RTC-Arms and Joints

October 2025

1 Manipulators

A manipulator is the mechanical arm or linkage system designed to interact with the environment by moving, positioning, and orienting objects. It is the part of the robot that performs the actual 'work', such as picking up a component, welding, and assembling the parts.
It is analogous to human arm

1.1 Components of Robotic Manipulators

Base: Provides stability and support for the manipulator.
Links: Rigid components that connect different parts of the manipulator.
Joints: Movable components that allow flexibility and motion, similar to human joints.
Actuators: Devices that drive the movement (either linear or rotatory) of the manipulator.Actuators that are used in our arms are mostly Servo motors,stepper motor,DC.
End-Effectors: Tools or devices at the end of the manipulator, such as grippers or welding torches, that perform specific tasks

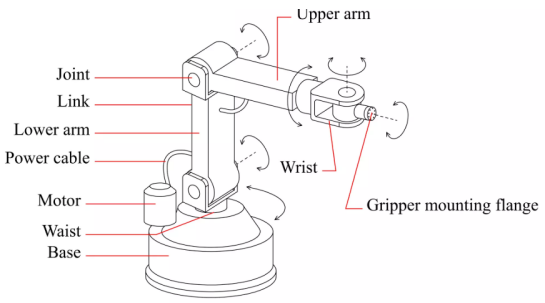

Figure 1: Components of a Robotic Arm

1.2 Workspace

The workspace (also called reachable space or working envelope) of a manipulator is the total volume or region in space that the robot's end-effector can reach.
It is the area or volume a manipulator can actually work
Jointspaces:The joint space of a robot manipulator is the mathematical space formed by all possible values of its joint variables.

1.3 Degrees of Freedom

In robotics, the Degrees of Freedom (DOF) of a manipulator refer to the number of independent movements or parameters that define its configuration or position in space.

1.4 Safelimit

The safe limit of a robot manipulator refers to the maximum permissible range of motion, speed, force, or torque that ensures that the robot operates within mechanical and control constraints and the system remains safe for humans and equipment.

1.5 Major Divisions of Components of Robotics

Voltaic Logics are used in all these components.
Sensors: It is a device that detects physical quantities from the environment and converts them into measurable electrical signals. It allows robots to perceive information such as position, force, or temperature. Sensors enable feedback control and interaction with the environment.
Processors: It is an electronic unit that interprets and executes instructions to control a system's operations. It performs data processing, calculations, and decision-making tasks. In robots, processors coordinate sensor input and actuator output.

Actuators:It is a device that converts electrical signals into physical motion. It enables a robot to move its joints or end-effectors. Actuators provide the mechanical power needed for performing tasks.

1.6 Operating Voltage

It is the range of electrical voltage required for a device to function correctly. It ensures proper performance without damage or malfunction. Values below or above this range can cause instability or failure.

1.7 Static and Dynamic Output:

Static voltage is the electric potential that remains constant over time in a circuit or component. It represents a steady, unchanging voltage level without fluctuations.
Static output is the steady or constant output value of a system when input and operating conditions remain unchanged. It indicates the system's behavior under equilibrium or no-change conditions.
Dynamic Voltage : It is the voltage that varies with time due to changing load or operating conditions. It reflects fluctuations in electrical potential during system activity.
Dynamic output is the time-varying response of a system to changing inputs or conditions. It represents how the output evolves before reaching a steady state.

1.8 Stall Torque and operating Torque:

Stall torque: It is the maximum torque a motor can produce when its output shaft is not rotating. It occurs at zero speed with maximum current flow. Beyond this point, the motor cannot generate additional torque to start motion.
Operating Torque: It is the torque at which a motor runs efficiently under normal working conditions. It is lower than the stall torque and corresponds to rated speed and power. Operating torque ensures stable performance without overheating or overload.

1.9 Power Rating:

It is the maximum amount of power a device can handle or deliver safely during operation. It defines the upper performance limit without causing damage. Exceeding the power rating can lead to overheating or failure.
Drawn current is the amount of electrical current consumed by a device from its power source during operation. It depends on the load and operating conditions. Higher load or torque generally increases the drawn current.

1.10 Margin of Safe use:

Safety Buffer between the components Maximum ratings and its actual operating condition,Ensuring reliability and durability.

$$v = \frac{MaximumOutput}{applicationOutput} \geq 1$$

Generally, safety margin = 1.5

1.11 C Rating

C rating is a measure of how quickly a battery can safely discharge relative to its capacity. It indicates the discharge or charge current as a multiple of the battery's rated capacity.

$$DischargeCurrent = CRating \cdot BatteryCapacity$$

$$DischargeCurrent = \frac{TotalCharge(Ah)}{Dischargetime(h)}$$

C Rating =Number of Full Discharge per Hour
Higher C Rating implies higher Discharge Current

$$C.Rating = \frac{1}{Dischargetime(h)}$$

1.12 Mechanical Advantage (M.A.)

It is the ratio of the output force produced by a machine to the input force applied to it. It shows how efficiently a machine helps lift or move a load using less effort.

$$M.A = \frac{Load}{Effort}$$

if $M.A > 1$, Machine amplifies the force
if $M.A < 1$, Force is reduced

1.13 Planetary Motors:

Planetary motors are gear motors that use a planetary gear system, where multiple gears (planets) rotate around a central gear (sun gear) inside a ring gear. They provide high torque output, compact size, and efficient power transmission, making them ideal for robotics and precision machinery

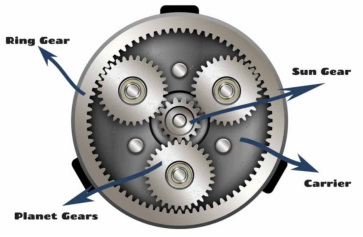

Figure 2: Planetary Motors

1.14 Stepper Motor:

A stepper motor is an electromechanical device that converts electrical pulses into precise mechanical movements. It rotates in discrete steps, with each pulse moving the shaft by a fixed angle.

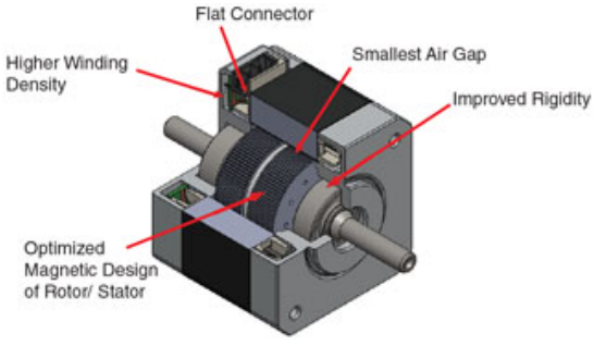

Figure 3: Stepper Motors