DEPARTMENT OF MECHATRONICS ENGINEERING

Map Representation in Mobile Robot Localization

Map representation is a fundamental aspect of mobile robot localization.A **map** provides a spatial model of the environment that helps the robot determine its location based on sensor data.

Role of Maps in Localization

- Maps are used to **compare sensor observations** with known environment features.
- They help in:
  - Matching observed data to known structures.
  - Predicting expected sensor readings.
  - Guiding movement and navigation.

Types of Maps

a. Metric Maps

- Represent geometric properties of the environment.
- Focused on **accuracy and scale**.

i. Occupancy Grid Maps

- Divide the environment into a grid.
- Each cell contains a probability of being occupied.
- Widely used in indoor robot applications.
- Example: **2D or 3D grid maps** built using LiDAR or sonar.

ii. Landmark-based Maps

- Store specific landmarks or features (e.g., corners, markers).
- Each landmark has a known position.
- Used in Extended Kalman Filter (EKF) localization.

b. Topological Maps

- Represent the environment as a **graph**.
- Nodes = significant locations (e.g., rooms or intersections).
- Edges = navigable paths between nodes.
- More abstract, memory-efficient, and used in large-scale navigation.

c. Hybrid Maps

- Combine metric and topological maps.
- Offer both geometric precision and high-level abstraction.

Map Construction (SLAM)

- **Simultaneous Localization and Mapping (SLAM)**: build a map while localizing.
- Often used when no prior map is available.
- Algorithms: EKF-SLAM, Graph-SLAM, FastSLAM.

Map Storage and Resolution

- **Resolution**: determines the level of detail.
    - Higher resolution = better accuracy, higher memory usage.
- **Compression** techniques help reduce storage without losing essential details.

Probabilistic Map Representation

- Maps often represent **uncertainty** in the environment.
- Example: in Occupancy Grid Maps, each cell has a probability p(mi,j)p(m_{i,j}) indicating whether it is occupied.

Matching Sensor Data to Maps

- Sensor models are used to **predict measurements** given a map.
- The robot **compares actual sensor data** to expected values from the map.
- Techniques used:
    - **Scan matching** (e.g., LiDAR).
    - **Feature matching** (e.g., visual landmarks).

    - **Correlation** of sensor data with map data.

Challenges in Map Representation

- Dealing with **dynamic environments** (moving objects).
- **Sensor noise** and inaccuracies.
- **Large-scale mapping** and real-time performance.
- Keeping maps **up-to-date** over time.

Applications

- Indoor service robots.
- Self-driving cars (use HD maps with road markings, traffic signs).
- Drones for aerial mapping.