ME639: Assignment 1

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Q2)

- **Mobile Robot**
  Mobile robots can be remotely controlled through a device or are entirely automated and capable of locomotion. They are also known as Unmanned Ground Vehicles (UGVs). They are mostly fully autonomous and work independently.
  - Autonomous Mobile Robots
  - Autonomous transportation with mobile robot KMR iiwa

- **Aerial Robot**
  These robots are also known as Unmanned Aerial Vehicles (UAVs). They can be remotely controlled from distant places based on the strength of signal communication. These robots fly in the air and have a very precise location system through which they locate or travel to any point set up by the controller. These have minimal human intervention.
  - MQ-9 REAPER
  - Black Hornet

- **Underwater Robot**
  Underwater robots are also known as Autonomous Underwater Vehicles (UAVs). The underwater robots are used for some complex and dangerous tasks. They are unmanned. Therefore, they are much safer and more reliable underwater for any purpose. They can be controlled from a distant place.
  - Aquanaut
  - Amazing Underwater Robots

- **Exoskeletons**
  These kinds of robots are generally built for a particular purpose. The exoskeletons are initially fed with humans' data and then programmed to work similarly or in a better way than what we used to. Therefore, exoskeletons record our information and act accordingly.
  - Robot Leg
  - Robot Suit HAL

- **RRR - PUMA Type**
  PUMA-type robots have 3 degrees of freedom which comprise three rotational degrees. It has two degrees with parallel axes of rotation, whereas the third axis is perpendicular to the other two.
  - LR Mate 200iD (FANUC & Waste Robot)
  - FANUC M710iC 50

- ➢ NOKIA PUMA type
- ➢ AUTOMATICA - Nigel Stanford

❖ **RRP - SCARA Type**

SCARA-type robots have 3 degrees of freedom, comprising two rotational degrees and one prismatic degree. The axes of all three degrees are parallel to each other.

- ➢ TP80
- ➢ ERS series SCARA robot (ERS - ESTIC Robotic Tightening)
- ➢ DENSO robotics

❖ **RRP - Stanford Type**

Stanford-type robots have 3 degrees of freedom, comprising two rotational degrees and one prismatic degree. They have all three axes perpendicular to each other.

- ➢ Instant Insanity - Computer Vision & Robotics

Q3) The most common types of motors are -

- ➢ **AC Synchronous Motors -** These motors use AC voltage. Their rotor speed is the same as the speed of the stator. These constitute electro-magnets and also have a coil wound around a circular disc.

- ➢ **AC Induction Motors (Asynchronous) -** These motors work on an AC voltage source. We have a coil to create the magnetic field, which oscillates due to AC voltage. Numerous closed loops rotate the motor as there is a change in flux in the loop, which creates equal and opposite forces in the diagonally opposite points of the loop. These motors do not use any brushes and hence have a higher lifetime. To control the speed of the motor, we will have to vary the frequency of the AC signal.

- ➢ **Brushed DC Motors -** The brushed motors have copper windings which create a magnetic field that attracts the permanent magnets placed at opposite sides of the motor. These magnets are of different polarities, attracting the energised core in the same direction and rotating the shaft connected to it. The shaft is connected to 3 cores which get energised one after the other. There are brushes which supply current to a particular core at a time because the core is placed between two small conducting plates. These plates are the governing factor for energising the core. If we reverse the current direction, then the shaft will move in the direction opposite to the initial direction. We have a metal core to produce the magnetic field, and they are laminated to reduce the eddy currents and other losses. These motors work on DC voltage. We can control the speed of the motor by varying the DC voltage.

- ➢ **Brushless DC Motors (BLDC) -** These motors work on DC voltage. They do not have brushes, unlike the brushed DC motors. These motors have the same inner part as the brushed DC motors except for the brushes. Another factor is that the BLDC have more magnets when compared to the brushed DC motors. The BLDC also have 3 phases for input power and is controlled by an ESC(Electronic Speed Controller) unit. There are 3 phases, of which two are Vcc and GND, whereas one terminal is left floating to vary the magnet's polarity, hence rotating the shaft.

- **Servo Motors** - These are DC motors but can also work with an AC source. These have a standard DC motor with feedback control. An encoder and a potentiometer control the feedback. The Servo motors also have gears to provide more torque, although reducing the speed of the motor. Through feedback control, we can vary the position and the direction of rotation. We can have better precision with better feedback control.

- **Stepper Motors** - These motors also use DC voltage and are brushless motors. These motors have the stator on the outside and the rotor on the inside. In these motors, we only have two coils divided into equal parts and placed alternately. We also have ferromagnetic groves on the inner surface of the stator and on the rotor. In these motors, a set of two diagonally opposite magnets are energised, to align the permanent magnet, indeed turning the rotor at a certain angle. We have the grooves containing small magnets for further minor rotations, reducing the rotation degree. To control the stepper motors, we require a stepper driver.

Q6)

Q6) We need to show that the columns of the rotation matrix R_0^1 are orthogonal to each other.

Now the ~~to~~ rotation matrix R_0^1 can be given as -

$$R_0^1 = \begin{bmatrix} \hat{i}_1 \cdot \hat{i}_0 & \hat{j}_1 \cdot \hat{i}_0 & \hat{k}_1 \cdot \hat{i}_0 \\ \hat{i}_1 \cdot \hat{j}_0 & \hat{j}_1 \cdot \hat{j}_0 & \hat{k}_1 \cdot \hat{j}_0 \\ \hat{i}_1 \cdot \hat{k}_0 & \hat{j}_1 \cdot \hat{k}_0 & \hat{k}_1 \cdot \hat{k}_0 \end{bmatrix}$$

The columns ~~vect~~ can be represented as three vector quantities

$$a_1 = \begin{bmatrix} \hat{i}_1 \cdot \hat{i}_0 \\ \hat{i}_1 \cdot \hat{j}_0 \\ \hat{i}_1 \cdot \hat{k}_0 \end{bmatrix} \quad a_2 = \begin{bmatrix} \hat{j}_1 \cdot \hat{i}_0 \\ \hat{j}_1 \cdot \hat{j}_0 \\ \hat{j}_1 \cdot \hat{k}_0 \end{bmatrix} \quad a_3 = \begin{bmatrix} \hat{k}_1 \cdot \hat{i}_0 \\ \hat{k}_1 \cdot \hat{j}_0 \\ \hat{k}_1 \cdot \hat{k}_0 \end{bmatrix}$$

Let a_1, a_2 and a_3 be individual vector components represented in three perpendicular ~~dir~~ directions

Now let's take the dot product of a_1, a_2 ~~and~~

$$a_1 \cdot a_2 = (\hat{i}_1 \cdot \hat{i}_0) \cdot (\hat{j}_1 \cdot \hat{i}_0) + (\hat{i}_1 \cdot \hat{j}_0)(\hat{j}_1 \cdot \hat{j}_0) + (\hat{i}_1 \cdot \hat{k}_0)(\hat{j}_1 \cdot \hat{k}_0)$$

$$= (\hat{i}_1 \cdot \hat{j}_1)(\hat{i}_0)^2 + (\hat{i}_1 \cdot \hat{j}_1)(\hat{j}_0)^2 + (\hat{i}_1 \cdot \hat{j}_1)(\hat{k}_0)^2$$

$\because \hat{i}_1 \cdot \hat{j}_1 = 0$

$\Rightarrow a_1 \cdot a_2 = 0$ $\therefore$ Vectors a_1 and a_2 are orthogonal to each other.

Now let's take the dot product of a_2 and a_3

$$a_2 \cdot a_3 = (\hat{j}_1 \cdot \hat{i}_0) \cdot (\hat{k}_1 \cdot \hat{i}_0) + (\hat{j}_1 \cdot \hat{j}_0)(\hat{k}_1 \cdot \hat{j}_0) + (\hat{j}_1 \cdot \hat{k}_0) \cdot (\hat{k}_1 \cdot \hat{k}_0)$$

$$= (\hat{j}_1 \cdot \hat{k}_1)(\hat{i}_0)^2 + (\hat{j}_1 \cdot \hat{k}_1)(\hat{j}_0)^2 + (\hat{j}_1 \cdot \hat{k}_1)(\hat{k}_0)^2$$

$\because \hat{j}_1 \cdot \hat{k}_1 = 0$

$\Rightarrow a_2 \cdot a_3 = 0$

$\because$ Vectors a_2 and a_3 are orthogonal to each ~~other~~ other.

Now let's take the dot product of vectors a_1 and a_3

$$a_1 \cdot a_3 = (\hat{i}_1 \cdot \hat{i}_0)(\hat{k}_1 \cdot \hat{i}_0) + (\hat{i}_1 \cdot \hat{j}_0) \cdot (\hat{k}_1 \cdot \hat{j}_0) + (\hat{i}_1 \cdot \hat{k}_0) \cdot (\hat{k}_1 \cdot \hat{k}_0)$$

$$= (\hat{i}_1 \cdot \hat{k}_1)(\hat{i}_0)^2 + (\hat{i}_1 \cdot \hat{k}_1)(\hat{j}_0)^2 + (\hat{i}_1 \cdot \hat{k}_1)(\hat{k}_0)^2$$

$\because \hat{i}_1 \cdot \hat{k}_1 = 0$

$\Rightarrow a_1 \cdot a_3 = 0$

$\therefore$ Vectors a_1 and a_3 are orthogonal to each other.

Q7)

Q7) We need to show that $\det(R_0^1) = 1$

The rotation matrix R_0^1 is given as

$$R_0^1 = \begin{bmatrix} \hat{i}_1 \cdot \hat{i}_0 & \hat{j}_1 \cdot \hat{i}_0 & \hat{k}_1 \cdot \hat{i}_0 \\ \hat{i}_1 \cdot \hat{j}_0 & \hat{j}_1 \cdot \hat{j}_0 & \hat{k}_1 \cdot \hat{j}_0 \\ \hat{i}_1 \cdot \hat{k}_0 & \hat{j}_1 \cdot \hat{k}_0 & \hat{k}_1 \cdot \hat{k}_0 \end{bmatrix}$$

We know that R_0^1 is an orthogonal matrix

$$\therefore (R_0^1)(R_0^1)^T = I$$

Now we take determinant on both sides of the above eqn

$$\det(R_0^1) \cdot \det[(R_0^1)^T] = \det(I)$$

$$\because \det(R_0^1) = \det(R_0^1)^T$$

$$\therefore (\det(R_0^1))^2 = \det(I)$$

$$(\det(R_0^1))^2 = 1$$

$$\det(R_0^1) = \pm 1$$

For our convenience we take $\det(R_0^1) = 1$