IOT Position Application for In-home Robots

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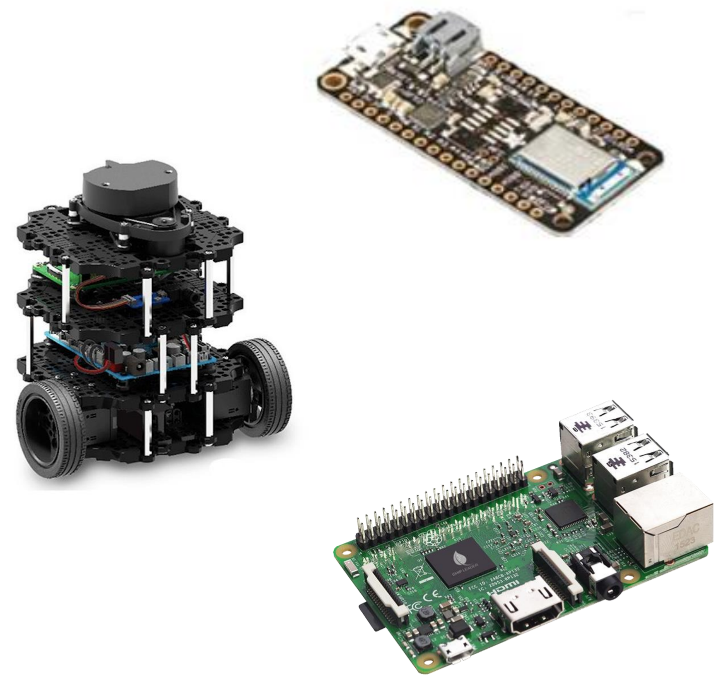
IOT Device Localization & Routing

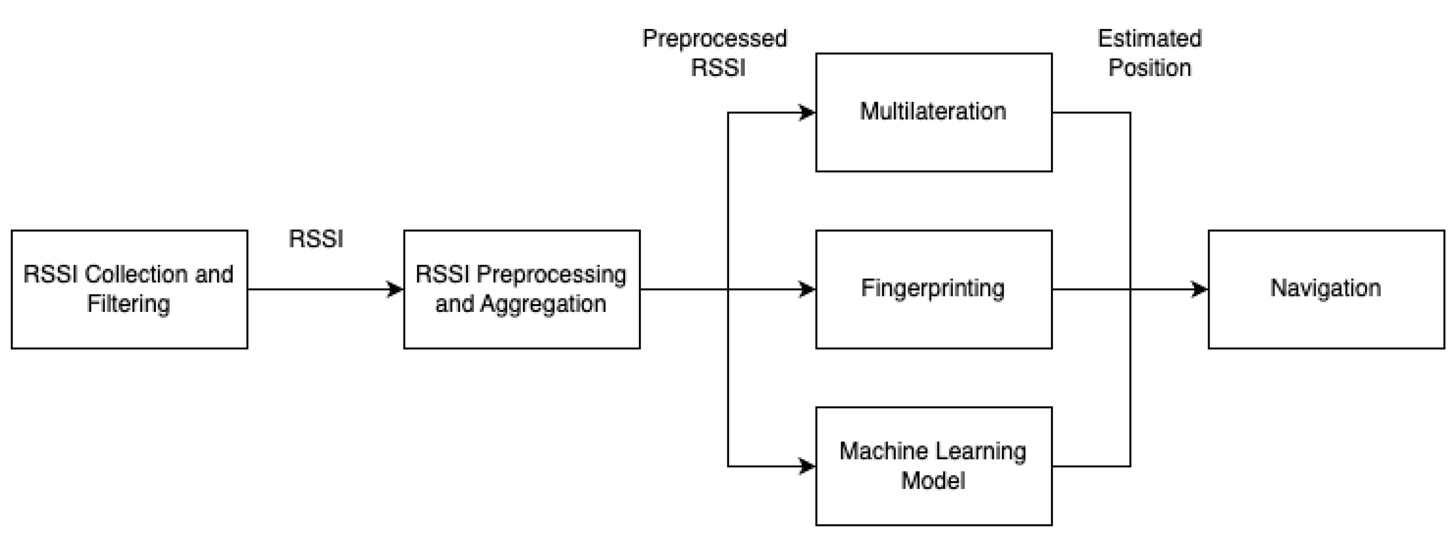
- The development of an accurate IoT localization algorithm involves building dynamic radio maps by collecting RSSI values in diverse indoor environments for precise IoT device location prediction.
- Experiment with localization algorithms to identify the most suitable approach.
- Investigate wireless SLAM approaches for optimal routing paths in home robotics by utilizing indoor datasets to test the algorithm.

Requirements (HW & SW)

- Adafruit BLE tags are used as peripheral nodes or beacons for transmitting the bluetooth signals.
- Raspberry Pi serves as the central node for receiving RSSI values from the BLE beacons.
- TurtleBot 3 is the robotic platform employed in this project.
- Operating system: ROS Neotic distribution on Ubuntu.
- Software Dependencies: Bluepy, PyTorch, Scikit-Learn, Numpy



ROS Implementation



System Overview

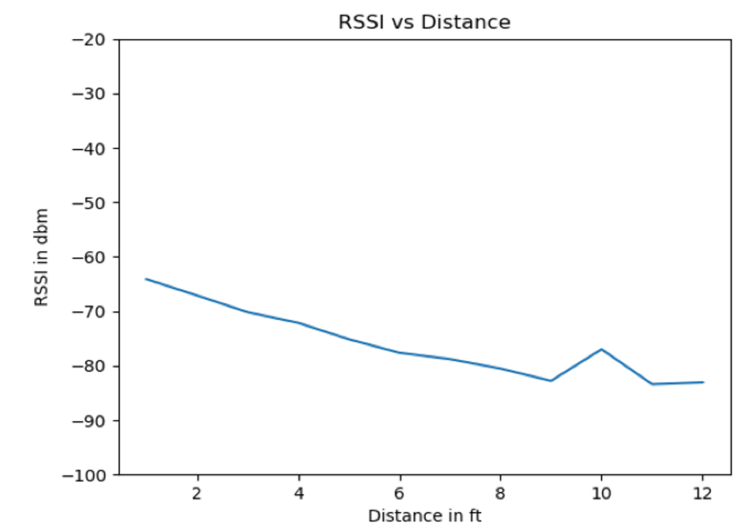
- RSSI Collection and Filtering: Scan all available bluetooth signal sources in the environment, and filter out unrelated signal sources.
- RSSI Preprocessing and Aggregation: Perform smoothing, noise reduction and output a more robust RSSI estimation.
- Multilateration: Utilizing the log-distance path loss model to estimate the distances between the robot's current position and all known signal sources. This enables further calculation of the robot's current location.
- Fingerprinting: Infer the most probable current location based on the previously created radio map and the RSSI signals received by the robot.
- Navigation: Based on the estimated location information obtained from the previous steps, navigate the robot to the desired destination.

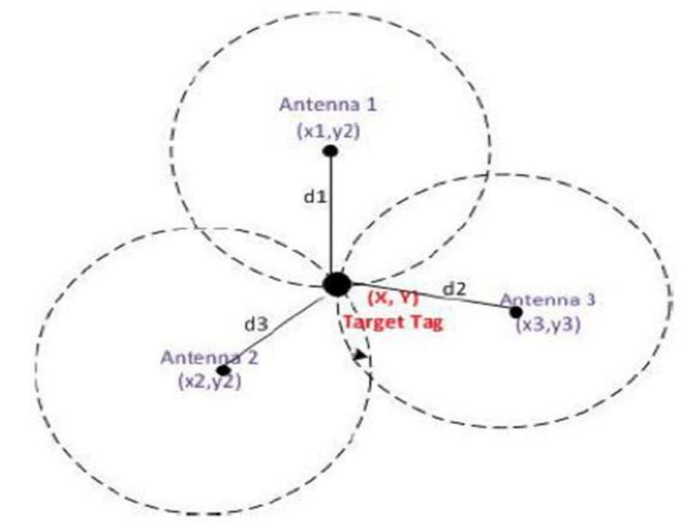
RSSI vs Distance - Trilateration/Multilateration

- RSSI measures power of the received signal and is sensitive to signal attenuation and multipath fading.
- The RSSI values decrease as the distance from the transmitter increases due to the inverse proportional relationship and the power decay of the transmitted signal.
- Relationship can be modelled by the log-normal shadowing model.

$$P_r(d) = P_0 - 10n \log \frac{d}{d_0}$$

- Trilateration: Estimates the IoT device location by intersecting spheres centered at three or more reference points, using measured RSSI values.
- Multilateration: Enhances localization accuracy by incorporating more reference points and utilizing advanced mathematical techniques like least squares estimation.





Machine Learning based RSSI Fingerprinting

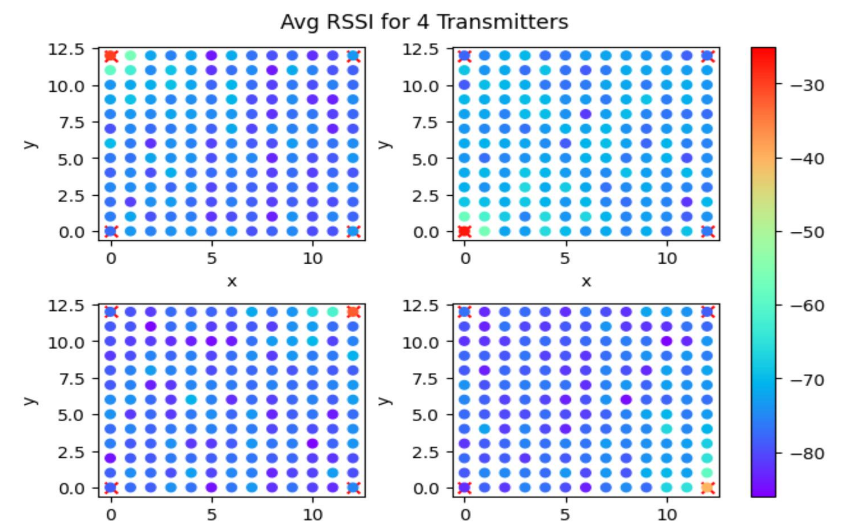
The Radio Map is constructed to be used for fingerprinting localization and training the ML model. Two approaches were tried to obtain the radio map:

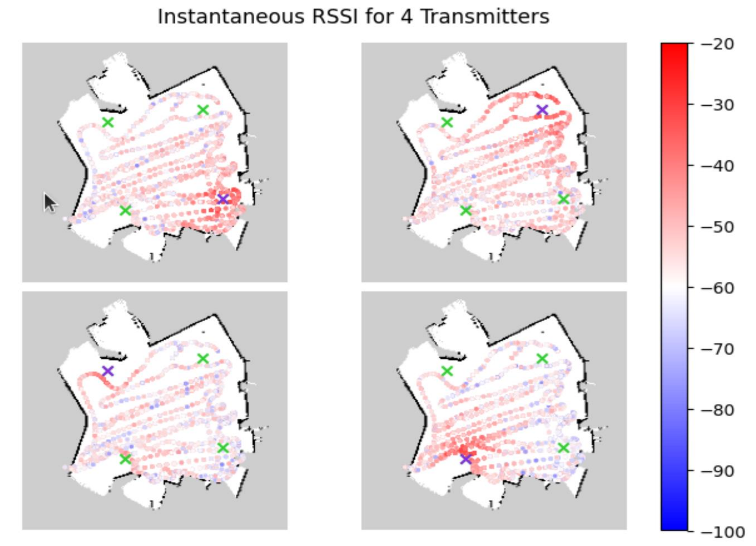
Static

- Four transmitters are placed at the four corners as signal sources.
- The robot is placed at each grid cell individually to collect RSSI data, with a duration of one minute for each grid cell.

Instantaneous

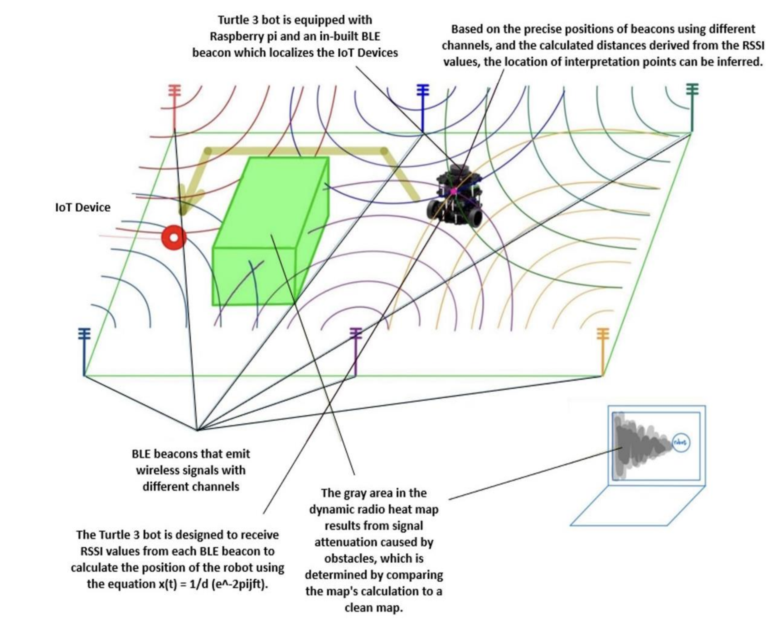
- Using SLAM, the robot utilizes its LiDAR sensor to create a usable map of the entire room.
- Navigated the robot within the area simultaneously recording the RSSI received from the transmitters and the robot's estimated positions.

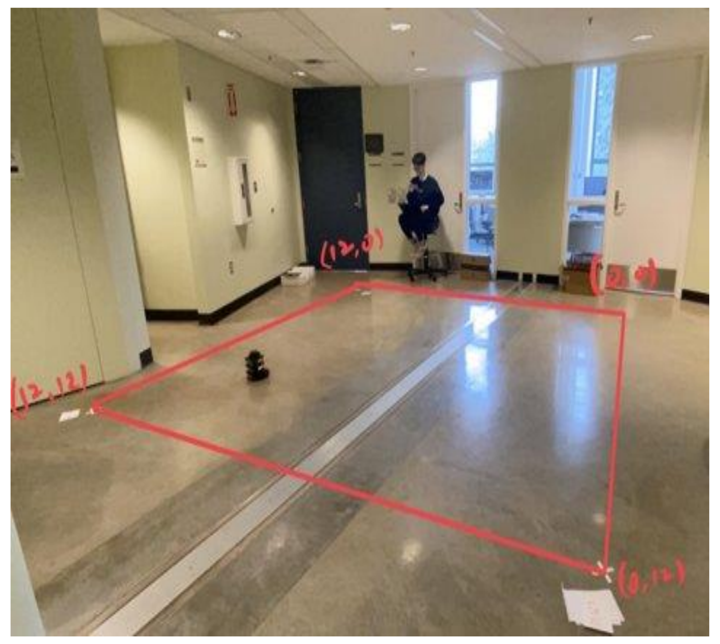




- Machine Learning algorithms used: K-NN & MLP
- Machine Learning based approach achieved less localization error (~1.5 feet) compared to Multilateration algorithm in simulation.

Prototype Implementation

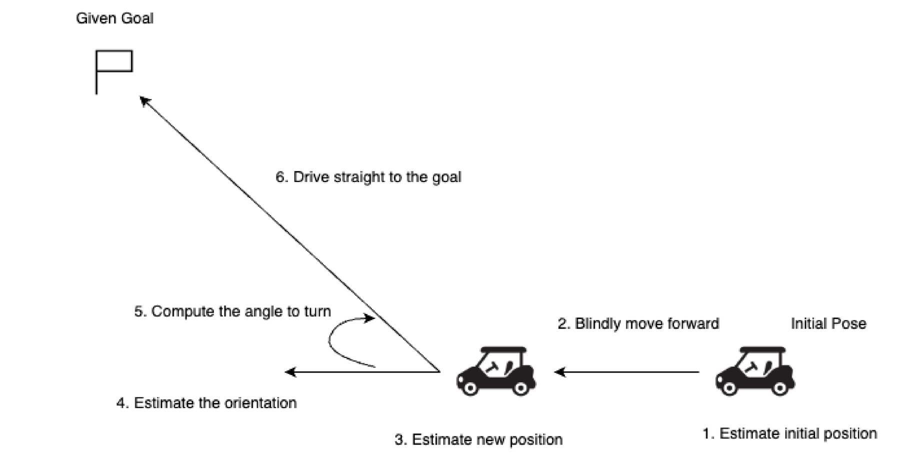




Performed the experiment in indoor environment in the Line-of-Sight scenario.

Robot Navigation

- Estimates the orientation of the robot by instructing it to move straight for a short distance. The vector derived from the starting and ending points is then used as an estimate of the robot's orientation.
- Calculates the vector from the robot's current position (as the starting point) to the destination (as the endpoint) and determines the required angle of rotation for the robot to face the destination and the required distance to reach the destination.
- Attempts to move straight towards the destination and halts upon reaching it. If the robot is not close enough to the destination, the above steps are repeated.



Conclusion, Future Work, and References

Future Work

- Exploring different machine learning models for localization to enhance the accuracy
- Evaluate the performance in different indoor setting and in the presence of obstacles
- Using Channel State Information (CSI) in combination with RSSI to get some additional insights for localization

Conclusion

We developed RSSI localization algorithms for IoT devices using Multilateration and ML-based fingerprinting methods, and were successfully able to navigate the in-home robot to reach the device. Further research is needed to enhance adaptability in various indoor environments.

References

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