Indoor Robot Localization and Mapping using ZigBee Radio Technology

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1 Project Description

In this project, we will implement a localization and mapping algorithm using a differential drive wheeled mobile robot operating in an indoor environment. The robot will be equipped with an onboard microcontroller for implementing the proposed localization and mapping algorithm. The robot is supposed to receive signal strength information from a set of ZigBee[1] radio modules (called herein active beacons) mounted on three-dimensional (3D) coordinates (ceiling of the robot's workspace, for example). The proposed localization and mapping algorithm is expected to determine the position and orientation (pose) of the mobile robot and 3D coordinates of active beacons (in this project, these are XBee modules[2] that support the ZigBee protocol). Appropriate actuator commands are then applied for the robot to follow a set of two-dimensional waypoints within the robot's workspace. The information from the active beacons will allow the robot to estimate the locations of beacons and its pose in an indoor environment simultaneously using an extended Kalman filter[3] (simultaneous localization and mapping). Based on the estimated pose of the robot and the position of beacons, the necessary linear and angular velocities (actuator commands) will be applied to the robot's left and right wheels in order to follow the path defined by pre-determined waypoints.

2 System Inputs/Outputs

2.1 Robot System

A block diagram of the Robot System can be seen in Figure 1.

2.1.1 Inputs

- Power (12 V) – The main source of power for the Robot System

[1] https://en.wikipedia.org/wiki/ZigBee
[2] See http://www.digikey.com/ for details.
[3] https://en.wikipedia.org/wiki/Kalman_filter

- Pre-defined waypoints – A list of pre-determined waypoints defining the robot's path
- Beacon's received signal strength and ID – Obtained from message received from Beacon System over 2.4 GHz wireless signal using ZigBee protocol
- Noise from environment – An element of the 2.4 GHz wireless signal that changes based on the environment

2.1.2 Outputs

- Robot's estimated pose – The estimated pose of the robot calculated by the system, also used internally
- Beacons' estimated position – The estimated positions of the beacons calculated by the system, also used internally
- Robot's path following waypoints – The robot's current status in the path defined by the pre-determined waypoints
- Request for signal strength and ID – A request sent to the beacon system over 2.4 GHz wireless signal using ZigBee protocol

2.2 Beacon System

A block diagram of a single beacon in the Beacon System can be seen in Figure 2. This system is intended to be scaled to whatever number of beacons is required for the operation of the Robot System, therefore only one block diagram is included.

2.2.1 Inputs

- Power (3.3 V) – The main source of power for the beacon system
- Request for signal strength and ID – A request received from the robot system over 2.4 GHz wireless signal using ZigBee protocol

2.2.2 Outputs

- Beacon's received signal strength and ID – Sent to robot system over 2.4 GHz wireless signal using ZigBee protocol

3 Modes of Operation for Robot System

- *Initialization* - This mode will run at startup and will handle the activation/initialization of subsystems. This mode will also reset any components that require it. The only input required for this mode is power.

- *Calibration* - Once the system has been initialized, this mode will be entered. During this mode, the Robot System will perform a preliminary discovery of all active beacons within range. It will then run calibration functions to calculate necessary constants and parameters used in later modes. The two inputs required in this mode are power, beacon received signal strength and ID, and environment noise. This mode will also utilize the output for requesting signal strength and ID.

- *Discovery* - This mode will handle the discovery of active beacons in the environment. Unlike the calibration mode, this mode will run at set intervals during operation of the system in order to prevent loss of wireless signal. The required inputs for this mode of operation are power, beacon's received signal strength and ID, and noise from environment. The output during this mode of operation is the request for signal strength and ID.

- *Navigation* - This is the main mode of the system, it will handle the navigation of the Robot System along the path defined by the pre-determined waypoints. This mode utilizes all inputs and outputs of the system, with the outputs being displayed for status information.

4 Modes of Operation for Beacon System

- *Active* - When in this mode, the beacon is ready to receive and respond to signal strength requests from the Robot System. This mode allows the beacon to run independently of all other beacons. This mode utilizes all inputs and outputs of the system in order to receive and fulfill requests made by the Robot System. Due to the low power consumption of the Xbee module, there is no need for a sleep mode at this time.

5 Block Diagrams

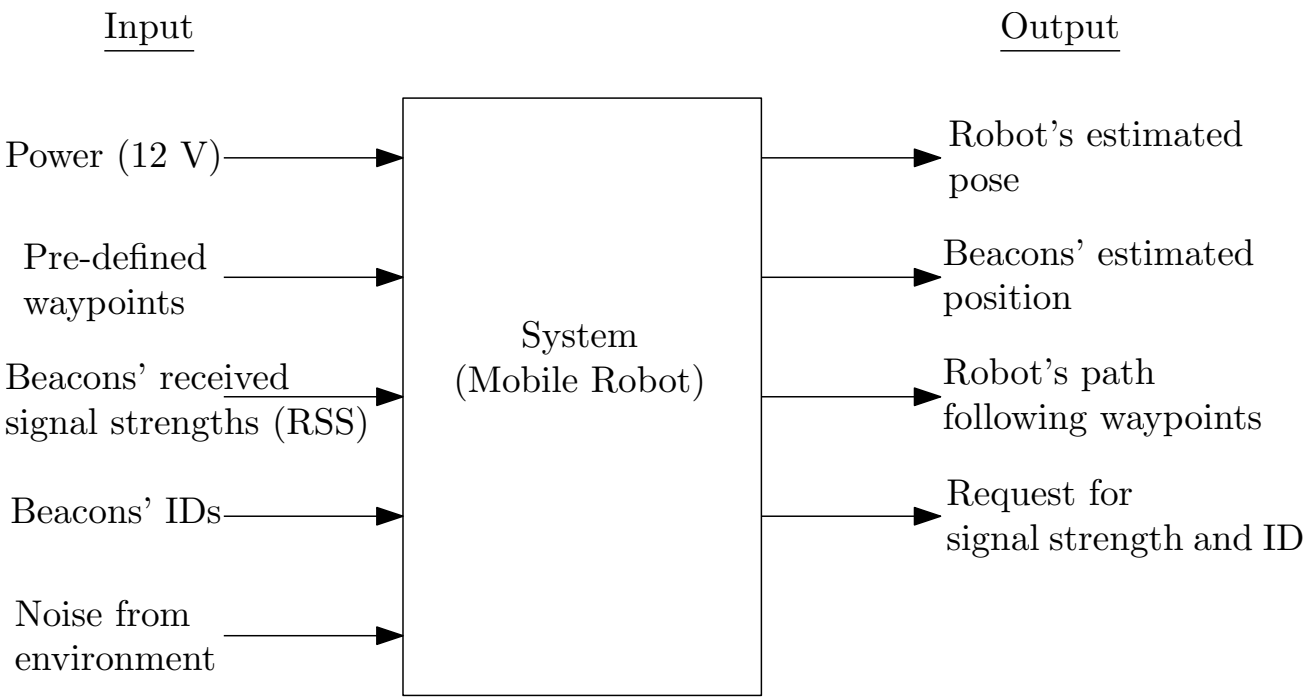

Figure 1: High level block diagram of the Robot System

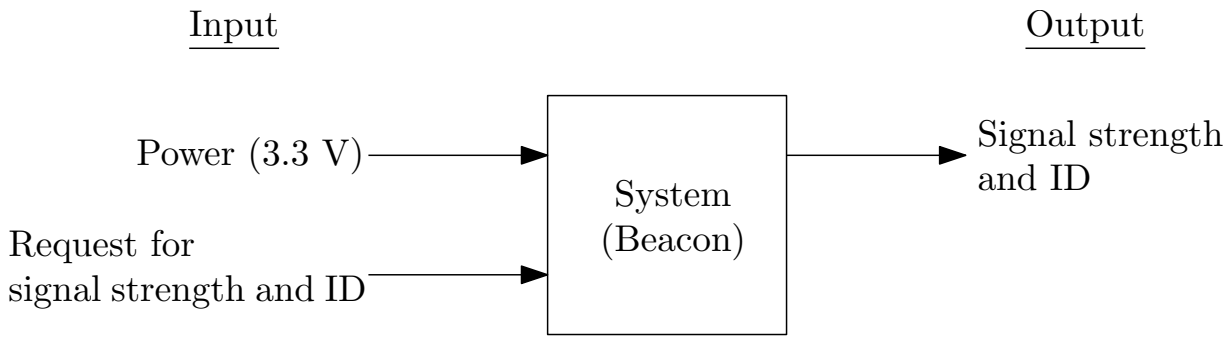

Figure 2: High level block diagram of the Beacon System