Task 3.2: SLAM

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- Localizing a robot without a predefined map is a challenging problem often referred to as "Simultaneous Localization and Mapping" (SLAM). SLAM is a method used for autonomous vehicles that lets you build a map and localize your vehicle in that map at the same time. SLAM algorithms allow the vehicle to map out unknown environments. Engineers use the map information to carry out tasks such as path planning and obstacle avoidance. Various sensors and algorithms can be used for SLAM, depending on the level of accuracy and complexity required.

Here's an overview of the sensors and algorithms that are commonly used for this problem:

1. **Sensors:**

   - **Lidar (Light Detection and Ranging):** Lidar sensors emit laser beams and measure the time it takes for the beams to reflect off objects and return. This data can be used to create a 2D or 3D map of the environment and provide accurate distance measurements.
   - **Visual Cameras:** Cameras capture images of the environment, and computer vision algorithms can be used to identify landmarks, objects, and features. Visual odometry techniques estimate the robot's movement based on image changes.
   - **IMU (Inertial Measurement Unit):** IMUs provide information about the robot's acceleration, angular velocity, and orientation. Although IMUs suffer from drift over time, they can be integrated with other sensors to improve accuracy.
   - **Wheel Encoders:** Wheel encoders measure the rotation of the robot's wheels, which can help estimate its movement and distance traveled.

- There are other types of sensors like GPS, Radar, Ultrasonic sensors.

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2. **Algorithms:**

   - **Graph-based SLAM:** Graph-based SLAM represents the environment as a graph, where nodes are robot poses and landmarks. Constraints are added based on sensor measurements, and the graph is optimized to find the most likely map and robot trajectory. This approach is versatile and can handle various sensors, making it suitable for both 2D and 3D mapping.
   - **Particle Filter (Monte Carlo Localization):** Particle Filter-based SLAM uses particles to represent possible robot poses. It's well-suited for scenarios with high uncertainty and non-linear sensor models. It's adaptable to various sensors and environments but can require significant computational resources.
   - E**xtended Kalman Filter (EKF):** EKF SLAM estimates the robot's state using a combination of sensor measurements and a motion model. It's commonly used with sensors like IMUs and wheel encoders. EKF has limitations in handling non-linearities and can suffer from divergence if not properly tuned.