Demo Abstract: MARVEL: Multiple Antenna based Relative Vehicle Localizer

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ABSTRACT

Access to relative location of nearby vehicles on the local roads or on the freeways is useful for providing critical alerts to the drivers, thereby enhancing their driving experience as well as reducing the chances of accidents. The problem of determining the relative location of two vehicles can be broken into two smaller subproblems: (i) Relative lane localization, where a vehicle determines if the other vehicle is in left lane, same lane or right lane with respect to it, and (ii) Relative front-rear localization where it needs to be determined which of the two vehicles is ahead of the other on the road. In this demo, we show a novel antenna diversity based solution, MARVEL, that solves the problem of relative lane localization.

Categories and Subject Descriptors

C.2.4 [**Computer-Communication Networks**]: Distributed Systems—*Distributed Applications*; J.m [**Computer Applications**]: Computers in Other Systems—*Consumer Products*; H.m [**Information Systems**]: Information Systems Applications—*Miscellaneous*

General Terms

Design, Experimentation, Measurement, Performance

Keywords

Smartphone, Wireless Ranging, Location Classification

1. INTRODUCTION

The use of GPS equipped smartphones has been increasing rapidly. But the GPS devices on the phones do not have sufficient accuracy to localize the vehicles up to the lane-level. Availability of traffic information at the micro-level or lane-level granularity is useful for multiple applications that have the potential to not only reduce the chances of accidents but also enhance the driving experience. Some applications are as follows: (i) Alerting the drivers of upcoming obstacles or potholes that are in the same lane as the vehicle, and further guiding the driver to move to the appropriate lane to avoid them; (ii) Alerting the drivers if there is a vehicle in the blind zone or if this vehicle is tailgating another vehicle, thereby reducing the chances of collision; (iii) Alerting the driver that the vehicle ahead is slowing down if the two vehicles are in the same lane; (iv) Detecting the lane-level location of slow moving vulnerable vehicles; and, (v) Determining the differences in speeds of different lanes, to assist in traffic planning.

Although, GPS technology is widely used for vehicular localization, various factors such as signal multipath, unknown delays due to ionosphere and troposphere, error in the clocks of GPS devices, and inaccuracies in the locations of satellites [3] reduce its accuracy. Device manufacturers such as Garmin report the average GPS accuracy to be 3 meters [3] even for devices equipped with newer WAAS (Wide Area Augmentation System) and DGPS (Differential GPS) technology which is not enough for relative localization of verhicles. In our own experiments (See Figure 2), we observed that error in GPS readings exceed 1.8m in 54% of the cases. Thus, GPS miscomputes the *relative location* of the other vehicle in 54% of the cases. Similarly, radar [6, 1], laser [7], and acoustic [2] based sensors and cameras [4] are some other common devices that have also been used for localization of vehicles. However, those sensors are usually limited in range to line of sight, difficult to install especially on existing vehicles and exhibit a tradeoff between accuracy and cost. Similarly, using cameras for vehicle detection and lane recognition is highly susceptible to errors due to various factors such as: (i) Bad light conditions (e.g., night time, sun glare, headlight glare, shadows from nearby buildings); (ii) Improper weather conditions (e.g. snow, rain); and, (iii) Surrounding noise (e.g., faded lane marks, vehicles parked on roadside, roadside crash barriers, trees, store fronts etc.).

In our recent work [5], we proposed a novel multi-antenna diversity based solution called MARVEL, that determines the relative location of two vehicles among the six possible possibilities (See Figure 1). MARVEL comprises of two components for every vehicle. The first component is a smartphone that could also be the personal smartphone of the driver of the vehicle. The second component comprises of four wireless radios located at various positions on the lateral sides of the vehicle. The smartphone (or the MARVEL application running on it) is used to communicate with other smartphones in other vehicles as well as to display alert messages. The four wireless radios communicate with radios located on other vehicles as well as with the smartphone located in the same vehicle and help in determining the relative location of vehicles.

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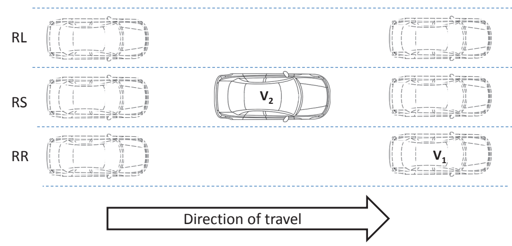

Figure 1: Vehicle V_1 can be in six different relative positions with respect to V_2: Front-Left, Front-Right, Front-Same, Front-Right, Rear-Left, Rear-Same and Rear-Right. Note that Front-Left, Front-Right, Rear-Left, and Rear-Right also include the cases that V_2 is immediately to the left or right of V_1.

The basic idea of MARVEL is shown in Figure 3. Each vehicle is mounted with two wireless radios on either side of the vehicle. Observe that when the two cars are in the same lane, then links AD and BC are roughly symmetrical. Thus, the path loss values of these two links would be similar. However, when the cars are in different lanes, the links are not symmetrical. Specifically, when V_1 is in the left lane of V_2, link BC has low path loss compared to path loss on link AD since BC is a direct line of sight path with no obstacles while AD passes through bodies of 2 vehicles (or 4 walls and the engine compartment of one of the vehicles). So it is possible that the relative signal strength of these two links can be used to distinguish the three scenarios, thereby solving the relative lane localization problem. In the same setup, adding two more radios to each vehicle, similarly provides us with more information that can be utilized to solve relative front-rear localization problem.

In our scheme [5], the smartphone transitions between three different phases (see Figure 4). In the monitoring phase, the smartphone monitors the accelerometer readings. Once the accelerometer readings cross a certain threshold (indicating a possible lane change event), our algorithm moves to next phase. In the Beacon Phase, one of the two phones directs its four wireless radios to send a predetermined number of beacons, while the radios on the other vehicle listen for the beacons, thereby estimating the path loss between the 16 pairs of wireless radios. After the path loss values of the 16 possible links are obtained by a smartphone from the 4 associated wireless radios in that vehicle, the algorithm moves to the third phase where it determines the relative location of the two vehicles.

We identified the problem of finding another vehicle's position, among the six possible positions as a supervised classification problem and addressed it using machine learning algorithms. By systematically exploring the placement of the radios at different positions of the vehicle (See Figure 5), we found that the best accuracy is achieved when using the model created by placing four radios above the four wheels of a car. Figure 5 shows four out of many radio position combinations we have tried with two cars.

We also evaluated the classification accuracy on different vehicle types, various road types and traffic conditions. Using the collected data set, we created an SVM classification

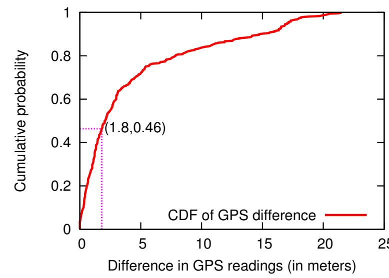

Figure 2: Comparison of GPS trace of two smartphones located in the same car: Cumulative distribution function of GPS error (in meters).

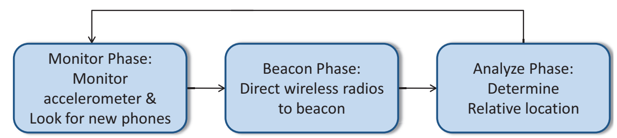

Figure 4: Transitions made by the smartphone among the three phases.

Table 1: Test results of the classifier trained by mixing all the driving data.

Testing data set	Accuracy
Mixed data	96.8%
Two sedans, Local, Moderate traffic	98.5%
Two sedans, Freeway, Moderate traffic	97.9%
Coupe and SUV, Local, Moderate traffic	97.7%
Coupe and SUV, Freeway, Moderate Traffic	99.4%
Coupe and SUV, Local, Heavy Traffic	92.8%
Coupe and SUV, Freeway, Heavy Traffic	95.7%
Two sedans on a freeway with curves	94.0%

model with high prediction accuracy. The results are presented in Table 1.

Our experiments [5] show that MARVEL determines relative location of two vehicles with 96% accuracy when tested on data sets with different traffic conditions and different

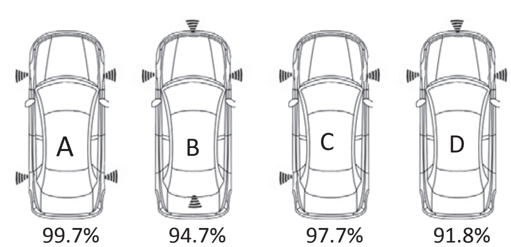

Figure 5: Some combinations of placement of the wireless radios and the corresponding relative lane localization accuracy. A and B have four radios attached while C and D have 3 radios. The first classifier from configuration A has the highest prediction accuracy.

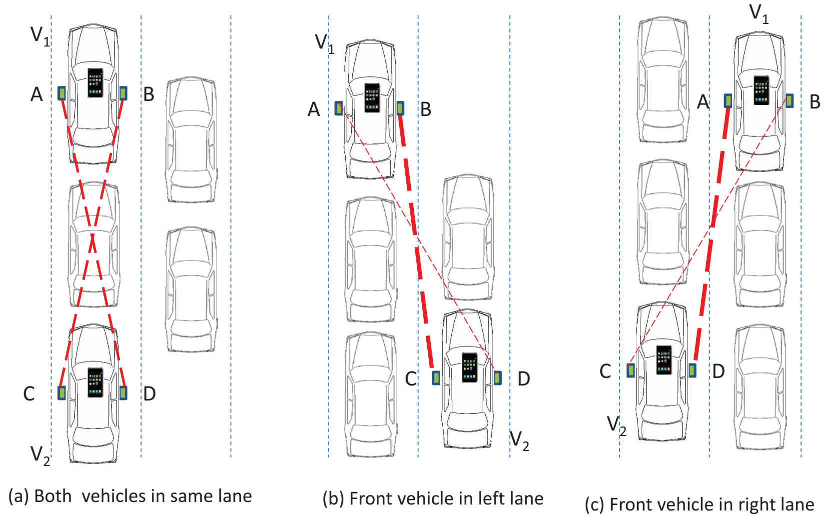

Figure 3: RSSI based Relative Lane Localization with two radios: A, B, C, and D are radios mounted on vehicles V_1 and V_2. The expected RSSI for two links AD and BC are shown for three different cases with thicker lines representing links with higher RSSI value.(a) When V_1 and V_2 are in the same lane, then the path loss for links AD and BC is almost symmetrical (Regardless of whether a vehicle is present between V_1 and V_2). (b) When V_1 is to the left of V_2, then BC is a direct line of sight link while AD passes through bodies of 2 vehicles (including one vehicle's heavy machinery compartment). (c) When V_1 is to the right of V_2, link AD is stronger but BC is weaker. Nearby vehicles may affect the signal strengths to a certain degree due to multipath.

road types. We believe that many driving advisory applications such as pothhole avoidance, sudden brake alert, and blind spot warning can be developed using MARVEL.

2. DEMONSTRATION

In this demo, we implement the Beacon Phase and the Analyze Phase of MARVEL using multiple toy-vehicles that can be moved on multiple lanes drawn on a cardboard. Each toy vehicle will have two TelosB motes attached on each side. A laptop connected with a *central* TelosB mote will be used to gather real-time results from the vehicles for the purpose of visualization. Apart from showing a miniaturized proof-of-concept for MARVEL under normal conditions, through the demo we intend to show that MARVEL also works under various unfavorable conditions such as: (i) Presence of multiple vehicles in the neighborhood that interfere with the wireless signals transmitted between radios; (ii) Presence of urban obtacles such as sound walls and store front next to roadways; and (iii) When vehicles have different physical profiles.

In the demo, we implement these scenarios by deploying multiple toy vehicles with different physical dimensions on the cardboard track. Urban obstacles are modeled using the miniature walls on the sides of the cardboard track. It would be possible for demo participants to move the cars around and observe the performance of our lane-localization algorithm. Moving a toy vehicle will change its relative location with respect to other vehicles, threby changing the signal strength values of the links among the TelosB motes. This change would be conveyed by the motes on the vehicles to the mote connected to the laptop. A laptop-based application will automatically show this change in the relative lane locations. Apart from moving the cars manually, we will also be running a continuous video on one of the other laptops that will show the following: (i) How the wireless radios are installed on actual vehicles; and, (ii) A video showing that after moving the toy cars, MARVEL is able to update the relative position of the two vehicles.

3. ACKNOWLEDGEMENTS

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