RFID-Based Cooperative Asset Detection and Localization

Ken Nguyen, Yu Xia, Chris Le
Department of Mechanical and Aerospace Engineering at University of California, Irvine
Sponsored by Professor Solmaz S. Kia

UCI Samueli School of Engineering

Overview

- This project aims to use radio frequency identification (RFID) technology to devise an all-weather asset detection and localization method for objects that may be hidden from obstacles in an unknown environment.
- The main robot is equipped with an RFID antenna and scans through the environment to locate a target that is pre-equipped with a passive RFID tag.
- Several reference robots equipped with passive RFID tags aid the main robot in navigating the environment.

Existing Solutions

- **VICON Motion Capture System:**
  - Advantage: Accuracy (Usually in millimeter scale)
  - Disadvantage: Expensive (Requires many infrared cameras).
- **Optical Camera and Machine Vision Algorithm:**
  - Advantage: Adaptation to new environment.
  - Disadvantage: Requires prior training to recognize objects.

Maximize RFID Detection Range

- **Key Designs:**
  - Higher dBi: more coverage in the x-y direction.
  - Matching Network: RFID tag impedance is matched to chip impedance to minimize power loss (at 915 MHz)

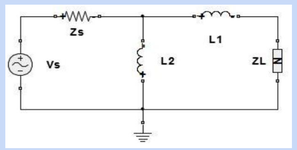

Figure 1: Circuit of a L-section matching tuning network
Inductor 1 = 2.327e-9 H
Inductor 2 = 3.9e-8 H
Resistor = 50 Ω

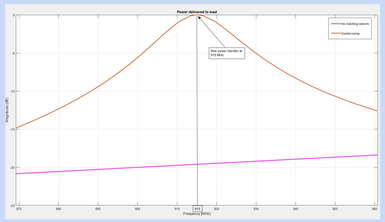

Figure 2: Power Delivered to Load:
No Matching Network vs. Double Tuning
At 915 MHz, there is no power (dB) loss by matching the chip to RFID tag impedance

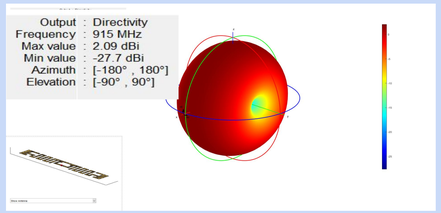

Figure 3: Radiation Pattern of RFID tag at 915 MHz
Ultra-high frequency (UHF) RFID tag at 915 MHz has good coverage in the transmitting direction.

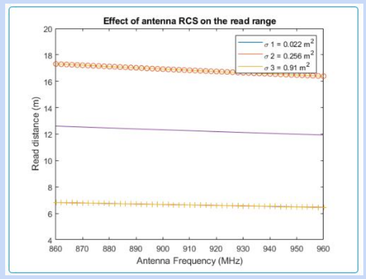

Figure 4: Effect of Radar Cross Section on read distance
Results: 16.8m detection range

Design Solution

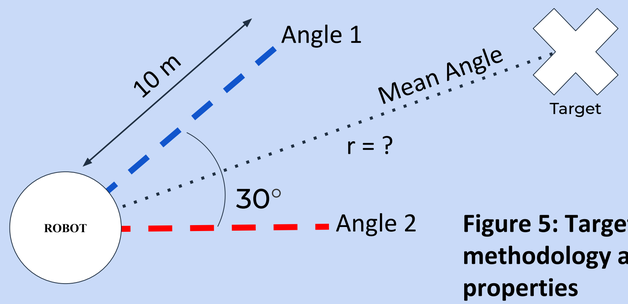

Figure 5: Target localization methodology and antenna properties

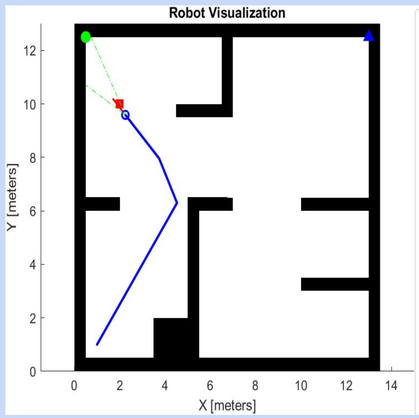

Figure 6: Target detection and localization using the mean angle

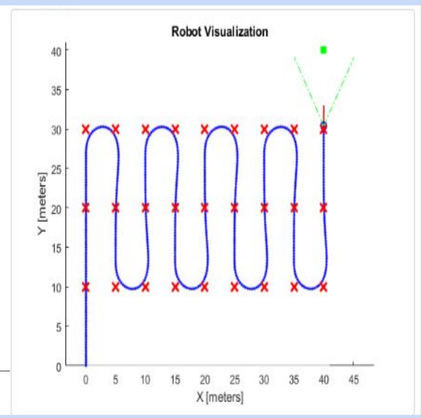

Figure 7: Robot sweeping path via waypoints

- **Requirements**
  - Scan area: 40x40 meters
  - Antenna's detection range and field of view: 10 m and 30°, respectively.
  - Time allotted to detect and locate target: 5 minutes
- **Methodology**
  - Robot follows a sweeping ("lawn mower") path via waypoints.
  - Upon detection, the robot uses the rotating directional antenna to determine the two angles/directions that the target is within (**see Fig. 5**).
  - The robot moves along the mean angle/direction of the two angles found until it gets closer to the target.
  - The method of finding a mean angle and moving along that angle is repeated because a random error is added to the mean angle in order to simulate the imperfections of an antenna's field of view.

Future Improvements

- Implement an obstacle avoidance algorithm into the current one.
- Develop a more efficient algorithm that determines the path that the robot follows.
  - The sweeping ("lawn mower") path method ensures the whole area is scanned, but there is some wasted time/energy because the robot will most likely rescan previously scanned areas (**see Fig. 7**).

Impact on Society

- RFID-based asset detection and localization can applied to search and rescue missions.
- The ability for RFID to work through obstacles allows it to work phenomenally in harsh environments such as areas with a plethora of debris caused by a fire or dense forests.

Safety Consideration

- Research on the adverse health effects from electromagnetic waves emitting from an RFID antenna is inconclusive.
- Interference RFID technology can be life threatening if it is used within proximity of interference-sensitive medical devices such as pacemakers and implantable cardioverter defibrillators (ICDs) [1].

Acknowledgements

Special thanks to Professor Solmaz Kia for your guidance and mentorship.

References

[1]"Radio Frequency Identification RFID", *U.S. Food and Drug Administration*, 2018. [Online]. Available: https://www.fda.gov/radiation-emitting-products/electromagnetic-compatibility-emc/radio-frequency-identification-rfid.