<u>SLAM</u>

Simultaneous Localization and Mapping (SLAM), a method used in robotics, enables a robot to map its surroundings while also figuring out where it is in relation to that map. Sensor data and a specified starting point are often needed for traditional SLAM techniques. There are methods for performing SLAM without a known map or prior knowledge of the environment, though. This is frequently referred to as "online SLAM" or "exploration SLAM."

Your robot will need sensors to gather data about its surroundings. Common sensors used in SLAM include cameras, LIDAR (Light Detection and Ranging), IMUs (Inertial Measurement Units), wheel encoders, etc. While you might not have a known map, you still need an initial estimate of the robot's position and orientation. This can be obtained through dead reckoning (estimating position based on sensor data from wheel encoders and IMUs) or using sensor fusion techniques. As the robot moves through its environment, it needs to extract features from the sensor data. These features could be distinctive points in the environment, edges, corners, etc. These features serve as landmarks for the robot's position estimation. The robot needs to associate these extracted features across different time steps. This means it needs to determine which features in the current sensor data correspond to features it observed earlier. Using the data association, the robot can estimate how it has moved between time steps. This helps update its position estimate.

As the robot explores its environment, it gradually builds a map by combining the sensor data and the estimated robot poses. The map might be a collection of point clouds, a grid map, or other representations. As the robot revisits areas of the environment, it can detect loop closures, where it recognizes a place it has been before. This is crucial for refining the map and reducing cumulative errors.

SLAM involves solving a complex optimization problem that aims to minimize the discrepancy between the estimated robot poses, the observed features, and the constraints imposed by the robot's motion model. Graph-based optimization techniques like the Gauss-Newton or the Levenberg-Marquardt algorithms can be used for this purpose. Exploration SLAM is typically done in real-time as the robot moves through its environment. This requires efficient processing of sensor data and optimization techniques to keep up with the robot's movements.

Note that the accumulated errors in both robot pose estimation and map representation can lead to drift and inaccuracies over time. To mitigate this, robust sensor fusion techniques, loop closure detection, and advanced optimization methods are crucial.