapter is voice sensing or voice programming. Voice-programming systems can be used in robotics for oral communication of instructions to the robot. Voice sensing relies on the techniques of speech recognition to analyze spoken words uttered by a human and compare those words with a set of stored word patterns. When the spoken word matches the stored word pattern, this indicates that the robot should perform some particular actions which correspond to the word or series of words.

Video Content / Details of website for further learning (if any):
http://www.rm.mce.uec.ac.jp/sjE/index.php?Proximity+sensor

Important Books/Journals for further learning including the page nos.:
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001,
Robotica, An Official Journal of the IFAC 156-158

Course Name with Code : Industrial Robotics / 16MEE14

Unit : III Date of Lecture:

Topic of Lecture: Position sensors - Piezo Electric Sensor, LVDT, Resolvers, Optical Encoders, Pneumatic Position Sensors.

Introduction : (Maximum 5 sentences)

Piezo electric materials when stretched or compressed generate electric charges with one face of the material becoming positively charged and another face become negatively charged. Low pressure air allowed escaping through a port in front of the sensor.

Prerequisite knowledge for Complete understanding and learning of Topic:

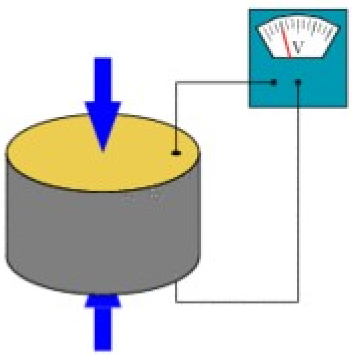
- Voltage
- Pressure
- Signal

Detailed content of the Lecture:

The various Position sensors are
– Piezo electric sensors
– LVDT
– Resolvers
– Optical encoders
– Pneumatic position sensors

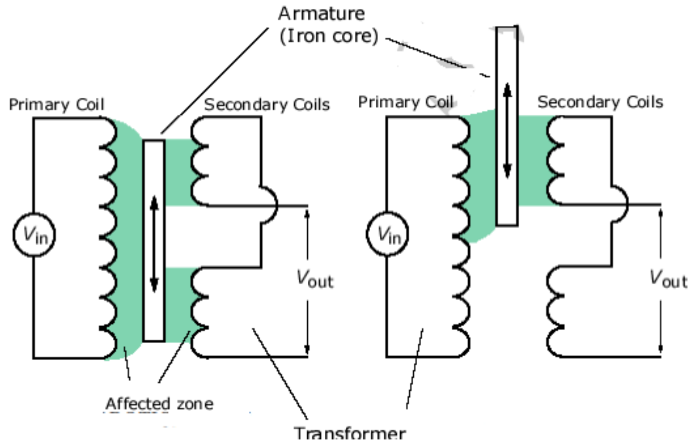
Piezoelectric sensor:

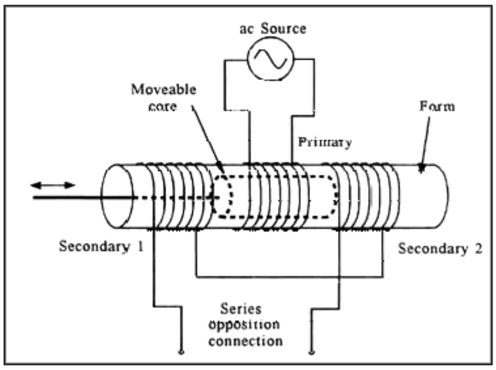
Piezo electric materials when stretched or compressed generate electric charges with one face of the material becoming positively charged and another face become negatively charged. As a result a voltage is produced. The net charge on a surface is proportional to the amount by which the charges have been displaced.



LVDT: Linear Variable Differential Transformer

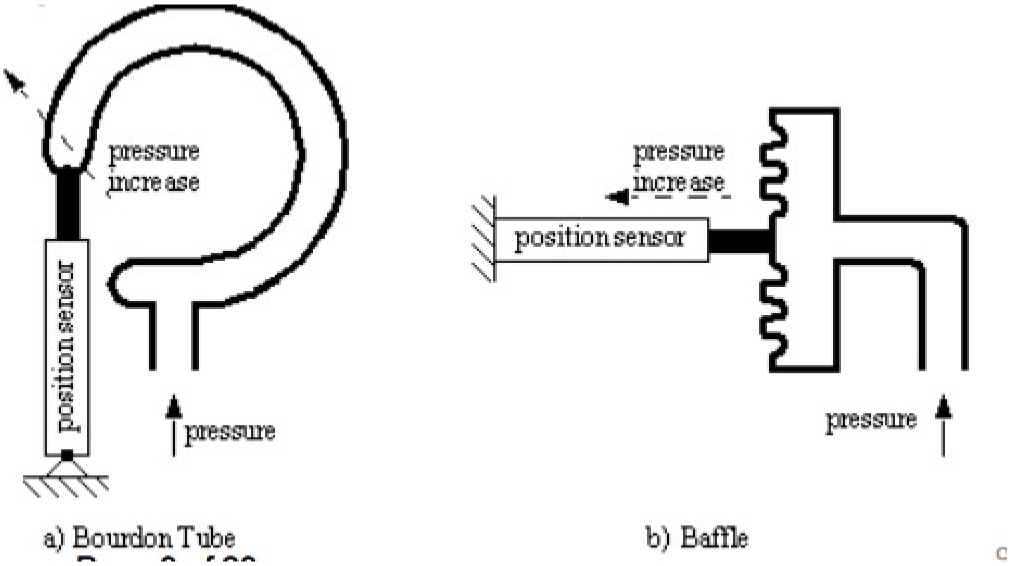
It consists of 3 coils – 1 primary coil – 2 secondary coils, Central coil is primary and other 2 are identical secondary coils which are connected in series, such a way their output oppose each other.





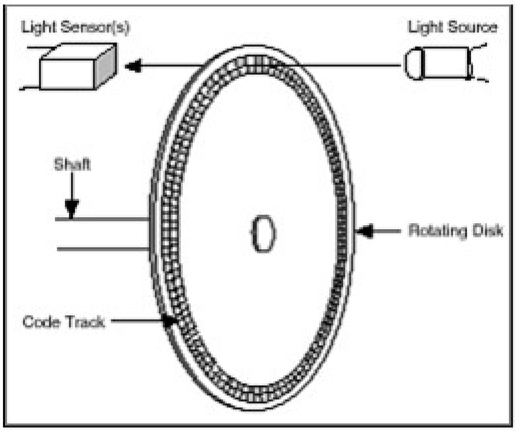
Magnetic core is moved through the central tube as a result of displacement being monitored. When there is an alternating voltage input to the primary coil, alternating e.m.f.s induced in secondary coils. With the magnetic core central, the amount of magnetic material in each coil is the same, since their output oppose each other the net result is zero output. When the core is displaced from the central position there is a greater amount of magnetic core in one coil than the other, resulting in greater e.m.f. is induced in one coil than the other. Operating range is from ±2 to ±400 mm with non-linearity errors of ±0.25% . The free end of the rod may be spring loaded for contact with the surface being monitored

Pneumatic position sensors:
Low pressure air allowed escaping through a port in front of the sensor. This escaping air, in the absence of any close by object, escapes and in doing so also reduces the pressure in nearby sensor output. If there is a close by object, the air cannot so readily escapes and this increases the sensor output port. Such sensors are used for the measurement of displacements of fractions of mm in a range of about 3 – 12 mm



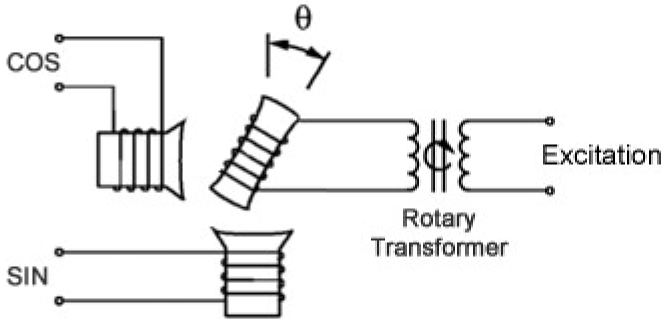
Encoders:
• Gives a digital output as a result of linear or angular position
– Incremental encoders
• Detects changes in rotation from some datum position
– Absolute encoders
• Gives actual angular position

A beam of light passes through slots in a disc and it is detected by a suitable light sensor. When the disc is rotated, a pulsed output is produced by the sensor with the number of pulses being proportional to the angle through which the disc rotates. Thus, angular position of the shaft is determined by the number of pulses produced since some datum position. The resolution is determined by the number of slots in the disc. If there are 60 slots in the disc, then resolution = 6°



Resolver:

Type of rotary electrical transformer used for measuring degrees of rotation. It is considered as an analog device. For position evaluation, resolver to digital converters is commonly used. They convert sine and cosine signal into binary signal that can be more easily be used by the controller



Video Content / Details of website for further learning (if any):

https://www.tekscan.com/products-solutions/position-sensors

Important Books/Journals for further learning including the page nos.:

M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, Journal of Field Robotics (JFR), Page No. 153-158.

Course Name with Code : **Industrial Robotics / 16MEE14**

Unit : **III** **Date of Lecture:**

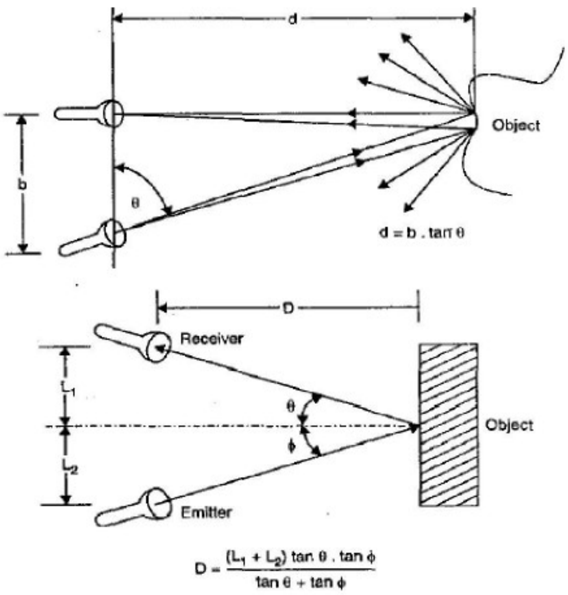
Topic of Lecture: Range Sensors - Triangulation Principle, Structured Lighting Approach, Time of Flight, Range Finders.

Introduction : (Maximum 5 sentences)
Range sensors find use in robot navigation and avoidance of the obstacles in the path. Specific range values are computed by first calibrating the system.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Trigonometry
- Light Property
- Emitter and Receiver

Detailed content of the Lecture:



Triangulation Method of Range Sensing.

Working principle of Range sensors

The distance between the object and the robot hand is measured using the range sensors Within it is range of operation. The calculation of the distance is by visual processing. Range sensors find use in robot navigation and avoidance of the obstacles in the path. The - location and the general shape characteristics of the part in the work envelope of the robot S done by special applications for the range sensors. There are several approaches like, triangulation method, structured lighting approach and time-of flight range finders etc. In these cases the source of illumination can be light- source, laser beam or based on ultrasonic.

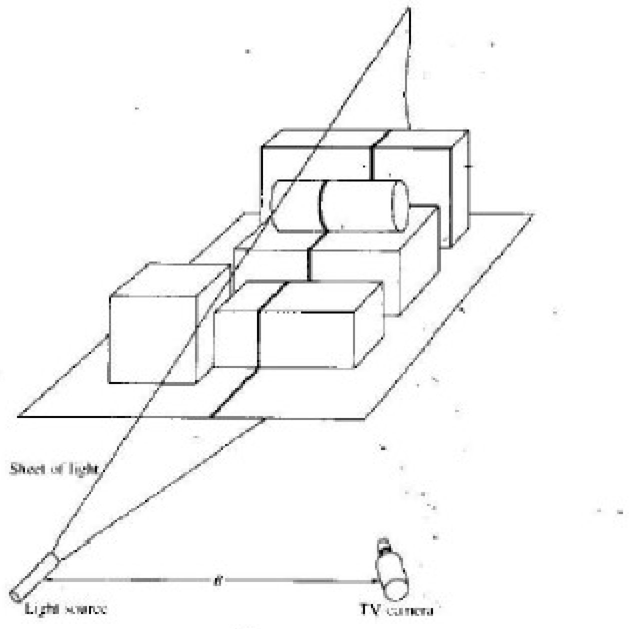
This is the simplest of the techniques, which is easily demonstrated in the Figure. The object is swept over by a narrow beam of sharp light. The sensor focussed on a small spot of the object surface detects the reflected beam of light. If ‗8‘ is the angle made by the illuminating source and ‗b‘is the distance between source and the sensor, the distance ‗c of the sensor on the robot is given as

$$d = b \cdot \tan\theta$$

The distance '*d*' can be easily transformed into 3D-co-ordinates

Structured Lighting Approach:

This approach consists of projecting a light pattern the distortion of the pattern to calculate the range. A pattern in use today is a sheet of light generated narrow slit. As illustrated in. Figure, the intersection of the sheet with objects in the‘ work space yields a light stripe which is viewed through a television camera displaced a distance B from the light source. The stripe pattern is easily analyzed by a computer to obtain range information. For example, an inflection indicates a change of surface, and a break corresponds to a gap between surfaces.



Range measurement by structured lighting approach.

Specific range values are computed by first calibrating the system. One of the simplest arrangements is shown in Figure, which represents a top view of Figure. In this, arrangement, the light source and camera are placed at the same height, and the sheet of light is perpendicular to the line joining the origin of the light sheet and the center of the camera lens.

Video Content / Details of website for further learning (if any):
https://lightningprocess.com/what-is-the-lightning-process/

Important Books/Journals for further learning including the page nos.:

M.P.Groover, “Industrial Robotics – Technology, Programming and Applications”, McGraw-Hill, 2001, International Journal of Robotics Research (IJRR), 154-158

Course Name with Code : Industrial Robotics / 16MEE14

Unit : III

Date of Lecture:

Topic of Lecture: Laser Range Meters, Proximity Sensors Inductive, Hall Effect sensor

Introduction : (Maximum 5 sentences)

Proximity sensors are devices that indicate when one object is close to another Object. The ferromagnetic material brought close to this type of sensor results in change in position of the flux lines of the permanent magnet leading to change in inductance of the coil.

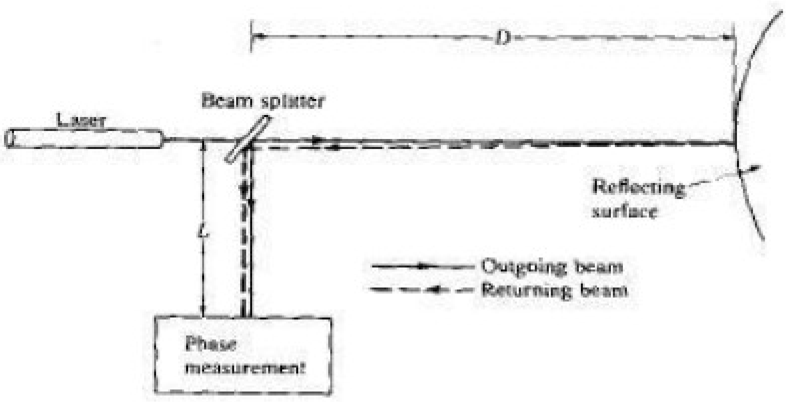
Prerequisite knowledge for Complete understanding and learning of Topic:

- Phase
- Array
- Magnetic field

Detailed content of the Lecture:

Laser range meters:

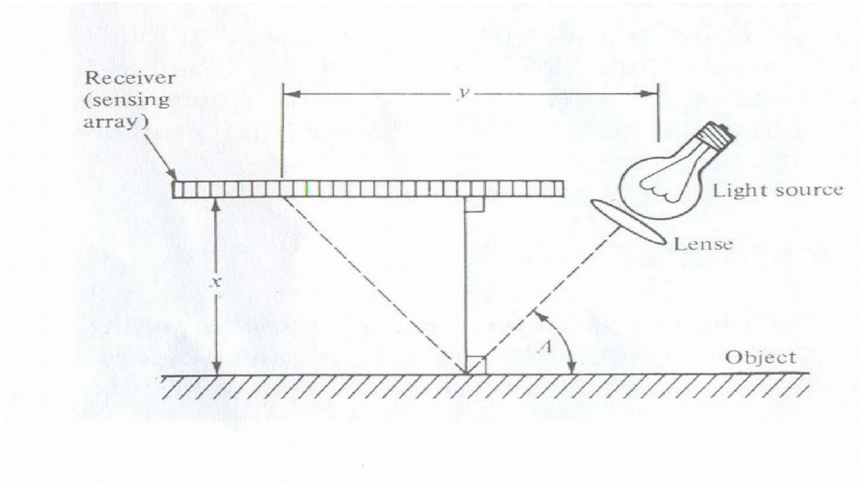
A pulsed-laser system described by larvis [produces a two-dimensional array with values proportional to distance. The two-dimensional scan is accom plished by deflecting the laser light via a rotating mirror. The 66 working range of this device is on the order of I to 4 m, with an accuracy of ± 0.25 cm. Figure shows a collection of three-dimensional objects, and Figure is the corresponding sensed array displayed as art image in which the intensity at each point is proportional to the distance between the sensor and the reflecting surface at that point (darker is closer). The bright areas around the object boundaries represent discontinuity in range determined by post processing in a computer An alternative to pulsed light is to use a continuous-beam laser and measure the delay (i.e., phase shift) between the outgoing and returning beams.



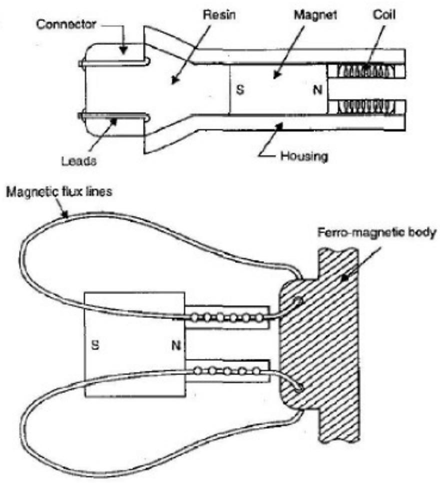
Proximity and Range Sensors

Proximity sensors are devices that indicate when one object is close to another Object. How close the object must be in order to activate the sensor is dependent on the particular device. The distances can be anywhere between several millimeters and several feet. Some of these sensors can also be used to measure the distance between the object and the sensor, and these devices are called range sensors. Proximity and range sensors would typically be located on the wrist or end effectors since these are the moving parts of the robot. One practical use of a proximity sensor in robotics would be to detect the presence or absence of a work part or other object. Another important application is for sensing human beings in the robot work cell. Range sensors would be useful for determining the location of an object (e.g., the work part) in relation to the robot. A variety of technologies are available for designing proximity and range sensors. These technologies include optical devices, acoustics, electrical field techniques (e.g., eddy currents and magnetic fields), and others. We will survey only a few of the possibilities in the following paragraphs.

Figure: Scheme for a proximity sensor using reflected light against a sensor array. x = O.5y tan (A)
Where x = the distance of the object from the sensor y = the lateral distance between the light source and the reflected light beam against the linear array. This distance corresponds to the number of elements contained within the reflected beam in the sensor array A = the angle between the object and the sensor array as illustrated in Fig. Use of this device in the configuration shown relies on the fact that the surface of the object must be parallel to the sensing array.



Inductive Proximity Sensors:



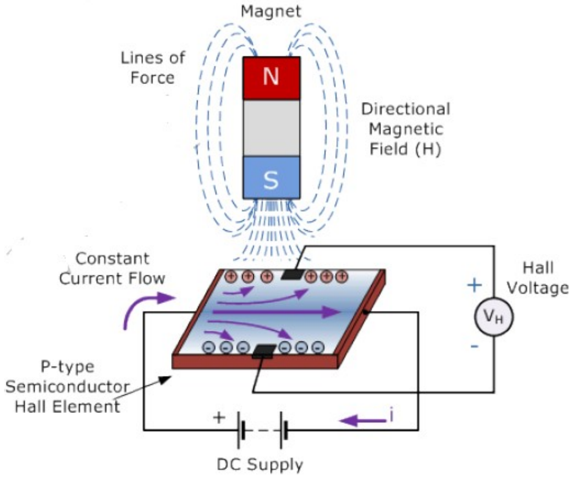
Inductive Sensor.

The ferromagnetic material brought close to this type of sensor results in change in position of the flux lines of the permanent magnet leading to change in inductance of the coil. The induced current pulse in the coil with change in amplitude and shape is proportional to rate of change of flux line in magnet.
Construction:
The proximity inductive sensor basically consists of a wound coil located in front of a permanent magnet encased inside a rugged housing. The lead from the coil,

embedded in resin is connected to the display through a connector. The effect of bringing the sensor in close proximity to a ferromagnetic material causes a change in the position of the flux lines of the permanent magnet.

Hall effect:
•When a beam of charged particles passes through a magnetic field, forces act on the particles and the beam is deflected from the straight line path
•A current flowing in the conductor is like a beam of moving charges and thus can be deflected by a magnetic field

Working:
•Consider electrons moving in a conductive plate with a magnetic field at right angles to the plane of the plate
•As a consequence of the magnetic field, the moving electrons are deflected to one side of the plate and thus that side becomes negatively charged, while the opposite side becomes positively charged since the electrons are directed away from it
•This charge separation produces an electric field in the material



Video Content / Details of website for further learning (if any):
https://dir.indiamart.com/impcat/inductive-proximity-sensor.html

Important Books/Journals for further learning including the page nos.:
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, IEEE Robotics and Automation Magazine (RAM), Page No. 155-158.

Course Name with Code : Industrial Robotics / 16MEE14

Unit : III **Date of Lecture:**

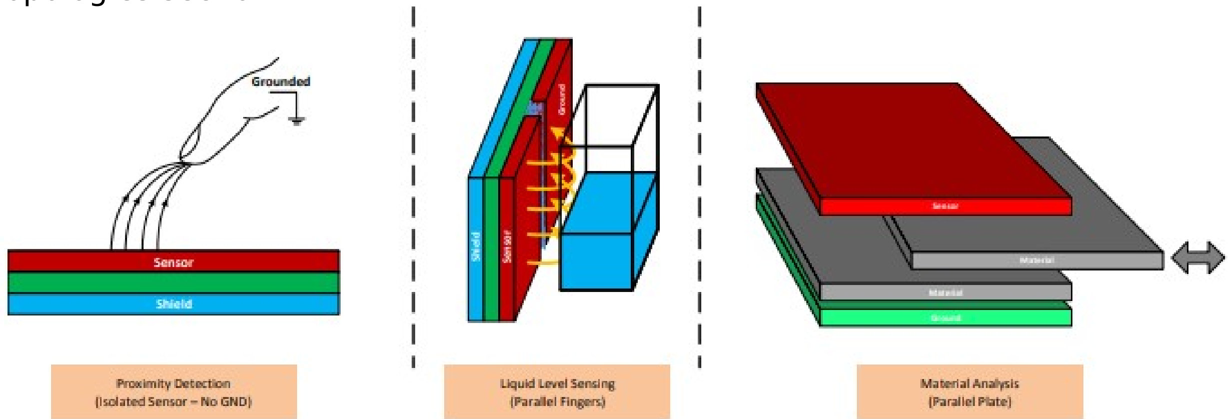
Topic of Lecture: Capacitive, Ultrasonic and Optical Proximity Sensors

Introduction : (Maximum 5 sentences)
A capacitive sensor is a proximity sensor that detects nearby objects by their effect on the electrical field created by the sensor. Ultrasonic sensors work by sending out a sound wave at a frequency above the range of human hearing. Optical sensors are a class of sensors that have attracted a great deal of attention for analytical applications.

Prerequisite knowledge for Complete understanding and learning of Topic:

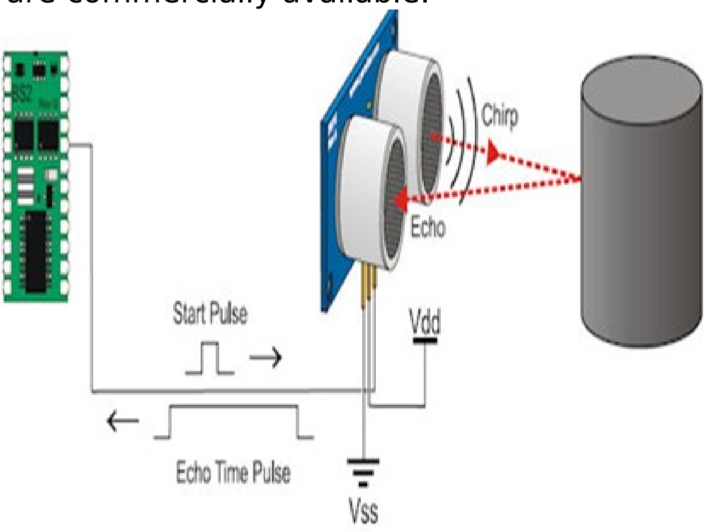
- Shield
- Pulse
- Echo

Detailed content of the Lecture:
Capacitive sensing is a technology based on capacitive coupling that takes the capacitance produced by the human body as the input. It allows a more reliable solution for applications to measure liquid levels, material composition, mechanical buttons, and human-to-machine interfaces. A basic capacitive sensor is anything metal or a conductor and detects anything that is conductive or has a dielectric constant different from air. Figure displays three basic implementations for capacitive sensing: proximity/gesture recognition, liquid level sensing, and material analysis. More details about the sensor topology can be found in the Capacitive Sensor Topologies section.

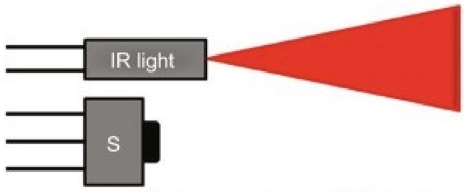


Ultrasonic Obstacle Detection
Ultrasonic sensors are used to detect the presence of targets and to measure the distance to targets in many robotized processing plants and process plants. Sensors

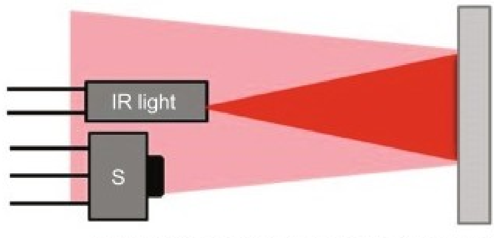
with an ON or OFF digital output are available for detecting the presence of objects and sensors with an analog output which changes relatively to the sensor to target separation distance are commercially available.



Ultrasonic obstacle sensor consists of a set of ultrasonic receiver and transmitter which operate at the same frequency. The point when the something moves in the zone secured the circuit's fine offset is aggravated and the buzzer/alarm is triggered.
Photodiodes are devices that consume light energy to produce an electric current. Photodiodes are also referred to as photodetectors or photo-sensors. Common applications of photodiodes for robotics include the detection of the presence of light, color, position, or intensity. Combinations of light-emitting diodes (LEDs) and photodiodes are commonly used together in many optical sensor systems.
Infrared sensors are commonly used for sensing of objects and detection of distances. An infrared sensor emits a pulse of infrared light from an emitter. As shown in Fig. 4.6, the light will be reflected and hit a detector if an object is present. Based on the angle of the returning infrared light, the distance to the object can be calculated. Infrared sensors are used in robotics for distance measurement, object detection and avoidance, and terrain sensing.



No object present, no IR light is detected by the sensor



Object present, IR light is detected by the sensor

Video Content / Details of website for further learning (if any):
https://brigade-electronics.com/products/ultrasonic-obstacle-detection/

Important Books/Journals for further learning including the page nos.:
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, International Journal of Humanoid Robotics, Page No. 156-158

Course Name with Code : Industrial Robotics / 16MEE14

Unit : III **Date of Lecture:**

Topic of Lecture: Touch Sensors, Binary Sensors, Analog Sensors

Introduction : (Maximum 5 sentences)
Touch sensors ate used to indicate that contact has been made between two objects without regard to the magnitude of the contacting force.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Contact
- Analog
- Digital

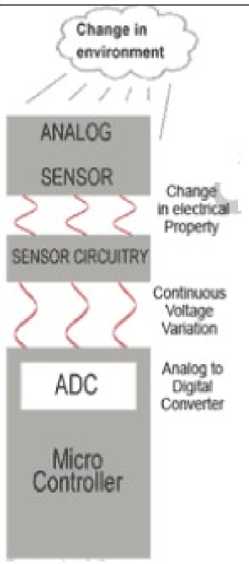
Detailed content of the Lecture:

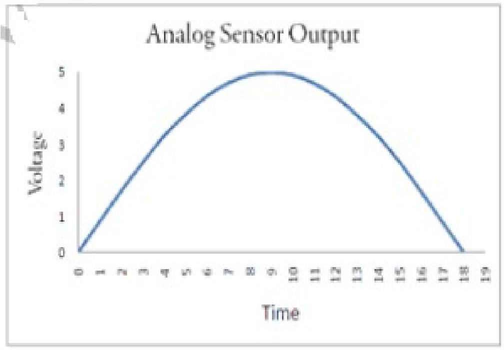
Touch Sensors

Touch sensors ate used to indicate that contact has been made between two objects without regard to the magnitude of the contacting force. Included within this category are simple devices such as limit switches, micro switches, and the like. The simpler devices are frequently used in the design of interlock systems in robotics. For example, they can be used to indicate the presence or absence of parts in a fixture or at the pickup point along a conveyor. Another use for a touch-sensing device would be as part of an inspection probe which is manipulated by the robot to measure dimensions on a work part. A robot with 6 degrees of freedom would be capable of accessing surfaces on the part that Would be difficult for a three-axis coordinate measuring machine, the Inspection system normally considered for such an inspection task. Unfortunately, the robot's accuracy would be a limiting factor in contact inspection work.

Analog Sensors

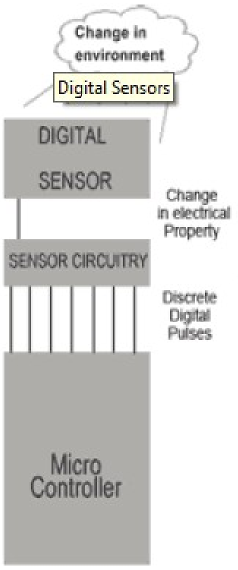
• Gives the change in electric property to signify the change in environment
•Sensor circuits are designed to monitor these changes and provide a voltage difference

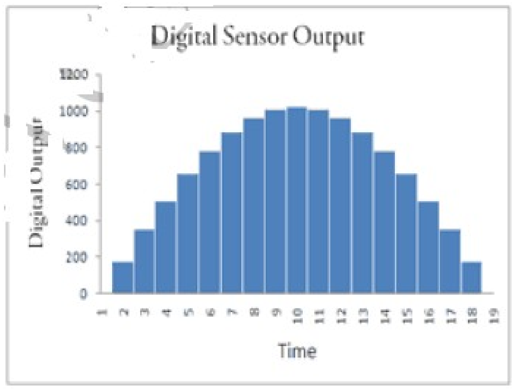




Digital Sensors

• Output of this sensor can be either ON or OFF or it can be 1 or 027





Video Content / Details of website for further learning (if any):
https://in.element14.com/sensor-touch-sensor-cap-res-technology

Important Books/Journals for further learning including the page nos.:
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, International Journal of Robotics and Automation, Page No. 157-158

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Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

Course Name with Code : Industrial Robotics / 16MEE14

Unit : III **Date of Lecture:**

Topic of Lecture: Wrist Sensors, Compliance Sensors, Slip Sensors

Introduction : (Maximum 5 sentences)
Humans can grasp an object without information such as a coefficient of friction or weight. To implement this grasping motion with the robot hand, sensors have been proposed that detect an incipient slip within the contact surface or stick-slip.

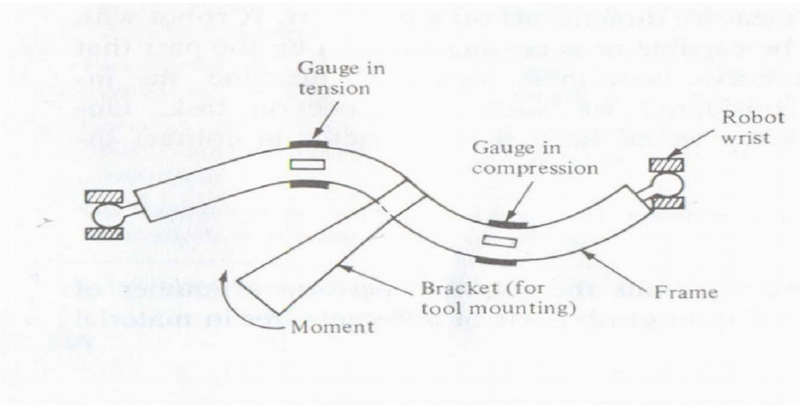
Prerequisite knowledge for Complete understanding and learning of Topic:

- Force
- Voltage
- Slip

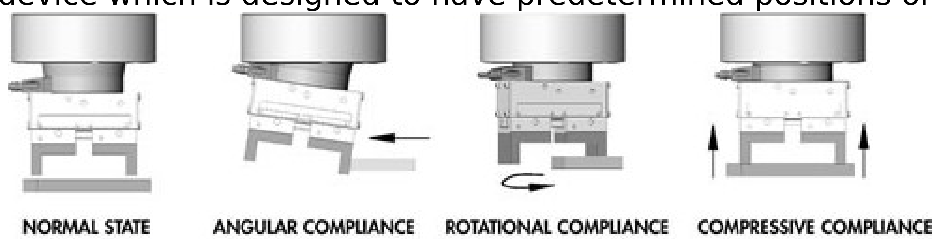
Detailed content of the Lecture:

Force-sensing wrist

The purpose of a force-sensing wrist is to provide in formation about the three components of force (F_x, F_y and F_z)and the three moments (M_x, M_y and M_z being applied at the end-of-the-arm. One possible construction of a force-sensing wrist is illustrated in Fig. 6- 1. The device consists of a metal bracket fastened to a rigid frame. The frame is mounted to the wrist of the robot and the tool is mounted to the center of the bracket. The figure shows how the sensors might react to a moment applied to the bracket due to forces and moments on the tool.



Compliance refers to flexibility and suppleness. A non-compliant (stiff) robot end effector is a device which is designed to have predetermined positions or trajectories.



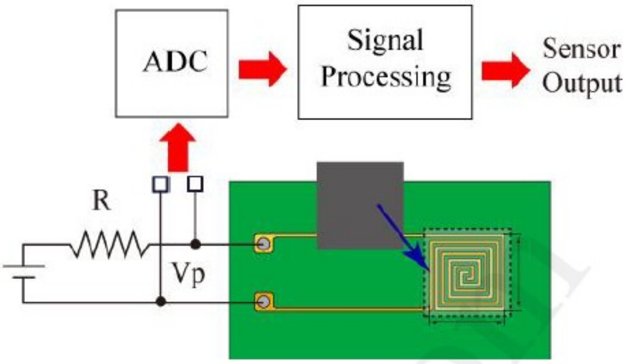
Slip Sensing

Slip can be defined as relative movement of one object's surface over another when in contact

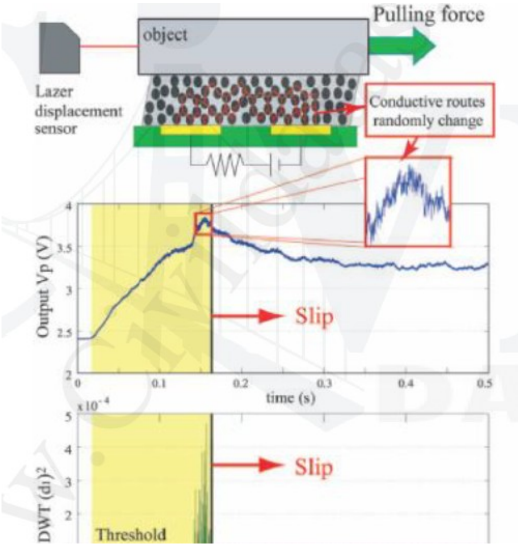
•In an assembly operation, it is possible to test the occurrence of slip to indicate some predetermined contact forces between the object and assembled part

•To implement this grasping motion with the robot hand, sensors have been proposed that detect an incipient slip within the contact surface or stick-slip

Humans can grasp an object without information such as a coefficient of friction or weight. To implement this grasping motion with the robot hand, sensors have been proposed that detect an incipient slip within the contact surface or stick-slip. The sensor is constructed of electrode and pressure conductive rubber (Inaba Rubber Co.,Ltd.) as shown in figure.



The voltage difference Vp is measured and the signal processing is performed. Then the initial slip can be detected. The pressure conductive rubber was a high polymer material primarily composed of silicone rubber with carbon particles uniformly distributed within.



Video Content / Details of website for further learning (if any):
https://www.tekscan.com/products-solutions/embedded-force-sensors

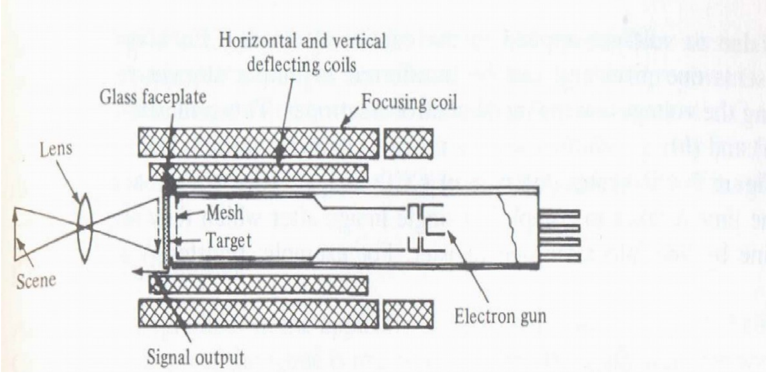
Important Books/Journals for further learning including the page nos.:
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, Industrial Robot: An International Journal, Page No. 157-158.

Course Name with Code : Industrial Robotics / 16MEE14

Unit : III Date of Lecture:

Topic of Lecture: Camera, Frame Grabber, Sensing and Digitizing Image Data, Signal Conversion, Image Storage, Lighting Techniques
Introduction : (Maximum 5 sentences) There are a variety of commercial imaging devices available. Camera technologies available include the older black-and-white vidicon camera, and the newer, second generation, solid state cameras. Solid state cameras used for robot vision include charge coupled devices (CCD), charge injection-devices (CID), and silicon bipolar sensor cameras.
Prerequisite knowledge for Complete understanding and learning of Topic: • A/D Converter • Lens • Electron
Detailed content of the Lecture: **SENSING AND DIGITIZING FUNCTION IN MACHINE VISION** In this preceding section identified three functions: sensing and digitizing, image processing and analysis, and application. Image sensing requires some type of image formation device such as a cam digitizer which stores video frame in the computer memory image sensing and digitizing functions into several steps. The initial step involves capturing the image of the scene with the vision camera. The image consists of relative light intensities corresponding to the various portions of the scene. These light intensities are continuous analog values which must be sampled and converted into digital form. The second step, digitizing, is achieved by an analog-to-digital (AID) converter. The AID converter is either a part of a digital video camera or the !P' end of a frame grabber. The choice is dependent on the type of hardware in the system. The frame grabber, representing the third step, is an image storage and computation device which stores a given pixel array. The frame grabber can vary in capability due which simply stores an image to significant computation capability. In the more 2owcTtUl [grabbers, thresholding, windowing, and histogram modification calculations can he carried out under computer control. The stored image is then subsequently processed and analyzed by the combination of the frame grabber and the vision controller. **Imaging Devices** There are a variety of commercial imaging devices available. Camera technologies available include the older black-and-white vidicon camera, and the newer, second generation, solid state cameras. Solid state cameras used for robot vision include charge coupled devices (CCD), charge injection-devices (CID), and silicon bipolar sensor cameras. For our purposes, we review two such devices in this subsection, the vidicon camera and the charge-coupled. Figure illustrates the vidicon camera. In the operation of this system the lens forms an image on the glass faceplate of the camera. The faceplate has an inner surface which is coated with two layers of material. The first layer consists of an electrode film deposited on the faceplate of the inner surface. The second layer is a thin photosensitive material covered over the conducting film. The photosensitive layer consists of a high density of small areas. These areas are similar to the pixels mentioned previously. Each area generates a decreasing electrical

resistance in response to increase illumination. A charge is created in each small area upon illumination. AI’ electrical charge pattern is thus generated corresponding to the image form



Lighting Techniques

An essential ingredient in the application of machine vision is proper lighting. Good illumination of the scene is important because of its effect on the level of complexity of image-processing algorithms required. Poor lighting makes the task of interpreting the scene more difficult. Proper lighting techniques should provide high contrast and minimize specular reflections and shadows unless specifically designed into the system. ‘Ihe basic types of lighting devices used in machine vision may be grouped into the following categories:

1. Diffuse surface devices.
2. Condenser projectors. A condenser projector transforms an expanding light source into a condensing light source. This is useful in imaging optics..
3. Flood or spot projectors. Flood lights and spot lights are used to illuminate surface areas.
4. Collimators. Collimators are used to provide a parallel beam of light on the subject.
5. Imagers. Imagers such as slide projectors and optical enlargers form an image of the target at the object plane.

Video Content / Details of website for further learning (if any):
https://knowthecode.io/labs/basics-of-digitizing-data/episode-14

Important Books/Journals for further learning including the page nos.:
M.P.Groover, “Industrial Robotics – Technology, Programming and Applications”, McGraw-Hill, 2001, Advanced Robotics, Page No. 161-172.

Course Name with Code : Industrial Robotics / 16MEE14

Unit : III **Date of Lecture:**

Topic of Lecture: Image Processing and Analysis , Data Reduction, Segmentation, Feature Extraction, Object Recognition

Introduction : (Maximum 5 sentences)

The data analysis common usage for data reduction: digital conversion. The function of both schemes is to eliminate the bottleneck that can occur from the large volume of data in image processing. Digital conversion reduces the number of gray levels used by the machine vision system. For example, an 8-bit register used for each pixel would have 28 = 256 gray levels.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Template
- Pixel
- Recognition

Detailed content of the Lecture:

IMAGE PROCESSING AND ANALYSIS

The discussion in the preceding section described how images are obtained, digitized, and stored in a computer. For use of the stored image in industrial applications, the computer must be programmed to operate on the digitally stored image. This is a substantial task considering the large amount of data that must be analyzed. Consider an industrial vision system having a pixel density of 350 pixels per line and 280 lines (a total of 98,000 picture elements), and a 6-bit register for each picture element to represent various gray levels. This would require a total of 98,000 x 6 = 588,000 bits of data for each. This is a formidable amount of data to be processed in a short period of time and has led to various techniques to reduce the magnitude of the image processing problem. These techniques include:

1. Image data reduction
2. Segmentation
3. Feature extraction
4. Object recognition

We will discuss these techniques of image data analysis in the subsections.

Image Data Reduction

In image data reduction, the objective is to reduce the volume of data. AS a preliminary step in the data analysis common usage for data reduction: digital conversion. The function of both schemes is to eliminate the bottleneck that can occur from the large volume of data in image processing. Digital conversion reduces the number of gray levels used by the machine vision system. For example, an 8-bit register used for each pixel would have 28 = 256 gray levels. Depending on the requirements of the application, digital conversion can be used to reduce the number of gray levels by using fewer bits to represent the pixel light intensity. Four bits would reduce the number of gray levels to 16. This kind of conversion would significantly reduce the magnitude of the image-processing problem. Example 7-4 For an image digitized at 128 points per line and 128 lines, determine (a) the total number of bits to represent the gray level values required if an 8 bit AID converter is used to indicate various shades of gray, and (b) the reduction in data volume if only black and white values are digitized.

OBJECT RECOGNITION

In machine vision applications, it is often necessary to distinguish one object from another. This is usually accomplished by means of features that uniquely characterize the object. Some features of objects that can be used in machine vision include area, diameter, and perimeter. A feature, in the context of Vision systems, is a single parameter that permits ease of comparison and Identification. A list of some of the features commonly used in vision applications is given in Table 7-2. The techniques available to extract feature values for two dimensional cases can be roughly categorized as those that deal with boundary features and those that deal with area features. The various features can be used to identify the object or part and determine the part Lo caution and/or orientation. The region-growing procedures described before can be used to determine the area of an object's image. The perimeter or boundary that encloses a Specific area can be determined by noting the difference in pixel intensity at boundary and simply counting all the pixels in the segmented region that are adjacent to pixels not in the region; that is, on the other side of the intensity change that occurs In the pixel S at Object Recognition

The next step in image data processing is to identify the object the image represents. This identification problem is accomplished using the extracted feature information described in the previous subsection. The recognition algorithm must be powerful enough to uniquely identify the object. Object recognition techniques used in industry today may be classified into two major categories:

Template-matching techniques

Structural techniques

Template-matching techniques are a subset of the more general statistical pattern recognition techniques that serve to classify objects in an image into predetermined categories.

Video Content / Details of website for further learning (if any):

https://www.coursera.org/lecture/matlab-image-processing/image-segmentation-djpNF

Important Books/Journals for further learning including the page nos.:

M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, Robotics and Autonomous Systems, Page No. 172-181.

Course Name with Code : **Industrial Robotics / 16MEE14**

Unit : **IV** **Date of Lecture:**

Topic of Lecture: Forward Kinematics, Inverse Kinematics and Differences

Introduction : (Maximum 5 sentences)

- Forward kinematics refers to the use of the kinematic equations of a robot to compute the position of the end- effector from specified values for the joint parameters.
- The reverse process that computes the joint parameters that achieve a specified position of the end- effector is known as inverse kinematics

Prerequisite knowledge for Complete understanding and learning of Topic:

Forward kinematics refers to the use of the kinematic equations of a robot to compute the position of the end-effector from specified values for the joint parameter.

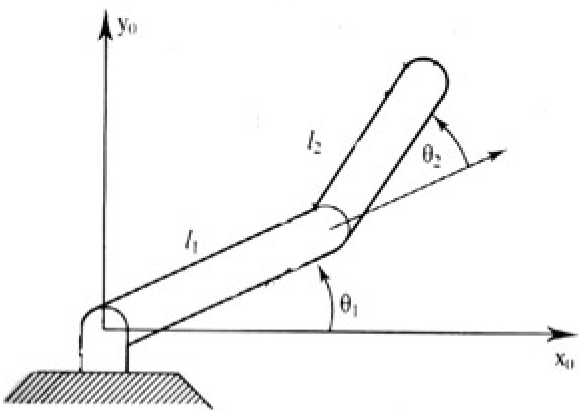
Detailed content of the Lecture:

Forward kinematics:

The transformation of coordinates of the end-effector point from the joint space to the world space is known as forward kinematic transformation.

Reverse kinematics:

The transformation of coordinates from world space to joint space is known as backward or reverse kinematic transformation.



Robotic arm Kinematics deals with the analytic study of the motion of a robot arm with respect to a fixed reference coordinate system as a function of time. The mechanical manipulator can be modelled as an open loop articulated chain with several rigid links connected in series by either revolute‘ or prismatic‘ joints driven by the actuators. For a manipulator, (the position and orientation of the end-effector are derived from the given joint angles and link parameters, the scheme is called the forward kinematics problem.

If, on the other hand, the joint angles and the different configuration of the manipulator are derived from the position and orientation of the end effector, the scheme is called the reverse kinematics problem. Representing the Position Considering the revolute type of joint only, the position of the end effector can be represented by the joint angles, 0 02,...,. 0,, as,

$$P_{JOINT} = (\theta_1, \theta_2, \theta_3, \dots \theta_n)$$

The position of the end-effector can also be defined in world space as

$$P_{WORLD} = (x, y, z)$$

Video Content / Details of website for further learning (if any):
https://www.google.com/search?q=Forward+Kinematics,
+Inverse+Kinematics+and+Differences&source=lnms&tbm
=vid&sa=X&ved=2ahUKEwj2zr2_5sztAhUZ4zgGHTVDAMoQ_AUoAnoECBkQBA
&biw=1024&bih=657

Important Books/Journals for further learning including the page nos.: 26

M.P.Groover, “Industrial Robotics – Technology, Programming and Applications”, McGraw-Hill, 2001, https://www.irjet.net/archives/V4/i2/IRJET-V4I2269.pdf

Course Name with Code : Industrial Robotics / 16MEE14

Unit : IV Date of Lecture:

Topic of Lecture: Forward Kinematics and Reverse Kinematics of Manipulators with Two Degrees of Freedom

Introduction : (Maximum 5 sentences)

- Robot is a machine that collects the information about the environment using some sensors and makes a decision automatically.
- Today robot are used in various field like as medical, industry, military operation, in space and some dangerous place.
- But the controlling of robot manipulator has been challenges with higher DOF.
- Position and orientation analysis of robotic manipulator is an essential step to design and control.
- The position and orientation analysis of a serial manipulator is given.

Prerequisite knowledge for Complete understanding and learning of Topic:

- 2-DOF manipulator is modeled in PROE. In MATLAB, inverse kinematics is solved by geometric method.

Detailed content of the Lecture:

Forward Kinematics

A manipulator is composed of serial links which are affixed to each other revo-lute or prismatic joints from the base frame through the end-effector. Calculat-ing the position and orientation of the end-effector in terms of the joint vari-ables is called as forward kinematics

$x = L1\cos\theta1 + L2\cos\theta12$,(1)

$y = L1\sin\theta1 + L2\sin\theta12$, where $\theta12 = \theta1 + \theta2$.(2)

Inverse kinematics of the planar 2-R manipulator

Explained above, the task in this case is to find $\theta1, \theta2$, given x,y. There are multiple ways of solving this problem, and some of these are noted below.2.2.1 Trigonometric method Note that Eqs. (1,2) are nonlinear in $\theta1, \theta2$, but these are linear in the sines and cosinesof $\theta1, \theta12$.

Taking advantage of this, we solve for

$\cos\theta 1, \sin\theta 1 : \cos\theta 1 = (x - l2\cos\theta 12)/L1 (3)$ $\sin\theta 1 = (y - l2\sin\theta 12)/l1 ; L1 > 0. (4)$
Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=f9kxhj5bR6w
Important Books/Journals for further learning including the page nos.: 85 M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, https://www.ijedr.org/papers/IJEDR1504082.pdf

Course Name with Code : Industrial Robotics / 16MEE14

Unit : IV Date of Lecture:

Topic of Lecture: Forward Kinematics and Reverse Kinematics of Manipulators with Three Degrees of Fre

Introduction : (Maximum 5 sentences)

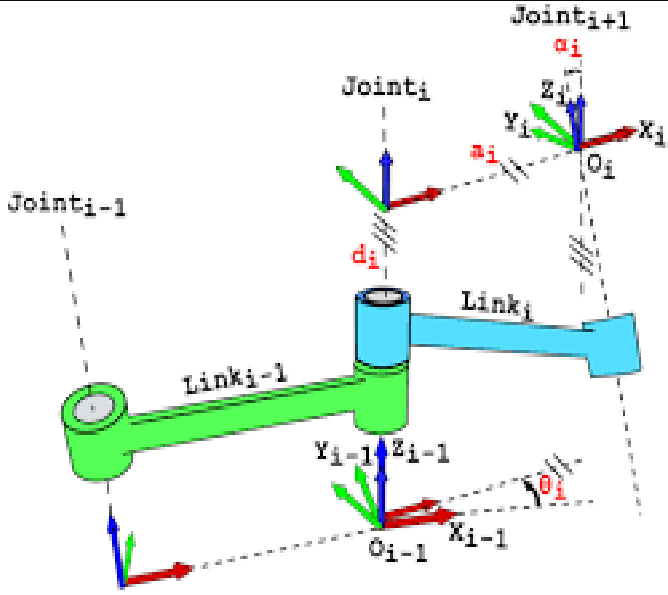
- Robot is a machine that collects the information about the environment using some sensors and makes a d
- Today robot are used in various field like as medical, industry, military operation, in space and some da work. But the controlling of robot manipulator has been challenges with higher DOF.
- Position and orientation analysis of robotic manipulator is an essential step to design and control.
- Introduction of the position and orientation analysis of a serial manipulator is given. A robot manipulato either serial or parallel manner.

Prerequisite knowledge for Complete understanding and learning of Topic:

- An alternative design of a three-degrees-of-freedom manipulator based on the concept of an in-parallel ac

Detailed content of the Lecture:

- The forward kinematics problem is concerned with the relationship between the individual joints of t orientation of the tool or end-effector.
- The forward kinematics problem is to determine the position and orientation of the end-effector, given th
- The joint variables are the angles between the links in the case of revolute or rotational joints, and the sliding joints.
- For a single particle in a plane two coordinates define its location so it has two degrees of freedom;
- A single particle in space requires three coordinates so it has three degrees of freedom;
- Two particles in space have a combined six degrees of freedom



Video Content / Details of website for further learning (if any):
https://www.google.com/search?q=Manipulators+with+Three+Degrees+of+Freedom+(In+2-
+wikipedia&safe=strict&source=lnms&tbm=vid&sa=X&ved=2ahUKEwiw9o_p2sztAhWjjuYKH
24&bih=657

Important Books/Journals for further learning including the page nos.:85
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001,
https://journals.sagepub.com/doi/full/10.5772/62100

Course Name with Code : Industrial Robotics / 16MEE14

Unit : IV **Date of Lecture:**

Topic of Lecture: Forward Kinematics and Reverse Kinematics of Manipulators with Four Degrees of Freedom

Introduction : (Maximum 5 sentences)

Forward kinematics refers to the use of the kinematic equations of a robot to computer the position of the

Forward kinematics is a transformation matrix to calculate the relationship between position and orientati

This part is very important to calculate the position and/or orientation error to calculate the controller's qualif

Prerequisite knowledge for Complete understanding and learning of Topic:

- The past decades, a number of parallel manipulators have been extensively studied.

Detailed content of the Lecture:

A 4-Degree of Freedom Manipulator in (3D) Three Dimensions

- The configuration of a manipulator in three dimensions.
- The manipulator has 4 degrees - of freedom: joint I (type T joint) allows rotation about the z axis;
- Joint 2 (type R) allows rotation about an axis that is perpendicular to the z axis;
- Joint 3 is a linear joint which is capable of sliding over a certain range;
- Joint 4 is a type R joint which allows rotation about an axis that is parallel to the joint 2 axis. Thus, we ha

of the joint positions relative to the world coordinate system. Using P_4 (x_4, y_4, z_4), which is the position of joint 4, as an example,

$$x_4 = x - \cos\theta(L_4 \cos\psi) \quad (4\text{-}12)$$

$$y_4 = y - \sin\theta(L_4 \cos\psi) \quad (4\text{-}13)$$

$$z_4 = z - L_4 \sin\psi \quad (4\text{-}14)$$

The values of L, ϕ, and θ can next be computed:

$$L = [x_4^2 + y_4^2 + (z_4 - L_1)^2]^{-1} \quad (4\text{-}15)$$

$$\sin\phi = \frac{z_4 - L_1}{L} \quad (4\text{-}16)$$

$$\cos\theta = \frac{y_4}{L} \quad (4\text{-}17)$$

Video Content / Details of website for further learning (if any):
https://www.google.com/search?q=Forward+Kinematics+and+Reverse+Kinematics+of+Manipulators+with+Fo

Important Books/Journals for further learning including the page nos.: (85 -108)
M.P.Groover, “Industrial Robotics – Technology, Programming and Applications”, McGraw-Hill, 2001, https://

Course Name with Code : Industrial Robotics / 16MEE14

Unit : IV Date of Lecture:

Topic of Lecture: Deviations and Problems

Introduction : (Maximum 5 sentences)

Mean

The **arithmetic mean** is a number often used to describe the "average" value of a data set. The arithmetic mean {number \,of \,values}number of values sum of the values

Median

The **median** is the "middle" value. To find the median, arrange the values in numerical order. If the number of v mean of the two middle values.

Range

The **range** is a number that describes the spread or dispersion of a data set. The range is the difference between t range = (greatest value) – (least value)

Prerequisite knowledge for Complete understanding and learning of Topic:

- Anything that varies from the accepted norm or standard is called a **deviation**

Detailed content of the Lecture:

Standard Deviation

The Standard Deviation is a measure of how spread out numbers are.

Its symbol is **σ** (the greek letter sigma)

The formula is easy: it is the **square root** of the **Variance.**

Variance

The Variance is defined as:

The average of the **squared** differe

To calculate the variance follow these steps:

- Work out the Mean (the simple average of the numbers)
- Then for each number: subtract the Mean and square the result (the squared difference).
- Then work out the average of those squared differences. (Why Square?)

Answer:

Mean = 600 + 470 + 170
= 19705
= 394

To calculate the Variance, take each difference, square it, and then average the result:

Variance

σ^2 = $206^2 + 76^2 + (-224)^2 +$

= 42436 + 5776 + 50176

= 108520**5**

= 21704

So the Variance is **21,704**

And the Standard Deviation is just the square root of Variance, so:

Standard Deviation

σ = $\sqrt{21704}$

= 147.32...

= **147** (to the near

Video Content / Details of website for further learning (if any):

https://www.google.com/search?q=Deviations+and+Problems&safe=strict&hl=en&source=lnms&tbm=vid&sa=

Important Books/Journals for further learning including the page nos.: 31

M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, https://j

Course Name with Code : Industrial Robotics / 16MEE14

Unit : IV Date of Lecture:

Topic of Lecture: Teach Pendant Programming

Introduction : (Maximum 5 sentences)

- A **teach pendant** is a device which can be used to control a robot remotely.
- Using a **teach pendant**, someone can work with a robot without being tethered to a fixed terminal. These
- Several features are included on a typical teach pendant.
- The device usually has an emergency stop button, so that operations can be immediately shut down if

Prerequisite knowledge for Complete understanding and learning of Topic:

- More modern teach pendants can also be wireless teach pendant programming is a method by which the c

Detailed content of the Lecture:

1.Data Entry Buttons

The data entry buttons are used to input data, normally in response to prompts that appear on the pendant disp The data entry buttons include YES/NO, DEL, the numeric buttons, the decimal point and the REC/DON press the REC/DONE button to signal that they have completed a task.

2. Emergency Stop Switch:

The emergency stop switch on the Teach Pendant immediately halts program execution and turns off arm po

3. User LED:

The pendant is in background mode when the user LED is in not lit and none of the predefined

functions are being used. The user LED is lit whenever an application program is making use of the Teach Pe

4. Mode Control Buttons:

The mode control buttons change the state being used to move the robot, switch control between the Teach Pe

5. Manual Control Buttons:

When the Teach Pendant is in manual mode, these buttons select which robot joint will move, or the coordina

6. Manual State LEDs:

The manual state LEDs indicates the type of manual motion that has been selected.

7. Speed Bars:

The speed bars are used totion. Pressing control the speed barthe rob near the outer ends will move the robot f

8. Slow Button:

The slow button selects between the two different speed ranges of the speed bars.

9. Predefined Function Buttons:

The predefined function buttons have specific, system- wide functions assigned to them, like display of coordinates, clear error, etc.

10.Programmable Function Buttons:

The programmable function buttons are used in custom application programs, and their functions will vary dep

11.Soft Buttons:

The soft buttons have different function or the selection made from the predefined function buttons.

Video Content / Details of website for further learning (if any):
https://www.google.com/search?q=teach+pendant+programming+in+wikipedia&safe=strict&hl=en&source=lnms&tbm=vid&

Important Books/Journals for further learning including the page nos.: 189
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, http://

Course Name with Code : Industrial Robotics / 16MEE14

Unit : IV Date of Lecture:

Topic of Lecture: Lead through programming, Robot programming Languages

Introduction : (Maximum 5 sentences)

- One method is called lead-through programming.
- This requires that the manipulator be driven through the various motions needed to perform a given task,
- C++ and Python, often used together as each one has pros and cons. C++ is used in control loops, image
- Python is used to handle high-level behaviors and to quickly develop tests or proof of concepts.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Robots process sensor data perform cognition and plan actions using computer programs that are execute

Detailed content of the Lecture:

LEAD THROUGH PROGRAMMINC METHODS

In lead through programming, the robot is moved through the desired path in order to record the path into the co

1. Powered leadthrough
2. Manual lead through

1. Powered lead through

- The powered lead through method makes use of a teach pendant to the various joint motors, and to powe
- Each point is recorded into memory for subsequence playback during the work cycle.
- The teach pendant is usually a small held control box with combinations of toggle switches, dials, and various robot programming methods, the powered lead through method is probably the most common to
- It is largely limited to poi point motions rather than continuous movement because of the difficulties us industrial robot applications consist of the manipulator. These include part transfer tasks, machine Loadi

2. Manual lead through

- The manual lead through method (also sometimes called the through" method) is more readily used for movements.
- Welding is another example in which continuous-path programming is required and this is sometimes accomplished with the manual leadthrough method.
- In the manual leadthrough method, the programmer physically grasps the robot arm (and end effectors) a
- If the robot is large and awkward to physically move, a special programming apparatus is often substitute

- This apparatus has basically the same geometry as the robot, but it is easier to manipulate during prog programming apparatus) which is depressed during those movements of the manipulator that will become
- This allows the programmer the ability to make extraneous moves of the arm without their being included
- The motion cycle is divided into hundreds or even thousands of individual closely spaced points along th
- The control systems for both leadthrough procedures operate in either of two modes: teach mode or run r the program.
- The two leadthrough methods are relatively simple procedures that have en developed and enhanced ov environments.
- The skill requirements of the programmers are relatively modest and these procedures can be readily app

ROBOT PROGRAMMING LANGUAGES

The textual robot languages possess a variety of structures and capabilities. These languages are still evolving what a future generation might be like.

First Generation Languages

- The "first generation" languages use a combination of command statements and teach pendant procedure
- They were developed largely to implement motion control with a textual programming language, and are
- Typical features include the ability to define manipulator motions (using the statements to define the seq interpolation, branching, and elementary sensor commands involving binary (on—off) signals.
- In other words, the first generation languages possess capabilities similar to the advanced teach pendant r
- Common limitations of first generation languages include inability specify complex arithmetic computati data, and a limit capacity to communicate with other computers. Also, these languages cam be readily ex

Second Generation Languages

- The second generations languages overcome many of the limitations of the generation languages an intelligent.
- This enables the robot to accomplish more complex tasks. These languages have been called "structur computer programming languages.
- Commercially available sec generation languages include AML, RAIL, MCL, and VAL II. Program in th

Video Content / Details of website for further learning (if any):

https://www.google.com/search?q=Robot+programming+Languages&source=lnms&tbm=vid&sa=X&ved=2ahU

Important Books/Journals for further learning including the page nos.: 189

M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001,https://www.researchgate.net/publication/222439039_ADA_A_language_for_robot_programming

Course Name with Code : Industrial Robotics / 16MEE14

Unit : IV Date of Lecture:

Topic of Lecture: VAL Programming

Introduction : (Maximum 5 sentences)

- The VAL robot language is permanently stored as a part of the VAL system.
- This includes the programming language used to direct the system for individual applications.
- The VAL language has an easy to understand syntax. It uses a clear, concise, and generally self-explanatory instruction set.
- All commands and communications with the robot consist of easy to understand word and number sequences. Control programs are written on the same computer that controls the robot.

Prerequisite knowledge for Complete understanding and learning of Topic:

- **VAL** is a computer based control system and **programming** language which has been designed specifically for use with industrial robots.

Detailed content of the Lecture:

Monitor

The VAL monitor is an administrative computer program that oversees operation of a system. It accepts user input and initiates the appropriate response; follows instructions from user-written programs to direct the robot; and performs the computations necessary to control the robot.

Editor

The VAL editor is an aid for entering information into a computer system, and modifying existing text. It is used to enter and modify robot control programs. It has a list of instructions telling a computer how to do something. VAL programs are written by system users to describe tasks the robot is to perform.

Location

Location is a position of an object in space, and the orientation of the object. Locations are used to define the positions and orientations the robot tool is to assume during program execution.

VAL Operating System

- The top level is called the VAL operating system, or monitor, because it administers operations of the system, including interaction with the user;
- The second level is used for diagnostic work on the controller hardware. The system monitor is

a computer program stored VAL programmable read-only memory (PROM) in the Computer/Controller.
Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=-GPvbIbgKNM
Important Books/Journals for further learning including the page nos.: 220 M.P.Groover, “Industrial Robotics – Technology, Programming and Applications”, McGraw-Hill, 2001, https://vibgyorpublishers.org/journals/International-Journal-of-Robotic-Engineering.php

MUTHAYAMMAL ENGINEERING COLLEGE

LECTURE HANDOUTS

L - 36

(An Autonomous Institution)

MECH

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)

IV / VII

Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

Course Name with Code : Industrial Robotics / 16MEE14

Unit : IV Date of Lecture:

Topic of Lecture: Motion Commands, Sensor Commands, End effecter commands, and Simple programs

Introduction : (Maximum 5 sentences)

- The robot's operating system updates the states of all the effectors (servos, motors, LEDs, etc.) They achi many times per second.
- To be smoothly turn a robot's head to the right, the head must accelerate, travel at constant velocity for a
- This is accomplished by making many small adjustments to the motor torques

Prerequisite knowledge for Complete understanding and learning of Topic:

- Robots it is possible to set up a co-ordinate system at any point within the working area.

Detailed content of the Lecture:

1.Motion command.

The basic architecture of a motion control system contains: A motion controller, which calculates and co motion planning) and, in closed loop systems.

2.Sensor command

A **sensor** is a device, module, machine, or subsystem whose purpose is to detect events or changes in its en processor.

3. End Effecter

In robotics, an end effecter is the device at the end of a robotic arm, designed to interact with the environmen In the strict definition, which originates from serial robotic manipulators, the end effector means the last link (or

4.Simple program

And	Break	Call
Common	Continue	Display
Do	Else	End
Float (or Decimal)	Float2 (or Decimal2)	Goto
If	Int (or Whole)	Int2 (or Whole2)
Loop	Or	Return
Set	Step	Task
Text	To	

Video Content / Details of website for further learning (if any):

https://www.google.com/search?q=motion+commands,+sensor+commands,+end+effector+commands,+and+sim OGq08ztAhU54zgGHVoxDSEQ_AUoAXoECBAQAw&biw=1024&bih=657
Important Books/Journals for further learning including the page nos.: 223 M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, http://w

Course Name with Code : Industrial Robotics / 16MEE14

Unit : V Date of Lecture:

Topic of Lecture: AGV

Introduction : (Maximum 5 sentences)
An automated guided vehicle or automatic guided vehicle (AGV) is a portable robot that follows along marked long lines or wires on the floor, or uses radio waves, vision cameras, magnets, or lasers for navigation. They are most often used in industrial applications to transport heavy materials around a large industrial building, such as a factory or warehouse. Application of the automatic guided vehicle broadened during the late 20th century.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Wired
- Guide tape
- Laser target navigation

Detailed content of the Lecture:
Automated guided vehicles (AGV) increase efficiency and reduce costs by helping to automate a manufacturing facility or warehouse. The first AGV was invented by Barrett Electronics in 1953. The AGV can tow objects behind them in trailers to which they can autonomously attach. The trailers can be used to move raw materials or finished product. The AGV can also store objects on a bed. The objects can be placed on a set of motorized rollers (conveyor) and then pushed off by reversing them. AGVs are employed in nearly every industry, including, pulp, paper, metals, newspaper, and general manufacturing. Transporting materials such as food, linen or medicine in hospitals is also done.

An AGV can also be called a laser guided vehicle (LGV). In Germany the technology is also called Fahrerlose Transportsysteme (FTS) and in Sweden förarlösa truckar. Lower cost versions of AGVs are often called Automated Guided Carts (AGCs) and are usually guided by magnetic tape. AGCs are available in a variety of models and can be used to move products on an assembly line, transport goods throughout a plant or warehouse, and deliver loads.

The first AGV was brought to market in the 1950s, by Barrett Electronics of Northbrook, Illinois, and at the time it was simply a tow truck that followed a wire in the floor instead of a rail. In 1976, Egemin Automation (Holland, MI) started working on the development of an automatic driverless control system for use in several industrial and commercial applications. Out of this technology came a new type of AGV, which follows invisible UV markers on the floor instead of being towed by a chain. The first such system was deployed at the Willis Tower (formerly Sears Tower) in Chicago, Illinois to deliver mail throughout its offices.

The term "automated guided vehicle" (AGV) is a general one that encompasses all transport systems capable of functioning without driver operation.

With inertial guidance, a computer control system directs and assigns tasks to the vehicles. Transponders are embedded in the floor of the work place. ... A gyroscope is able to detect the slightest change in the direction of the vehicle and corrects it in order to keep the AGV on its path.

AGVs are used in a variety of applications. They're often used for transporting raw materials such as metal, plastic, rubber or paper. For example, AGVs can transport raw materials from receiving to the warehouse or deliver materials directly to production lines.

Wired

A slot is cut in to the floor and a wire is placed approximately 1 inch below the surface. This slot is cut along the path the AGV is to follow. This wire is used to transmit a radio signal. A sensor is installed on the bottom of the AGV close to the ground. The sensor detects the relative position of the radio signal being transmitted from the wire. This information is used to regulate the steering circuit, making the AGV follow the wire.

Guide tape

AGVs (some known as automated guided carts or AGCs) use tape for the guide path. The tapes can be one of two styles: magnetic or colored. The AGV is fitted with the appropriate guide sensor to follow the path of the tape. One major advantage of tape over wired guidance is that it can be easily removed and relocated if the course needs to change. Colored tape is initially less expensive, but lacks the advantage of being embedded in high traffic areas where the tape may become damaged or dirty. A flexible magnetic bar can also be embedded in the floor like wire but works under the same provision as magnetic tape and so remains unpowered or passive. Another advantage of magnetic guide tape is the dual polarity. small pieces of magnetic tape may be placed to change states of the AGC based on polarity and sequence of the tags.

Video Content / Details of website for further learning (if any):

https://www.agv.com/de/en/agv/pista-gp-rr-full-face-helmet.html

Important Books/Journals for further learning including the page nos.:

M.P.Groover, “Industrial Robotics – Technology, Programming and Applications”, McGraw-Hill, 2001, Journal of Robotics and Automation Page No: T1(520-522)

Course Name with Code : Industrial Robotics / 16MEE14

Unit : V Date of Lecture:

Topic of Lecture: RGV

Introduction : (Maximum 5 sentences)

The Rail Guided Vehicle System is based on intelligent, high-speed and floored rail guided vehicles fitted for a wide range of load handling applications. This technology is an efficient, cost-effective and fast option for complex sorting applications or connecting very distant points. It is also an interesting alternative to long conveyor lines when the load handling units are not standardized

Prerequisite knowledge for Complete understanding and learning of Topic:

RGV, AGV and IGV are used to realize the automatic handling and reprinting of ... the external environment, the requirements for the operator are also relatively ...

Detailed content of the Lecture:

Our system is formed by the Rail Guided Vehicles (RGVs) and their floor-fixed track rail (including running rails, rail switching devices, lifts and maintenance areas, among others). In addition, we may provide specific elements (i.e. fences, access controls or light barriers) that are required to ensure a completely safe working environment for operators.

No matter how complex the transport route, thanks to our modular and flexible design, smooth and constant transportation is always guaranteed. Redundancy is also a key factor of this handling solution, as all RGVs within the system are interchangeable.

Main configurable characteristics:

RGV system performance;
Type of handled load units: pallets, containers, totes, cartons, frames…;
Number and type of load handling devices;
Load capacity: total weight;
Working conditions.

Rail Guided Vehicle (RGV) is a flexible transportation vehicle developed by SMC's own technology. It can link multiple destinations and be a good & economic alternative of conveyor by its characteristic that it can eliminate complex and fixed layout of conveyors, which enables simple and easily maintainable transportation system.

In a system multiple vehicles can be operated according to the transportation requirement. RGV system constitutes of transportation rail, vehicles and controller. RGV rail can be installed linear or circular.RGV is controlled by distribution control system and can be expanded easily as the system parameter changes. This characteristic cannot be obtained in normal conveyor system.

Features

- Independent operation of vehicle by individual controller on each vehicle
- Low noise & vibration
- Modular design of drive unit to enable less parts and easy maintenance
- Relatively accurate positioning by an encoder
- Distribution control system

Application

1. Super high speed-RGV application
2. Driving speed 265m/min, C/V loading speed 30m/min
3. Inactivity server motor & S-curve urgent acceleration/deceleration
4. Installation of absolute encoder in external timing belt

Video Content / Details of website for further learning (if any):
https://www.agv.com/de/en/agv/pista-gp-r-full-face-helmet.html

Important Books/Journals for further learning including the page nos.:

M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, Journal of Robotics and Automation Page No: T1(520-522)

MECH

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Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

IV / VII

Course Name with Code : Industrial Robotics / 16MEE14

Unit : V Date of Lecture:

Topic of Lecture: Implementation of Robots in Industries

Introduction : (Maximum 5 sentences)

Innovations in robotics, Robots in the future will be more autonomous, Get company-wide support
Get consensus on the definition of success

Prerequisite knowledge for Complete understanding and learning of Topic:

Robots are very complicated systems and working with them **requires knowledge** in a varied set of disciplines. We have to be good at mechanics, electronics, electrics, programming, sensing, and even psychology and cognition.

Detailed content of the Lecture:

Robotics are not just for the automotive industry anymore. With a wave of innovations in dexterity, vision, mobility, connectivity and safety, robots are finding a place in a wide range of industries that are becoming increasingly aware of their benefits.

Robots are becoming more and more mainstream, and a wide range of innovations are helping spur this along. "They will be smarter, more selective, more integrated, versatile, stronger, teachable, compact, affordable, more hygienic," Ritson described. "Programming is also getting easier. It might not be easier enough…but it's certainly getting easier."

Robots in the future will be more autonomous—more mobile and agile, with more dexterity. "There are even robots out there already that can get a signal from down the line and they understand that they have to change their end-of-arm tooling," Ritson said. "This is what's coming."
Color cameras and 3D vision are helping with product quality and consistency. And robots are even getting more perceptive along the way. "They see what they need to do, they fix what they need to do, they understand what they need to fix and then they fix it," Ritson said.

There's a world of innovation in the works. Ritson and her team spoke with innovation centers and universities developing new technologies to learn about the robotic capabilities on the horizon. In one example, developers taught a robot how to play Jenga—a very interactive game that requires a high level of dexterity. Rather than program it to do the required pushing and pulling, they equipped it with artificial intelligence to provide advanced learning in a shorter period of time. In other innovative examples, robots were equipped with sensors so sensitive to the touch, they can pick up raspberries without crushing them. "Think about how you could apply that in manufacturing," Ritson urged.

Though fulfilling labor needs is a significant driver behind the growth of robotics in manufacturing, it does not mean that manufacturing jobs are going away. What industry will need going forward are problem solvers, intuitive thinkers and trained specialists, Ritson said. “We will have to retrain workers and redeploy them where they can be of greater use,” she said. Future skills will be needed to maintain, operate, deploy and engineer robotics. “We’re in the midst of that change right now, and new jobs are going to be created.”

We’ve been conditioned for robots for 50 years, Ritson insisted, pointing to the Jetsons cartoons that many of us grew up with, along with a range of other futuristic ideas that are now a reality. “The future will be humans working with robots,” she said. “We see it happening all the time.”
What Ritson provided at the conference was a whirlwind tour of the highlights happening in robotics today and coming down the pike. The full report, she said, goes into much greater detail, with examples of implementation, where they see the market growing, and more.

Step 1: Get company-wide support
There are many individuals and departments that would be impacted by a robotic solution. Before doing anything, there needs to be education and discussion among several parties, including senior management, plant managers, senior engineering, manufacturing engineering, maintenance, IT, safety managers, shop floor staff, and HR. Anyone impacted by the purchase, installation, operation, and maintenance of the robotic system needs to be a part of the discussion from the very beginning.
It’s absolutely critical that everyone understand the basic facts about robotic automation—that it has a short return on investment (ROI), can open opportunities for the company, and does not replace shop workers. There always will be jobs that robots can’t do, but robots can take over the monotonous and dangerous activities, enabling staff to have more fulfilling roles that involve quality control and operating the robot.

Step 2: Get consensus on the definition of success
To get agreement from multiple parties and manage expectations, it’s important to have agreement on what criteria make the project successful. The most important measurement is often the ROI, and on average, companies consider two years to be an appropriate payback period. When calculating ROI, there are many factors beyond comparing the hourly labor costs of a human operator versus the capital cost of a robot

Video Content / Details of website for further learning (if any):
https://www.uipath.com/rpa/intelligent-process-automation

Important Books/Journals for further learning including the page nos.:
M.P.Groover, “Industrial Robotics – Technology, Programming and Applications”, McGraw-Hill, 2001, Journal of Robotics and Automation Page nos: T1(453-467)

Course Name with Code : Industrial Robotics / 16MEE14

Unit : V Date of Lecture:

Topic of Lecture: Implementation of Robots in Industries

Introduction : (Maximum 5 sentences)
Innovations in robotics, Robots in the future will be more autonomous, Get company-wide support
Get consensus on the definition of success

Prerequisite knowledge for Complete understanding and learning of Topic:
Robots are very complicated systems and working with them **requires knowledge** in a varied set of disciplines. We have to be good at mechanics, electronics, electrics, programming, sensing, and even psychology and cognition.

Detailed content of the Lecture:
7 Steps to Implement a Robotic Automation Program

1. Identify opportunities to automate. It is essential to determine process adaptability to automation. Each unique process is more open/ viable to automation or not based on various factors such as process size, industry, current process, and SLAs.

2. Validate the opportunity. Check how adaptable the process is to being automated. If we look at most processes, we notice that they typically comprise both transaction and decisioning parts. Automation can be designed to achieve some quick wins on the transactional part which is the more time-consuming repetitive task.

3. Select a design model. Select the best model for your requirement. You may need to redesign the process to maximize the scope for automation. In some cases, this yields additional benefits. Design the automation plan that suits the business structure. Customize the automation model to suit the process needs. As one example of customizing a model, in one of the processes HGS recently automated for product build, we split the process into three distinct subprocesses: capturing the input, building the right codes, and then updating the systems. While building the right codes is where we need the product build experts, a lot of time was also spent on capturing the input and on updating the systems. In this case, we redesigned the process using automation to capture the inputs. Then our experts built codes, and automation was used to update the systems. This result was a 75 percent increase in efficiency for this particular process.

4. Develop the automation plan. Conduct a thorough study of the process and understand all the

“exception” scenarios. Automate time-consuming repetitive tasks in processes that include these. Develop the automation implementation plan in phases, considering all of the level 3 scenarios. Instead of automating all scenarios, automate about 75% and have experts handling the rest of the scenarios. Evaluate plan performance at every phase and move to the next phase.

5. Deploy the pilot phase. When you develop an automation plan and are ready to implement it, run a pilot project first. This allows you to observe the effectiveness and overall performance of your automation plan with an actual process in realtime. Take the results of the pilot project and make improvements accordingly. Look at the results of the pilot and then include those scenarios that need to be automated and those that can remain an exception. It is good to involve the right stakeholders to understand the long-term plan and then plan the next steps. That has been a key takeaway: collaboration and involvement of client and relevant stakeholders. Sometimes there is a difference in testing and live environment, and there could be training for roll out.

6. Roll out the plan. Besides development of automation, build a plan needs for training and handling contingency depending on the criticality of the process. It is good to ensure that while people are trained on the revised process there is also documentation on the process before automation to handle any contingency due to a change in applications or systems.

7. Maintain your automation activity. Automation isn’t always a one-time activity, and it isn’t something you execute and then forget about. There will be changes in the process and systems, and there should be a good change management process to handle any changes. Estimate the impact of change in systems or process and have a plan ready for this. At this last phase, prepare a change management plan. It is critical to get all stakeholders to buy in. In some systems, even a field included in a drop-down menu may have an impact on the output, so there should be a plan to manage these.

Video Content / Details of website for further learning (if any):
https://www.uipath.com/rpa/intelligent-process-automation

Important Books/Journals for further learning including the page nos.:
M.P.Groover, “Industrial Robotics – Technology, Programming and Applications”, McGraw-Hill, 2001, Journal of Robotics and Automation Page nos: T1(453-467)

Course Name with Code : Industrial Robotics / 16MEE14

Unit : V Date of Lecture:

Topic of Lecture: Implementation of Robots in Industries

Introduction : (Maximum 5 sentences)
Innovations in robotics, Robots in the future will be more autonomous, Get company-wide support Get consensus on the definition of success

Prerequisite knowledge for Complete understanding and learning of Topic:
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2. Validate the opportunity. Check how adaptable the process is to being automated. If we look at most processes, we notice that they typically comprise both transaction and decisioning parts. Automation can be designed to achieve some quick wins on the transactional part which is the more time-consuming repetitive task.

3. Select a design model. Select the best model for your requirement. You may need to redesign the process to maximize the scope for automation. In some cases, this yields additional benefits. Design the automation plan that suits the business structure. Customize the automation model to suit the process needs. As one example of customizing a model, in one of the processes HGS recently automated for product build, we split the process into three distinct subprocesses: capturing the input, building the right codes, and then updating the systems. While building the right codes is where we need the product build experts, a lot of time was also spent on capturing the input and on updating the systems. In this case, we redesigned the process using automation to capture the inputs. Then our experts built codes, and automation was used to update the systems. This result was a 75 percent increase in efficiency for this particular process.

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Video Content / Details of website for further learning (if any):
https://www.uipath.com/rpa/intelligent-process-automation

Important Books/Journals for further learning including the page nos.:
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, Journal of Robotics and Automation Page nos: T1(453-467)

Course Name with Code : Industrial Robotics / 16MEE14

Unit : V Date of Lecture:

Topic of Lecture: Various Steps; Safety Considerations for Robot Operations

Introduction : (Maximum 5 sentences)
7 Industrial Robotics Hazards, Safety Options for Robotic Systems, Robot Safeguarding, Control and Safeguarding Personnel

Prerequisite knowledge for Complete understanding and learning of Topic:
Human Errors. Human error occurs in day-to-day activity and this is no different with regard to a **robotic** work cell.

Detailed content of the Lecture:

- Human Errors. Human error occurs in day-to-day activity and this is no different with regard to a **robotic** work cell. ...
- Control Errors. ...
- Unauthorized Access. ...
- Mechanical Failures. ...
- Environmental Sources. ...
- Power Systems. ...
- Improper Installation.
- A **robot safety** standard is a collection of guidelines for **robot** specifications and **safe** operations in which all involved in the manufacture, sales and use of **robots** must follow. Often, standards are created by a diverse group of industry interests to ensure the standards benefit everyone.

Safety Options for Robotic Systems

- Fencing, Arc Glare Shields and Dividers. These are the most common **safety** option. ...
- Light Curtains and **Area** Scanners. Fencing tends to have three sides, with one **area** open for loading parts. ...
- Emergency Stop (E-Stop) Emergency stop, or e-stop, is a function that is used in case of emergency.

Robot Safeguarding

1. The proper selection of an effective robotic safeguarding system should be based upon a hazard analysis of the robot system's use, programming, and maintenance operations. Among the factors to be considered are the tasks a robot will be programmed to perform, start-up and command or programming procedures, environmental conditions, location and installation requirements, possible human errors, scheduled and unscheduled maintenance, possible robot and system malfunctions, normal mode of operation, and all personnel functions and duties.

2. An effective safeguarding system protects not only operators but also engineers, programmers, maintenance personnel, and any others who work on or with robot systems and could be exposed to hazards associated with a robot's operation. A combination of safeguarding methods may be used. Redundancy and backup systems are especially recommended, particularly if a robot or robot system is operating in hazardous conditions or handling hazardous materials. The safeguarding devices employed should not themselves constitute or act as a hazard or curtail necessary vision or viewing by attending human operators.

Risk Assessment. At each stage of development of the robot and robot system a risk assessment should be performed. There are different system and personnel safeguarding requirements at each stage. The appropriate level of safeguarding determined by the risk assessment should be applied. In addition, the risk assessments for each stage of development should be documented for future reference.

Safeguarding Devices. Personnel should be safeguarded from hazards associated with the restricted envelope (space) through the use of one or more safeguarding devices:

- Mechanical limiting devices;
- Nonmechanical limiting devices;
- Presence-sensing safeguarding devices;
- Fixed barriers (which prevent contact with moving parts); and
- Interlocked barrier guards.
-

Awareness Devices. Typical awareness devices include chain or rope barriers with supporting stanchions or flashing lights, signs, whistles, and horns. They are usually used in conjunction with other safeguarding devices.

Safeguarding the Teacher. Special consideration must be given to the teacher or person who is programming the robot. During the teach mode of operation, the person performing the teaching has control of the robot and associated equipment and should be familiar with the operations to be programmed, system interfacing, and control functions of the robot and other equipment. When systems are large and complex, it can be easy to activate improper functions or sequence functions improperly. Since the person doing the training can be within the robot's restricted envelope, such mistakes can result in accidents. Mistakes in programming can result in unintended movement or actions with similar results. For this reason, a restricted speed of 250 mm/§ or 10 in/§ should be placed on any part of the robot during training to minimize potential injuries to teaching personnel.
Several other safeguards are suggested in the ANSI/RIA R15.06-1992 standard to reduce the hazards associated with teaching a robotic system.

Video Content / Details of website for further learning (if any):
https://www.moldmakingtechnology.com/articles/considerations-for-assessing-robotics-requirements

Important Books/Journals for further learning including the page nos.:
M.P.Groover, “Industrial Robotics – Technology, Programming and Applications”, McGraw-Hill, 2001, Journal of Robotics and Automation Page nos: T1(469-474)

Course Name with Code : Industrial Robotics / 16MEE14

Unit : V Date of Lecture:

Topic of Lecture: Economic Analysis of Robots

Introduction : (Maximum 5 sentences)
Economic analysis, Types of economic tools, Major Divisions of Economics, Economic Factors

Prerequisite knowledge for Complete understanding and learning of Topic:
Economic analysis is the study of economic systems. Robot economics is the study of the market for robots.

Detailed content of the Lecture:
Robot economics is the study of the market for robots. ... As (in part) a factor of production, robots are complements and/or substitutes for other factors, such as labor and (non-robot) capital goods.
Economic analysis is the study of economic systems. It may also be a study of a production process or an industry. The analysis aims to determine how effectively the economy or something within it is operating. For example, an economic analysis of a company focuses mainly on how much profit it is making.
In brief, get acquainted with the terms such as Variables, Ceteris Paribus, Functions, Equations, Identities, Graphs and Diagrams, Lines and Curves, Slopes, Limits and Derivatives, Time Series and so on. These are the basic tools of economic analysis.

Types of economic tools
- Social cost-benefit analysis.
- Input-output analysis.
- Economic impact study.
- Business case.
- Other economic tools.

Major Divisions of Economics
- Consumption.
- Production.
- Exchange.
- Distribution.
- Public Finance.

Robotic labor machines can produce vastly higher quantities than humans, creating higher supplies of finished goods. The robots present manufacturers with a savings in costs as well, paying much fewer wages to humans and paying slightly higher overhead costs for electricity and machine upkeep.
Economic Factors

- Tax Rate.
- Exchange Rate.
- Inflation.
- Labor.
- Demand/ Supply.
- Wages.
- Law and policies.
- Governmental Activity

Called the father of modern economics, Samuelson became the first American to win the Nobel Prize in Economics (1970) for his work to transform the fundamental nature of the discipline.

Video Content / Details of website for further learning (if any):
https://www.cfr.org/event/robots-and-future-jobs-economic-impact-artificial-intelligence

Important Books/Journals for further learning including the page nos.:
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, Journal of Robotics and Automation Page nos: T1(348-351)

Course Name with Code : Industrial Robotics / 16MEE14

Unit : V

Date of Lecture:

Topic of Lecture: Pay back Method

Introduction : (Maximum 5 sentences)
payback method, calculate the payback period,Advantages of the payback period, Payback period

Prerequisite knowledge for Complete understanding and learning of Topic:
Payback period is the length of time required for an investment to recover ... *process prior* to investment decisions for large industrial projects.

Detailed content of the Lecture:
The **payback method** simply projects incoming cash flows from a given project and identifies the break even point between profit and paying back invested money for a given process. However, the **payback method** does not take into account the time value of money.

How to calculate the payback period

1. Averaging method. Divide the annualized expected cash inflows into the expected initial expenditure for the asset. ...
2. Subtraction method. Subtract each individual annual cash inflow from the initial cash outflow, until the payback period has been achieved.

The shortest payback period is generally considered to be the most acceptable. This is a particularly good rule to follow when a company is deciding between one or more projects or investments. The reason being, the longer the money is tied up, the less opportunity there is to invest it elsewhere.
The advantages of the payback period are that it is especially useful for a business that tends to make relatively small investments, and so does not need to engage in more complex calculations that take other factors into account, such as discount rates and the impact on throughput.
The payback period disregards the time value of money. It is determined by counting the number of years it takes to recover the funds invested. For example, if it takes five years to recover the cost of an investment, the payback period is five years. Some analysts favor the payback method for its simplicity

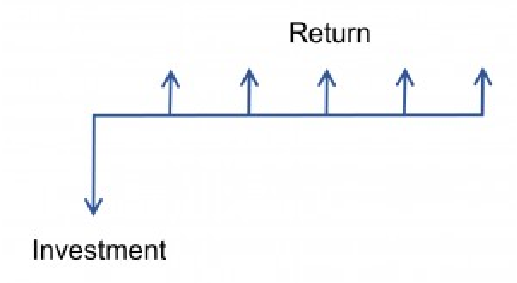
$$\text{Payback period} = \frac{\text{Investment required}}{\text{Net annual cash inflow}^{*}}$$

Usage

The payback period is used to make investment decisions.

Organizations usually have a choice between many projects to undertake, each with their own advantages and disadvantages. When all other factors are similar, the payback period can be used as a decision making tool, since a fast payback period will rapidly flow into the business' cash flow and balance sheet (financial health).

The payback period is an ideal metric for the relatively common scenario where a large upfront investment generates a steady return over time. Usually this return is accompanied by a considerable amount of project risk (if you build it, they will come….. or will they?) hence a quick payback period will mitigate the market risk of making the investment.



Video Content / Details of website for further learning (if any):
https://study.com/academy/lesson/payback-analysis-formula

Important Books/Journals for further learning including the page nos.:
M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, Journal of Robotics and Automation Page nos: T1(351-353)

Course Name with Code : Industrial Robotics / 16MEE14

Unit : V **Date of Lecture:**

Topic of Lecture: EUAC Method

Introduction : (Maximum 5 sentences)
EUAC Types, Annual Cash Flow Four Essential Points, Calculate the EUAC, Calculate Annualized Salvage Value, Calculate Updated EUAC.

Prerequisite knowledge for Complete understanding and learning of Topic:
Euac method Although science sometimes involves learning Scientific Method Steps ... The registration process is the prerequisite to attend the conference of the ... To gain knowledge of its application contexts.

Detailed content of the Lecture:
Unlike standard life cycle cost analysis, the Estimated Uniform Annual Cost (**EUAC**) **method** expresses life cycle costs as an annualized estimate of cash flow instead of a lumpsum estimate of present value.

1. Raise 1 + Interest Rate to the Power of n. ...
2. Subtract 1 from the Result. ...
3. Divide the Result. ...
4. Multiply the Result by the Interest Rate. ...
5. Calculate the EUAC. ...
6. Calculate Annualized Salvage Value. ...
7. Calculate Updated EUAC.

The **annual worth** is the net of all the benefits and costs incurred over a one-year period. ... This virtual number is called the **equivalent uniform annual worth** (EUAW) and is equal to the total **benefit** and cost of the system as if it was spread evenly throughout the years of its life.

Annual Cash Flow Four Essential Points

1. **EUAW** = PW(A/P,i,n)
2. **EUAW** is.
3. In Excel® use "-PMT" to **calculate EUAW**.
4. For an irregular cash flow over the analysis period, first **determine** the PW then convert to **EUAW**.

Introduction of this study, initial costs were developed using at wopronged approach of 1) establishing initial costs using commonly available industry construction estimating data, and 2).modifying these initial costs using rank order data derived from a survey of roofing contractors. Initial costs were established using Means Building Construction Cost Data 2005. This initial cost data was the adjusted in accordance with average rankings as identified in a survey of 50 commercial roofing contractors located throughout the United States, who were asked to list the rank order of each system in terms of installed cost. The adjusted costs for each system as determined by this method are summarized in Table 2. Replacement Cost In order to develop an effective life cycle cost comparison, the cost for the eventual replacement of the roofing system must be determined. Unlike the initial roof installation, replacement cost will include both the equivalent cost of the initial installation as well as the tear off and disposal costs of the original roof. Although costs for replacement after tear off and disposal can be calculated using the original installation cost values, tear off and disposal costs must be determined independently.
Video Content / Details of website for further learning (if any): https://www.reusecompany.com/ears-easy-approach-to-requirements-syntax-a-practical-approach
Important Books/Journals for further learning including the page nos.: M.P.Groover, “Industrial Robotics – Technology, Programming and Applications”, McGraw-Hill, 2001, Journal of Robotics and Automation Page nos:T1(353-354)

Course Name with Code : Industrial Robotics / 16MEE14

Unit : V Date of Lecture:

Topic of Lecture: Pay back Method Tutorials

Introduction : (Maximum 5 sentences)

1.Introduction payback method
2.How to calculate the payback period
3.Advantages of the payback period

Prerequisite knowledge for Complete understanding and learning of Topic:

Payback period is the length of time required for an investment to recover ... process prior to investment decisions for large industrial projects.

Detailed content of the Lecture:

The **payback method** simply projects incoming cash flows from a given project and identifies the break even point between profit and paying back invested money for a given process. However, the **payback method** does not take into account the time value of money.

How to calculate the payback period

1. Averaging method. Divide the annualized expected cash inflows into the expected initial expenditure for the asset. ...
2. Subtraction method. Subtract each individual annual cash inflow from the initial cash outflow, until the **payback period** has been achieved.

The shortest **payback period** is generally considered to be the most acceptable. This is a particularly **good** rule to follow when a company is deciding between one or more projects or investments. The reason being, the longer the money is tied up, the less opportunity there is to invest it elsewhere.

The **advantages** of the **payback period** are that it is especially useful for a business that tends to make relatively small investments, and so does not need to engage in more complex calculations that take other factors into account, such as discount rates and the impact on throughput.

The **payback period** disregards the time value of money. It is determined by counting the number of years it takes to recover the funds invested. For example, if it takes five years to recover the cost of an investment, the **payback period** is five years. Some analysts favor the **payback method** for its simplicity

Video Content / Details of website for further learning (if any): https://corporatefinanceinstitute.com/resources/knowledge/modeling/payback-period/
Important Books/Journals for further learning including the page nos.: M.P.Groover, "Industrial Robotics – Technology, Programming and Applications", McGraw-Hill, 2001, Journal of Robotics and Automation Page nos:T1(353-354)