Evaluating Accuracy of DSRC GPS for Pedestrian Localization in Urban Environments

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Abstract— **Dedicated Short-Range Communications (DSRC) are a standard of communications designed for vehicle-to-vehicle and vehicle-to-infrastructure communication. This technology offers significant promise for improving pedestrian safety, as it allows pedestrians to communicate directly with nearby infrastructure elements and vehicles, and offers more precise GPS localization. Our work shows the current standard is too imprecise at low speeds, and as such cannot be used for pedestrian localization. We propose a method to increase the accuracy of DSRC GPS readings at low velocities and to increase precision by utilizing both iPhone and DSRC GPS readings.**

I. INTRODUCTION

DSRC was developed in 1999 by the United States Federal Communications Commission as a short range, low-latency, line of-sight wireless data transmission standard designed for interactions between vehicles and infrastructure in urban environments. DSRC messages use the Basic Safety Message (BSM) for safety-related applications, which is described below. Non-safety related information is communicated with the other message formats, which can include toll collection data, digital maps, intersection signal status, and other information. Some messages can also provide more detailed information on intersection geometries and positioning by using known coordinates of DSRC intersection nodes in conjunction with differential GPS algorithms [2].

A. *BSM Message*

The main message standard used in positioning without the use of DSRC-enabled intersections as reference points is the Basic Safety Message (BSM). The BSM is comprised of a set of data frames, each containing data elements or data frames. The elements included in the BSM are defined in the ASN.1 coding standard, and can include information on vehicles, weather conditions, road conditions, positioning, and other information. All BSMs include a set of basic elements, denoted as Part 1. This includes basic positional information, motion information (such as speed, heading, etc.), brake system status, and vehicle size. All remaining information is optional, and can be included in Part 2 of the BSM. The BSM is encoded as a binary file, with each data element allocated a specific number of bytes (as described in the ASN.1 coding standard[3][4]). Messages are sent to DSRC-enabled devices, which decode the message into its components. As each data element has a maximum number of bytes allocated, the granularity of the data is determined by the number of bytes it has access to in the message.

B. *Goals*

Mobility-impaired pedestrian often have greater needs for intersection navigation than average pedestrians. The long-term goal of our work is to improve the safety of mobility-impaired pedestrians when crossing busy intersections. In order to implement a more robust system for this community, we need to be able to accurately communicate their needs to surrounding infrastructure and vehicles. Currently, pedestrians have no way to communicate with cars or intersection controllers other than Accessible Pedestrian Signals, which have been previously proven to be ineffective for increasing safety[1]. In addition, cell phone GPS has a reported accuracy of 10 meters, which is not precise enough to measure the position of a pedestrian within a typical intersection. The primary intention of this paper is to experiment with implementing a DSRC-enabled device with which a pedestrian can communicate with nearby DSRC-enabled nodes to improve their safety when navigating an intersection. Current DSRC enabled devices report a GPS accuracy of less than one meter, which would theoretically provide enough precision to ensure safer pedestrian mobility in urban settings.

II. EXPERIMENT DETAILS

The BSM message allocates four bytes for each coordinate value (latitude and longitude), expressed in 1/10th microdegrees. Our experiment seeks to improve the ability of pedestrian-infrastructure communication by measuring the accuracy of localization of DSRC devices and normal GPS devices found in cell phones. iPhones Location Manager allocates 8 bytes for each coordinate value, allowing for precision to the femtodegree (10^{-15}).

We used the Arada Systems LocoMate ME Mobile V2X Sleeve to allow our iPhone to receive BSM messages for positioning and recorded these alongside GPS readings from the iPhone's onboard GPS. GPS signals are received by an Arada Systems DSRC-enabled device (denoted as the "transmitter"), and are then sent to the Mobile Sleeve (denoted as the "receiver") as a BSM message, which is passed to the iPhone. The two Arada devices were kept at a distance of 6-18 inches throughout all tests.

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We used an iPhone 7 for testing and performed trials at several urban environments in Pittsburgh to test performance under different settings.

We use the track test to test the accuracy of the GPS devices in an environment with no nearby buildings or obstructions. This test should indicate the best possible accuracy for each device. Intersection tests involved walking in a circle around all crosswalks in an intersection. Every path was taken in the direct center of each crosswalk around the intersection. All attempts were made to walk at a constant rate of approximately 1 m/s, but due to traffic and signal timings our actual walking speed fluctuates between 0.75 and 1.25 m/s. Different intersections were tested to experiment with different building heights and urban canyons.

The roadside test involved walking alongside a road, making a 90 degree turn, and walking down a second road. This was to test the performance of the GPS units when the pedestrian took a path similar to that of a vehicle.

Finally, the driving test tested the performance of the GPS units in high speed setting. This was designed to measure the normal performance of the DSRC GPS, as DSRC is specifically designed for vehicle-to-vehicle communication at high speeds. This test involved taking measurements while driving at speeds of 40-60 miles per hour. The transmitter and receiver were both placed on the front dashboard to allow clear communication with as little obstruction as possible. The two devices were kept approximately 12 inches apart for the duration of the test, and maintained a constant relative distance.

In all tests, both the iPhone GPS and the DSRC messages were recorded for the same length of time.

The iPhone GPS reliably updates once every second. The Arada DSRC Sleeve attempts to update as often as ten times per second, but in our experiments the update rate ranges from 8.82 readings per second to 0.16 readings per second. This large range in update rates is attributable to messages being lost while transmitted between the two Arada devices.

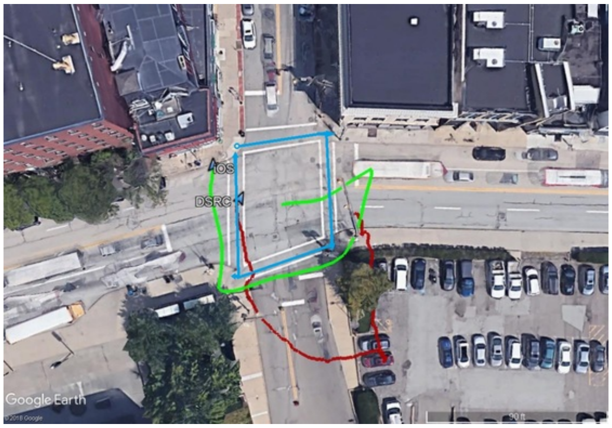

Fig. 1: Craig St. and Forbes Ave.

III. Results and Analysis

Diagrams of the intersections tests are found in Figure 1 and in the Appendix. Red lines represent the coordinate readings from the DSRC information, and Green lines represent the coordinate readings from the iPhone 7. The actual path taken is denoted in blue (black for the track test).

In the track test as well as Avenue and Regular Canyons, the iPhone GPS performs significantly better than the reported 10 meter accuracy. Actual accuracy of the iPhone in urban environments is around 1-2 meters.

In contrast, the DSRC device reported accuracy significantly worse than its claimed <1 meter accuracy. In the best tests, the DSRC GPS accuracy was 5 meters, and in the worst case around 200 meters. As most intersections are less than 15 meters wide, these readings show the DSRC granularity is too large for localization in urban intersection environments.

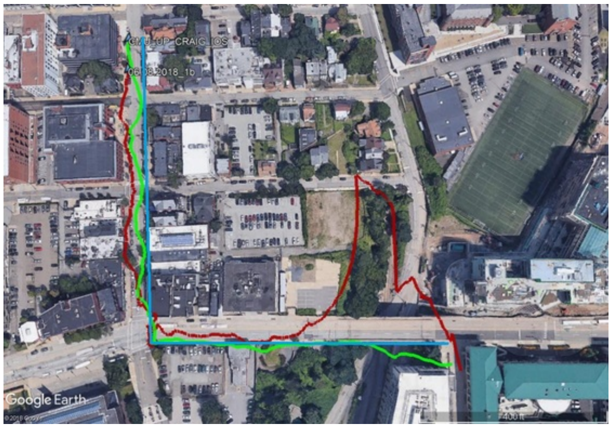

Fig. 2: Roadside Test

Fig. 3: Driving Test

Figure 3 show the results of the driving test. At higher speeds, DSRC GPS reports accuracy of under 0.5 meters, compared to 2 meter accuracy with iPhone. This either suggests that DSRC GPS is utilizing speed as a correction measure, or that DSRC is attempting to ”push” measurement readings onto roads with the assumption that vehicles are utilizing the communication protocol.

Figure 2 shows the roadside test. DSRC performed no better in this trial than in the original pedestrian intersection tests, meaning DSRC is likely not correcting measurements by assuming all readings are taken from roads. This leads to the conclusion that speed is a major factor in DSRC GPS readings. However, this reliance on speeds leads to overfitting in pedestrian environments, as pedestrian navigation is much slower than vehicle navigation.

IV. CONCLUSIONS AND FUTURE WORK

Our findings show the DSRC communication is currently too inaccurate for use in localization of pedestrians. The two main problems in DSRC communication is the highly variable refresh rate, and the inaccuracy of measurement at low speeds.

DSRC packet loss has been previously been shown to be volatile in research studies involving truck platoons. Gao et. al. showed that numerous factors can contribute to packet loss with broadcast messages (such as BSM). Line of sight obstruction as well as latency caused by lower level components of the DSRC transmitter can have a detrimental effect on the data delivery ratio[5]. In future tests, we will position the transmitter and receiver to minimize any line of sight obstructions, and will look into the hardware of the transmitter/receiver to maximize the number of GPS readings per second.

In addition, we plan to isolate the internal corrections using speed to help predict for position. If we can access GPS data before they are adjusted and cast into a BSM message, we can achieve greater accuracy, as the low differences in speed are causing inaccuracies in position measurements.

We plan to implement these solutions and retest the DSRC sleeve to attempt to obtain accuracy of at least 5 meters. Many past research projects have detailed algorithms to combine inaccurate GPS readings to obtain higher precision than a single GPS receiver. Schrader showed that in the best case, multiple GPS devices used in conjunction can yield up to a 27% improvement in precision compared to a single GPS unit[6]. Trinklein performed an experiment using two clusters of GPS receivers each with 3 meter accuracy. The clusters were kept at a constant distance of 4.5 meters, but the system as a whole was mobile. Trinklein's algorithm was able to exploit the constant relative distance between the two clusters to achieve approximately 1 meter accuracy[7]. Hedgecock et. al. developed an algorithm to obtain position with accuracy of 15 centimeters given two or more GPS receivers with 2.5 meter accuracy. This algorithm utilized raw GPS data and satellite positioning information to correct errors due to satellite velocities and temporal differences in readings[8].

We plan to implement a variation of these algorithms to use both the iPhone GPS and DSRC GPS signals together to obtain precision of under 1 meter, allowing for precise pedestrian localization in small-scale urban environments, such as intersections.

V. APPENDIX

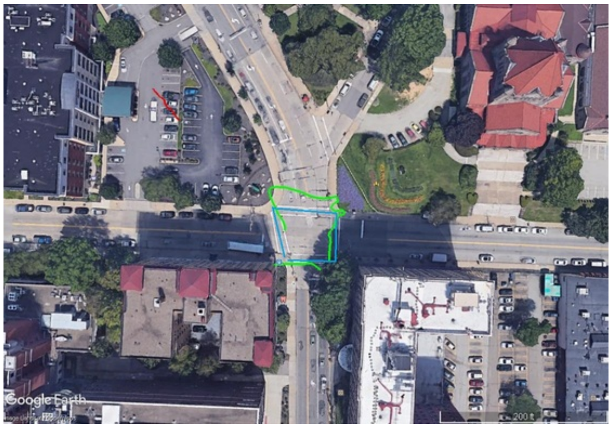

Fig. 4: Centre Ave. and Aiken Ave.

Fig. 5: Baum Blvd. and Euclid St.

Fig. 6: Baum Blvd. and Liberty Ave.

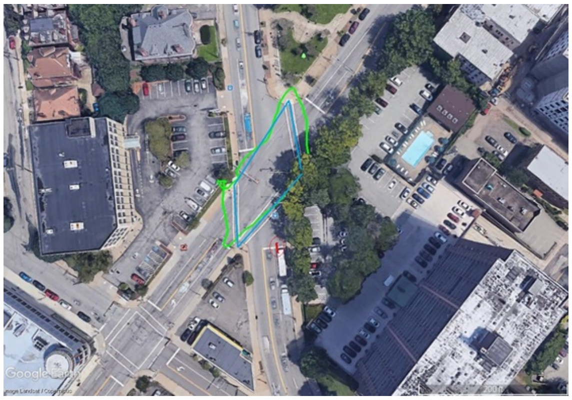

Fig. 7: Baum Blvd. and S. Negley St.

Fig. 8: Centre Ave. and Cypress St.

Fig. 9: Centre Ave. and Graham St.

Fig. 10: Centre Ave. and S. Highland Ave.

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