Smart Robotic Cart: A Prototype

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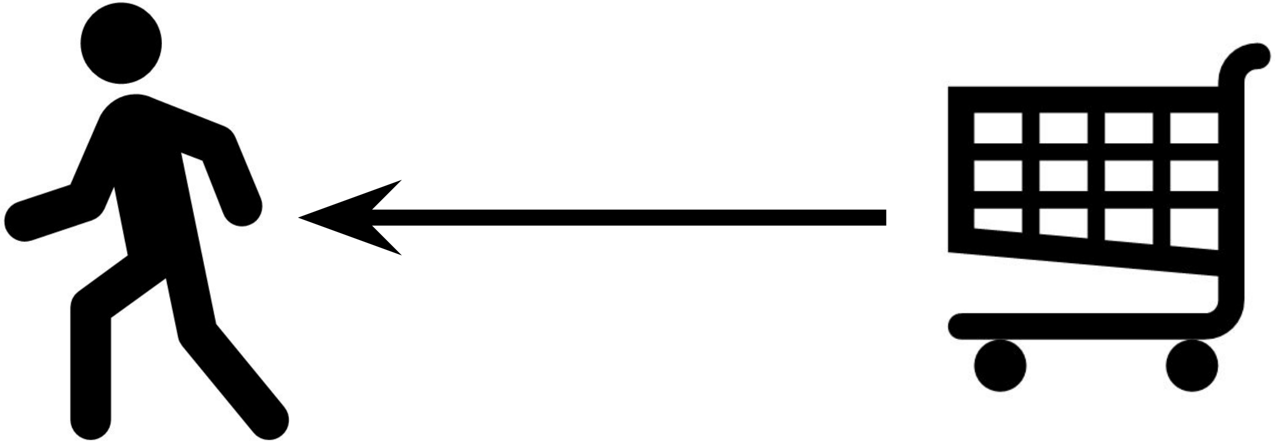
Problem Statement

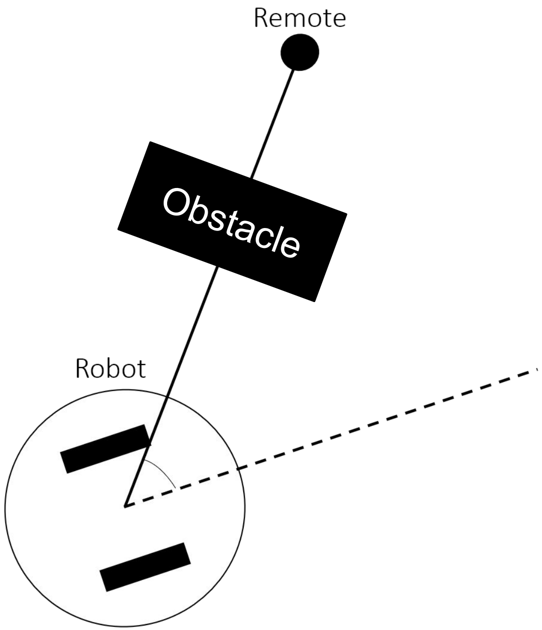
- Design a robotic cart that follows the user
- Does not use line-of-sight sensors to locate the user



Line-of-Sight Sensing

Line-of-Sight sensors must have an open path between the sensor and the object being sensed (no obstacles between)

- Existing smart carts use line-of-sight sensors
- If line-of-sight is not required, the robotic cart could still maintain communication with the remote on the user and be able to locate the user when an obstacle comes between them



Proposed Solution

Utilize wireless analog radio frequency (RF) signals

Benefits:

- Cost-effective
- Signals propagate through objects, so communication does not require line-of-sight

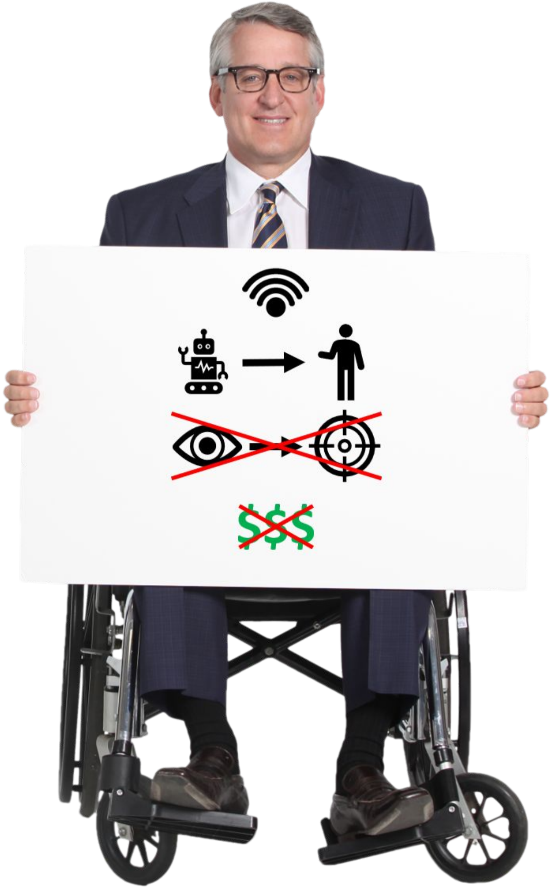
Downside:

- RF signals are noisy due to reverberations

Project Goals

The robotic cart system should:

- Utilize **<u>wireless signal strength</u>** to locate the user
- Move to follow the user
- Not use line-of-sight sensors to follow the user
- Have a **<u>cost-effective</u>** design

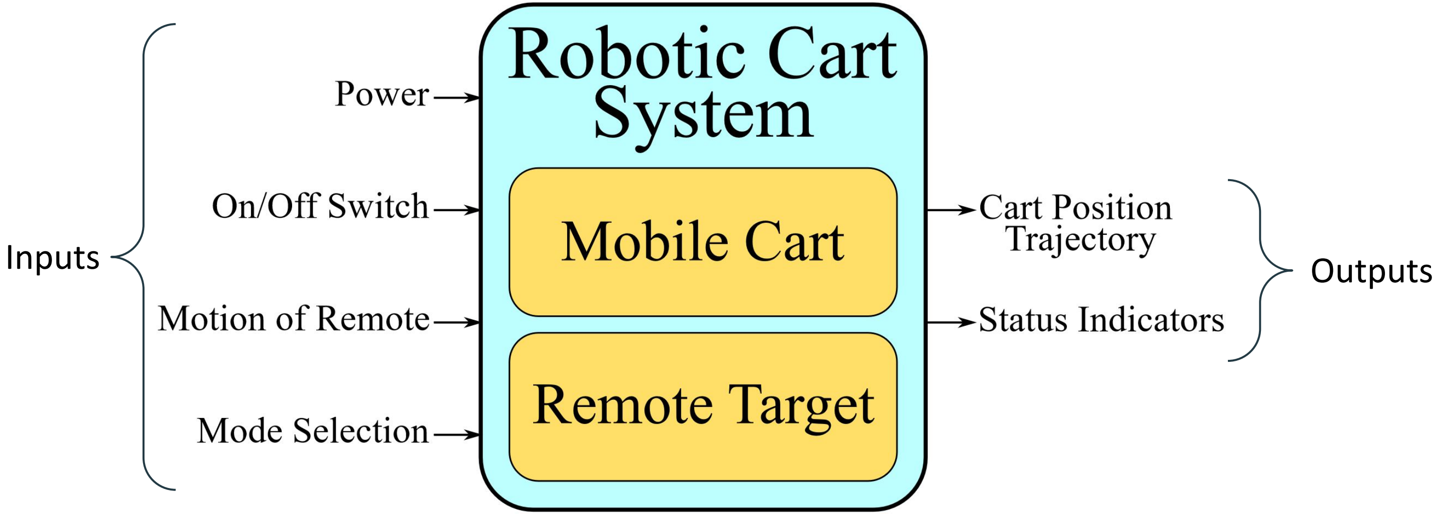


Robotic Cart Specifications

- Cart should be able to follow the remote target
- Cart should remain a distance of 1 [m] to 1.5 [m] from the remote target
- Cart should be able to attain a speed of at least 1 [m/s]
- Cart should not require line-of-sight to follow remote

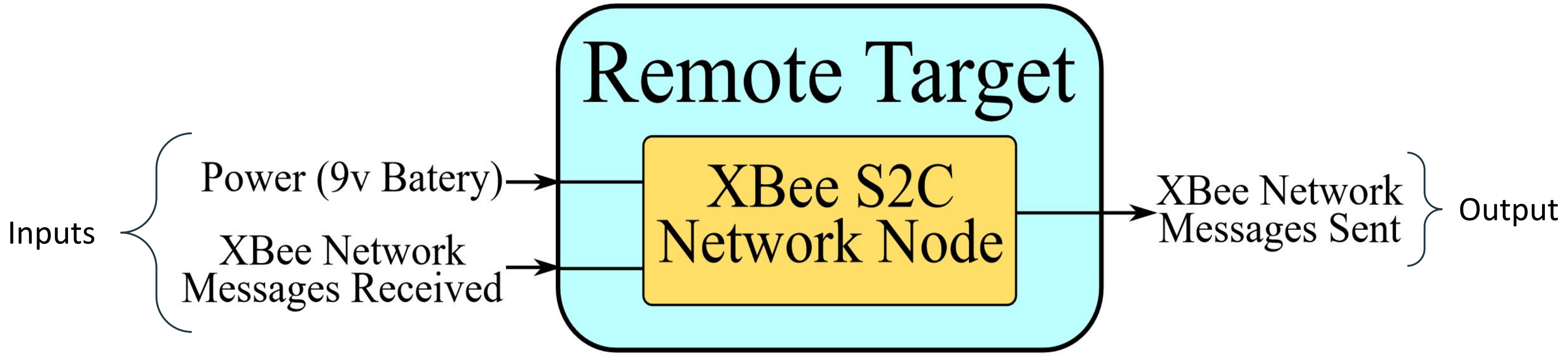
Robotic Cart System Block Diagram

- Four inputs
- Two outputs



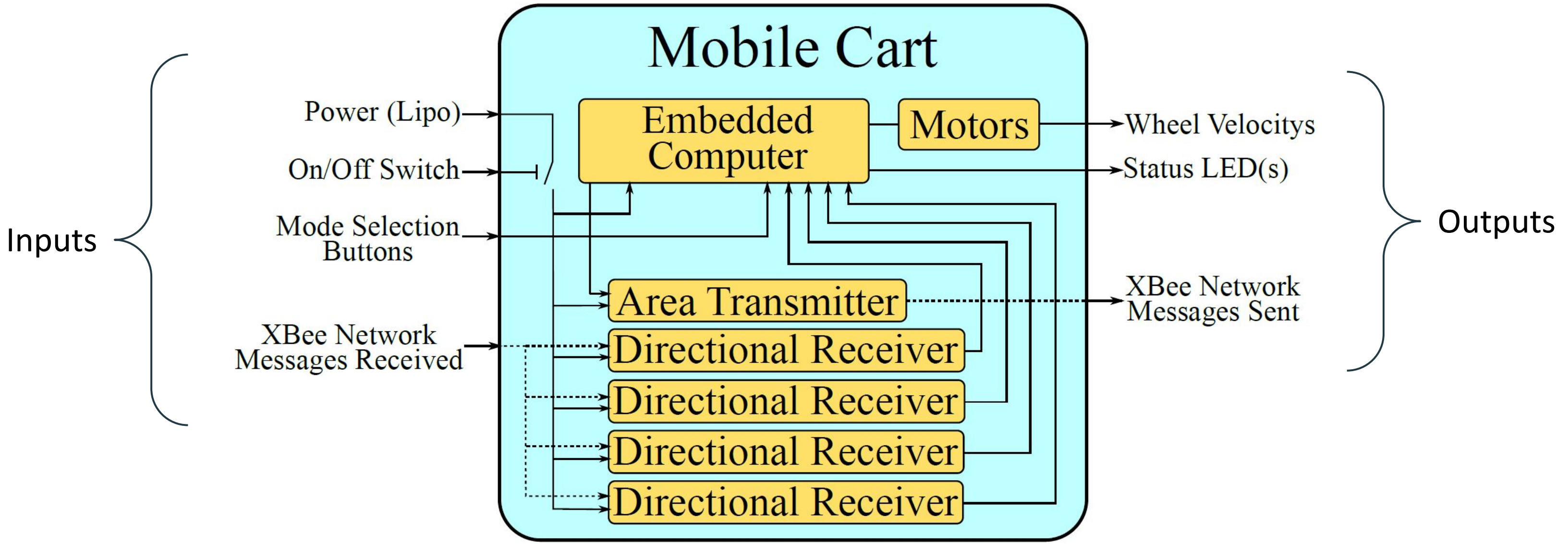
Remote Target Subsystem Block Diagram

- Two inputs
- One output



Mobile Cart Subsystem Block Diagram

- Four inputs
- Three outputs



Main System Components

- Budget Bot Chassis - Physical framework of robotic cart
- BeagleBone Blue - Embedded computer to control robotic cart
- XBee S2C Module - Wireless communication module

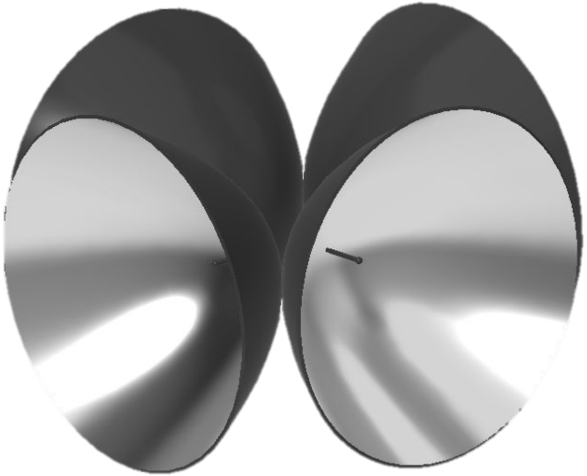
Budget Bot Chassis

BeagleBone Blue

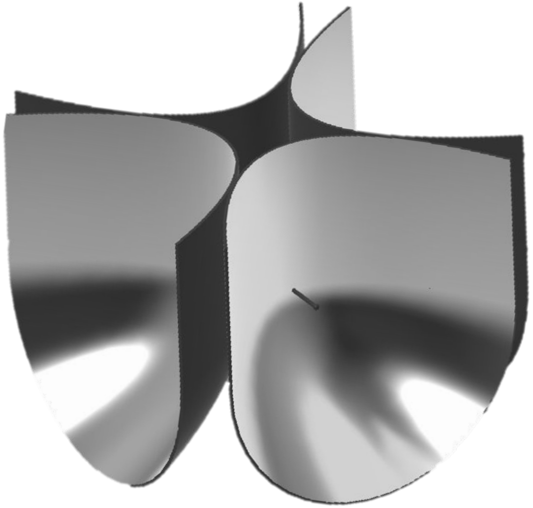
XBee S2C Module

Reflector Arrays

- Two designs
  - Paraboloidal - focuses signals coming directly into reflector
  - Parabolic/Paraboloidal - better reception of signals from above



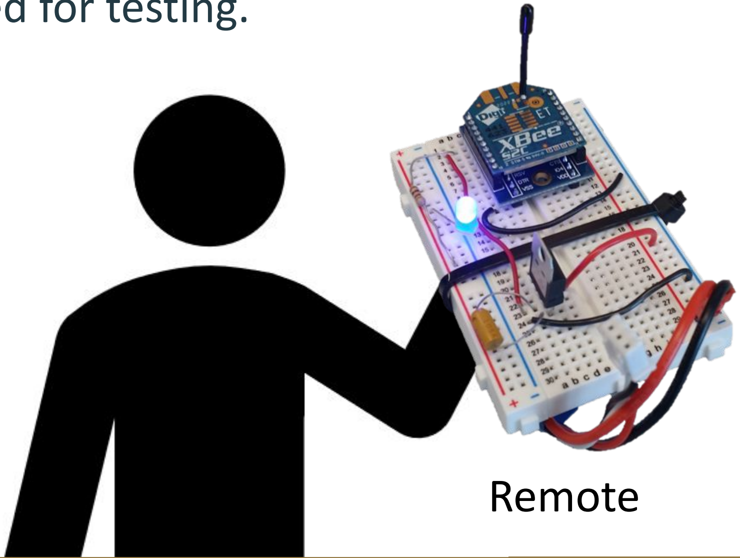
Model 1: Paraboloidal Reflector



Model 2: Combined Parabolic/Paraboloidal Reflector

System Prototype

We created a prototype robotic cart using the paraboloidal reflector design. This prototype was used for testing.

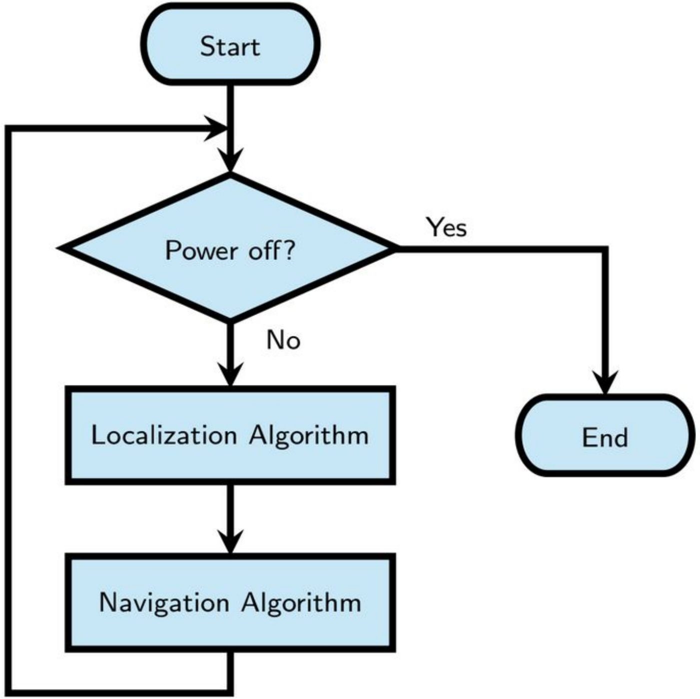


Remote

Robot

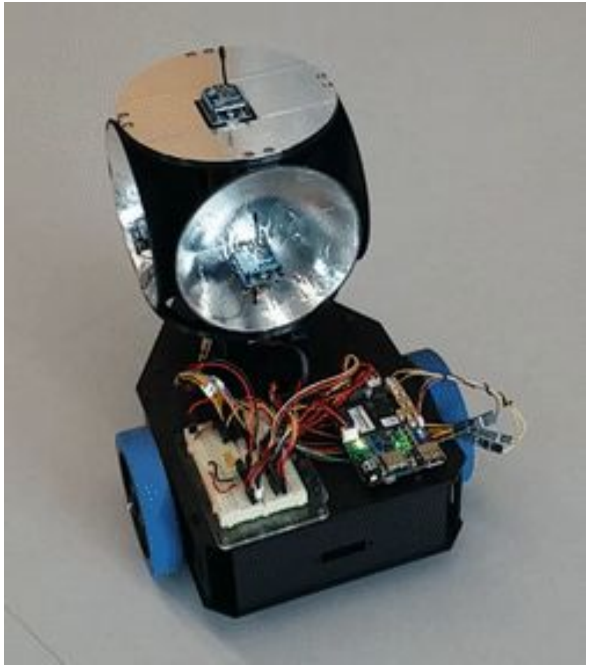
Operation of Mobile Cart System

Repeatedly execute Localization and Navigation Algorithms until powered down



Localization Algorithm

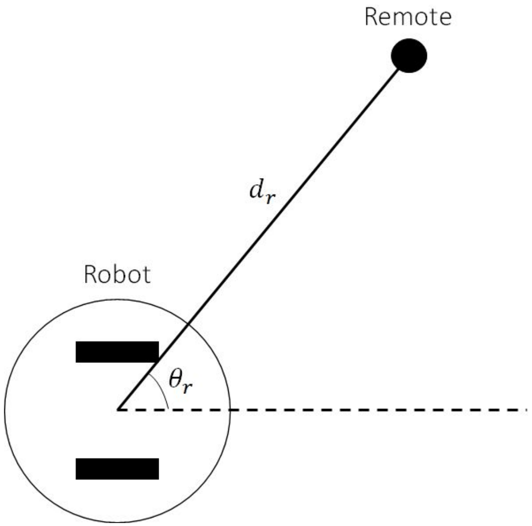
1. Coordinator sends request for signal strength measurement to remote
2. Remote responds with its measured signal strength
3. Receivers measure signal strength of message from remote
4. Rotate reflector array 9 degrees
5. Repeat steps 1-4 until 10 measurements have been taken
6. Calculate distance to remote using strength of signal received by remote
7. Calculate angle to remote as the direction of the maximum signal strength measured by the receivers



Navigation Algorithm

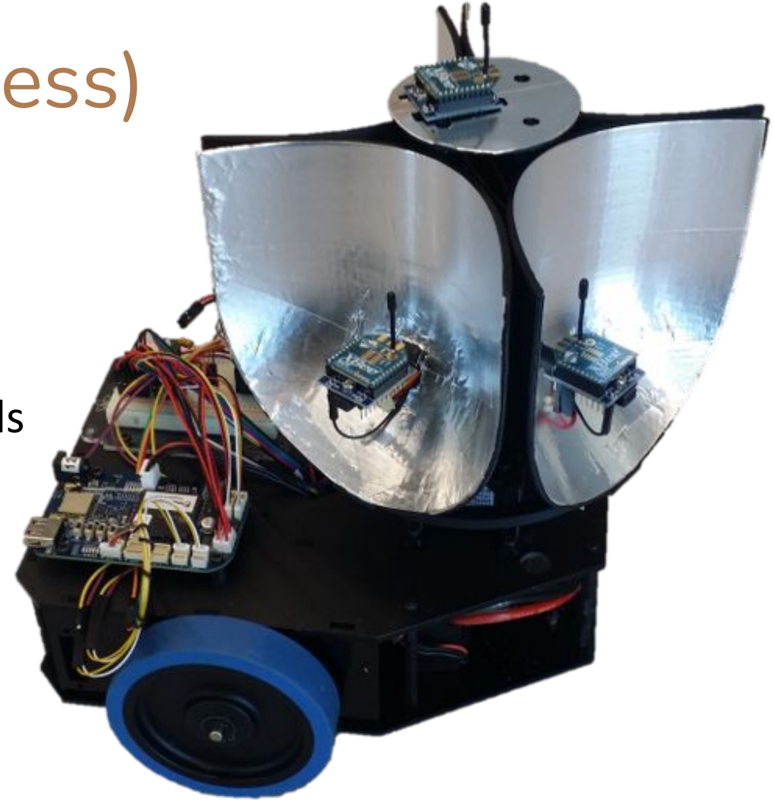
Distance to remote: d_r
Angle to remote: θ_r
Proportional control gain for linear velocity: K_v
Proportional control gain for angular velocity: K_ω

1. Calculate linear velocity $v = sign(d_r \cos\theta_r) K_v d_r$
2. Calculate angular velocity $\omega = K_\omega \theta_r$
3. Apply speeds to wheel motors to move the robot



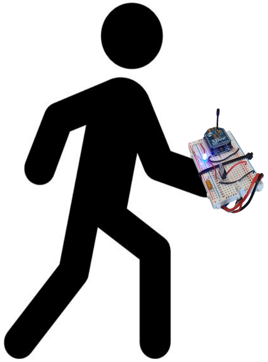
Robot Model 2 (In Progress)

- Uses the combined parabolic/paraboloidal reflector shape
- Intended to allow better reception of signals from above
- This model is not yet tested



Current Challenges

- Accuracy of angle estimation is low and causes some errors in the robots trajectory to the remote
    - Possible solution: Implement the Extended Kalman Filter (EKF) algorithm to filter out noise
- Distance estimation is not consistent and will drastically change if the user stands between the remote and the robot



Conclusion

- Designed and implemented a cost-effective robotic cart that is able to locate and follow the user
- We are continuing to refine our design to better solve the problem