Course Material

Name of the Course : **ROBOTICS AND AUTOMATION**

Name of the Unit : **INTRODUCTION TO ROBOTICS**

Name of the Topic : Need for Robots, Asimov's laws of robotics, Basic components-Classification, Characteristics-Work volume, spatial resolution and repeatability, Precision and accuracy. Coordinate system- Drives & Control systems, Actuators, Applications of Robots.

1. **AIM AND OBJECTIVES**: To develop ideas on Robotics working process and coordinate system.

2. **PRETEST- MCQ**

1. Robot is derived from Czech word
   (A) Rabota
   (B) Robota
   (C) Rebota
   (D) Ribota
   Ans:B
2. A Robot is a
   (A) Programmable
   (B) Multi-functional manipulator
   (C) Both (A) and (B)
   (D) None of the above
   Ans:C

3. 3-The main objective(s) of Industrial robot is to
   (A) To minimise the labour requirement
   (B) To increase productivity
   (C) To enhance the life of production machines
   (D) All of the above
   Ans:D
4. 4-The following is true for a Robot and NC Machine
   (A) Similar power drive technology is used in both
   (B) Different feedback systems are used in both
   (C) Programming is same for both
   (D) All of the above
   Ans:A

5. 14-The following drive is used for lighter class of Robot.
   (A) Pneumatic drive
   (B) Hydraulic drive
   (C) Electric drive
   (D) All of the above
   Ans:A

3. PRE-REQUISITES:

To have a basic knowledge of sensors, actuatorsand its workingprocess.

4. THEORY:

What Is a Robot?

Robots today are being utilized in a wide variety of industrial application. The most majority of industrial robots are mechanical arms attached to a fixed base, with some form of programmable control for automatic execution of motion. There are a variety of definitions of an industrial robot, two of which are as follows

A robot is a re programmable multi-function manipulator designed to move material parts, tools or specialised devices, through variable programmed motions for the performance of a variety of tasks.

An industrial robot is a re-programmable device designed to both manipulate and transport parts, tools or specialised manufacturing implements through variable programmed motions for the performance of specific manufacturing tasks

Robotics is the engineering science and technology of robots, and their design, manufacture, application, and structural disposition. It requires a working knowledge of electronics, mechanics, and software.

The word 'robot' first appeared in 1921 but was not a technical term. It was used by a Czech playwright called Karel Capek in a satirical play called 'Rossums Universal Robots' to describe slave labourers who had their souls removed to make them work harder. In, 1942 Isaac Asimov wrote a short science fiction story in which the word 'robotics' was first used and presented 3 laws of robotics.

1.Robots must not injure humans
2. Robots must obey orders
3. Robots must protect their own existence

Issues of industrial robot usage! How to tackle the issues of industrial relation?!!! RIA (Robotics Industries Association) has put up the following promise for the Opponents of robot usage in the industry:

Not to replace workers, only replace equipment.

Use only for (hazardous, boring, demoralizing, and repetitive tasks).

Only if it can result in shorter work week, higher pay, and better working conditions for human.

Classes of Robot Most of physical robots fall into one of the three categories:
• Manipulators/robotic arms which are anchored to their workplace and built usually from sets of rigid links connected by joints.
• Mobile robots which can move in their environment using wheels, legs, etc.
• Hybrid robots which include humanoid robots are mobile robots equipped with manipulators.
To qualify as a robot, a machine must be able to:
1) Sensing and perception: get information from its surroundings.
2) Carry out different tasks: Locomotion or manipulation, do something Physical–such as move or manipulate objects
3) Re-programmable: can do different things
4) Function autonomously and/or interact with human beings
Why Use Robots?!!!
There are many different reasons for using a robot but the central reasons are:

Application 4D environments	4A tasks
Dangerous (exploring inside a volcano) Dirty Dull (such as domestic cleaning) Difficult (cleaning the inside of a long pipe and space missions)	Automation Augmentation Assistance Autonomous

Most robots today are used to do repetitive (boring and dull) actions or jobs considered too dangerous and difficult for humans. They are also used in factories to build things like cars and electronics. Some robots are even designed to explore underwater and on other planets! Another reason we use robot is because it is cheaper, easier and sometimes the only way we can get things done! Robots can explore inside gas tanks, volcanoes, Mars and other places too dangerous for humans to go! Robots also can do one thing over and over again without getting bored – is that something you could do? Think about it – standing in one place doing the same thing all day and night would get pretty boring! Another reason to use robots is because they never get sick; don't need to take a day off, and best of all they don't ever complain!

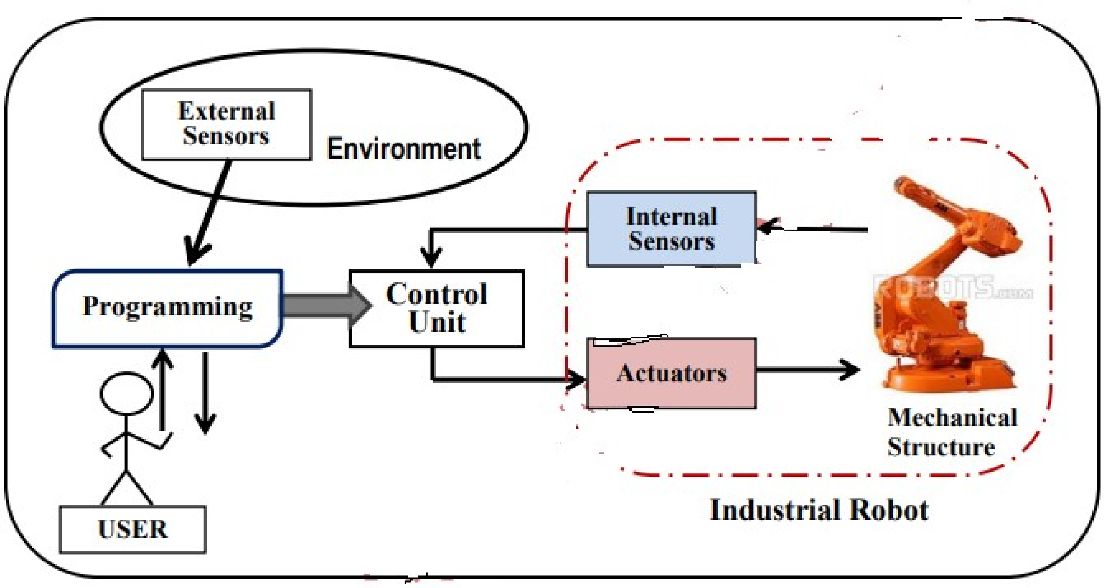
There are four major reasons why Nissan Corporation uses automation and in particular industrial robots.

- Quality improvement.
- Better cost effectiveness.
- Improvement of working environment
- Flexibility to change

Limitations of Robotics

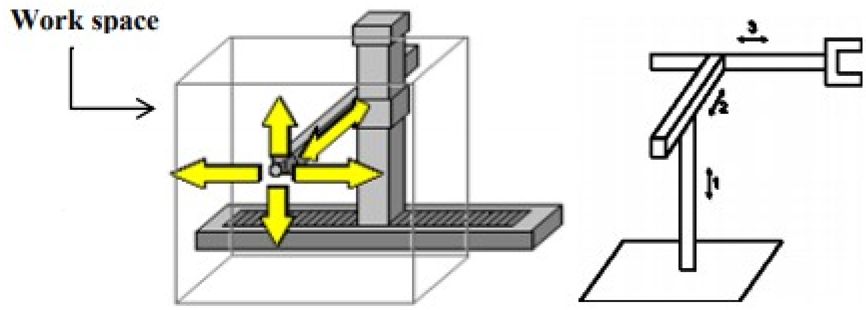
- ♣ Are not creative or innovative
- ♣ Can not think independently
- ♣ Can not make complicated decisions
- ♣ Can not learn from mistakes
- ♣ Can not adapt quickly to changes in their surroundings

Architecture of Robotic Systems An industrial robot contains several electrical and mechanical components acting together as a system. The controller contains an operating system and software that dictates how the system operates and communicates. Sensors work together for gathering information (Localization and positioning).



Configuration of Industrial Robot Over the years robot manufacturers have developed many types of robots of differing configurations and mechanical design, to give a variety of spatial arrangements and working volumes. The majority of these manipulators fall into one of these six configurations: Cartesian (PPP), Cylindrical (RPP), Spherical (RRP), SCARA (RRP), Articulate/Revolute (RRR) and robot. The work envelope or work volume is defined as the space within which the robot cans manipulator the end of its wrist. The shape of work volume is determined by the type of robot configuration.

1- Cartesian Type Configuration (PPP), (X Y Z)



It is form by 3 prismatic joints, whose axes are coincident with the X, Y and Z planes. These robots move in three directions, in translation, at right angles to each other. Cartesian manipulator is useful for table-top assembly applications and, as gantry robots for transfer of material and cargo.

Advantages:

3 linear axes

Easy to visualize Rigid structure

Easy to program off-line

Disadvantage:

Can only reach in front of itself

Requires large floor space for size of work envelop

Axes hard to seal

2- Cylindrical Type Configuration (RPP), (θ, r, z)

For cylindrical type manipulator, its first joint is revolute which produces a rotation about the based, while its second and third joints are prismatic. The robot arm is attached to the slide so that it can be moved radially with respect to the column.

Advantages:

2 linear axes, 1 rotating axis

Can reach all around itself

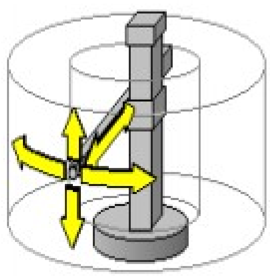
Reach and height axes rigid

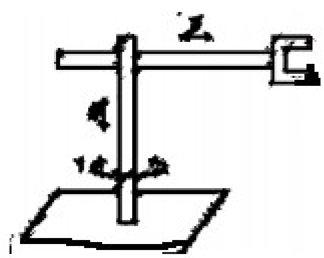
Disadvantage:

Cannot reach above itself

Base rotation axis is less rigid than a linear axis

Will not reach around obstacles





3- Spherical Type Configuration (RRP), (θ, β, z)

The first two joints of this type of manipulators are revolute, while its third Joint is prismatic. It used for a small number of vertical actions and is adequate for loading and unloading of a punch. Advantages:

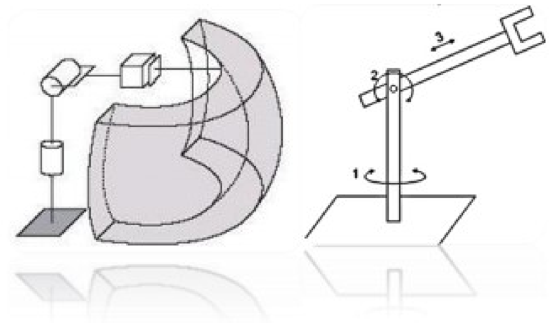
1 linear axis, 2 rotating axes

Long horizontal reach

Disadvantage:

Cannot reach around obstacles

Generally has short vertical reach



4- Scara Type Configuration (RRP or PRR), (θ, φ, z)

The word SCARA stands for Selective Compliant Articulated Robot for Assembly. There are two type of SCARA robot configuration: either the first two joints are revolute with the third joint as prismatic, or the first joint is revolute with the second and third Joints as prismatic. Although some of the SCARA robots have the RRP structure.

Advantages:

1 linear axis, 2 rotating axes

Height axis is rigid

Large work area floor space

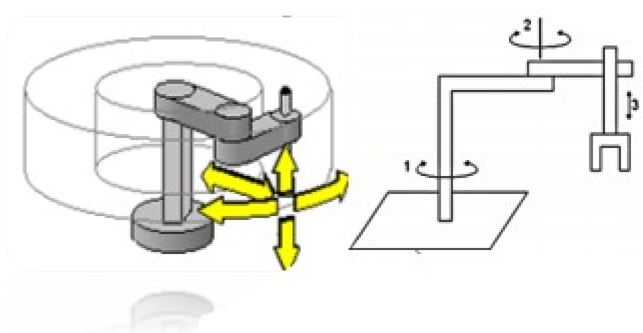
Can reach around obstacles

Two ways to reach a point

Disadvantage:

Difficult to program off-line

Highly complex arm



5- Revolute Type Configuration (RRR), (θ, β, α)

Also called articulated manipulator that looks like an arm with at least three rotary joints. They are used in welding and painting; gantry and conveyor systems move parts in factories. Advantages:

3 rotating, axes

Can reach above or below obstacles

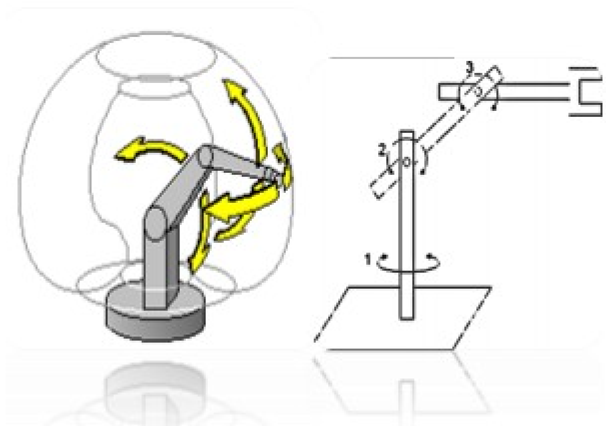
Largest work area for least work space

Two or four ways to reach a point

Disadvantage:

Difficult to program off-line

The most complex manipulator



6- Parallel Type Configuration (RRR), (θ, β, α)

It is a complex mechanism which is constituted by two or more kinematics chains between, the base and the platform where the end-effectors are located.

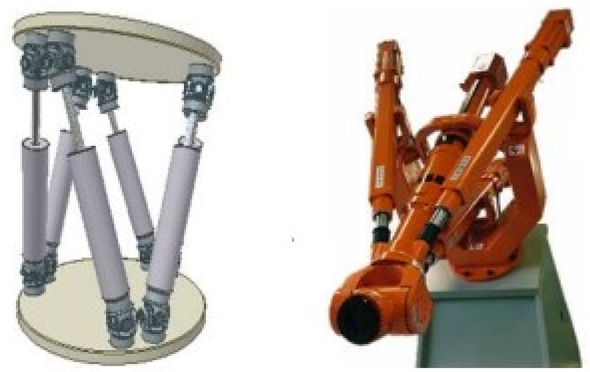
Advantages:

Motors can be proximal:

higher bandwidth, easier to control

Disadvantage: Generally less motion

kinematics can be challenging

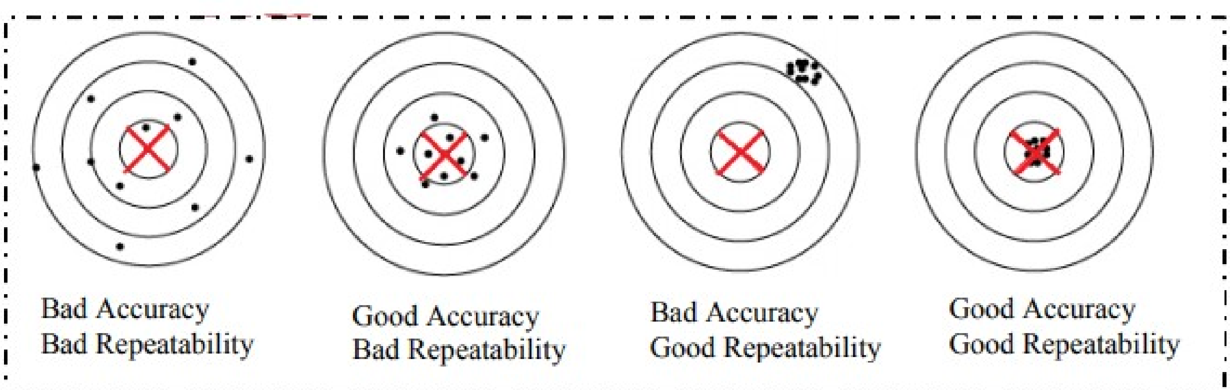


Workspace : is the volume of space reachable by the end-effector, Everywhere a robot reaches must be within this space.Tool orientation and size also important.

Repeatability and Accuracy of an Industrial

Robot Accuracy: Accuracy refers to a robot's ability to position its wrist end at a desired target point within the work volume.

Repeatability: Repeatability describes how a points are repeated at the same place or target.



Robot Classification

- **Arm Configuration:**
  - Cartesian Coordinate.
  - Cylindrical Coordinate.
  - Spherical Coordinate.
  - Scara Coordinate.
  - Revolute Coordinate.

- **Drive System:**
  - Electrical.
  - Hydraulic.
  - Pneumatic.

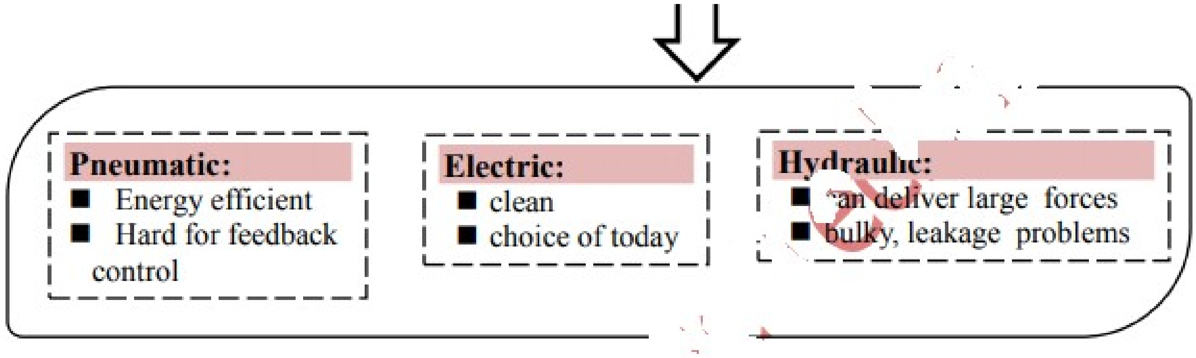
- **Drive Gear System:**
  - Direct Drive Robots.
  - Geared Robots.

- **Level of Technology:**
  - Low Technology: (material handling, using simple assemble 2-4 axes of movement, stop at extremes).
  - Medium Technology: (pick & place, material handling, 4-6 axes).
  - High Technology: (material handling, pick and place, loading, painting and welding, 6-9 axes).

- **Field of Applications:**
  - Industrial Robot.
  - Medical Robot.
  - Space Robot.
  - Military Robot.
  - Aerial Robot.
  - Etcetra ………..

- **Tooling Applications:**
  - Painting robot.
  - Welding robot.
  - Gluing robot.
  - Deburring robot.
  - Etcetra ………..

Motors and Actuators Technologies Actuators and Motors are devices that make robot move “robot muscle “. For most industrial robots, the actuators are coupled to the respective robot link through a, gear train. The effect of the gear reduction is largely to decoupled the system by reducing the coupling among the joints. However, the present of gears introduces friction, backlash and drive train compliance. The commonly used actuators are:



Electrical Drive Small and medium size robots are usually powered by electric drives via gear trains using servomotors and stepper motors. Most commonly used are dc motors, although for larger robots, ac motors may be utilised. A new design based on direct drives (without gear trains) is being developed.

Advantages: Better accuracy &repeatability,Require less floor space ,More towards precise work such as assembly applications

Disadvantage: Generally not as speedy and powerful as hydraulic robots, Expensive for large and powerful robots, can become fire hazard

Hydraulic Drive Larger robots are usually powered by hydraulic drives . Hydraulic drive system can provide rotational motion (rotary vane actuators) and linear motion (hydraulic pistons). Advantages: More strength-to-weight ratio ,Can also actuate at a higher speed Disadvantage: Require large floor space,Tendency to oil leakage.

Pneumatic Drive Generally used For smaller robots that possess fewer degrees of freedom (2- 4 joint motions). They are limited to pick-and-place tasks with fast cycles. Pneumatic drive system can be applied to the actuation of piston devices to provide linear motions. Rotational motions can be achieved by rotary actuators

Advantages: Cheaper & lower technology options for control of speed, Safe to use and Light in weight

Disadvantage: Require large floor space ,Tendency to oil leakage

Actuators: Electrical, Hydraulic, Pneumatic, Artificial Muscle

Sensors: Camera, Encoder, Photo Electronic, GPS, Compass, Gyroscope, Inertial navigation, Laser Range Scanners, Pressure.

5. POST MCQ TEST:

1. _____ is a general purpose, programmable machine possessing certain human like characteristics.

   (A) Robot

   (B) Manipulator

   (C) Gripper

   (D) None of the above

   Ans:A

2. _____ is area of engineering and science which understand the different principles, structure and programming of robot.

   (A) Mechatronics

   (B) Robotics

   (C) Aeronautics

   (D) None of the above

   Ans:B

3. From Which of the following is application of robot.

   (A) Welding

   (B) Machine loading & unloading

   (C) Both (A) & (B)

   (D) None of the above

   Ans:C

4. ___ is also known as work volume of robot.

   (A) Work envelope

   (B) Speed of movement

   (C) Load carrying capacity

(D) Precision of movement

Ans:A

5. From which of the following is benefit of robot.

(A) Variety of task

(B) Computer control

(C) Repetitive task

(D) All of the above

Ans:D

4. CONCLUSION

- Understood basics of Introduction of robotics working process.
- Understood the concept of drive system of robotics.

5. REFERENCES

1. Mikell.P.Groover,"Industrial Robotics-Technology, Programming and Applications", McGraw Hill, second edition 2012.

2. Introduction to Robotics: Mechanics and Control Hardcover – Import, 27 July 2004

by John J. Craig

6. VIDEOS

https://www.youtube.com/watch?v=xrwz9IxpMJg

7. ASSIGNMENTS

State the advantages and limitations of robot with example.

Course Material

Name of the Course : **ROBOTICS AND AUTOMATION**

Name of the Unit :**SENSORS IN ROBOTICS**

Name of the Topic : Position sensors (Piezo Electric sensor, LVDT, Optical Encoders)-Proximity (Inductive, Capacitive, Hall Effect & Ultrasonic), Range sensors (Laser Meters, Lighting Approach & Time of Flight Range Finder)-Image Processing & Analysis:-Image Data reduction-Feature extraction-Object Recognition.

1. **AIM AND OBJECTIVES**: To develop ideas on sensors in Robotics.

2. **PRETEST- MCQ**

1. The speed at which robot is capable of manipulating its end effector is known as the____.

(A) Velocity of robot

(B) Maximum reach

(C) Speed of movement

(D) Load carrying capacity

Ans:C

2. The capacity of robot to carry load is known as_____.

(A) Load carrying capacity

(B) Work envelope

(C) Maximum reach

(D) None of the above

Ans: A

3. ____ is a collection of mechanical linkage connected by joints.

(A) End effector

(B) Gripper

(C) Sensor

(D) Manipulator

Ans: D

4. Grippers are used to_____.

   (A) Hold the objects

   (B) Sense the objects

   (C) Move the objects

   (D) Both (A) & (C)

   Ans: D

5. Sensors are the transducers that are used to____.

   (A) Measure physical quantity

   (B) Hold the objects

   (C) Fix the objects

   (D) None of the above

   Ans: A

3. PRE-REQUISITES:

To have a basic knowledge of sensors, actuatorsand its workingprocess.

4. THEORY:

Introduction toSensors

Sensors are devices that are used to measure physical variables like temperature, pH, velocity, rotational rate, flow rate, pressure and many others. Today, most sensors do not indicate a reading on an analog scale (like a thermometer), but, rather, they produce a voltage or a digital signal that is indicative of the physical variable they measure. Those signals are often imported into computer programs, stored in files, plotted on computers and analyzed todeath.

Sensors come in many kinds and shapes to measure all kinds of physical variables. However, many sensors have some sort of voltage output. There are a number of implications to that.

- If a sensor has a voltage output, then it is a voltage source that is controlled by the physical variable itmeasures.
- If the sensor is a voltage source, you need to remember that no physical voltage sources are ideal, and non-ideal voltage sources are usually best described with aThevinin Equivalent Circuit that contains the voltage source and an internalresistance.
- If a source has an internal resistance, there is a possibility of loading the source. If a significant load is attached to the source, the terminal voltage will drop. At that point, the terminal voltage is not what you expect it to be (from calibrations, spec sheets,etc.)

Need of Sensors

Seismic monitors provide an early warning system for earthquakes.

The latest sensor equipment includes heart rate, electrical voltage, gas, light, sound, temperature, and distance sensors. Data is collected via the sensors and then transmitted to the computer. Up to date software is used to collect, display and store the experimental data. The computer software can then display this data in different formats - such as graphs, tables or meter readings, which make it easy for students to understand the process and bring science to life.

The significance of sensor technology is constantly growing. Sensors allow us to monitor our surroundings in ways we could barely imagine a few years ago. New sensor applications are being identified everyday which broadens the scope of the technology and expands its impact on everyday life.

In Industry

On the factory floor, networked vibration sensors warn that a bearing is beginning to fail. Mechanics schedule overnight maintenance, preventing an expensive unplanned shutdown. Inside a refrigerated grocery truck, temperature and humidity sensors monitor individual containers, reducing spoilage in fragile fish orproduce.

In the Environment

Networks of wireless humidity sensors monitor fire danger in remote forests. Nitrate sensors detect industrial and agricultural runoff in rivers, streams and wells, while distributed seismic monitors provide an early warning system for earthquakes. Meanwhile built-in stress sensors report on the structural integrity of bridges, buildings and roadways, and other man-made structures.

For Safety and Security

Fire fighters scatter wireless sensors throughout a burning building to map hot spots and flare-ups. Simultaneously, the sensors provide an emergency communications network.

Miniature chemical and biological sensors in hospitals, post offices, and transportation centres raise an alarm at the first sign of anthrax, smallpox or other terror agents.

Position Sensors

In this tutorial we will look at a variety of devices which are classed as Input Devices and are therefore called "Sensors" and in particular those sensors which are Positional in nature. As their name implies, Position Sensors detect the position of something which means that they are referenced either to or from some fixed point or position. These types of sensors provide a "positional" feedback. One method of determining a position, is to use either "distance", which could be the distance between two points such as the distance travelled or moved away from some fixed point, or by "rotation" (angular movement). For example, the rotation of a robots wheel to determine its distance travelled along the ground. Either way, Position Sensors can detect the movement of an object in a straight line using Linear Sensors or by its angular movement using RotationalSensors.


A robot with visual and force sensors

Sensors used in Robotics

The use of sensors in robots has taken them into the next level of creativity. Most importantly, the sensors have increased the performance of robots to a large extent. It also allows the robots to perform several functions like a human being. The robots are even made intelligent with the help of Visual Sensors (generally called as machine vision or computer vision), which helps them to respond according to the situation. The Machine Vision system is classified into six sub-divisions such as Pre-processing, Sensing, Recognition, Description, Interpretation, andSegmentation.

Different types of sensors:

There are plenty of sensors used in the robots, and some of the important types are listed below:

- ProximitySensor,
- Range Sensor,and
- TactileSensor.

ProximitySensor:

This type of sensor is capable of pointing out the availability of a component. Generally, theproximity sensor will be placed in the robot moving part such as end effector. This sensor will be turned ON at a specified distance, which will be measured by means of feet or millimeters. It is also used to find the presence of a human being in the work volume so that the accidents can bereduced.

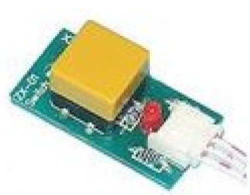
Range Sensor:

Range Sensor is implemented in the end effector of a robot to calculate the distance between the sensor and a work part. The values for the distance can be given by the workers on visual data. It can evaluate the size of images and analysis of common objects. The range is measured using the Sonar receivers & transmitters or two TV cameras.

Tactile Sensors:

A sensing device that specifies the contact between an object, and sensor is considered as the*Tactile Sensor*. This sensor can be sorted into two key types namely:

- Touch Sensor,and
- ForceSensor.



Touch Sensor

The touch sensor has got the ability to sense and detect the touching of a sensor and object. Some of the commonly used simple devices as touch sensors are micro switches, limit switches, etc. If the end effector gets some contact with any solid part, then this sensor will be handy one to stop the movement of the robot. In addition, it can be used as an inspection device, which has a probe to measure the size of a component.

The force sensor is included for calculating the forces of several functions like the machine loading & unloading, material handling, and so on that are performed by a robot. This sensor will also be a better one in the assembly process for checking the problems. There are several techniques used in this sensor like Joint Sensing, Robot – Wrist Force Sensing, and Tactile ArraySensing.

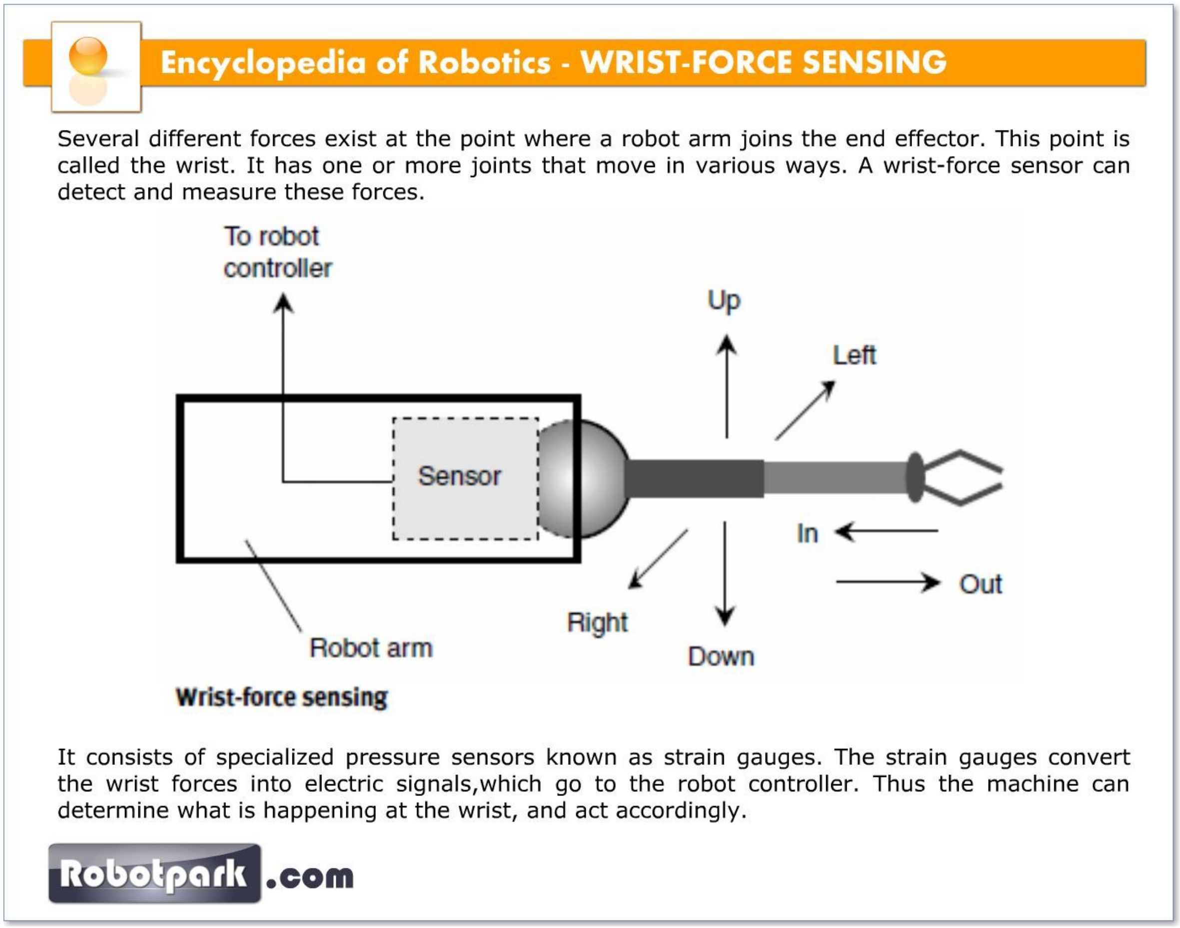
Wrist-ForceSensing

Several different forces exist at the **point where a robot arm joins the end effector**. This point is called the **wrist**. It has one or more joints that move in various ways. **A wrist-force sensor** can detect and measure these forces. **It consists of specialized pressure sensors known as strain gauges**. The strain gauges convert the wrist forces into electric signals,which go to the robot controller. Thus the machine can determine what is happening at the wrist, and act accordingly.

Wrist force is complex. Several dimensions are required to represent all the possible motions that can take place. The illustration shows a hypothetical robot wrist, and the forces that can occur there. The orientations are right/left, in/out, and up/down. Rotation is possible along all three axes. These forces are called pitch, roll, and yaw. A wrist-force sensor must detect, and translate, each of the forces independently. A change in one vector must cause a change in sensor output for that force, and no others.

Compliantgeometry

The compliant geometry of the robot allows the body to deform. The side of the body is to be covered with textile. An impact at any point on its textile cover will deform the textile slightly but also tilt the top of the body away from the impact. A compliant body has many safety advantages in populated environments, such as a party or conference reception. Many robots use a mobile outer shell to detect collisions, e.g. in the Rug Warrior (Jonesand



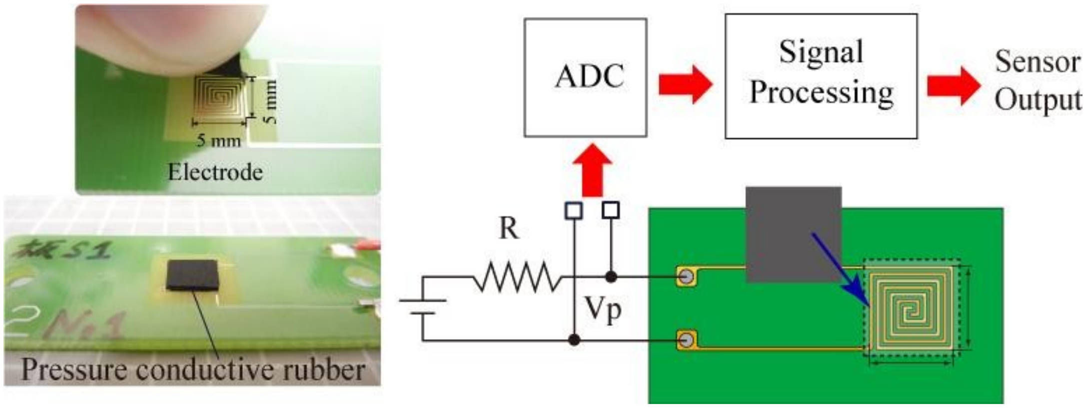
Flynn, 1993). In ButlerBot however, the body itself s the detector. While compliance has been investigated for couplings and joints (see e.g. Trease et al., 2005; Meyer et al., 2004), we are not aware of other work using the whole body as a compliant system. Inside the robot is a light-weight support structure. The tray of ButlerBot is supported by 4 poles which have foam dampers at the end. Additionally 4 strings stretch from the centre of the tray down to the edge of the base like the stays of a boat mast, see figures 1b and 2. Each string incorporates a spring to allow flexibility. The 4 poles are mounted off-centre, which allows the tray effectively to shake in the horizontal X-Y plane. The springs have a sensor attached (potentiometer Pot in figure 2) in order to measure their extension. This allows estimating the position of the tray at the top and the amplitude and direction of the shaking. There is a sensor in the spring aligned with the X-axis and another sensor in the spring aligned with theY-axis.

Slip sensing

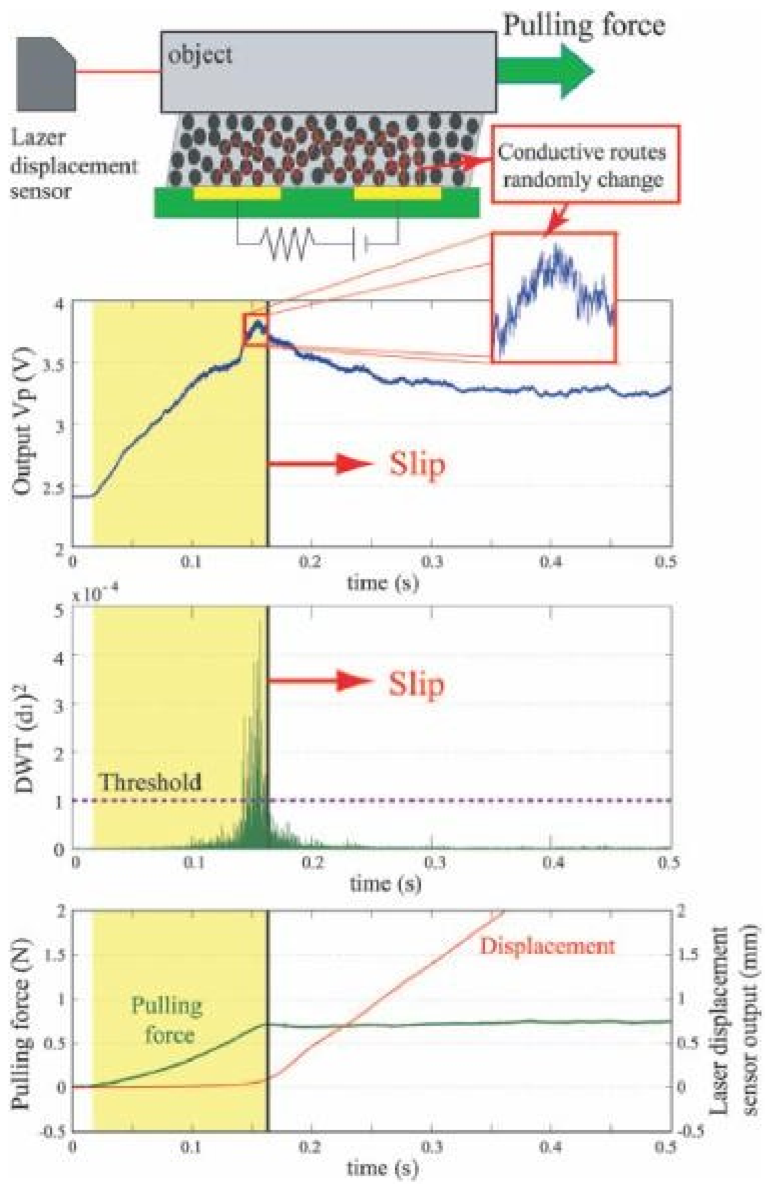
Humans can grasp an object without information such as a coefficient of friction or weight. To implement this graspingmotion with the robot hand, sensors have been proposed that detect an incipient slip within the contact surface or stick-slip.

Method of slip detection

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.



As shown in figure, the object is placed on the surface of the sensor. The upper graph shows the output of the slip sensor when pulling force is applied to the object. The lowest graph shows the pulling force and its position shifts through slippinge. First, the pulling force is increased until about 0.15s, after which it remains roughly constant. Specifically, it can be considered that a transition from static friction to dynamic friction occurs at the place marked with a verticalline in thefigure.

In an unloaded condition, the electrical resistance is infinity. However, the electrical resistance changes when the normal force was added, because the mutual contact between carbon particles increases. Moreover, when added a tangential force, the electrical resistance randomly changes by changing the mutual contact between carbon particles.

Here, looking at the enlarged portion of the upper graph, a complex change in the voltage emerges immediately before the occurrence of slip (the time of the initial slip). Upon performing a frequency analysis with respect to this voltage change, it was found that the sensor output Vp at the time of the initial slip includes a high frequency component of severalkHztoseveral10kHz.In this regard, such high-frequency change does not occur when thechangeinforceisinnormaldirection.The slip sensor presented here extracts this high-frequency component by applying the discrete wavelet transform (DWT) and detects the initialslipoftheobject.The middle graph presents the results of DWT power using Haar wavelets. It is clear that immediately before slip occurs, the DWT powerincreases.

Frame Grabbers

Hundreds of frame grabbers are on the market to allow integration of digital and analog machine-vision cameras with host computers. Varying features make each one unique for a particular application. When evaluating frame grabbers for a specific application, developers must be aware of specific camera types (either digital or analog), the sensor types they use (area or linescan), their systems requirements, and the cost of peripherals.

Digital Frame Grabbers

To guarantee low latency between image acquisition and processing, frame grabbers with digital camera interfaces such as Camera Link cameras are often used, especially in high-speed semiconductor applications. The Camera Link standard’s Full configuration allows a maximum of 680 Mbytes/s (64-bit at 85 MHz), currently the highest bandwidth on the market. High-speed applications can also benefit from onboard tap reordering that can be accomplished with many frame grabbers. This removes the burden of recomposing an entire image from complex multitap cameras (several simultaneous data channels) from the host computer. Other features, such as the recently available power-over-Camera Link standard, offer simpler integration (a single cable for power and data) of compatible Camera Link cameras when this feature is available on the framegrabber.

Analog Frame Grabbers

Even with established standards such as RS-170, NTSC, CCIR, and PAL, great differences exist among analog frame grabbers. Differences appear through jitter, digization quality, and colour separation, all of which affect image quality. However, because it is difficult to compare frame grabbers from datasheet specifications, many OEMs benchmark several models before making aselection.
Some analog frame grabbers can handle multiple cameras either through multiple analog interfaces or multiplexing techniques, thus reducing the number of frame grabbers used in multi camera systems. When multiplexing video on a frame grabber, the resynchronization time required with each switching reduces the total frame rate. In the case of a multiple simultaneous input configuration, onboard memory will guarantee that images are transferred without loss of data.

Area-Array Cameras

Today's frame grabbers commonly offer onboard FPGAs to perform neighbourhood operations such as convolution, off-loading the task from the host PC. This allows functions such as Bayer colour interpolation and dead-pixel management to be performed directly on the frame grabber. While some cameras offer Bayer interpolation internally, most frame grabbers can also handle the task. Several ways exist to interpolate camera data when a Bayer pattern is used. The most simple linear interpolation gives relatively poor image quality; an intermediate quality method is bilinear interpolation; the highest quality is obtained by nonlinearinterpolation.
Similarly, dead-pixel management can be used to correct the images and reconstruct or interpret neighborhood pixel values. Each pixel is compared to its neighbors, and if there is a very high- or low-intensity pixel, a dead pixel may exist and a new value is computed using kernel-based algorithms. Although the host computer can perform these operations internally, it requires substantial processingpower.

Frame grabbers that support line scan cameras are mostly used in applications requiring a high level of synchronization between the movement of objects on a conveyor and image acquisition. To interface to such conveyors, frame grabbers usually provide interfaces to TTL, RS-644, optocouplers, and pulse dividers (to adjust the encoder pulse-per-line ratio) and support for bidirectional encoders (where opposing movements are necessary). Linescan cameras can be difficult to integrate in cases where lines are generated constantly. Large quantities of data are generated and could create data-transfer issues-some frame grabbers may lose lines of image data.

Frame grabbers can also interface to trilinear line scan colour cameras. These cameras use a sensor comprising three lines, each covered with a colour filter-typically red, green, and blue. Here, the pixel information of each colour line does not represent the same physical location in space, so it is necessary to realign each colour. For example, if the camera has red, green, and blue filters, in that order, the green channel has to be delayed by one line and the blue by two to match the red channel. This spatial registration can be easily performed on a frame grabber, off-loading the PC of this function.

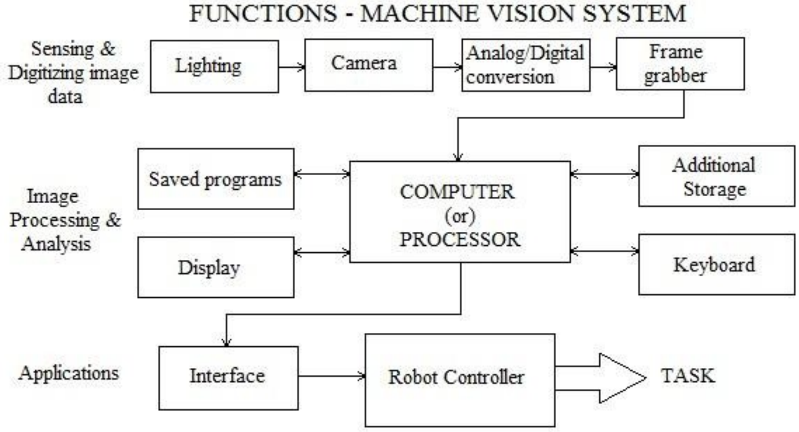
The ease of integrating a frame grabber into a vision system is determined by how simple it is to synchronize image acquisition with external events controlled using TTL, RS- 644/LVDS, and optocouplers. The most general use of I/Os is for triggers: an external signal from a sensor or programmable logic device indicates that an image must be captured. In many applications, external lighting is required, and the frame grabber offers dedicated signal lines to synchronize strobe lighting with the camera's integration period. Most frame grabbers offer additional digital I/Os that can be used for other types of acquisition orsynchronization.

Machine VisionSystem

Machine vision system is a *sensor* used in the robots for viewing and recognizing an object with the help of a computer. It is mostly used in the industrial robots for*inspection*purposes.Thissystemisalsoknownas*artificialvisionorcomputervision*.It has several components such as a camera, digital computer, digitizing hardware, and an interface hardware & software. The machine vision process includes three important tasks, namely:

- Sensing & Digitizing ImageData
- Image Processing &Analysis
- Applications

FUNCTIONS - MACHINE VISION SYSTEM



Sensing & Digitizing ImageData:

A *camera* is used in the sensing and digitizing tasks for viewing the images. It will make use of special lighting methods for gaining better picture contrast. These images are changed into the digital form, and it is known as the *frame of the vision data*. A *frame grabber* is incorporated for taking digitized image continuously at 30 frames per second. Instead of scene projections, every frame is divided as a matrix. By performing sampling operation on the image, the number of pixels can be identified. The pixels are generally described by the elements of the matrix. A pixel is decreased to a value for measuring the intensity of light. As a result of this process, the intensity of every pixel is changed into the digital value and stored in the computer's memory.

Image Processing & Analysis:

In this function, the *image interpretation* and *data reduction* processes are done. The threshold of an image frame is developed as a binary image for reducing the data. The data reduction will help in converting the frame from raw image data to the feature value data. The feature value data can be calculated via computer programming. This is performed by*matching* the image descriptors like size and appearance with the previously stored data on thecomputer.

The image processing and analysis function will be made more effective by *training* the machine vision system regularly. There are several data collected in the training process like length of perimeter, outer & inner diameter, area, and so on. Here, the camera will be very helpful to identify the match between the computer models and new objects of feature valuedata.
Applications:

Some of the important applications of the machine vision system in the robots are:

- Inspection
- Orientation
- Part Identification
- Location

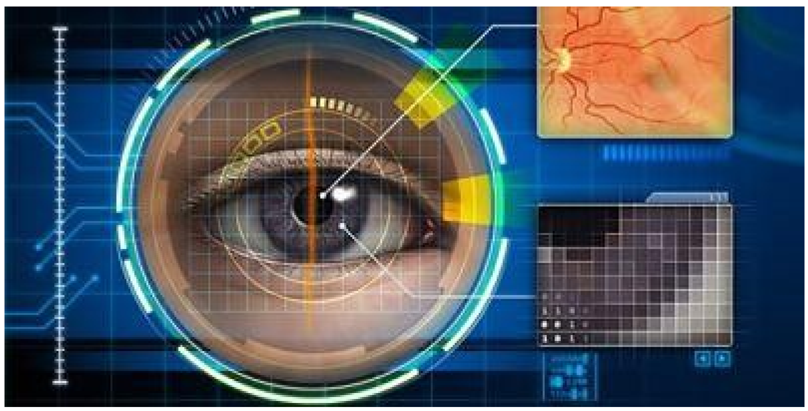
Signal conversion

Our interface modules are the links between the real physical process and the control system. Use the [EExia]-version of this function modules to assure a save data transmission from the potentially explosive area to the non-hazardous area and vice-versa. *Select the respective product properties below. The right-hand column adjusts the product list immediately and displays only products corresponding to your specifications.*

Image Processing

Robotic vision continues to be treated including different methods for processing, analyzing, and understanding. All these methods produce information that is translated into decisions for robots. From start to capture images and to the final decision of the robot, a wide range of technologies and algorithms are used like a committee of filtering and decisions.

Another object with other colors accompanied by different sizes. A robotic vision system has to make the distinction between objects and in almost all cases has to tracking these objects. Applied in the real world for robotic applications, these machine vision systems are designed to duplicate the abilities of the human vision system using programming code and electronic parts. As human eyes can detect and track many objects in the same time, robotic vision systems seem to pass the difficulty in detecting and tracking many objects at the same time.



Machine Vision

A robotic system finds its place in many fields from industry and robotic services. Even is used for identification or navigation, these systems are under continuing improvements with new features like 3D support, filtering, or detection of light intensity applied to anobject.

Applications and benefits for robotic vision systems used in industry or for service robots:

- automatingprocess;
- objectdetection;
- estimation by counting any type ofmoving;
- applications for security andsurveillance;
- used in inspection to remove the parts withdefects;
- defense applications;
- used by autonomous vehicle or mobile robots fornavigation;
- for interaction in computer-humaninteraction;

In this article, I make an overview of vision tools and libraries used for machine vision as well as most common vision sensors used by engineers to apply machine vision in the real world using robots.

Object trackingsoftware

A tracking system has a well-defined role and this is to observe the persons or objects when these are under moving. In addition, the tracking software is capable of predicting the direction of motion and recognizes the object or persons.

OpenCVis the most popular and used machine vision library with open-source code and comprehensive documentation. Starting with image processing, 3D vision and tracking, fitting and many other features, the system include more than 2500 algorithms. The library interfaces have support for C++, C, Python and Java (in work), and also can run under Windows, Linux, Android or Mac operating systems.

SwisTrack

Used for object tracking and recognition, SwisTrackis one of the most advanced tools used in machine vision applications. This tracking tool required only a video camera for tracking objects in a wide range of situations. Inside, SwisTrack is designed with a flexible architecture and uses OpenCV library. This flexibility opens the gates for implementing new components in order to meet the requirements of the user.

visual navigation

Autonomous navigation is one of the most important characteristics for a mobile robot. Because of slipping and some incorrigible drift errors for sensors, it is difficult for a mobile robot to realize self-location after a long distance navigation. In this paper, the perceptual landmarks were used to solve this problem, and the visual serving control was adopted for the robot to realize self-location. At the same time, in order to detect and extract the artificial landmarks robustly under different illuminating conditions, the color model of the landmarks was built in the HSV color space. These functions were all tested in real time under experiment conditions.

Edge Detector

Edge Detector Robot from IdeaFires is an innovative approach towards Robotics Learning. This is a simple autonomous Robot fitted with Controller and Sensor modules. The Edge Detector Robot senses the edges of table or any surface and turns the robot in such a way that it prevents it from falling.

5. POST MCQ TEST:

1. The more correct a senor can measure, the more ________ it is:
   a. Accurate
   b. Precise
   c. Scaled
   d. Extent
   Ans:a

2. Touch screen of mobile phone uses:

   a. AFR Sensor
   b. Pellistor
   c. Viscometer
   d. Tactile sensors
   Ans:d

3. Which type of sensor is used to measure the distance between the vehicle and other objects in its environment:

   a. Ultrasonic sensor
   b. Tactile sensor
   c. Motion sensor
   d. None of these
   Ans: a

4. Which of the following is not application of Robotics?

   A. Industries
   B. Military
   C. Medicine
   D. Hills
   Ans : D

5. Which of the following is not an essential components for construction of robots?

   A. Power Supply
   B. Actuators
   C. Sensors
   D. Energy
   Ans : D

5. CONCLUSION

Understood basics of Introduction of robotics sensors.

Understood the concept of Image processing and analysis of robotics.

6. REFERENCES

1. Mikell.P.Groover,"Industrial Robotics-Technology, Programming and Applications", McGraw Hill, second edition 2012.
2. Advanced Robotics and Intelligent Machines J.O.Grey:D.G.by John J.Craig.

7. VIDEOS

https://www.youtube.com/watch?v=9wYkWJeS3lM

8. ASSIGNMENTS

State the advantages and limitations of robot sensors with example.

Course Material

Name of the Course : **ROBOTICS AND AUTOMATION**

Name of the Unit :**END EFFECTORS**

Name of the Topic :Wrist configuration, Pitch, Yaw, Roll – Types of Grippers -Mechanical Grippers-Pneumatic and Hydraulic Grippers-Vacuum Cups-Magnetic Grippers –Two Fingered and Three fingered Grippers-Robot/End effectors Interface-Selection and Design Considerations.

1. **AIM AND OBJECTIVES**: To develop ideas onRobotic end effectors.

2. **PRETEST- MCQ**

1. Internal state sensors are used for measuring __________ of the end effector.

   a. Position
   b. Position & Velocity
   c. Velocity & Acceleration
   d. Position, Velocity & Acceleration
   Answer: Position, Velocity & Acceleration

2. ___________ sensors determines the relationship of the robot and its environment and the objects handled by it
   a. Internal State sensors
   b. External State sensors
   c. Both (A) and (B)
   d. None of the above

   Answer: Both (A) and (B)

3. _____________ is not a programming language for computer controlled robot?
   a. VAL
   b. RAIL
   c. HELP
   d. AMU

   Answer: AMU

4. ________________ terms refers to the rotational motion of a robot arm?
   a. swivel
   b. axle
   c. retrograde
   d. roll
   Answer: roll

5. ______________ is the name for space inside which a robot unit operates?
   a. environment
   b. spatial base
   c. exclusion zone
   d. work envelope
   Answer: work envelope

3. PRE-REQUISITES:

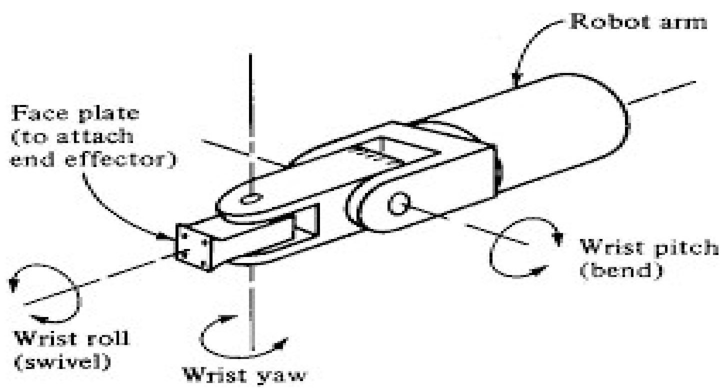
To have a basic knowledge of sensors, actuatorsand basic components of a robot.

4. THEORY:

Wristconfiguration

Roll- This is also called wrist swivel, this involves rotation of the wrist mechanism about the arm axis.

Pitch- It involves up & down rotation of the wrist. This is also called as wrist bend.



Yaw- It involves right or left rotation of the wrist.

Notation TRL:

ƒ Consists of a sliding arm (L joint) actuated relative to the body, which can rotate about both a vertical axis (T joint) and horizontal axis (R joint)

Notation TLO:

ƒ Consists of a vertical column, relative to which an arm assembly is moved up or down
ƒ the arm can be moved in or out relative to the column

Notation LOO:

ƒ Consists of three sliding joints, two of which are orthogonal Other names include rectilinear robot and x-y-z robot.

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 assemblyoperations.

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 weldingoperations.

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 theirpath.

PayLoad

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 robotsearch.

Robot Parts and Functions

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 ateach pendant. Many of today's industrial robot arms use an interface that resembles or is built on the Windows operatingsystem.

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 oftasks.

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 toignore.

Introduction Robot DriveSystems

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 therobot.

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.

TypesofActuators

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

*Hydraulicactuators

*Pneumatic actuators

MechanicalDriveSystems

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

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

Electric DriveSystem:

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 110robot*.

Hydraulic DriveSystem:

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 forbothlinearandrotationaljoints.Therotarymotionsareprovidedbytherotaryvane 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.*

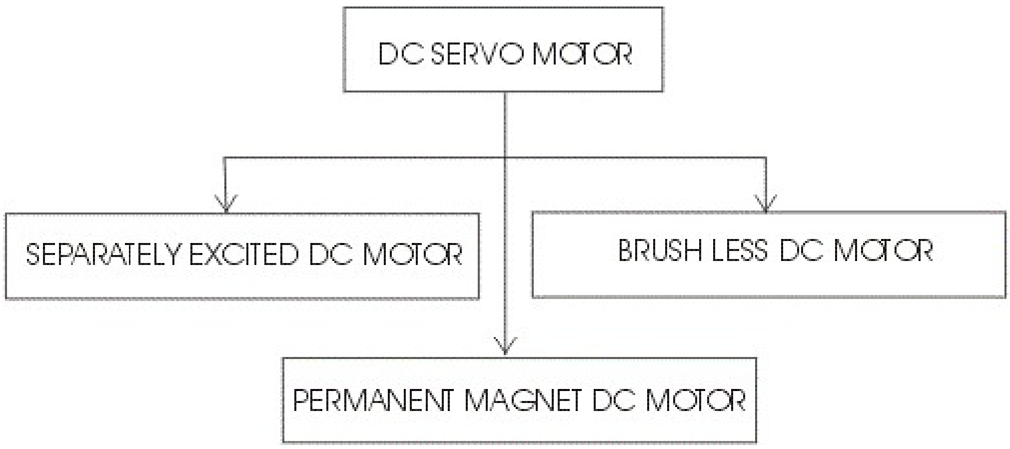
Pneumatic DriveSystem:

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 *fasteroperations.*

DC Servo Motors | Stepper Motor

Under Electrical Motor

As we know that any electrical motor can be utilized as servo motor if it is controlled by servomechanism. Likewise, if we control a DC motor by means of servomechanism, it would be referred as **DC servo motor**. There are different types of DCmotor, such shunt wound DC motor, series DC motor, Separately excited DC motor, permanentmagnet DC motor, Brushless DC motor etc. Among all mainly separately excited DC motor, permanent magnet DC motor and brush less DC motor are used as servo.



DC Servo Motor

The motors which are utilized as **DC servo motors**, generally have separate DC source for field winding and armature winding. The control can be archived either by controlling the field current or armature current. Field control has some specific advantages over armature control and on the other hand armature control has also some specific advantages over field control. Which type of control should be applied to the **DC servo motor**, is being decided depending upon its specific applications. Let's discus **DC servo motor working principle** for field control and armature control one by one.

Field Controlled DC Servo Motor

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 ahumanoid robot which are also not end effectors—they are part of the robot's mobility.

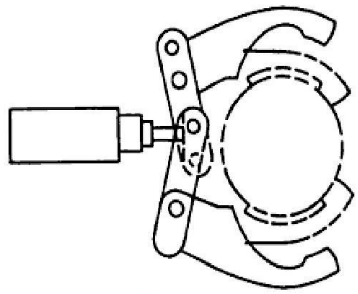


Figure 1 External gripper.

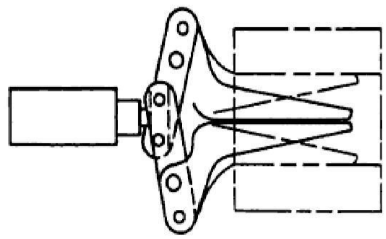


Figure 2 Internal gripper.

End effectors may consist of a gripper or a tool. When referring to robotic prehension there are four general categories of robot grippers, these are:

1. Impactive – jaws or claws which physically grasp by direct impact upon theobject.
2. Ingressive – pins, needles or hackles which physically penetrate the surface of the object (used in textile, carbon and glass fibrehandling).
3. Astrictive – suction[*vague*] forces applied to the objects surface (whether by vacuum, magneto- orelectroadhesion).
4. Contigutive – requiring direct contact for adhesion to take place (such as glue, surface tension orfreezing).

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 d evice 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 bygrippers:

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.

MagneticGrippers

Magnetic grippers are most commonly used in a robot as an end effector for grasping the*ferrous*materials. It is another type of handling the work parts other than themechanical grippers and vacuum grippers.

Types of magnetic grippers:

The magnetic grippers can be classified intotwo common types, namely: Magnetic grippers with

- Electromagnets
- Permanentmagnets

Electromagnets:

Electromagnetic grippers include a controller unit and a DC power for handling the materials. This type of grippers is easy to control, and very effective in releasing the part at the end of the operation than the permanent magnets. If the work part gripped is to be released, the polarity level is minimized by the controller unit before the electromagnet is turned off. This process will certainly help in removing the magnetism on the work parts. As a result, a best way of releasing the materials is possible in this gripper.

Permanent magnets:

The permanent magnets do not require any sort of external power as like the electromagnets for handling the materials. After this gripper grasps a work part, an additional device called asstripper push – off pin will be required to separate the work part from the magnet. This device is incorporated at the sides of thegripper.

The advantage of this permanent magnet gripper is that it can be used in hazardous applications like explosion-proof apparatus because of no electrical circuit. Moreover, there is no possibility of spark production aswell.

Benefits:

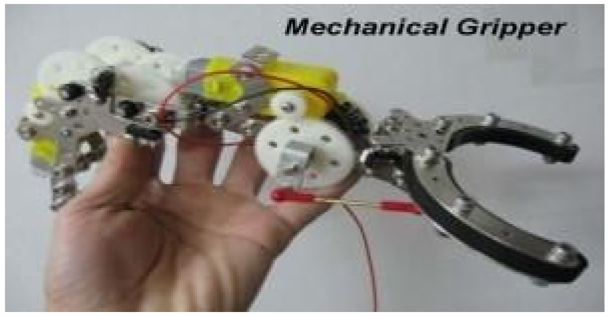
- This gripper only requires one surface to grasp thematerials.
- The grasping of materials is done veryquickly.
- It does not require separate designs for handling different size of materials.
- Itiscapableofgraspingmaterialswithholes,whichisunfeasiblein

the vacuum grippers.

Drawbacks:

- The gripped work part has the chance of slipping out when it is moving quickly.
- Sometimes oil in the surface can reduce the strength of thegripper.
- The machining chips may stick to the gripper duringunloading.

MechanicalGripper



A mechanical gripper is used as an end effector in a robot for grasping the objects with its mechanically operated fingers. In industries, two fingers are enough for holding purposes. More than three fingers can also be used based on the application. As most of the fingers are of replaceabletype, it can be easily removed andreplaced.

A robot requires either hydraulic, electric, or pneumatic drive system to create the input power. The power produced is sent to the gripper for making the fingers react. It also allows the fingers to perform open and close actions. Most importantly, a sufficient force must be given to hold the object.

In a mechanical gripper, the holding of an object can be done by two different methods such as:

- Using the finger pads as like the shape of the workpart.
- Using soft material fingerpads.

In the first method, the contact surfaces of the fingers are designed according to the work part for achieving the estimated shape. It will help the fingers to hold the work part for some extent.

In the second method, the fingers must be capable of supplying sufficient force to hold the work part. To avoid scratches on the work part, soft type pads are fabricated on the fingers. As a result, the contact surface of the finger and co – efficient of friction are improved. This method is very simple and as well as less expensive. It may cause slippage if the force applied against the work part is in the parallel direction. The slippage can be avoided by designing the gripper based on the force exerted.

$\mu\ n_f F_g = w$ ………………… 1

μ => co – efficient of friction between the work part andfingers

n_f => no. of fingers contacting

F_g => Force of the gripper

w => weight of the grasped object

The equation 1 must be changed if the weight of a work part is more than the force applied to cause the slippage.

$\mu\ n_f F_g = wg$ ….……………. 2

g => g factor

During rapid grasping operation, the work part will get twice the weight. To get rid out of it, the modified equation 1 is put forward by Engelberger. The g factor in the equation 2 is used to calculate the acceleration andgravity.
The values of g factor for several operations are given below:

- g = 1 – acceleration supplied in the oppositedirection.
- g = 2 – acceleration supplied in the horizontaldirection.
- g = 3 – acceleration and gravity supplied in the samedirection.

A pneumatic gripper is a specific type of pneumatic actuator that typically involves either parallel or angular motion of surfaces, A.K.A. "tooling jaws or fingers" that will grip an object. When combined with other pneumatic, electric, or hydraulic components, the gripper can be used as part of a "pick and place" system that will allow a component to be picked up and placed somewhere else as part of a manufacturingsystem.
Some grippers act directly on the object they are gripping based on the force of the air pressure supplied to the gripper, while others will use a mechanism such as a gear or toggle to leverage the amount of force applied to the object being gripped. Grippers can also vary in terms of the opening size, the amount of force that can be applied, and the shape of the gripping surfaces—frequently called "tooling jaws or fingers". They can be used to pick up everything from very small items (a transistor or chip for a circuit board, for example) to very large items, such as an engine block for a car. Grippers are frequently added to industrial robots in order to allow the robot to interact with otherobjects.
Common industrial pneumatic components include:

- pneumatic direct operated solenoid valve
- pneumatic pilot operated solenoid valve
- pneumatic external piloted solenoidvalve
- pneumatic manualvalve
- pneumatic valve with air pilot actuator
- pneumaticfilter
- pneumatic pressureregulator
- pneumaticlubricator

HydraulicGrippers

Posted by admin on Tuesday, September 24, 2013 · 1 Comment
Grippers are devices used with pick-and-place robotic systems to pick up or place an object on an assembly line, conveyor system, or other automated system. Fingered tooling—or jaws—is attached to the grippers to grip or hold theobject.

They come in a variety of styles and powered designs. Three common types are parallel, three-finger, and angled designs. The most common are parallel designs, with two fingers that close on a workpiece to grip it or open it out by creating pressure on the inside. Three-finger designs hold the workpiece in the center, and have three fingers offset by 120°. Finally, angled designs feature jaws that work at a variety of different angle openings (for example, 30°, 40°, etc.).

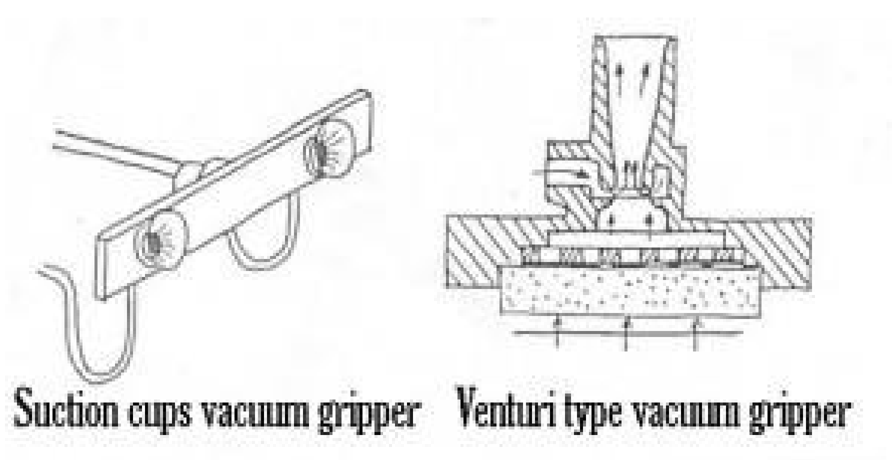
In addition, three choices of power are available; the most common being pneumatic grippers; electromechanical grippers are second most common; and the least common being hydraulic grippers. Hydraulic grippers are most often used in conjunction with a piece of equipment that only has a hydraulic power source for actuators.
Most hydraulic grippers are designed for a hydraulic system where the cylinder diameter is made with less surface area, meaning that a hydraulic gripper would have the same force at 60 bar as a pneumatic gripper of the same size at 6 bar.

In general, hydraulic and pneumatic grippers have the same basic actuation principle. They include direct acting piston designs as well as piston wedge designs.
The direct acting piston design is used when a hydraulic force acts directly on a piston that is directly connected to the jaw or finger that is touching or gripping the part.
The piston wedge design features a hydraulic force acting on a piston while the piston itself is acting on a wedge. The wedge translates this force to the jaws or fingers, providing the grip force to grip the part. The wedge can give a mechanical advantage as it can increase grip force while keeping the piston diameter and pressure to the piston the same. This allows more grip force in a smaller package compared to the directing piston.

Unlike electromechanical grippers, which have motors on each actuator, one single motor powers the hydraulic fluid that supplies energy to multiple devices throughout a plant.When selecting a hydraulic gripper, it is important to consider the following:

- Part weight and size to belifted
- Partmaterial
- Clearance issues around the part that could interfere with the grippingpart
- The environment the gripper will be used in (corrosive, food or beverage, etc.)
- The motion path of the robot or linear device that is moving thegripper
- The power supply that will be available and the pressure ratingsavailable

Vacuumgrippers



Vacuum grippers are used in the robots for grasping the non – ferrous objects. It usesvacuum cups as the gripping device, which is also commonly known as suction cups. This type of grippers will provide good handling if the objects are smooth, flat, and clean. It has only one surface for gripping the objects. Most importantly, it is not best suitable for handling the objects with holes.

Vacuum cups:

Generally, the vacuum cups (suction cups) will be in the round shape. These cups will be developed by means of rubber or other elastic materials. Sometimes, it is also made of soft plastics. Moreover, the vacuum cups are prepared of hard materials for handling the soft materialobjects.

Two different devices are used in the suction cups for creating the vacuum. They are:

- Venturi
- Vacuumpump

Venturi device is operated with the help of shop air pressure, while the vacuum pump is driven either by means of vane or piston device. The vacuum pump has the ability to create the high vacuum. As the venturi is a simple device, it is more reliable and inexpensive. Both these devices are very well capable of providing high vacuum if there is a sufficient supply of air pressure.

Types of vacuum grippers:

- The ball joint type vacuum gripper is capable of changing into various contact angles automatically. Moreover, the bending moments in the vacuum cups are also decreased. It is used for carrying irregular materials, heavy objects,etc.
- A vacuum gripper with level compensator can be very helpful in balancing the objects with different levels. It also has the capability to absorb theshocks.

Applications of vacuum grippers:

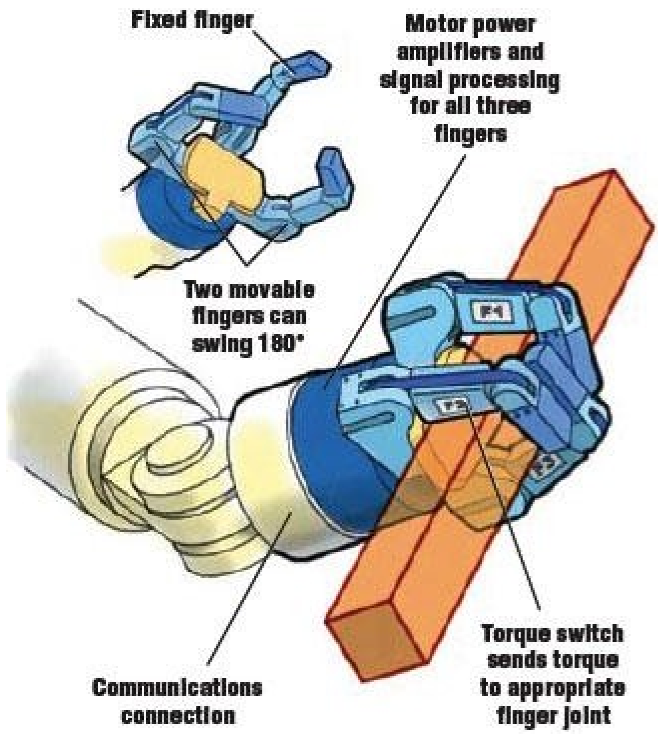
- Vacuum grippers are highly useful in the heavy industries, automobiles, compact disc manufacturing, and more for material handlingpurposes.
- It is also used in the tray & box manufacturing, labeling, sealing, bottling, and so on for packagingpurposes.

Two and Three-fingeredgripper

Three-fingered gripper

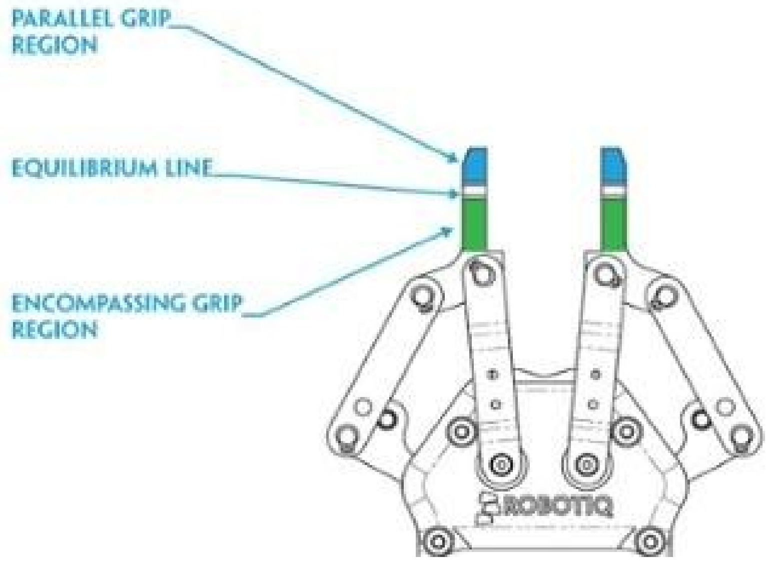
It's also costly to order custom-made handlers for special parts. To solve these problems, engineers at Barrett Technology Inc., Cambridge, Mass. (barrett.com), developed the Barrett Hand, a three-fingered gripper that can securely hold a wide variety of shapes and parts.

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 1.2kg.



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.

Two-fingered gripper



The mechanism driving the fingers of this Gripper is optimized to obtain twodistinct 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.

Coupling between the fingers

In addition to the mechanism used inside each of its fingers, the Gripper also relies on a special coupling architecture between the fingers. In fact, it is mechanically designed to ensure that the two fingers move in conjunction with each other in order to center the object grasped in the middle of the Gripper. This self-centering avoids the need to use expensive sensor sand is above allsafer.

In the same vein to make this Robot Gripper as reliable as possible, a self-locking feature has been incorporated into it between the actuator and the fingers. By doing so, we are sure that the Gripper will never release the object and let it fall if the power is shut down. It is also economically interesting, as the actuator doesn't need to apply torque continually when an object is grasped, thus in addition to the power saved, the lifespan of the Gripper is thereby maximized.

Selection and design considerations in robotgripper

The industrial robots use grippers as an end effector for picking up the raw and finished work parts. A robot can perform good grasping of objects only when it obtains a proper gripper selection and design. Therefore, Joseph F. Engelberger, who is referred as Father of Roboticshas described several factors that are required to be considered in gripper selection and design.

- The gripper must have the ability to reach the surface of a workpart.
- The change in work part size must be accounted for providing accuratepositioning.
- During machining operations, there will be a change in the work part size. As a result, the gripper must be designed to hold a work part even when the size isvaried.
- The gripper must not create any sort of distort and scratch in the fragile workparts.
- The gripper must hold the larger area of a work part if it has various dimensions, which will certainly increase stability and control inpositioning.
- The gripper can be designed with resilient pads to provide more grasping contacts in the work part. The replaceable fingers can also be employed for holding different work part sizes by its interchangeabilityfacility.

Moreover, it is difficult to find out the magnitude of gripping force that a gripper must apply to pick up a work part. The following significant factors must be considered to determine the necessary gripping force.

- Consideration must be taken to the weight of a workpart.
- It must be capable of grasping the work parts constantly at its centre ofmass.
- The speed of robot arm movement and the connection between the direction of movement and gripper position on the work part should beconsidered.
- It must determine either friction or physical constriction helps to grip the workpart.
- It must consider the co-efficient of friction between the gripper and workpart.

5. POST MCQ TEST:

1. The “End-effector” of a robot

   a. can be an actual tool

   b. is the robot “hand”

   c. may have a gripping action

   d. All of the above

   Ans:d

2. A program language:

   A. defines the form of the instruction

   B. is always machine dependent

   C. is never machine dependent

   D. All of the above

   Ans:A

3. Which of the following symbol modes are used to input of graphics to General CAD system?

   A. Live and Rectangle mode

   B. Arc and Circle mode

   C. Dimension and Alphanumeric mode

   D. All of the above

   Ans:D

4. Which technique enables the designer to mold and shape, rather than construct on object using a series of lines?

   A. Solid modeling

   B. Wire-frame modeling

   C. Surface modeling

   D. FEM (Finite Element Modeling)

   Ans:A

5. Computer-based controllers:

A. should be built in a modular fashion wherever possible

B. are very difficult to change

C. are very flexible

D. (a) and (c) above

Ans:D

6. CONCLUSION

Understood basics of robotic end-effectors.

Understood the concept of grippers in robotics.

7. REFERENCES

1. Mikell.P.Groover,"Industrial Robotics-Technology, Programming and Applications", McGraw Hill, second edition 2012.
2. Advanced Robotics and Intelligent Machines J.O.Grey:D.G.by John J.Craig.

8. VIDEOS

https://www.robotics.org/content-detail.cfm/Industrial-Robotics-Videos/Robotic-Grippers-at-RobotWorx/content_id/2692

9. ASSIGNMENTS

State therobot gripper working principles with example.

Course Material

Name of the Course : **ROBOTICS AND AUTOMATION**

Name of the Unit :**ROBOT KINEMATICS**

Name of the Topic :Forward Kinematics, Inverse Kinematics and the difference, Forward Kinematics and Inverse Kinematics of manipulators with two, three degrees or freedom (in two dimensional), four degrees of freedom (in three dimensional) – derivations. Homogenous transformation matrix, translational and rotational matrix, Denavit&Hartenberg representation.

1. **AIM AND OBJECTIVES**: To develop ideas onRobot Kinematics.

2. **PRETEST- MCQ**

   1. The technical name of a hand attached to the wrist of the robot
      a. Gripper
      b. End-effector
      c. Joint
      d. Any of the above

      Answer: b
   2. For a robot unit to be considered a functional industrial robot, typically, how many degrees of freedom would the robot have?
      a. three
      b. four
      c. eight
      d. six

      Answer: d
   3. Which of the basic parts of a robot unit would include the computer circuitry that could be programmed to determine what the robot would do?
      a. controller
      b. sensor
      c. arm
      d. end effector

      Answer:a
   4. ________ terms refers to the use of compressed gasses to drive (power) the robot device?
      a. hydraulic
      b. piezoelectric
      c. photosensitive
      d. pneumatic

      Answer:d
   5. ___________ terms IS NOT one of the five basic parts of a robot?
      a. end effectors
      b. controller
      c. drive
      d. peripheral tools

      Answer: d

3. PRE-REQUISITES:

To have a basic knowledge of robotics drive systemand end effectors.

4. THEORY:

ForwardKinematics

A manipulator is composed of serial links which are affixed to each other revolute or prismatic joints from the base frame through the end-effector. Calculating the position and orientation of the end-effector in terms of the joint variables is called as forward kinematics. In order to have forward kinematics for a robot mechanism in a systematic manner, one should use a suitable kinematics model. Denavit-Hartenberg method that uses four parameters is the most common method for describing the robot kinematics. These parameters ai-1, α −1i , di and θi are the link length, link twist, link offset and joint angle, respectively. A coordinate frame is attached to each joint to determine DH parameters. Zi axis of the coordinate frame is pointing along the rotary or sliding direction generalmanipulator.

InverseKinematics

The inverse kinematics problem of the serial manipulators has been studied for many decades. It is needed in the control of manipulators. Solving the inverse kinematics is computationally expansive and generally takes a very long time in the real time control of manipulators. Tasks to be performed by a manipulator are in the Cartesian space, whereas actuators work in joint space. Cartesian space includes orientation matrix and position vector. However, joint space is represented by joint angles. The conversion of the position and orientation of a manipulator end-effector from Cartesian space to joint space is called as inverse kinematics problem. There are two solutions approaches namely, geometric and algebraic used for deriving the inverse kinematics solution, analytically. Let's start with geometric approach.

TeachPendant

A Control Box For Programming The Motions Of A Robot. Also Called A "Teach Box," The Robot Is Set To "Learning" Or "Teach" Mode, And The Pendant Is Used To Control The Robot Step By Step. Teach Pendants Are Typically Handheld Devices And May Be Wired Or Wireless.

Robot Programming

According to the consistent performance by the robots in industries, the robot programming can be divided in two common types such as:

- Leadthrough ProgrammingMethod
- Textual RobotLanguages

Leadthrough ProgrammingMethod:

During this programming method, the traveling of robots is based on the desired movements, and it is stored in the external controller memory. There are two modes of a control system in this method such as a run mode and teach mode. The program is taught in the teach mode, and it is executed in the run mode. The leadthrough programming method can be done by two methods namely:

Powered LeadthroughMethod

Manual LeadthroughMethod

a) Powered LeadthroughMethod:

The powered leadthrough is the *common* programming method in the industries. A *teach pendant* is incorporated in this method for controlling the motors available in the joints. It is also used to operate the robot wrist and arm through a sequence of points. The playback of an operation is done by recording these points. The control of complex geometric moves is *difficult*to perform in the teach pendant. As a result, this method is good for *point to point* movements. Some of the key applications are spot welding, machine loading & unloading, and part transferprocess.

b) Manual LeadthroughMethod:

In this method, the robot's *end effector* is moved physically by the programmer at the desired movements. Sometimes, it may be difficult to move large robot arm manually. To get rid of it a*teach button* is implemented in the wrist for special programming. The manual leadthrough method is also known as *Walk Through method*. It is mainly used to perform continuous path movements. This method is best for spray painting and arc welding operations.

Textual Robot Languages:

In 1973, WAVE language was developed, and it is the first textual robot language as well. It is used to interface the machine vision system with the robot. Then AL language was introduced in 1974 for controlling multiple robot arms during arm coordination. VAL was nvented in 1979, and it is the common textual robot language. Later, this language was dated in 1984, and called as VAL II. The IBM Corporation has established their two own languages such as AMLand AUTOPASS, which is used for the assemblyoperations.
Other important textual robot languages are Manufacturing Control Language (MCL), RAIL, and Automatic Programmed Tooling (APT) languages.

Robot ProgrammingMethods

There are three basic methods for programming industrial robots but currently over 90% are programmed using the teach method.

Teach Method

The logic for the program can be generated either using a menu based system or simply using a text editor but the main characteristic of this method is the means by which the robot is taught the positional data. A teach pendant with controls to drive the robot in a number of different co-ordinate systems is used to manually drive the robot to the desired locations.

These locations are then stored with names that can be used within the robot program. The co-ordinate systems available on a standard jointed arm robot are:-

Joint*Co-ordinates*

The robot joints are driven independently in either direction.

GlobalCo-ordinates

The tool centre point of the robot can be driven along the X, Y or Z axes of the robots global axis system. Rotations of the tool around these axes can also be performed

ToolCo-ordinates

Similar to the global co-ordinate system but the axes of this one are attached to the tool centre point of the robot and therefore move with it. This system is especially useful when the tool is near to the workpiece.

WorkpieceCo-ordinates

With many robots it is possible to set up a co-ordinate system at any point within the working area. These can be especially useful where small adjustments to the program are required as it is easier to make them along a major axis of the co-ordinate system than along a general line. The effect of this is similar to moving the position and orientation of the global co-ordinatesystem.

This method of programming is very simple to use where simple movements are required. It does have the disadvantage that the robot can be out of production for a long time during reprogramming. While this is not a problem where robots do the same task for their entire life, this is becoming less common and some robotic welding systems are performing tasks only a few times before beingreprogrammed.

Lead Through

This system of programming was initially popular but has now almost disappeared. It is still however used by many paint spraying robots. The robot is programmed by being physically moved through the task by an operator. This is exceedingly difficult where large robots are being used and sometimes a smaller version of the robot is used for this purpose. Any hesitations or inaccuracies that are introduced into the program cannot be edited out easily without reprogramming the whole task. The robot controller simply records the joint positions at a fixed time interval and then plays this back.

Off-line Programming

Similar to the way in which CAD systems are being used to generate NC programs for milling machines it is also possible to program robots from CAD data. The CAD models of the components are used along with models of the robots being used and the fixturing required. The program structure is built up in much the same way as for teach programming but intelligent tools are available which allow the CAD data to be used to generate sequences of location and process information. At present there are only a few companies using this technology as it is still in its infancy but its use is increasing each year. The benefits of this form of programmingare:-

- Reduced down time forprogramming.
- Programming tools make programmingeasier.
- Enables concurrent engineering and reduces product leadtime.
- Assists cell design and allows processoptimisation

Programming Languages forRobotics

This article is all about giving an introduction about some of the programming languages which are used to design Robots.

There are many programming languages which we use while building Robots, we have a few programming languages which we always prefer to use in designing. Actually the programming languages which we use mainly depend on the hardware one is using in building robots.

Some of them are- URBI, C and BASIC. URBI is an open source language. In this article we will try to know more about these languages. Let's start with URBI.

URBI : URBI stands for Universal Real-time Behavior Interface. It is a client/server based interpreted language in which Robot works as a client and controller as a server. It makes us to learn about the commands which we give to Robots and receive messages from them. The interpreter and wrapped server are called as "URBI Engine". The URBI Engine uses commands from Client and receives messages to it. This language allows user to work on basic Perception-action principle. The users just have to write some simple loops on the basis of this principle directly in URBI.

PYTHON : There is another language which is used in designing Robots. Python is an object-oriented language which is used to access and control Robots. Python is an interpreted language; this language has an application in working with mobile robots, particularly those manufactured by different companies. With python it is possible to use a single program for controlling many different robots. However Python is slower than C++ but it has some good sides as well as it proved very easy to interact with robots using this language, it is highly portable and can be run in windows and MAC OSX plus it can easily be extendable using C and C++ language. Python is a very reliable language for string manipulation and textprocessing.

ROBOTC : Other Languages which we use are C, C++ and C # etc. or their implementation, like ROBOTC, ROBOTC is an implementation of C language. If we are designing a simple Robot, we do not need assembly code, but in complex designing we need well-defined codes.ROBOTC is another programming language which is C-based. It is actually a text based programming language. The commands which we want to give to our Robot, first written on the screen in the form of simple text, now as we know that Robot is a kind of machine and a machine only understands machine language. So these commands need to be converted in machine language so that robot can easily understand and do whatever it is instructed to do.Although commands are given in text form (called as codes) but this language is very specific about the commands which is provided as instruction. If we do even a minor change in given text it will not accept it as command. If the command which is provided to it is correct it colorizes that text, and we came to know that the given command in text form is correct (as we have shown in our example given below). Programming done in ROBOTC is very easy to do. Commands given are very straightforward. Like if we want our robot to switch on any hardwarepart, we just have to give code regarding to that action in text form. Suppose we want robot to turn motor of port, we just have to give command in this way:

Although program above is not exactly shown in the way in which it should be written, this is just to provide you a visualization of what we have told you. This is not written in an appropriate manner.ROBOTC provide advantage of speed, a Robot programmed in ROBOTC programming supports 45 times more speed than provided by other programming based on C plus it has a very powerful debuggingfeature.

ROBOTICS.NXT :

ROBOTICS.NXT has a support for a simple message-based control. It direct commands, nxt-upload is one of its programs which is used to upload any file. It works on Linux. After getting introduction on programming languages, it becomes necessary to know something about MRDS as well, MRDS is an environment which is designed especially for controlling robots.

Microsoft Robotics Developer Studio:

Microsoft Robotics Developer Studio is an environment given for simulation purpose of Robots. It is based on a .net library concurrent implementation. This environment has support so that we can add other services as well. It has features which not only include creating and debugging Robot Applications but also it becomes easy to interact with sensors directly. C# programming language is used as a primary language in it. It has 4 main components:

Â· Concurrency and coordination Runtime (CCR)

Â· Decentralized software services(DSS)

Â· Visual Programming Language(VPL)

Â· Visual simulation environment(VSE)

Concurrency and coordination Runtime is a synchronous programming library based on .net framework. Although it is a component of MRDS but it can be used with any application. DSS is also a .net runtime environment, In DSS services are exposed as resources which one can access through programs. DSS uses DSSP (Decentralizes software services protocol) and HTTP.

If we want to graphics and visual effects in our programming, we use VPL. Visual Programming language is a programming language which allows us to create programs by doing manipulations in programming languages graphically. We use boxes and arrows in this kind of programming while we want to show dataflow kind of things.

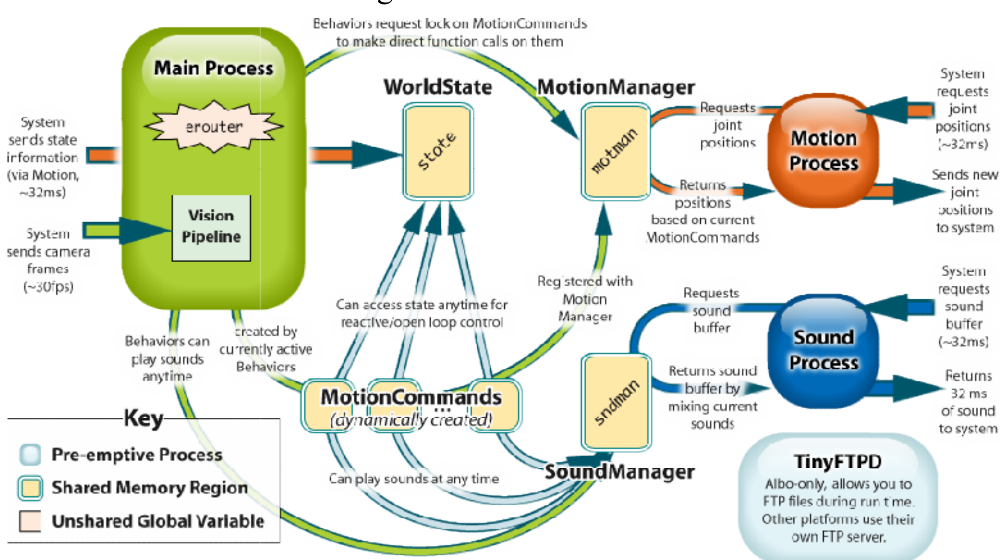
Visual programming language has huge application in animations. ThelastcomponentwhichwearegoingtodescribeisVisualSimulationEnvironment.VSEprovides simulates physical objects. VisualSimulationenvironmentisanintegrated environment for picture-based, object oriented and component based applicationsof simulation. Programming in robotics is a very vast topic that we cant cover in asingle article. Thisisjust an introduction for those who want to get an idea about using languages in building ofrobots

Motion Commands and the Control ofEffectors

Real-time systems are slaves to the clock. They achieve the illusion of smooth behavior by rapidly updating a set of control signals many times per second. For example, to smoothly turn a robot's head to the right, the head must accelerate, travel at constant velocity for a while, and then decelerate. This is accomplished by making many small adjustments to the motor torques. Another example: to get the robot's LEDs to blink repeatedly, they must be turned on for a certain period of time, then turned off for another length of time, and so forth. To get them to glow steadily at medium intensity, they must be turned on and off veryrapidly.

The robot's operating system updates the states of all the effectors (servos, motors, LEDs, etc.) every few milliseconds. Each update is called a "frame", and can accommodate simultaneous changes to any number of effectors. On the AIBO, updates occur every 8 milliseconds and frames are buffered four at a time, so the application must have a new buffer available every 32 milliseconds; other robots may use different update intervals. In Tekkotsu these buffers of frames are produced by the MotionManager, whose job is to execute a collection of simultaneously active MotionCommands (MCs) of various types every few milliseconds. The results of these MotionCommands are assembled into a buffer that is passed to the operating system (Aperios for the AIBO, or Linux for otherrobots).

Suppose we want the robot to blink its LEDs on and off at a rate of once per second. What we need is a MotionCommand that will calculate new states for the LEDs each time the MotionManager asks for an update. LedMC, a subclass of both MotionCommand and LedEngine, performs this service. If we create an instance of LedMC, tell it the frequency at which to blink the LEDs, and add it to the MotionManager's list of active MCs, then it will do all the work for us. There's just one catch: our application is running in the Main process, while the MotionManager runs in a separate Motion process. This is necessary to assure that potentially lengthy computations taking place in Main don't prevent Motion from running every few milliseconds. So how can we communicate with our MotionCommand while at the same time making it available to the MotionManager?



The solution is to construct MotionCommands in a memory region that is shared by both processes. Because we have continuous access to the MotionCommand, we can change its parameters even while it's active, to tell it to do different things. But it's dangerous to modify a MotionCommand while the MotionManager is in the midst of invoking it. Therefore, Tekkotsu provides a mutual exclusion mechanism called an MMAccessor that temporarily locks out the MotionManager when we need to invoke a MotionCommand's member functions from within

Main. Whenever we want to call such functions, we must lock down the MotionCommand by creating an MMAccessor first. Destroying the MMAccessor unlocks theMotionCommand.

There is one remaining wrinkle to the story. When a MotionCommand is passed to the MotionManager, it is assigned a unique ID called an MC_ID that identifies it within the MotionManager's active list. To lock the MotionCommand, we must pass this MC_ID value to the MMAccessor constructor. The MC_ID is also used when we tell the MotionManager to remove this MotionCommand from its active list. So the MC_ID must be saved somewhere. Normally it is kept in a protected data member within the Behavior instance so it can be shared by the doStart, doStop, and doEventmethods.

To summarize: MotionCommands must be instantiated in shared memory. An MC_ID, which is typically stored locally in the Behavior (not in shared memory), uniquely identifies the MotionCommand within the MotionManager's active list. Certain member functions of the MotionCommand will be called repeatedly from within the Motion process, by the MotionManager, to compute updated effector states. An MMAccessor, created in Main using the MC_ID, must be used to lock down an active MotionCommand so we can safely call its member functions from within the Main process. Translational and rotational matrix, Denavit&Hartenberg representation.

1.Derive the forward and reverse transformation of 2-Degree offreedom and 3- degree offreedomarm.

Forward Transformation of a 2-Degree of Freedom Arm

We can determine the position of the end of the arm in world space by defining a vector for link 1 and another for link 2.

$$\mathbf{r}_1 = [L_1 \cos\theta_1, L_1 \sin\theta_1] \quad (4\text{-}1)$$

$$\mathbf{r}_2 = [L_2 \cos(\theta_1 + \theta_2), L_2 \sin(\theta_1 + \theta_2)] \quad (4\text{-}2)$$

Vector addition of (4-1) and (4-2) yields the coordinates x and y of the end of the arm (point P_w) in world space

$$x = L_1 \cos\theta_1 + L_2 \cos(\theta_1 + \theta_2) \quad (4\text{-}3)$$

$$y = L_1 \sin\theta_1 + L_2 \sin(\theta_1 + \theta_2) \quad (4\text{-}4)$$

Reverse Transformation of the 2-Degree of Freedom Arm

In many cases it is more important to be able to derive the joint angles given the end-of-arm position in world space. The typical situation is where the robot's controller must compute the joint angles required to move its end-of-arm to a point in space defined by the point's coordinates. For the two-link manipulator we have developed, there are two possible configurations for reaching the point (x, y), as shown in Fig. 4-3. Some strategy must be developed to select the appropriate configuration. One approach is that employed in the control system of the Unimate PUMA robot. In the PUMA's control language, VAL, there is a set of commands called ABOVE and BELOW that determines whether the elbow is to make an angle θ_2 that is greater than or less than zero, as illustrated in Fig. 4-3. For our example, let us assume the θ_2 is positive as shown in Fig. 4-2. Using the trigonometric identities,

$$\cos(A + B) = \cos A \cos B - \sin A \sin B$$

$$\sin(A + B) = \sin A \cos B + \sin B \cos A$$

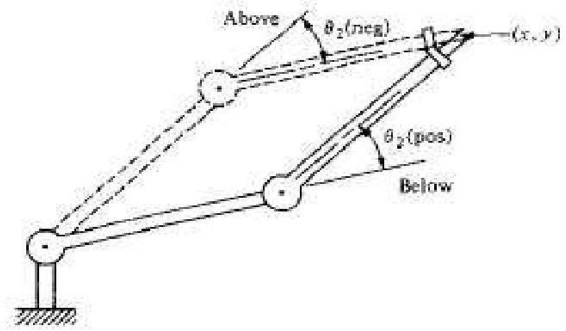


Figure 4-3 The arm at point $P(x, y)$, indicating two possible configurations to achieve the position.

we can rewrite Eqs. (4-3) and (4-4) as

$$x = L_1 \cos\theta_1 + L_2 \cos\theta_1 \cos\theta_2 - L_2 \sin\theta_1 \sin\theta_2$$
$$y = L_1 \sin\theta_1 + L_2 \sin\theta_1 \cos\theta_2 + L_2 \cos\theta_1 \sin\theta_2$$

Squaring both sides and adding the two equations yields

$$\cos\theta_2 = \frac{x^2 + y^2 - L_1^2 - L_2^2}{2L_1L_2} \tag{4-5}$$

Defining α and β as in Fig. 4-4 we get

$$\tan\alpha = \frac{L_2 \sin\theta_2}{L_2 \cos\theta_2 + L_1}$$
$$\tan\beta = \frac{y}{x} \tag{4-6}$$

Using the trigonometric identity

$$\tan(A - B) = \frac{\tan A - \tan B}{1 + \tan A \tan B}$$

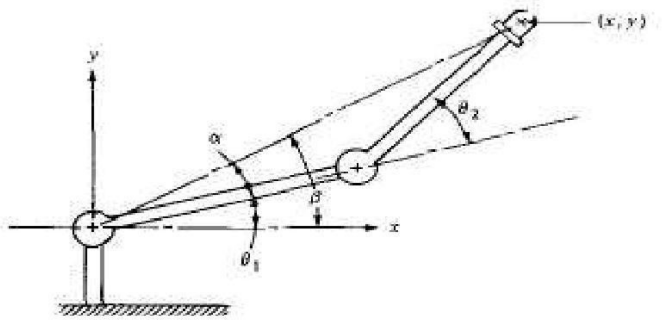


Figure 4-4 Solving for the joint angles.

we get

$$\tan\theta_1 = \frac{[y(L_1 + L_2 \cos\theta_2) - xL_2 \sin\theta_2]}{[x(L_1 + L_2 \cos\theta_2) + yL_2 \sin\theta_2]} \tag{4-7}$$

Knowing the link lengths L_1 and L_2 we are now able to calculate the required joint angles to place the arm at a position (x, y) in world space.

Adding Orientation: A 3-Degree of Freedom Arm in (2D) Two Dimension

The arm we have been modeling is very simple; a two-jointed robot arm has little practical value except for very simple tasks. Let us add to the manipulator a modest capability for orienting as well as positioning a part or tool. Accordingly, we will incorporate a third degree of freedom into the previous configuration to develop the RR:R manipulator shown in Fig. 4-5. This third degree of freedom will represent a wrist joint. The world space coordinates for the wrist end would

$$\left.\begin{aligned} x &= L_1 \cos\theta_1 + L_2\cos(\theta_1+\theta_2) + L_3\cos(\theta_1+\theta_2+\theta_3) \\ y &= L_1 \sin\theta_1 + L_2\sin(\theta_1+\theta_2) + L_3\sin(\theta_1+\theta_2+\theta_3) \\ \psi &= (\theta_1+\theta_2+\theta_3) \end{aligned}\right\} \quad (4\text{-}8)$$

We can use the results that we have already obtained for the 2-degree of freedom manipulator to do the reverse transformation for the 3-degree of freedom arm. When defining the position of the end of the arm we will use x, y, and ψ. The angle ψ is the orientation angle for the wrist. Given these three values, we can solve for the joint angles (θ_1, θ_2, and θ_3) using

$$x_3 = x - L_3\cos\psi$$

$$y_3 = y - L_3\sin\psi$$

Having determined the position of joint 3, the problem of determining θ_1 and

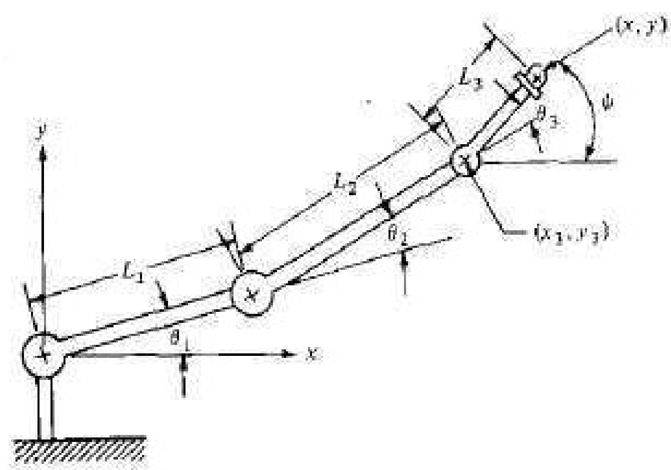


Figure 4-5 The two-dimensional 3 degree-of-freedom manipulator with orientation (type RR:R).

be.

θ_2 reduces to the case of the 2-degree of freedom manipulator previously analyzed.

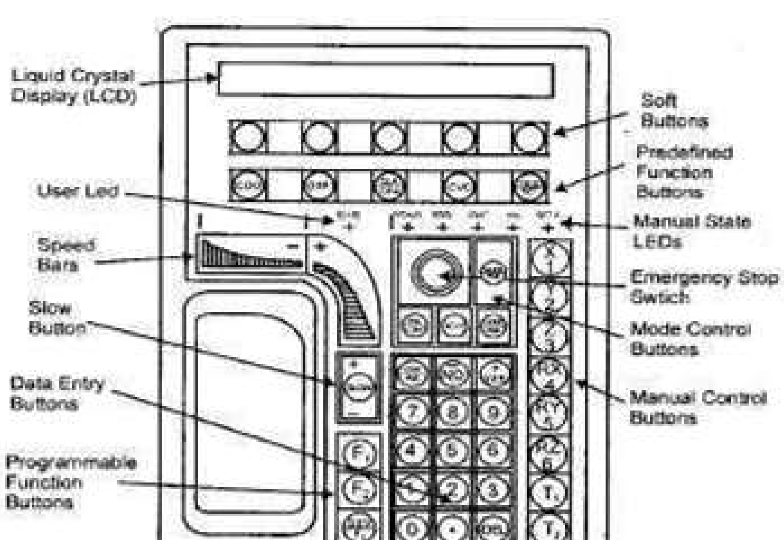
2. **Teach pendant forRobotsystem**

The teach pendant has the following primary functions:

- Serve as the primary point of control for initiating andmonitoringoperations. Guide the robot or motion device, while teachinglocations.
- Support applicationprograms.
- The Teach Pendant is used with a robot or motion device primarily toteach.

Robot locations for use: in application programs.

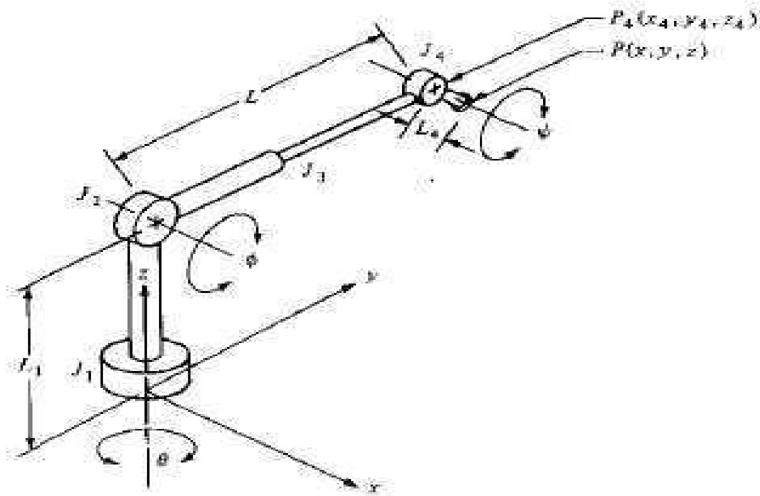
- The Teach Pendant is also used with custom. Applications that employ ―teach routine's that pause execution at specified points and allow an Operator to teach * re- teach the robot locations used by the program.
- There are two styles of Teach Pendants: the programmer‘s pendant, which is designed for use while an application is being written and debugged, and the operator‘s pendant, which is designed for use during normal system operation.
- The operator‘s pendant has a palm-activated switch, which is connected to the remote emergency stop circuitry of the controller.
- Whenever this switch is released, arm power is removed from the motion device.
- To operate the Teach Pendant left hand is put through the opening on the left-hand side of the pendant and the left thumb is used to operate the pendant speed bars.
- The right hand is used for all the other function buttons.



Derive the expression for direct and inverse kinematics of 4 degrees of freedom robot manipulator.

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; and joint 4 is a type R joint which allows rotation about an axis that is parallel



to the joint 2 axis. Thus, we have a TRL: R manipulator.

Let us define the angle of rotation of joint I to be the base rotation 0; the angle of rotation of joint 2 will be called the elevation angle 4.; the length of linear joint 3 will be called the extension L (L-represents a combination of links 2 and 3); and the angle that joint 4 makes with the x — y plane will be called the pitch angle 4.

The position of the end of the wrist, P, defined in the world coordinate system for the robot, is given by

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,

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

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

$$z_4 = z - L_4 \sin\psi \tag{4-14}$$

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

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

$$\sin\phi = \frac{z_4 - L_1}{L} \tag{4-16}$$

$$\cos\theta = \frac{y_4}{L} \tag{4-17}$$

The example we have just done is simple but not unrealistic. In order for a robot controller to be able to perform the calculations necessary quickly enough to maintain good performance they must be kept as simple as possible. The manipulator kinematics described in this example are very similar to those of the MAKER robot, by U.S. Robots. The only real difference is that the MAKER's wrist mechanism has more than a single joint.

One facet of our approach in the preceding analysis which should be noted by the reader is that we separated the orientation problem from the positioning problem. This approach of separating the two problems greatly simplifies the task of arriving at a solution.

5. POST MCQ TEST:

1.__ space trajectories are computationally extensive, and require a faster processing time.

(a) Joint

(b) Cartesian

(c) a& b

(d) none

Ans: [b]

2. An N-joint manipulator will have…………number of trajectory segments.

(a) 3N

(b) 5N

(c) (a) and (b)

(d) none of the above

Ans:c

3. Mathematical functions used in trajectory planning problems.

(a) Fourier

(b) Laplace

(c) Polynomial

(d) all the above.

Ans:a

4.________ schemes can be used in joint-space trajectory planning.

(a) Third- order polynomial

(b) fifth- order polynomial

(c) a& b

(d) none

Ans:c

5. Third-degree polynomial can be used with __________ number of constraint s.

(a) 1

(b) 2

(c) 3

(d) 4

Ans:d

6. CONCLUSION

Understood the concept ofrobot kinematics.

Understood the concept of robot degrees of freedom.

7. REFERENCES

1. Mikell.P.Groover,"Industrial Robotics-Technology, Programming and Applications", McGraw Hill, second edition 2012.
2. Advanced Robotics and Intelligent Machines J.O.Grey:D.G.by John J.Craig.

8. VIDEOS

https://www.youtube.com/watch?v=wcy0Y3Jgf14

9. ASSIGNMENTS

State therobot degrees of freedom principles with example.

Course Material

Name of the Course : **ROBOTICS AND AUTOMATION**

Name of the Unit :**ROBOT PROGRAMMING**

Name of the Topic :Teach pendant programming, Lead through programming, Robot languages: VAL Programming, Motion command, Sensor command, End Effectors command. RGV, AGV, Implementation of robots in industries, various steps, Safety considerations for robot operations. Economic analysis of robots: Pay back methods, EUAC method and Rate of return method.

1. **AIM AND OBJECTIVES**: To develop ideas onRobot Programming

2. **PRETEST- MCQ.**

1. If the orientation changes without the change of position then the transformation is ___
(a) Pure translation
(b) pure rotation
(c) Combined transformation
(d)none
Ans:b

2. ____________ can be considered as Differential motions of a frame.

(a) Differential translations

(b) differential rotations

(c) Differential transformations

(d) a, b, & c

Ans:d

3. The matrix representing the Euler angles orientation change is ___________

(a) Rot(a,)Rot(o,Rot(a,ψşφ

(b) Rot(o,ş)

(c)Rot(a,)Rot(a,Rot(o,ψφş

(d) none

Ans:a

4. Following is the robotic like device.

(a) Telecherics

(b) exo-skeleton

(c) locomotive device

(d) all the above

Ans:a

5. Number of linear co-ordinates in a cylindrical co-ordinate robot.

(a) 2

(b) 3

(c) 1

(d) 0 45.

Ans:a

3. PRE-REQUISITES:

To have a basic knowledge of robotics drive systemand kinematics.

4. THEORY:

TeachPendant

A Control Box For Programming The Motions Of A Robot. Also Called A "Teach Box," The Robot Is Set To "Learning" Or "Teach" Mode, And The Pendant Is Used To Control The Robot Step By Step. Teach Pendants Are Typically Handheld Devices And May Be Wired Or Wireless.

Robot Programming

According to the consistent performance by the robots in industries, the robot programming can be divided in two common types such as:

- Leadthrough ProgrammingMethod
- Textual RobotLanguages

Leadthrough ProgrammingMethod:

During this programming method, the traveling of robots is based on the desired movements, and it is stored in the external controller memory. There are two modes of a control system in this method such as a run mode and teach mode. The program is taught in the teach mode, and it is executed in the run mode. The leadthrough programming method can be done by two methods namely:

Powered LeadthroughMethod

Manual LeadthroughMethod

a) Powered LeadthroughMethod:

The powered leadthrough is the *common* programming method in the industries. A *teach pendant* is incorporated in this method for controlling the motors available in the joints. It is also used to operate the robot wrist and arm through a sequence of points. The playback of an operation is done by recording these points. The control of complex geometric moves is *difficult*to perform in the teach pendant. As a result, this method is good for *point to point* movements. Some of the key applications are spot welding, machine loading & unloading, and part transferprocess.

b) Manual LeadthroughMethod:

In this method, the robot's *end effector* is moved physically by the programmer at the desired movements. Sometimes, it may be difficult to move large robot arm manually. To get rid of it a*teach button* is implemented in the wrist for special programming. The manual leadthrough method is also known as *Walk Through method*. It is mainly used to perform continuous path movements. This method is best for spray painting and arc welding operations.

Textual Robot Languages:

In 1973, WAVE language was developed, and it is the first textual robot language as well. It is used to interface the machine vision system with the robot. Then AL language was introduced in 1974 for controlling multiple robot arms during arm coordination. VAL was nvented in 1979, and it is the common textual robot language. Later, this language was dated in 1984, and called as VAL II. The IBM Corporation has established their two own languages such as AMLand AUTOPASS, which is used for the assemblyoperations.

Other important textual robot languages are Manufacturing Control Language (MCL), RAIL, and Automatic Programmed Tooling (APT) languages.

Robot ProgrammingMethods

There are three basic methods for programming industrial robots but currently over 90% are programmed using the teach method.

Teach Method

The logic for the program can be generated either using a menu based system or simply using a text editor but the main characteristic of this method is the means by which the robot is taught the positional data. A teach pendant with controls to drive the robot in a number of different co-ordinate systems is used to manually drive the robot to the desired locations.

These locations are then stored with names that can be used within the robot program.

The co-ordinate systems available on a standard jointed arm robot are:-

Joint*Co-ordinates*

The robot joints are driven independently in either direction.

GlobalCo-ordinates

The tool centre point of the robot can be driven along the X, Y or Z axes of the robots global axis system. Rotations of the tool around these axes can also be performed

ToolCo-ordinates

Similar to the global co-ordinate system but the axes of this one are attached to the tool centre point of the robot and therefore move with it. This system is especially useful when the tool is near to the workpiece.

WorkpieceCo-ordinates

With many robots it is possible to set up a co-ordinate system at any point within the working area. These can be especially useful where small adjustments to the program are required as it is easier to make them along a major axis of the co-ordinate system than along a general line. The effect of this is similar to moving the position and orientation of the global co- ordinatesystem.

This method of programming is very simple to use where simple movements are required. It does have the disadvantage that the robot can be out of production for a long time during reprogramming. While this is not a problem where robots do the same task for their entire life, this is becoming less common and some robotic welding systems are performing tasks only a few times before beingreprogrammed.

Lead Through

This system of programming was initially popular but has now almost disappeared. It is still however used by many paint spraying robots. The robot is programmed by being physically moved through the task by an operator. This is exceedingly difficult where large robots are being used and sometimes a smaller version of the robot is used for this purpose. Any hesitations or inaccuracies that are introduced into the program cannot be edited out easily without reprogramming the whole task. The robot controller simply records the joint positions at a fixed time interval and then plays this back.

Off-line Programming

Similar to the way in which CAD systems are being used to generate NC programs for milling machines it is also possible to program robots from CAD data. The CAD models of the components are used along with models of the robots being used and the fixturing required. The program structure is built up in much the same way as for teach programming but intelligent tools are available which allow the CAD data to be used to generate sequences of location and process information. At present there are only a few companies using this technology as it is still in its infancy but its use is increasing each year. The benefits of this form of programmingare:-

- Reduced down time forprogramming.
- Programming tools make programmingeasier.
- Enables concurrent engineering and reduces product leadtime.
- Assists cell design and allows processoptimisation

Programming Languages forRobotics

This article is all about giving an introduction about some of the programming languages which are used to design Robots.

There are many programming languages which we use while building Robots, we have a few programming languages which we always prefer to use in designing. Actually the programming languages which we use mainly depend on the hardware one is using in building robots.

Some of them are- URBI, C and BASIC. URBI is an open source language. In this article we will try to know more about these languages. Let's start with URBI.

URBI : URBI stands for Universal Real-time Behavior Interface. It is a client/server based interpreted language in which Robot works as a client and controller as a server. It makes us to learn about the commands which we give to Robots and receive messages from them. The interpreter and wrapped server are called as "URBI Engine". The URBI Engine uses commands from Client and receives messages to it. This language allows user to work on basic Perception-action principle. The users just have to write some simple loops on the basis of this principle directly in URBI.

PYTHON : There is another language which is used in designing Robots. Python is an object- oriented language which is used to access and control Robots. Python is an interpreted language; this language has an application in working with mobile robots, particularly those manufactured by different companies. With python it is possible to use a single program for controlling many different robots. However

Python is slower than C++ but it has some good sides as well as it proved very easy to interact with robots using this language, it is highly portable and can be run in windows and MAC OSX plus it can easily be extendable using C and C++ language. Python is a very reliable language for string manipulation and textprocessing.

ROBOTC : Other Languages which we use are C, C++ and C # etc. or their implementation, like ROBOTC, ROBOTC is an implementation of C language. If we are designing a simple Robot, we do not need assembly code, but in complex designing we need well-defined codes.ROBOTC is another programming language which is C-based. It is actually a text based programming language. The commands which we want to give to our Robot, first written on the screen in the form of simple text, now as we know that Robot is a kind of machine and a machine only understands machine language. So these commands need to be converted in machine language so that robot can easily understand and do whatever it is instructed to do.Although commands are given in text form (called as codes) but this language is very specific about the commands which is provided as instruction. If we do even a minor change in given text it will not accept it as command. If the command which is provided to it is correct it colorizes that text, and we came to know that the given command in text form is correct (as we have shown in our example given below). Programming done in ROBOTC is very easy to do. Commands given are very straightforward. Like if we want our robot to switch on any hardwarepart, we just have to give code regarding to that action in text form. Suppose we want robot to
turn motor of port, we just have to give command in this way:

Although program above is not exactly shown in the way in which it should be written, this is just to provide you a visualization of what we have told you. This is not written in an appropriate manner.ROBOTC provide advantage of speed, a Robot programmed in ROBOTC programming supports 45 times more speed than provided by other programming based on C plus it has a very powerful debuggingfeature.

ROBOTICS.NXT :

ROBOTICS.NXT has a support for a simple message-based control. It direct commands, nxt- upload is one of its programs which is used to upload any file. It works on Linux. After getting introduction on programming languages, it becomes necessary to know something about MRDS as well, MRDS is an environment which is designed especially for controlling robots.

Microsoft Robotics Developer Studio:

Microsoft Robotics Developer Studio is an environment given for simulation purpose of Robots. It is based on a .net library concurrent implementation. This environment has support so that we can add other services as well. It has features which not only include creating and debugging Robot Applications but also it becomes easy to interact with sensors directly. C# programming language is used as a primary language in it. It has 4 main components:

Â· Concurrency and coordination

Runtime (CCR) Â· Decentralized

software services(DSS)

Â· Visual Programming

Language(VPL) Â· Visual

simulation environment(VSE)

Concurrency and coordination Runtime is a synchronous programming library based on .net framework. Although it is a component of MRDS but it can be used with any application. DSS is also a .net runtime environment, In DSS services are exposed as resources which one can access through programs. DSS uses DSSP (Decentralizes software services protocol) and HTTP.

If we want to graphics and visual effects in our programming, we use VPL. Visual Programming language is a programming language which allows us to create programs by doing manipulations in programming languages graphically. We use boxes and arrows in this kind of programming while we want to show dataflow kind of things.

Visual programming language has huge application in animations. ThelastcomponentwhichwearegoingtodescribeisVisualSimulationEnvironment.VSEprovides simulates physical objects.

VisualSimulationenvironmentisanintegrated environment for picture-based, object oriented and component based applicationsof simulation.

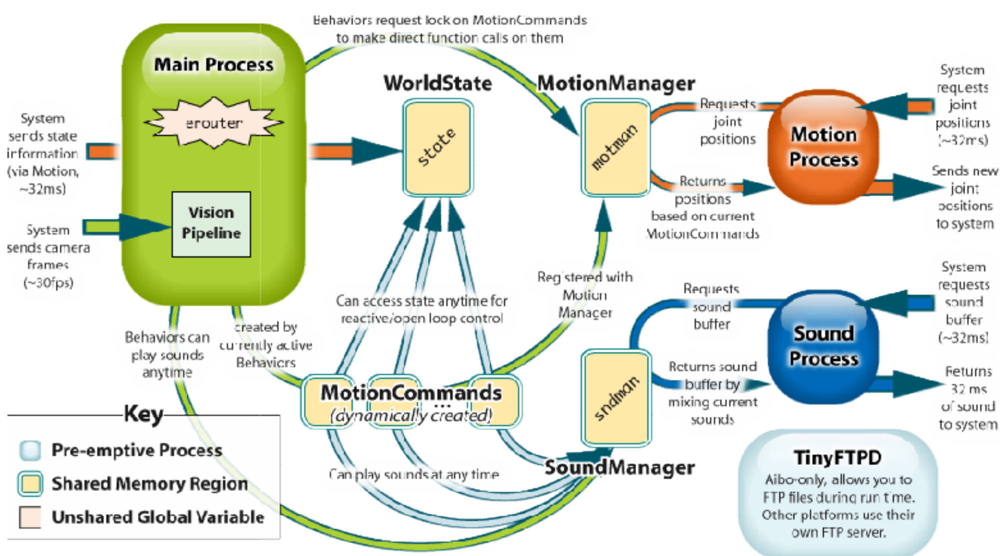
Programming in robotics is a very vast topic that we cant cover in asingle article. Thisisjust an introduction for those who want to get an idea about using languages in building ofrobots

Motion Commands and the Control ofEffectors

Real-time systems are slaves to the clock. They achieve the illusion of smooth behavior by rapidly updating a set of control signals many times per second. For example, to smoothly turn a robot's head to the right, the head must accelerate, travel at constant velocity for a while, and then decelerate. This is accomplished by making many small adjustments to the motor torques. Another example: to get the robot's LEDs to blink repeatedly, they must be turned on for a certain period of time, then turned off for another length of time, and so forth. To get them to glow steadily at medium intensity, they must be turned on and off veryrapidly.

The robot's operating system updates the states of all the effectors (servos, motors, LEDs, etc.) every few milliseconds. Each update is called a "frame", and can accommodate simultaneous changes to any number of effectors. On the AIBO, updates occur every 8 milliseconds and frames are buffered four at a time, so the application must have a new buffer available every 32 milliseconds; other robots may use different update intervals. In Tekkotsu these buffers of frames are produced by the MotionManager, whose job is to execute a collection of simultaneously active MotionCommands (MCs) of various types every few milliseconds. The results of these MotionCommands are assembled into a buffer that is passed to the operating system (Aperios for the AIBO, or Linux for otherrobots).

Suppose we want the robot to blink its LEDs on and off at a rate of once per second. What we need is a MotionCommand that will calculate new states for the LEDs each time the MotionManager asks for an update. LedMC, a subclass of both MotionCommand and
LedEngine, performs this service. If we create an instance of LedMC, tell it the frequency at which to blink the LEDs, and add it to the MotionManager's list of active MCs, then it will do all the work for us. There's just one catch: our application is running in the Main process, while the MotionManager runs in a separate Motion process. This is necessary to assure that potentially lengthy computations taking place in Main don't prevent Motion from running every few milliseconds. So how can we communicate with our MotionCommand while at the



same time making it available to the MotionManager?

The solution is to construct MotionCommands in a memory region that is shared by both processes. Because we have continuous access to the MotionCommand, we can change its parameters even while it's active, to tell it to do different things. But it's dangerous to modify a MotionCommand while the MotionManager is in the midst of invoking it. Therefore, Tekkotsu provides a mutual exclusion mechanism called an MMAccessor that temporarily locks out the MotionManager when we need to invoke a MotionCommand's member functions from within Main. Whenever we want to call such functions, we must lock down the MotionCommand by creating anMMAccessor first. Destroying the MMAccessorunlocks theMotionCommand.

There is one remaining wrinkle to the story. When a MotionCommand is passed to the MotionManager, it is assigned a unique ID called an MC_ID that identifies it within the MotionManager's active list. To lock the MotionCommand, we must pass this MC_ID value to the MMAccessor constructor. The MC_ID is also used when we tell the MotionManager to remove this MotionCommand from its active list. So the MC_ID must be saved somewhere. Normally it is kept in a protected data member within the Behavior instance so it can be shared by the doStart, doStop, and doEventmethods.
To summarize: MotionCommands must be instantiated in shared memory. An MC_ID, which is typically stored locally in the Behavior (not in shared memory), uniquely identifies the MotionCommand within the MotionManager's active list. Certain member functions of the MotionCommand will be called repeatedly from within the Motion process, by the MotionManager, to compute updated effector states. AnMMAccessor, created in Main using the MC_ID, must be used to lock down an active MotionCommand so we can safely call its member functions from within the Main process. Translational and rotational matrix, Denavit&Hartenberg representation.

5. POST MCQ TEST:

1. Based on finger movement, Mechanical gripper can be classified as __________
   a) Pivoting movement
   b)Linear or translational movement
   c) a& b
   d) None
   Ans:c

2. A Spherical coordinate robot should have ________ joints.
   (a) One revolute and two prismatic
   (b) Three prismatic
   (c) Two revolute and one prismatic
   (d) a, b& c
   Ans:c
3. Based on the coordinate system robots can be classified as_________ robots.
   (a) Cartesian
   (b) Spherical
   (c) Cylindrical
   (d) a, b& c

Ans:d

4).A manipulator with 6 DOF is ______________

(a) 1-D Manipulator

(b) 2-D Manipulator

(c) 3-D Manipulator

(d) Spatial Manipulator

Ans:d

5. Technology that is concerned with the use of mechanical, electronic and computer based systems in the operation and control of production.

(a) Mechanization

(b) Automation

(c) Industrialization.

(d) All the above

Ans:b

6. CONCLUSION

Understood the concept ofrobot programming.

7. REFERENCES

1. Mikell.P.Groover,"Industrial Robotics-Technology, Programming and Applications", McGraw Hill, second edition 2012.
2. Advanced Robotics and Intelligent Machines J.O.Grey:D.G.by John J.Craig.

8. VIDEOS

https://www.youtube.com/watch?v=wcy0Y3Jgf14

9. ASSIGNMENTS

State robot programming methods with example.