Mobile Target Tracking Using Radio Sensor Network

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1 Project Description

In this project, we will track a moving target using a mobile robot. This target tracking will be accomplished using a localization and mapping algorithm implemented using the mobile robot's on-board sensors as well as a network of radio sensors. This algorithm estimates the position and orientation of the mobile robot as well as the location of the radio units in the sensor network and the location of the moving target.

To be more specific we will implement the tracking of a moving target by a differential drive mobile robot in an indoor environment. This tracking will first be accomplished using an extension of the Extended Kalman Filter Simultaneous Localization and Mapping (EKF-SLAM) algorithm. The robot will estimate its position and orientation, the position of several static radio beacons, as well as a beacon serving as the moving target. A BeagleBone Black microcomputer will serve as the controller for the mobile robot as well as receiving signal strength and ID from the beacons and target. We will use ZigBee radio modules as our beacons mounted at three-dimensional (3D) coordinates around our indoor environment.

The EKF-SLAM algorithm will be implemented on the microcomputer. This will estimate the pose (position and orientation) of the mobile robot, the 3D coordinates of the radio beacons, and the coordinates of the moving target. A control algorithm will then be used to determine the appropriate actuator commands to the differential drive mobile robot's left and right wheels to move it towards the moving target based on their estimated pose and distance in a 2D plane.

After this basic moving target tracking is accomplished, we will attempt to make the moving target tracking even more accurate by incorporating a Velodyne LiDAR sensor. LiDAR stands for Light Detection And Ranging. A LiDAR sensor uses pulses of light to measure distance to a target. The LiDAR sensor will provide an estimate of the moving target's position with greater precision than the SLAM algorithm and reduce the target tracking error. As a further extension, we may also implement a basic obstacle avoidance algorithm using the robot's on-board sonar sensors.

2 System Architecture

A high-level system architecture of the current project is described by a block diagram shown in Figure 1. This mobile target tracking system takes the trajectory of a moving target as an input and outputs a tracking performance metric. The moving targets trajectory is an estimated quantity and the tracking performance metric is based on the difference between the estimated trajectory and the position of the mobile robot implimenting the target tracking system.

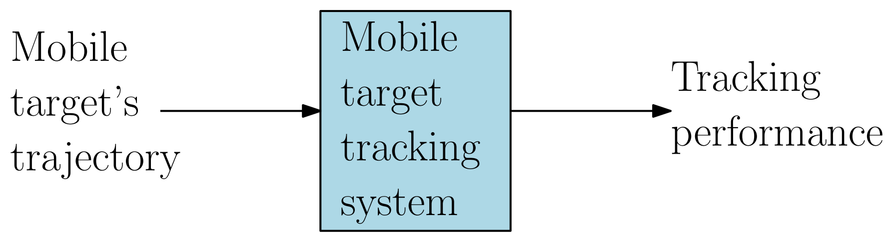

Figure 1: System level diagram.

A sub-system diagram for the target tracking system is shown in Figure 2. The subsystem takes the trajectory of a moving target as an input and outputs a tracing performance metric. The estimated trajectory of the moving target is fed into a tracking algorithm. This tracking algorithm provides the actuator commands to the mobile robot that will send it towards the moving target. These actuator commands are calculated based on the moving target trajectory, the position of the robot, and a map of the environment. The mobile robot also outputs the tracking metric based on its position relative to the mobile target. A feedback loop is implemented using a series of sensors. This feedback loop will attempt to minimize the trajectory performance metric by improving the trajectory estimate sent to the tracking algorithm.

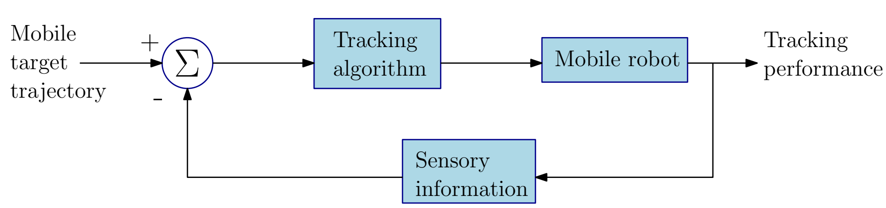

Figure 2: Subsystem level diagram.

3 Modes of Operations

- *Initialization Mode* - This mode runs at start up. It sets up the system work-space and starts/resets the external hardware. The only required input for this mode is power.
- *Operational Mode* - This mode is the main operational loop. It cycles between the Target Tracking Mode and Map Building Mode and serves to pass relevant information between them.

- *Map Building Mode* - This mode runs periodically during normal operation. During this mode the signals from the wireless beacons are used to update the position estimate of the robot, the active beacons, and the moving target. This mode requires power, the wireless beacon/target signals and the LiDAR position information as inputs. This mode outputs a wireless signal from the robot to activate the beacons, and a status display containing the updated positions

- *Target Tracking Mode* - This mode also runs periodically. This mode sends actuator commands to the robot's left and right wheels to move the robot towards the moving target based on the current estimate of positions from the Discovery mode. We may also implement obstacle avoidance using sonar in this mode. Inputs required for this mode include power, the position estimates from the Discovery mode, and sonar distance measurements. The outputs of this mode include the status display of current position estimates as well as the linear and angular velocity of the robot.