ME 639 : Introduction to Robotics

Assignment : 1

Krish Raj
20110160

Qn 2)

Mobile Robot
They are also known as Unmanned Ground Vehicles (UGVs). Mobile robots can be remotely controlled through a device or are entirely automated and capable of locomotion. They are mostly fully autonomous and work independently. These robots are used in a wide range of applications.

- Autonomous Mobile Robots
- Mobile Manipulator combines a cobot arm with an autonomous mobile robot for flexible production

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. This type of mobile robot is designed to fly in the air without a human pilot on board. These have minimal human intervention.

- MQ-9 REAPER
- Swarm exploration by tiny flying robots

Underwater Robot
An underwater robot, also known as an underwater autonomous vehicle (AUV) or remotely operated vehicle (ROV), is a type of robotic system designed to operate underwater without direct human intervention. These robots are used for a variety of tasks in marine environments, ranging from scientific research and exploration to industrial applications.

- Most amazing underwater robots
- Eelume underwater robot

Exoskeletons
Exoskeleton robots are mechanical devices designed to be worn by a person to enhance their physical capabilities and support various activities. These devices are typically worn externally on the body and can assist with tasks that require strength, endurance, or mobility.

- Robot Leg

- Advanced Exoskeletons Giving Humans Super Strength & Endurance

PUMA

PUMA-type robots have 3 degrees of freedom which comprise three rotational degrees. It has two degrees with parallel axes of rotation (RRR), whereas the third axis is perpendicular to the other two. PUMA robots are known for their early contributions to industrial automation and have played a significant role in shaping the field of robotics and manufacturing.

- Drawing with the PUMA Robot Arm
- FANUC M710iC 50 Robots

SCARA

A SCARA robot, which stands for "Selective Compliance Assembly Robot Arm" or "Selective Compliance Articulated Robot Arm," is a type of industrial robot designed for tasks that require high precision, speed, and repeatability, particularly in assembly and pick-and-place operations. SCARA robots have a specific mechanical structure that enables them to perform tasks in a horizontal plane while maintaining a fixed orientation. SCARA-type robots have 3 degrees of freedom, comprising two rotational degrees and one prismatic degree (RRP). The axes of all three degrees are parallel to each other.

- TP80
- 3D Printed Arduino SCARA Robot
- ESTIC Robotic

Stanford

The "Stanford-type" robot has 3 degrees of freedom (DOF) and an RRP (Rotational-Rotational-Prismatic) configuration is a specific type of robotic arm commonly used for educational and research purposes. This type of configuration allows for precise positioning and orientation of the end-effector in a 3D workspace.

- Computer Vision & Robotics

Qn 3)

AC Motors

AC motors are electric motors that operate using alternating current as their power source. These motors are commonly used in a wide range of applications due to their efficiency, reliability, and ease of control. AC motors are used in various industries, including manufacturing, transportation, household appliances, and more.

1. **Synchronous Motors** - These motors rotate at a fixed speed that is synchronized with the frequency of the AC power supply. They are used in applications that require precise speed control, such as industrial drives and synchronous clocks. These constitute electro-magnets and also have a coil wound around a circular disc.

2. **Induction Motors (Asynchronous)** - These are the most common type of AC motor. They don't rely on synchronization and are known for their simplicity, robustness, and low maintenance requirements. Induction motors are used in various applications, including industrial machinery, household appliances, and commercial equipment.

DC Motors

DC motors are electric motors that operate using direct current as their power source. These motors are widely used in various applications due to their controllability, efficiency, and versatility. DC motors come in different types and sizes, each with its own characteristics and advantages. They are used in manufacturing, automotive, robotics, and other industries.

1. **Brushed Motors** - Brushed DC motors are a type of electric motor that uses mechanical brushes and a commutator to control the flow of electrical current in the motor's coils. These motors have been widely used for decades in various applications, but they are being gradually replaced by more advanced motor technologies in many modern applications.

2. **Brushless Motors (BLDC)** - These motors work on DC voltage. They do not have brushes, unlike the brushed DC motors. These motors have the same inner parts as the brushed DC motors except for the brushes. These motors offer several advantages over traditional brushed DC motors, including improved efficiency, longer lifespan, and reduced maintenance requirements. BLDC motors have gained popularity in various industries, including automotive, aerospace, robotics, and consumer electronics.

Servo Motors - These are DC motors but can also work with an AC source. These have a standard DC motor with feedback control. They are known for their ability to provide precise control over speed, position, and torque. 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.

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. It is a type of electric motor that moves in discrete steps, making it particularly well-suited for applications requiring precise positioning and control without needing feedback devices like encoders. Stepper motors are commonly used in a wide range of applications, including 3D printers, CNC machines, robotics, cameras, and more.

Qn 6)

DATE: ________

(6) here, we need to show that the columns of the rotation matrix R_0^1 are orthogonal to each other.

Now, 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 can represents colums 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 direction.

Now, let take dot product of a_1 & a_2

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

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

$$a_1 \cdot a_2 = (\hat{i}_1 \cdot \hat{j}_1) \cdot [(\hat{i}_0)^2 + (\hat{j}_0)^2 + (\hat{k}_0)^2]$$

but, $\hat{i}_1 \cdot \hat{j}_1 = 0$

So, $a_1 \cdot a_2 = 0$ ——— (1)

we can say that vectors a_1 & a_2 are orthogonal to each other.

Now, let's take the product of a_1 & a_3

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

$$a_1 \cdot a_3 = (\hat{i}_1 \cdot \hat{k}_1) \cdot (\hat{i}_0)^2 + (\hat{i}_1 \cdot \hat{k}_1) \cdot (\hat{j}_0)^2 + (\hat{i}_1 \cdot \hat{k}_1) \cdot (\hat{k}_0)^2$$

we know that $\hat{i}_1 \cdot \hat{k}_1 = 0$

So, $a_1 \cdot a_3 = 0$ —— (2)

Thus, we can say vectors a_1 & a_3 are ~~orthogonal~~ orthogonals to each other.

Now, let's take the product of a_2 & a_3

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

$$a_2 \cdot a_3 = (\hat{j}_1 \cdot \hat{k}_1) \cdot (\hat{i}_0)^2 + (\hat{j}_1 \cdot \hat{k}_1) \cdot (\hat{j}_0)^2 + (\hat{j}_1 \cdot \hat{k}_1) \cdot (\hat{k}_0)^2$$

we know that $\hat{j}_1 \cdot \hat{k}_1 = 0$

So, $a_2 \cdot a_3 = 0$ —— (3)

Thus, from eqn (1), (2) & (3) we can say that the columns of the rotational matrix R_0^1 are orthogonal.

Qn 7)

(7) The rotation matrix R_0^1 is given as,

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

from the previous answer we know that the R_0^1 is an orthogonal matrix

$$\therefore (R_0^1)(R_0^1)^T = I \quad (\text{Identity matrix})$$

Now let's take determinant at both sides

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

but ~~let take~~ $\det(R_0^1) = \det[(R_0^1)^T]$

So,

$$[\det(R_0^1)]^2 = \det(I)$$

$$[\det(R_0^1)]^2 = 1 \quad [\because \det(I) = 1]$$

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

for our convenience we will take

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