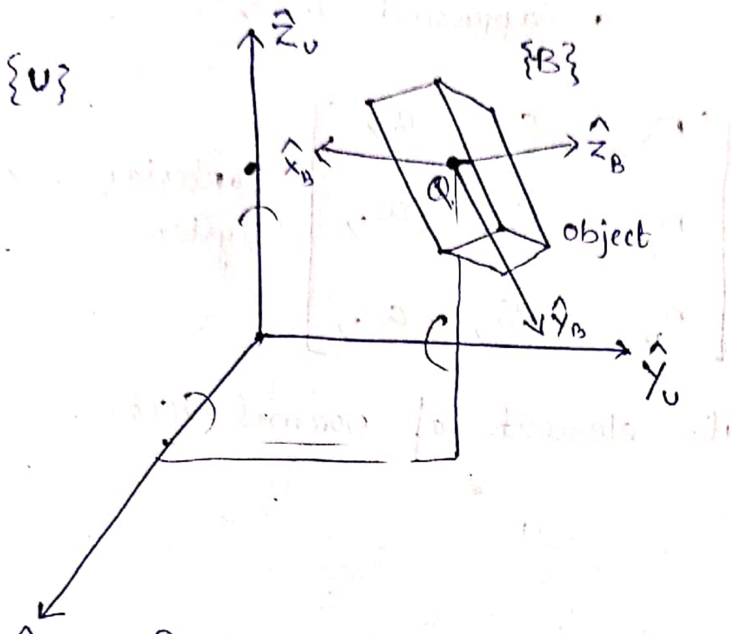
Robotics: Chapter 2.0

Robot Kinetics :-

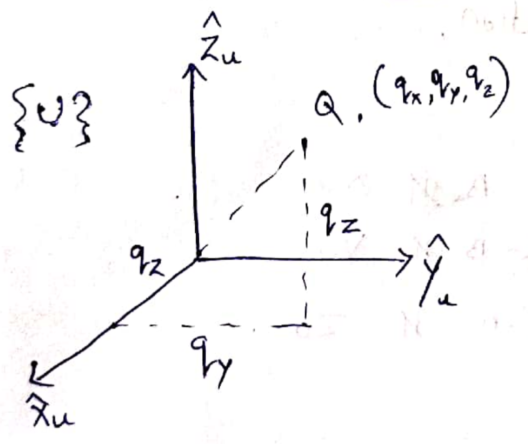
Mapping between Rotated Frames :-



- Mass centre = Q :
- Co-ordinate system = {B}
- Rotation/orientaiton = 3.

Rotation about x, y & z.

Representation of the position



Q w.r.t. U

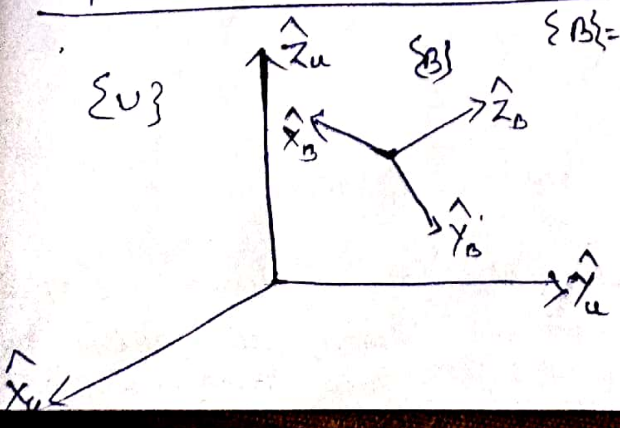
$$^{U}\bar{Q} = \begin{bmatrix} q_x \\ q_y \\ q_z \end{bmatrix}$$

3 x 1 matrix.

3 rows & 1 colum.

1 vector.

Representation of the Orientation



{B} = body co-ordinate systen. attach to the mass centre of the body.

X_B ∦ X_U
Y_B not parallel to Y_U
Z_B ∦ Z_U

} that means there has been some rotation.

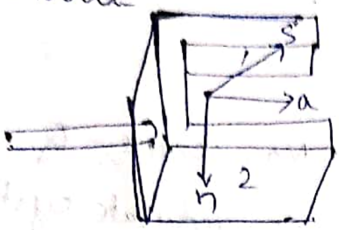
$$^{U}_{B}R = \left[{}^{U}\hat{X}_B ,\ {}^{U}\hat{Y}_B ,\ {}^{U}\hat{Z}_B \right]$$

3x3 matrix.

Rotation of B w.r.t U = ${}^{U}_{B}R$

3 vectors are $\hat{X}_B$, $\hat{Y}_B$, $\hat{Z}_B$

2 finger Gripper



n = normal vector
s = sliding "
a = approach "

$$\begin{bmatrix} n_x & s_x & a_x \\ n_y & s_y & a_y \\ n_y & s_y & a_y \end{bmatrix}$$ Cartesian co-ordinate System.

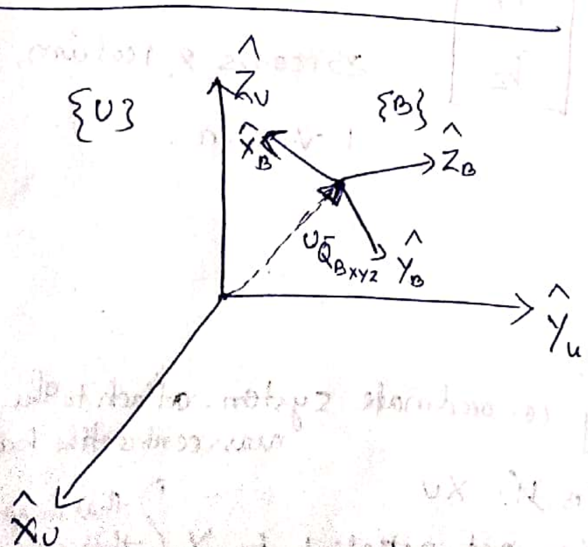
n_x, n_y, n_z are the elements of normal vector.

s_x, s_y, s_z " "

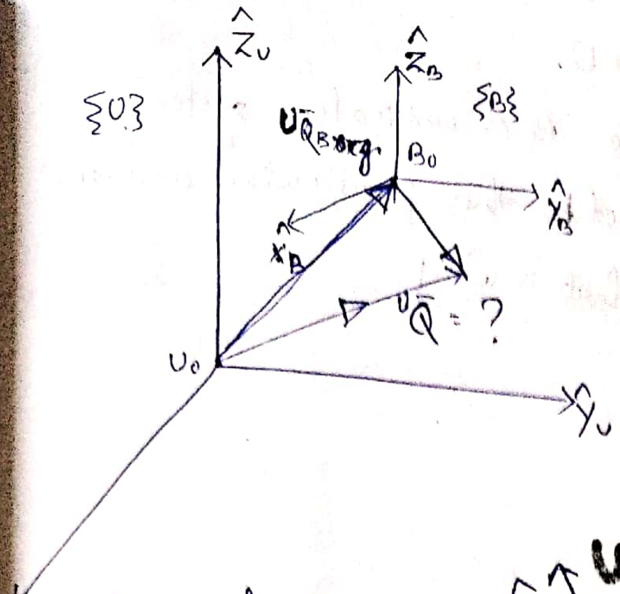
a_x, a_y, a_z, " "

Frame :- A set of four vectors which carrying position and orientation information.

Frame transformations



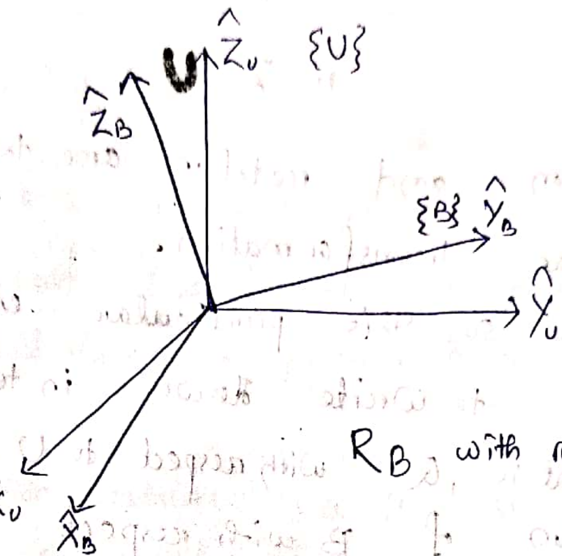
X-B ∥ X_U
Y-B ∥ Y_U
Z-B ∥ Z_U



$$^U\bar{Q} = {}^U\bar{Q}_{Borg} + {}^B\bar{Q}$$

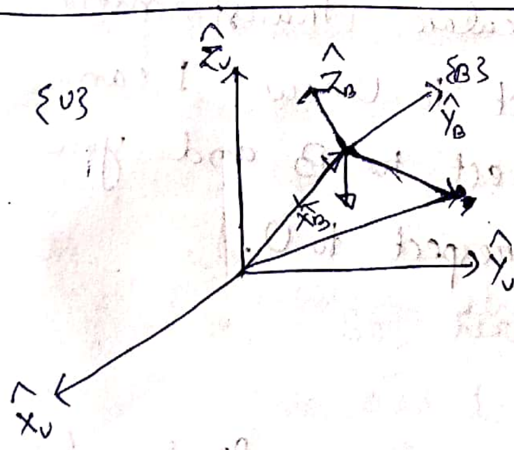
Rotation of a frame

$$^U\bar{Q} = {}^U_B R\, {}^B\bar{Q}$$



R_B with respect to U.

Translation and Rotation of a frame



$$^U\bar{Q} = {}^U_B R\, {}^B\bar{Q} + {}^U\bar{Q}_{Borg}$$

$$^U\bar{Q} = {}^U_B R\, {}^B\bar{Q} + {}^U\bar{Q}_{Borg}$$

$$\Rightarrow {}^U\bar{Q} = {}^U_B T\, {}^B\bar{Q}$$

X_B not parallel to X_U
Y_B " " Y_U
Z_B " " Z_U

Now I am just going to consider a more complicated situation, where I am just going to consider both translation as well as rotation and once again let me repeat that, this is the universal co-ordinate system; X-U, Y-U & Z-U and B is the body co-ordinate system, there has been some translation, that means, the origin has been shifted, so from here, to this particular point and this is actually the position vector, that is Q-B origin with respect to U.

And so, this particular B, the B co-ordinate system has got some rotation with respect to this particular universal co-ordinate system U and what is why,

X-B is not parallel to X-U,

Y-B " " Y-U

Z-B " " Z-U

So, translation and rotation are taken together inside this particular transformation.

Now, here so, this particular expression I am just going to write down in terms of the transformation matrix, that is, Q with respect to U is nothing but the transformation of B with respect to U.

So, in place of this rotation and this position now, I am using this particular transformation. Transformation of B with respect to U now I can multiply. So, this Q with respect to B and you will be getting this Q with respect to U.

$$^{U}\bar{Q} = {}^{U}_{B}T\, {}^{B}\bar{Q}$$

So, this is the way actually we can find out if we have both translation as well as rotation. Now, let us try to check the dimension matching of this particular matrix.

Now if you see in the last slide, we wrote the equation, that is, Q with respect to U.

$$\begin{bmatrix} {}^{U}\bar{Q}\,(3\times1) \end{bmatrix}_{3\times1} = \begin{bmatrix} {}^{U}_{B}R\,(3\times3) & {}^{U}\bar{Q}_{Borg}\,(3\times1) \end{bmatrix}_{3\times4} \begin{bmatrix} {}^{B}\bar{Q}\,(3\times1) \end{bmatrix}_{3\times1}$$

$$\Rightarrow \begin{bmatrix} {}^{U}\bar{Q}\,(3\times1) \\ 1 \end{bmatrix} = \begin{bmatrix} {}^{U}_{B}R\,(3\times3) & {}^{U}\bar{Q}_{Borg}\,(3\times1) \\ 0 \;\; 0 \;\; 0 & 1 \end{bmatrix} \begin{bmatrix} {}^{B}\bar{Q}\,(3\times1) \\ 1 \end{bmatrix}$$

$${}^{U}\bar{Q} = {}^{A}_{B}T \times {}^{B}\bar{Q}$$

is nothing but a 3 cross 1 matrix.

Now, this particular transformation matrix has got two things; One is called the rotation matrix and we have got the position vector.

Now this rotation matrix is a 3 cross 3 matrix and position vector is nothing but a 3 cross 1 matrix.

So, that means, I will have to multiply one 3 cross 1 matrix by one 3 cross 4 matrix just to get a 3 cross 1 matrix, which is not possible.

No, to solve this particular problem to make it possible actually, what I do is, here we do some modification sort of thing. So, here on this position term Q with respect to U we add 1, and here, just below the rotation matrix on the fourth row, we use 000 (three zeroes) and here, we add 1 and now, this particular transformation matrix will have the dimension that is, 4 cross 4.

So, this was 3 cross 4 previously.

Now, I have added one more row here.

So, this will become your 4 cross 4 and this particular thing will become 4 cross 1 matrix.

and this will also become 4 cross 1 matrix

Now if I just multiply, so, this 4 cross 1 with 4 cross 4 so, I will be getting this 4 cross 1 matrix. So it is matching.

Now, my question is like why do you put 1 here? & why 3 zeros here.

3.0 MANIPULATOR KINEMATICS

Defination of Kinematics :-

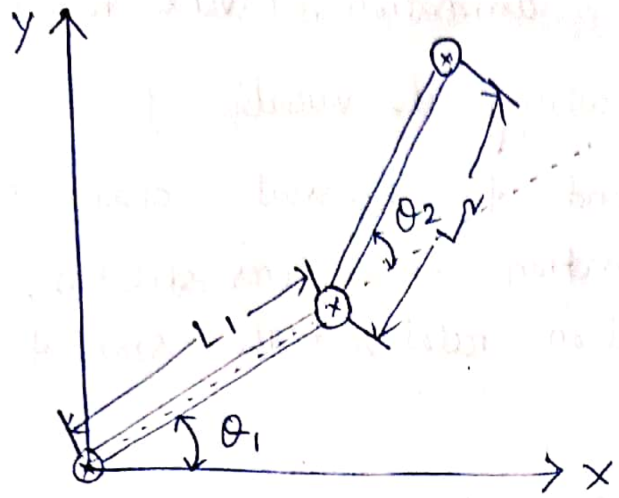
Robot kinematics applies geometry to the study of the movement of multi-degree of freedom kinematic chains that forms the structure of robotic systems.

Robot kinematics studies the relationship between the dimensions and connectivity of kinematic chains and the position, velocity and accelaration of each of the links in the robotic system, in order to plan and control movement and to compute actuator forces and torques.

Forward Kinematics

Forward kinematics refers to the use of the kinematic equations of a robot to compute the position of the end-effector from specified values for the joint parameters. The kinematic equations of the robot are used in robotics, computer games and animation.

Forward Kinematics of 2D ARM



Forward kinematics refers to the used of Kinematic eq^n of robot to compute the position of the end effector for the specified value of the joint parameter

It has two arms L_1 & L_2

L_1 is an angle of θ_1 from the base & L_2 is an angle of θ_2 from the L_1.

For the 1st arm

$X_1 = L_1 \cos\theta_1$

$Y_1 = L_1 \sin\theta_1$

Similarly for the 2nd arm

$X_2 = L_2 \cos(\theta_1+\theta_2)$

$Y_2 = L_2 \sin(\theta_1+\theta_2)$

$X = X_1 + X_2$

$Y = Y_1 Y_2$

$X = L_1 \cos\theta_1 + L_2 \cos(\theta_1+\theta_2)$

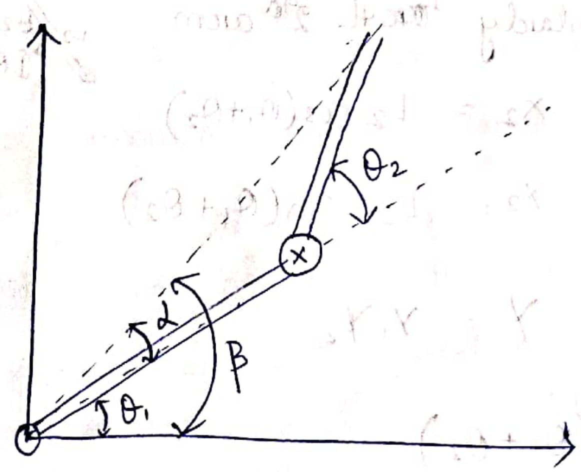
$Y = L_1 \sin\theta_1 + L_2 \sin(\theta_1+\theta_2)$

Inverse Kinematics :-

In robotics and computer animation, inverse kinematics is the mathematical process of calculating the variable joint parameters needed to place the end of a kinematic chain, such as a robot manipulator or animation character's skeleton, in a given position and orientation relative to the start of the chain.

Inverse kinematics is also used to recover the movements of an object in the world from some other data, such as a film of those movements, or a film of the world as seen by a camera which is it self making those movements.

Inverse of 2D ARM :-



Inverse kinematics makes use of kinematics eq to determine the joint parameters that provide a desired position for each of the robot endeffector.

$$X = L_1 \cos\theta_1 + L_2 \cos(\theta_1 + \theta_2)$$

$$= L_1 \cos\theta_1 + L_2 \cos\theta_1 \cos\theta_2 + L_2 \sin\theta_1 \sin\theta_2 \quad \text{—①}$$

$(\because \cos(\theta_1+\theta_2) = \cos\theta_1 . \cos\theta_2 + \sin\theta_1 . \sin\theta_2)$

$$Y = L_1 \sin\theta_1 + L_2 \sin(\theta_1 + \theta_2)$$

$$= L_1 \sin\theta_1 + L_2 \sin\theta_1 \cos\theta_2 + L_2 \cos\theta_2 \sin\theta_2 \quad \text{——— (2)}$$

$$\left\{ \because \sin(\theta_1 + \theta_2) = (\sin\theta_1 . \cos\theta_2 + \cos\theta_2 . \sin\theta_2) \right\}$$

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

$$\Rightarrow \theta_2 = \cos^{-1}\left(\frac{x^2 + y^2 - L_1^2 - L_2^2}{2 L_1 L_2} \right)$$

We also found two new angles α & β.

$$\theta_1 = \beta - \alpha$$

$$\tan\alpha = \frac{L_2 \sin\theta_2}{L_2 \cos\theta_2 + L_1} \quad \text{——— (1)}$$

$$\tan\beta = Y/x \quad \text{——— (2)}$$

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

$\therefore$ Here we substitute A as β & B as α.

$$\therefore \tan\theta_1 = \tan(\beta - \alpha)$$

$$\therefore \theta_1 = \tan^{-1}\left(\frac{Y(L_1 + L_2 \cos\theta_2) - x L_2 \sin\theta_2}{x(L_1 + L_2 \cos\theta_2) + Y L_2 \sin\theta_2} \right)$$

6.0 MACHINE VISION, IMPLEMENTATION PRINCIPLES and ISSUES and ROBOT APPLICATION

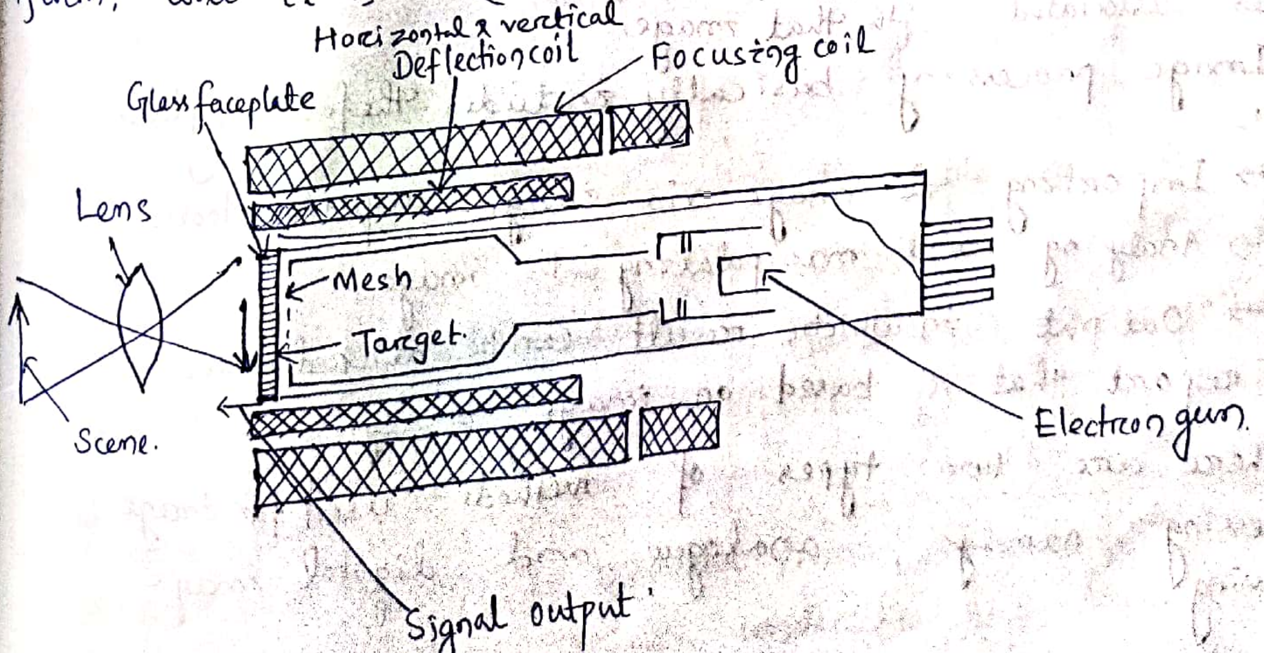
INTRODUCTION to MACHINE VISION :-

A machine vision system (MVS) is a type of technology that enables a computing device to inspect, evaluate and identify still or moving images.

A machine vision system typically consists of digital cameras and back-end image processing hardware and software. The camera at the front end captures images from the environment or from a focused object and then sends them to the processing system. Depending on the design or need of the MVS, the captured images are either stored or processed accordingly.

Sensing & Digitizing function in Machine Vision :-

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.



Cross section of a vidicon tube.

Functions - MACHINE VISION System :- Machine vision system is a sensor used in the robots for viewing and recognizing an object with the help of a computer.

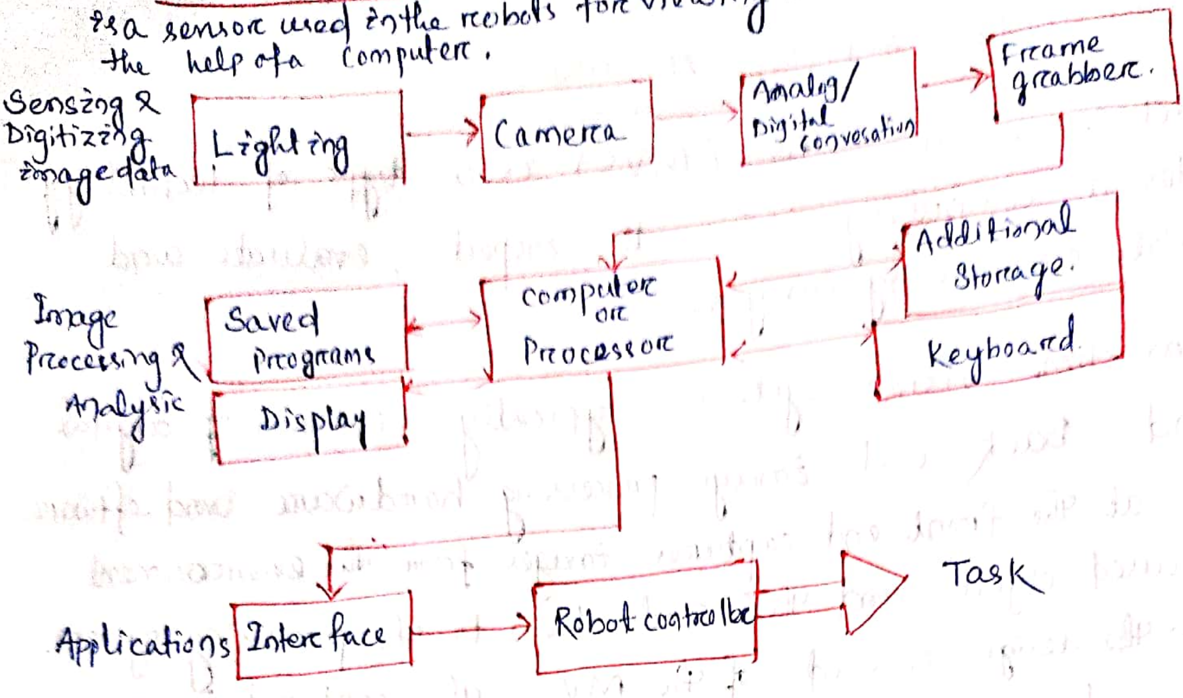


Image Processing and analysis :-

Image processing is a method to perform some operations on an image, in order to get an enhanced image or to extract some useful information from it. It is a type of signal processing in which input is an image and output may be image or characteristics/ features associated with that image.

Image processing basically includes the following three steps :-

→ Importing the image via image acquisition tools.
→ Analysing and manipulating the image.
→ Output in which result can be altered image or report that is based on image analysis.

There are two types of methods used for image processing namely, analogue and digital image processing.

Analogue image processing can be used for the hard copies like printouts and photographs.

Digital image processing techniques help in manipulation of the digital images by using computers.

Image analysis :- Image analysis is the extraction of meaningful information from images; mainly from digital images by means of digital image processing techniques. Image analysis tasks can be as simple as reading bar coded tags or as ~~the~~ sophisticated as identifying a person from their face.

Difference between Image processing and computer vision

Image processing	computer vision
→ Image processing is mainly focused on processing the raw input images to enhance them or preparing them to do other tasks.	→ computer vision is focused on extracting information from the input images or videos to have proper understanding of them to predict the visual input like human brain.
→ Image processing uses methods like anisotropic diffusion, Independent component analysis, different filtering etc.	→ Image processing is one of the methods that is used for computer vision along with ~~the~~ other Machine learning techniques.
→ Image processing is a subset of computer vision.	→ Computer vision is a superset of image processing.
→ Examples :- Some image processing applications are rescaling image (Digital zoom), correcting illumination, Changing tones etc.	→ Examples:- Object detection, Face detection, Hand writing recognition etc.

Computer vision :- In computer vision, computers or machines are made to gain high-level understanding from the input digital images or videos with the purpose of automating tasks that the human visual analysis system can do. It uses many techniques and image processing is just one of them.

Robot Applications :-

The current-day applications of robots can be categorized into two broad areas: industrial applications and non industrial applications.

Robot applications in the industries today are primarily in four fields.

(i) Material handling.
(ii) Operations
(iii) Assembly and
(iv) Inspection.

Material Handling:- The most basic robot applications in which the robot is required to pick a part or other material from one location and place it at another location.

Some examples are:-

1. Material transfer applications.
2. Machine loading / unloading applications.
3. Assembly operation.
4. Inspection.
5. Process applications like spot welding.

Processing Applications (Processions):-

Where the end-effector is a tool instead of a gripper are classified as processing applications.

Some of the processes where robots are efficiently utilized are

→ Welding
→ Spot - welding
→ Spray - painting
→ Paint - scraping.

Today, robots are used in the industries for many other processing applications like drilling and other machining operations, polishing, water jet cutting etc.

Assembly Applications:-

Assembly means fitting two or more discrete parts together to form a new product or sub assembly. The assembly operation involves considerable amount of handling, positioning and orienting of parts and applying controlled force to mate them together properly. Assembly operation can be mating of two parts, ~~[illegible]~~ placing two parts together and fastening them with a third part like screw, nut-bolt, rivet etc. or joining them.

Inspection Applications:-

Inspection function is required in every stage of manufacturing from raw materials to finished products. Robots can be used to inspect physical dimensions, surface finish, and other characteristics of the raw materials, intermediate stages of parts, finished parts, sub-assemblies or finished products. To perform the inspection task robot requires various sensors or vision system.

Capabilities of robots:-

The use of robots improves efficiency and accuracy on a variety of applications. Robot capabilities range from working on trivial tasks to industrial processes like welding and drilling to operating on humans undergoing surgery.

Robots are appliances/ machines that are controlled by a computer. They save time and money as they replace human labour for hazardous or repetitive tasks. Since they never grow tired, they can work long hours in harsh environments.

Obstructs avoidance :-

In robotics, obstacle avoidance is the task of satisfying some control objective subject to non-intersection or non-collision position constraints.

Obstacle avoiding robots can be used in almost all mobile robot navigation systems. They can be used for household work like automatic vacuum cleaning. They can also be used in dangerous environments, where human penetration could be fatal. An obstacle avoding robot is a type of autonomous mobile robot that avoids collision with unexpected obstacles.