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7) Show that columns of a rotation matrix are orthogonal.

- Lets take a 2×2 rotation matrix R

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} = R$$

$$\therefore \quad R^T = \begin{bmatrix} a_{11} & a_{21} \\ a_{12} & a_{22} \end{bmatrix}$$

We know, $R R^T = I$

$$\therefore \begin{bmatrix} a_{11}^2 + a_{12}^2 & a_{11} \cdot a_{21} + a_{12} \cdot a_{22} \\ a_{21} \cdot a_{11} + a_{22} \cdot a_{12} & a_{21}^2 + a_{22}^2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

∴ dot product of individual rows / columns or non diagonal terms is always zero.

∴ Columns of a rotation matrix are orthogonal.

8) Show that $\det(R_o') = 1$

- Since, $R^T R = I$

$$\det(R^T R) = \det(I) = 1$$

$$\therefore \det(R^T) \cdot \det(R) = 1$$

$$\because \det(R^T) = \det(R)$$

$$\therefore (\det(R))^2 = 1$$

$$\therefore \det R = \underline{1}$$

∴ H.P.

3.) Types of Motors:

1. Brushed DC: Divided into two parts: the stator (permanent magnets and the brushes) and the rotor. The DC current from the brushes energises and polarises the rotor, leading to repulsive and attractive forces from the permanent magnets. The speed can be controlled by controlling the DC input.
2. AC Induction: The stator magnetic field's polarity oscillates as we use AC current, which results in a magnetic flux. The rotor is made up of closed loops of conducting material. These start rotating based on the Lorentz law. Since there is no contact (brushes), these last longer. The speed can be controlled using the frequency of the AC current.
3. AC Synchronous: In these, the speed of the rotor is equal to the speed of the stator magnetic field. The rotor is made out of permanent/electromagnets. The AC current once again creates an oscillating magnetic field in the coil; the magnet of the rotor then follows it at the same speed.
4. BLDC (Brushless DC): Stator made up of coils, rotor made up of magnets. Controlled using ESC. The ratio of poles and magnets is pre-defined. It has triple-phase input. The changing polarity of coils rotates the rotor. The frequency of changing polarity controls the speed of the motor. The current from ESC is pulse DC.
5. Stepper: Stator(coils) on the outside, the rotor in the middle. Two-phase input. Changing the polarity of coils results in the formation of steps. Adding teeth helps reduce the size of each step. Need stepper driver to control.
6. Servos: Can be used with both AC and DC motors. The main point of difference is the feedback (encoder, potentiometer). It allows the motor to control the direction and position of the rotor at all times. We can control the width of the pulse to control the angle of rotation.

2.)

1. Manipulator:
    - https://www.youtube.com/watch?v=EqMPLnIRUvQ
    - https://www.youtube.com/watch?v=vSnvVuKg6d8
2. Mobile:
    - https://www.youtube.com/watch?v=VmV3m0QqNOY
    - https://www.youtube.com/watch?v=hcfMZ6qjdXM
3. Legged:
    - https://www.youtube.com/watch?v=fn3KWM1kuAw
    - https://www.youtube.com/watch?v=chPanW0QWhA
4. Aerial:
    - https://www.youtube.com/watch?v=GEJhb93rKlU
    - https://www.youtube.com/watch?v=g_qhMVNw7O4
5. Underwater:
    - https://www.youtube.com/watch?v=h2CLLBUpPZg
    - https://www.youtube.com/watch?v=FKyENV8l_JE
6. Humanoid:
    - https://www.youtube.com/watch?v=EWACmFLvpHE
    - https://www.youtube.com/watch?v=QdQL11uWWcI
7. Swarm:
    - https://www.youtube.com/watch?v=fsVJuN75vzE
    - https://www.youtube.com/watch?v=w77_yhkXzzo