7. Simultaneous Localization and Mapping

Simultaneous Localization And Mapping (SLAM) is one of the most fundamental problems in robotics. It arises when our robot doesn't have access to a map of the environment nor the pose where it is located. In this way, the SLAM problem is more complex than the two separate ones in the previous chapters, localization and mapping.

There are mainly two ways to address the SLAM problem: **Full SLAM** and **Online SLAM**.

7.1 Full SLAM

Estimates the whole path traversed at each step, that is:

$$p(x_{1:k}, m_{1:L} | z_{1:k}, u_{1:k})$$

This issue can be faced by means of the GraphSLAM technique, where landmarks and robot poses are represented as nodes in a graph linked by arcs stating odometry and/or observations. Its general idea is that arcs are constraints for the free movement of the nodes.

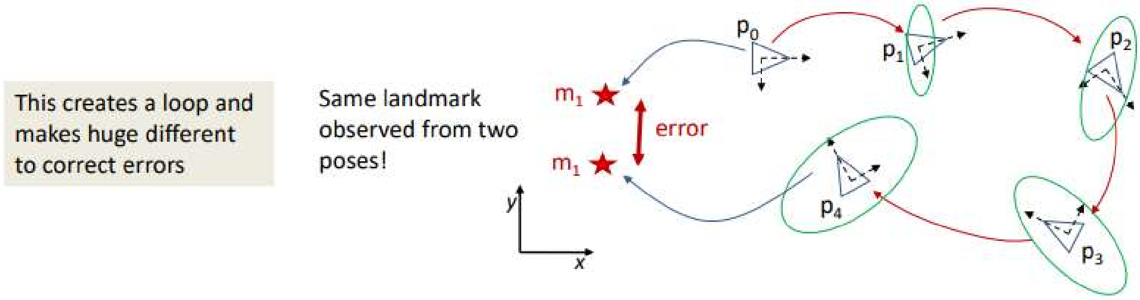

Fig 1. Example of SLAM with GraphSLAM.

A simplified version of this technique, Pose GraphSLAM, is typically prefered. In this case, nodes are unknown robot poses, and arcs represent odometry information or common observed landmarks from different poses.

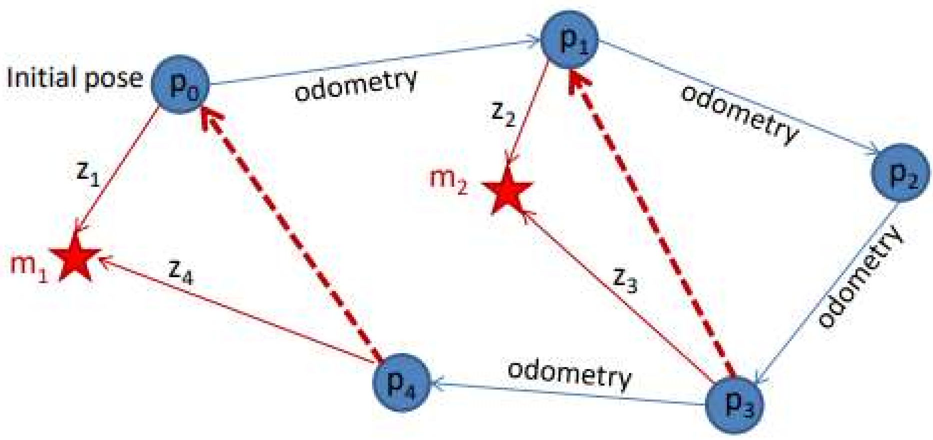

Fig 2. Example of SLAM with Pose GraphSLAM.

7.2 Online SLAM

Which only estimates the latest pose (we do not consider $x_{1:k-1}$), so:

$$p(x_k, m_{1:L} | z_{1:k}, u_{1:k})$$

A popular approach for dealing with this problem is the Extended Kalman Filter (EKF).

7.3 Additional remarks

As in the previous chapters, we assume here that **data association** is given, that is, we know which feature is being seen by each sensor observation!

OPTIONAL

Surf the internet looking for more general information about SLAM. You can include additional definitions, examples, images, videos,... anything you find interesting!

Lidar SLAM (Simultaneous Localization and Mapping) employs Lidar sensors to create a three-dimensional map of the surrounding environment while simultaneously determining the robot's position within that environment. Lidar, which stands for Light Detection and Ranging, is a sensor that uses laser light to measure distances with high precision. The Lidar sensor scans the surroundings by emitting laser beams in different directions and measuring the time it takes for the light to reflect back. This data is then used to construct a detailed map of the environment, including the location and characteristics of objects such as walls, obstacles, and landmarks.

It involves integrating successive Lidar scans to update the robot's pose (position and orientation) and refine the map as the robot moves through the environment. Key components include feature extraction from the Lidar point cloud, matching these features over time to identify landmarks or obstacles, and incorporating odometry information (e.g., data from wheel encoders) for more accurate localization. Lidar SLAM finds extensive applications in various fields, including robotics, autonomous vehicles, and industrial automation, where the ability to navigate and map complex environments with high precision is essential.

Youtube videos:

- https://youtube.com/shorts/HDWT54IWKcY?si=_8I81aeljzg1SW6X (https://youtube.com/shorts/HDWT54IWKcY?si=_8I81aeljzg1SW6X)
- 2D / 3D Dual SLAM Robot using ROS and LiDAR with Raspberry Pi https://youtu.be/34n1tF5OtQU?si=UgpQMxR1vLa1-QQ1 (https://youtu.be/34n1tF5OtQU?si=UgpQMxR1vLa1-QQ1)

Paper:

- Real-Time Loop Closure in 2D LIDAR SLAM https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7487258 (https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7487258)

END OF OPTIONAL PART