UWB in Tunnels

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Introduction

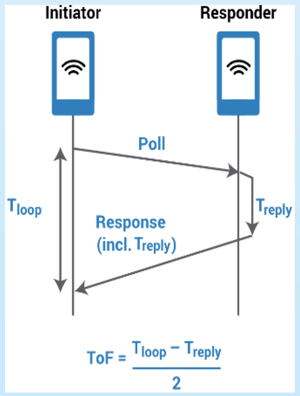
GPS signals are proven to be problematic when navigating inside a tunnel. Our solution is to create an app that locates a car going through a tunnel, without the use of GPS signals.

Ultra-wideband (UWB) ranging is already used for localization of objects inside closed spaces. Using this technology we made a proof-of-concept model of a car in a tunnel.

More about UWB

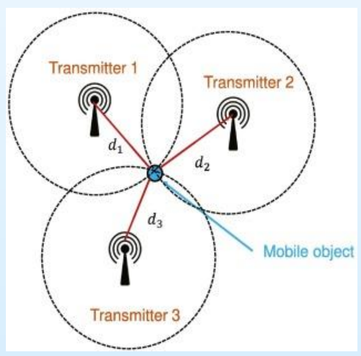
- UWB was chosen since it can provide high accuracy while remaining accessible for use. Other solutions include Bluetooth, which is less accurate, and ways of extending GPS underground, which is not very accessible and harder to test.

- UWB ranging works like echolocation: A high-frequency wave is sent out from module 1, and module 2, when the signal is received, sends it back. By calculating the Time of Flight and knowing the delay of antennas you can find the distance between the modules.



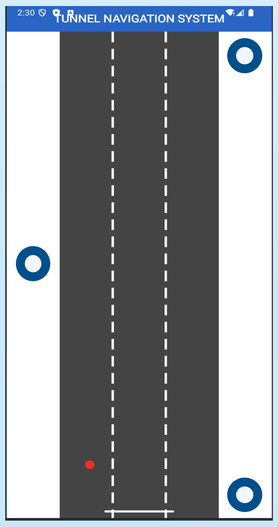
Model

Four ESP32 DW1000 boards are used as UWB modules. Three of them are used as anchors (static modules with known positions) and one as a tag (moving module planted on an RC car). The tag measure the time of flight and then calculates the distance from each anchor. This data is sent through Bluetooth serial, which is then logged in a .log file.
After the drive, the app parses the .log file for the different distance measurements.

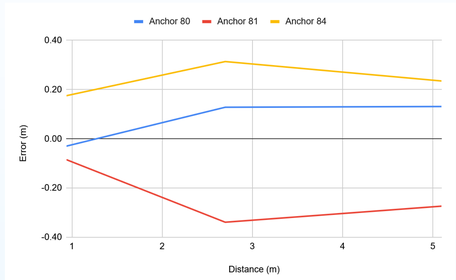


Once the data is parsed, for every three distances a trilateration algorithm is used to calculate the coordinates of the car based on the distances recorded from each anchor.

An image from our UI demonstrates our mapping for the tunnel. We decided to go with a 3-lane tunnel model, with anchors located at the specified spots noted by the blue circles. When the coordinate is calculated, the car, illustrated by the red dot, is moved to the calculated coordinate.



Accuracy of the Model



- Error in ranging to anchors at distances .94 meters, 2.7 meters and 5.1 meters.

- The accuracy of ranging between anchors and tags is impacted by the distance. Since our biggest test distance was 5.1 meters, the model's efficiency is likely to be different in a real tunnel, but since the testing shows that the error doesn't strictly increase or decrease with distance, it is hard to tell whether UWB ranging would be more or less effective in a real scenario compared to the model.
- A real-world scenario would include much less idealized conditions for modules, such as different orientation or heights, which can reduce the accuracy of the model.
- The ESP32 DW1000 board is meant to be easier to use, but because of that it lacks ability to better configure antenna position. In real scenario, a more flexible option could be used to improve accuracy.

References

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