Mobile Target Tracking Using Radio Sensor Network

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Outline

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- Mobile robotics is a cutting edge field
- Mobile robotics is an interdisciplinary field
- Mobile robotics has many applications

Introduction

Problem Description

Suppose that a mobile target is moving randomly in an unknown environment. The position and trajectory of the mobile target are also unknown. A mobile robot is supposed to follow this mobile target while maintaining a set distance.

Problem Statement

- Estimate position and orientation of the mobile robot
- Estimate position of the mobile target
- Estimate a map of the environment
- Find linear and angular velocities such that the robot will follow the target within a certain distance

- Warehouses
- Factories
- Search and rescue
- Research and education

- Modular
- Low Cost
- Functions in low light conditions
- High degree of accuracy

Outline

- Radio signal strength to calculate range
- Parabolic reflector to estimate angle of arrival
- Simultaneous localization and mapping using RFID tags
- Tracking of radio signal emitting mobile target

- Xbee Radio Network
- Pioneer 3-DX
- Robotics Operating System
- Beaglebone Black

- Zigbee Radio Protocol
- Star Network Topology
- Low Cost
- Easy to program

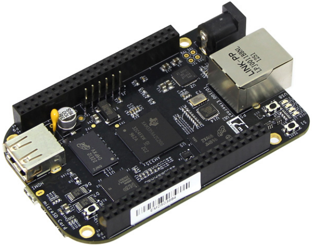
Background Study

Pioneer 3-DX

- Purpose built for research
- 500 bit wheel encoders
- 8 on board sonar sensors
- ARIA framework

- Collection of robotics middleware
- Hardware abstraction
- Node based system
- TCP/IP based communication

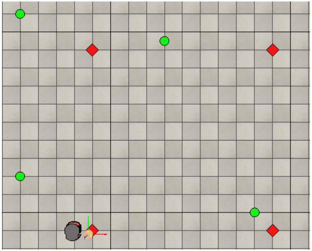
Background Study
BeagleBone Black



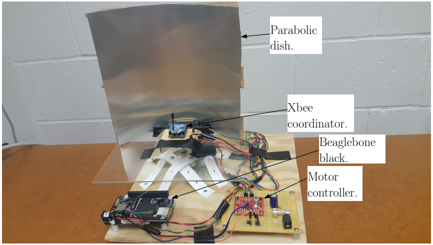
- 1 GHz Cortex A-8 ARM Processor
- UART interface
- Wifi Capable
- Low Cost

Background Study
Prior Work

- Radio receiver and robot control hardware
- Radio sensor network
- EKF-SLAM Simulation and Implementation



(a) V-REP scene of last year's simulation.



(b) Customized radio transceiver.

Figure: Prior work.

- Increase speed of wireless sensor signal acquisition
- Integrate LiDAR into existing system
- Improve overall accuracy of mapping, localization, and target tracking

Outline

Functional Requirements

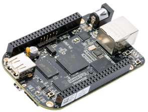
Specifications

- Total Cost of $500 or less.
- Localization of robots and beacons within 30 cm of true position.
- Tracking performance of moving target to within 30 cm.

Functional Requirements

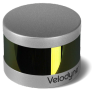
System Architecture

(a) Pioneer P3-DX



(b) Beaglebone Black

(c) Xbee Beacon



(d) Velodyne LiDAR Puck

Figure: Main components of the project.

Functional Requirements

System Level Block Diagram

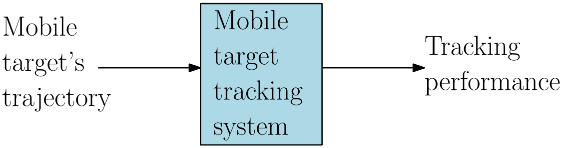


Figure: System level block diagram

Functional Requirements

Subsystem Level Block Diagram

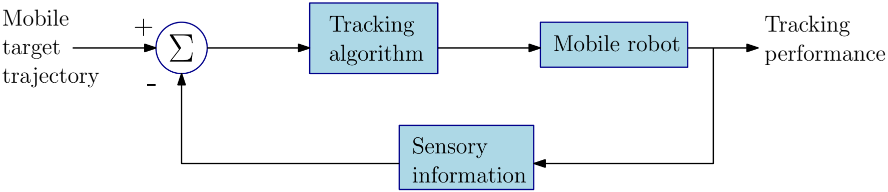


Figure: Subsystem level block diagram

Functional Requirements
EKF-SLAM Algorithm

EKF: *Extended Kalman Filter*
SLAM: *Simultaneous Localization and Mapping*

- Widely popular for resilience to noise.
- Three main steps:
    1. Predict
    2. Observe
    3. Update

Functional Requirements

EKF-SLAM Algorithm: Prediction

Actual Pose: $\mathbf{q} = [x, y, \theta]^T$
Estimated Pose: $\widehat{q} = [\widehat{x}, \widehat{y}, \widehat{\theta}]^T$
Predict State Covariance:

$$\mathbf{P} = \left[\begin{array}{c} (q_{T1} - q_1)^2, 0, 0 \\ 0, (q_{T2} - q_2)^2, 0 \\ 0, 0, (q_{T3} - q_3)^2 \end{array} \right]$$

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Functional Requirements
EKF-SLAM Algorithm: Observe

$$Y_t = [r_t, \theta_t]^T$$

Functional Requirements

EKF-SLAM Algorithm: Update

$$q_{k+1} = \begin{bmatrix} q_{k+1}^{+} \\ b^{s+1} \end{bmatrix}$$

$$P_{k+1} = \begin{bmatrix} P_{k+1}^{+} & P_{b^{(s+1)}q}^{T} \\ P_{b^{(s+1)}q} & P_{b^{(s+1)}b^{(s+1)}} \end{bmatrix}$$

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Discrete time model:

$$
\begin{aligned}
x_{k+1} &= x_k + T\nu_k \cos(\theta_k + \gamma_k), \\
y_{k+1} &= y_k + T\nu_k \sin(\theta_k + \gamma_k), \\
\theta_{k+1} &= \theta_k + T\nu_k \frac{\sin(\gamma_k)}{l}
\end{aligned}
$$

- MATLAB
- V-REP
  - Simulates robot kinematics and sensors.
  - Easily adapted to ROS implementation.

- Existing System
  - BeagleBone Black
  - Radio Receiver
  - Sensor Network
- Adapt/improve existing hardware for target tracking.
- Incorporate Velodyne LiDAR.

Outline

Parts List

Part	Price	Quantity
XBee S2C w/ whip antenna	$18.19	6
XBee Interface Board	$5.31	6
Perforated Circuit Board	$2.84	4
Stepper Motor	$14.95	1
Motor Controller	$19.95	1
3.3 V Regulator	$0.79	10
9 V Battery Clip	$0.39	10

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Deliverables

- Experimental and Simulation Results
- Complete Documentation
- Final Presentation and Report

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Future Directions

- Incorporate object avoidance using sonar and Braitenburg algorithm
- Improve existing EKF-SLAM implementation
- Incorporate Velodyne LiDAR

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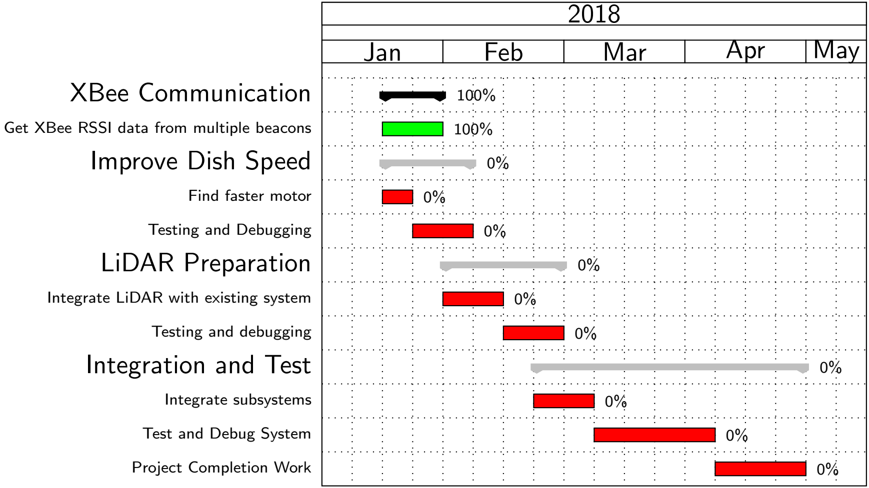
Timeline and Milestones



For Further Reading I

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