DEPARTMENT OF MECHATRONICS ENGINEERING

Robotics is an interdisciplinary field that integrates mechanical engineering, electrical engineering, computer science, and artificial intelligence to design, build, and operate robots. Robots are automated machines capable of sensing, processing information, and performing tasks in the physical world. A robotic system is composed of several interdependent components that work in unison to achieve autonomy or semi-autonomy: **hardware**, **perception**, **planning**, and **movement**.

1. Robot Hardware

Hardware forms the physical structure and body of a robot. It includes both the **mechanical** and **electronic** components that enable robots to interact with their environment.

1.1 Mechanical Components

- **Actuators**: Motors (electric, hydraulic, pneumatic) that drive motion.
- **End Effectors**: Grippers, welding torches, or other tools attached to robotic arms.
- **Links and Joints**: Form the skeleton and articulation points of a robot.
- **Chassis/Wheels/Legs**: Provide locomotion capabilities.

1.2 Electrical Components

- **Power Supply**: Batteries, solar panels, or wired connections.
- **Microcontrollers and Embedded Systems**: The "brain" at a low level.
- **Sensors**: Essential for perception (covered in next section).
- **Communication Modules**: Wi-Fi, Bluetooth, CAN bus for intra/inter-device communication.

2. Perception

Perception enables robots to sense and interpret the environment. This is the gateway to intelligent behavior.

2.1 Sensors

- **Visual Sensors**: Cameras (RGB, stereo, depth cameras like Intel RealSense or LiDAR).
- **Auditory Sensors**: Microphones and audio processing.
- **Proprioceptive Sensors**: Encoders, gyroscopes, IMUs (Inertial Measurement Units).
- **Tactile Sensors**: Touch, pressure sensors for fine manipulation.
- **Environmental Sensors**: GPS, ultrasonic, infrared, temperature, etc.

2.2 Sensor Fusion

Combining data from multiple sensors to increase accuracy. For instance, GPS + IMU + wheel encoders for precise localization.

2.3 Perception Algorithms

- **Computer Vision**: Object detection (YOLO, Faster R-CNN), tracking, segmentation.
- **SLAM (Simultaneous Localization and Mapping)**: For autonomous navigation.
- **Machine Learning**: For pattern recognition, scene understanding.

3. Planning

Planning is the process of deciding how a robot should act to achieve its goal, considering constraints and obstacles.

3.1 Motion Planning

- **Path Planning Algorithms**: A*, Dijkstra’s, RRT (Rapidly-exploring Random Trees), PRM (Probabilistic Roadmaps).
- **Trajectory Planning**: Generating smooth, continuous paths over time.
- **Obstacle Avoidance**: Dynamic and static obstacle handling using sensors and maps.

3.2 Task Planning

- **High-level Decision Making**: Finite State Machines (FSMs), Behavior Trees.
- **AI Planning**: STRIPS, PDDL (Planning Domain Definition Language) for abstract goal achievement.

3.3 Reactive vs Deliberative Planning

- **Reactive**: Quick, rule-based responses (e.g., Braitenberg vehicles).
- **Deliberative**: Planning ahead using models of the environment.

4. Movement (Control and Locomotion)

Movement translates planning into real-world motion via actuation and control algorithms.

4.1 Control Systems

- **Feedback Control**: PID (Proportional-Integral-Derivative), LQR (Linear Quadratic Regulator).
- **Feedforward Control**: Anticipatory actions based on known dynamics.
- **Inverse Kinematics/Dynamics**: Computing required joint configurations or torques.

4.2 Locomotion Techniques

- **Wheeled Robots**: Differential drive, omnidirectional wheels.
- **Legged Robots**: Bipedal, quadrupedal (e.g., Boston Dynamics' Spot).
- **Flying Robots (Drones)**: Multirotor control.
- **Swimming Robots**: Bio-inspired underwater vehicles.

4.3 Navigation

- **Localization**: Determining robot’s position using GPS, SLAM.
- **Map Building**: Using occupancy grids, topological maps.
- **Path Execution**: Translating trajectories into motor commands.