Scotty Maps

Team B7: Jeff Chen, Ifeanyi Ene, Weelie Guo
18-500 Capstone Design, Spring 2024
Electrical and Computer Engineering Department
Carnegie Mellon University

Product Pitch

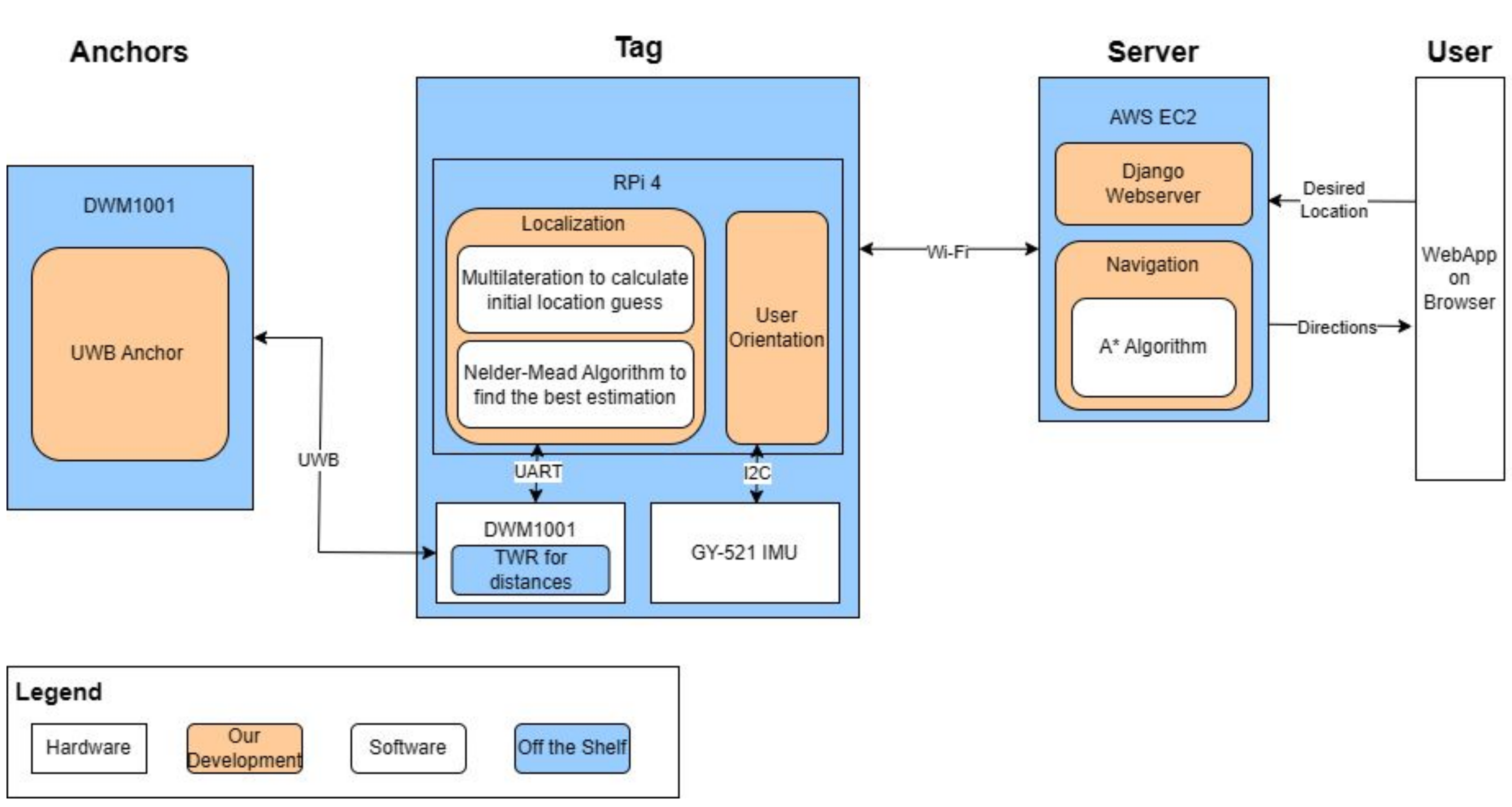
- **Scotty Maps** is an indoor localization and navigation system built to guide students directly to their destination in unfamiliar buildings.
- **Use Case:** Our goal is to design a accurate localization system of average accuracy of **< 1 meter** with high update frequency of **> 2 Hz**, along with long battery life of **> 4 hours**. We wish to keep costs down to **$75** per tag device, as well as an infrastructure installation cost of **$100** per hallway.
- **Design requirements:** To keep costs down, we would like a range of at least **25 meters** on our wireless transceivers. Our transceivers should have a distance accuracy of **< 0.23 meters** for accurate localization. Our compute latency (algorithms and sending costs) should take **< 500 ms**.
- **Results:** Our localization system achieves accuracy of an average of **0.2 meters**, with an update frequency of **10.1 Hz**. Its total latency from the user moving to displaying the movement on the user interface is **0.84 seconds.**

System Architecture

Our system design consists of a network of Ultra Wideband transceivers (DWM 1001 boards functioning as anchors) placed at fixed locations.

Our tag consists of a Raspberry Pi, which is connected to a DWM 10001 board. It communicates with the network of anchors to obtain distances from each. From there, it then estimates the user's position, before sending that information to the server. The tag also has an IMU, which is used to provide the heading and orientation of the user.

The server hosts our web application and displays the user's position on a map. The user interacts with the web application on their browser to be view their location and select rooms they wish to navigate towards.



Conclusions & Additional Information

http://www.ece.cmu.edu/~ece500/projects/s24-teamb7/

Our aspiration of our project is to revolutionize indoor navigation, surpassing the limitations of traditional GPS in indoor environments. We have achieved many of our goals by offering high-accuracy positioning of 0.2 meters, along with responsive tracking of a frequency of 10.1 Hz.

Throughout the process, we have learned many things related to planning our schedules many weeks in advance, as well as making tradeoffs for creating a better system.

System Description

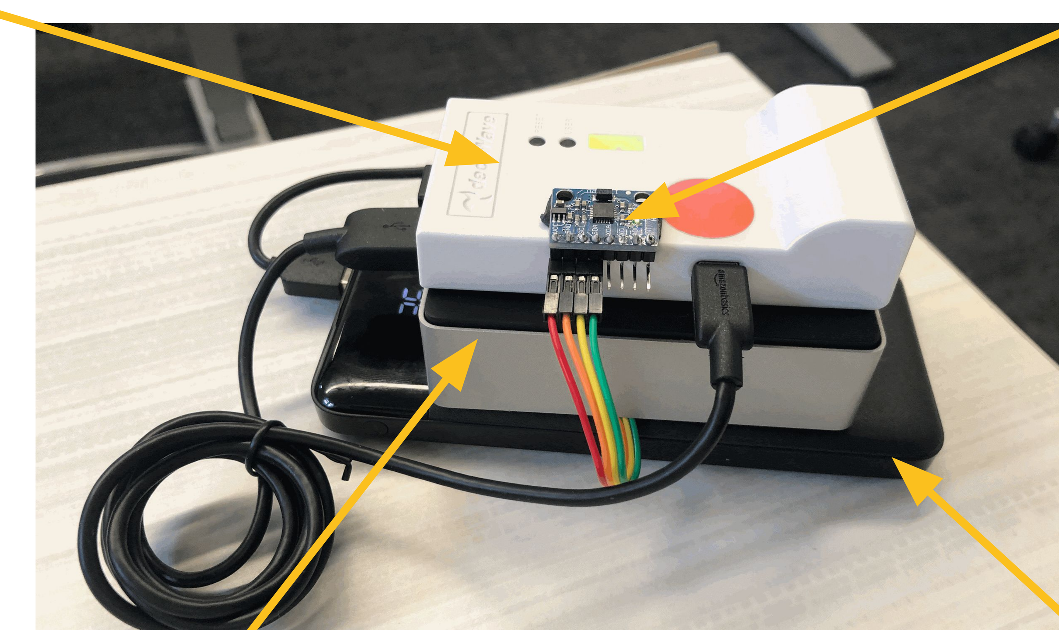
The tag device uses TDOA (Time Difference of Arrival) to find its distance from each of the anchors. The measurements are then sent to the Raspberry Pi 4, which uses the Nelder-Mead optimization algorithm to find our estimated position given these distances. Additionally, the IMU is used to get the orientation of the user about the Z-axis.

The tag communicates its predicted location and orientation to the server, which then displays the position and rotation on a map. Once the user enters a room number, the best path for them to take to their intended destination is found using an A* pathfinding algorithm. The web app then displays a route line as well as natural language directions to guide the user to the room.

Handheld tag device

DWM 1001 Transceiver

IMU

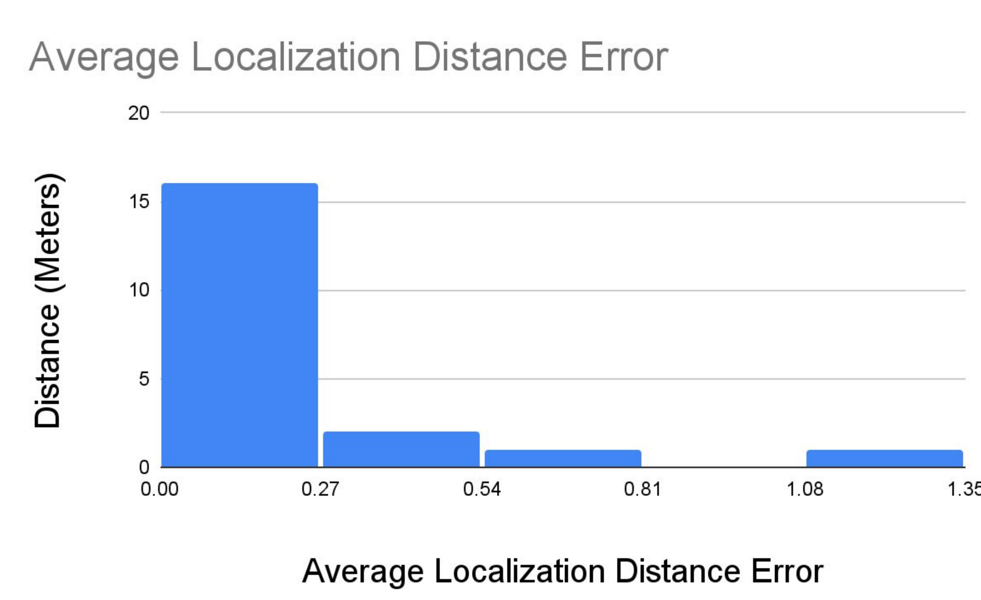


Raspberry Pi

Battery Pack

System Evaluation

Accuracy Testing



Results:
By comparing the predicted distance of our localization system versus our actual position, we find that the average error is 0.20 meters.

Latency Testing

Category	Goal	Actual
Distance Update Frequency	> 2 Hz	10.1 Hz
Tag to WebApp Latency	< 250 ms	67 ms
Total Latency	< 2 sec	0.84 sec

Trade-offs

Position Solvers

Linear Algebra	• Very fast (~1 ms runtime) • Only works for 3 tags
Gradient Descent	• Very stable (< 0.5 m fluctuation) • Slow (~100 ms runtime)
Nelder-Mead algorithm	• **Lower Precision (~ 1 m error)** • **Relatively fast (~10 ms runtime)**

Electrical & Computer ENGINEERING
Carnegie Mellon