Poster Abstract: VeLoc: Finding Your Car in the Parking Lot

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Abstract

We present VeLoc, a smartphone-based vehicle localization approach that tracks the vehicle's parking location without GPS or WiFi signals. It uses only the embedded accelerometer and gyroscope sensors. VeLoc harnesses constraints imposed by the map and landmarks (e.g., speed bumps) recognized from inertial data, employs a Bayesian filtering framework to estimate the location of the vehicle. We have conducted experiments in three parking structures of different sizes and configurations, using three vehicles and three kinds of driving styles. We find that VeLoc can always localize the vehicle within $10m$, which is sufficient for the driver to trigger a honk using the car key.

1 Introduction

Remembering where a vehicle was parked has proven a hassle in large parking structures. Existing RF signature based indoor localization technology [1] is not applicable where such signals may not be available such as at underground parking lots. Instrumenting additional sensors may solve the problem but at the cost of significant overheads in time, money and human efforts.

VeLoc is a vehicle localization system that utilizes accelerometer and gyroscope sensors in the smartphone to provide accurate vehicle localization. It does not rely on GPS or RF signals, neither requires any additional sensors to instrument the parking ground.

Realizing such an inertial-based solution, however, involves non-trivial challenges. First, the driver may place the phone in arbitrary positions and rough ground may jolt the phone to change its position during the course. How to estimate the pose (i.e., the relative orientation of the smartphone to the vehicle) despite all such uncertainty and disturbances? Second, inferring the vehicle's traveling distance or even trajectory is still difficult due to the lack of periodic acceleration patterns, which are fundamental in step-counting techniques [3,4] for human movements. Also, identifying the types of landmarks reliably despite different parking structures, vehicles and driving styles remains an open question. Finally, since both the pose and landmark detection results contain errors, how can one track the location of a vehicle accurately, such that the driver can always find the vehicle?

As shown in Figure 1, VeLoc contains three components to deal with the above challenges. A *pose estimation* module estimates the pose of the smartphone inside vehicle. A *landmark detection* module finds unique patterns corresponding to different types of landmarks and classify them reliably. A *location estimation* module determines the vehicle's final location from the map and detected landmarks.

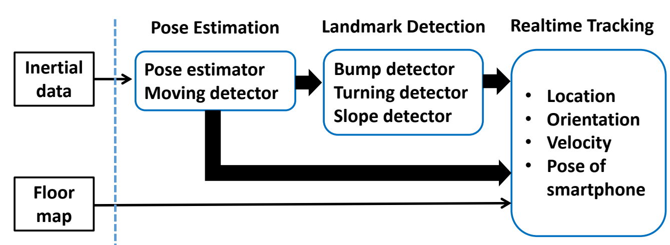

Figure 1. Three components of VeLoc. Inertial data is used to compute the smartphone's pose in the vehicle, then it is further processed to detect certain landmarks during driving, and the augmented particle filter harnesses constraints from landmark detection and the floor map for vehicle localization.

The intuition behind VeLoc is that although a noisy trajectory does not directly reveal a vehicle's location, using the constraints imposed by the parking structures map and detected landmarks can eliminate uncertainties to localize the vehicle (illustrated in Figure 2).

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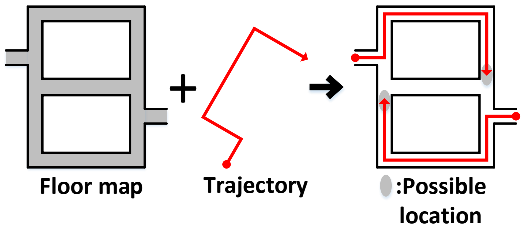
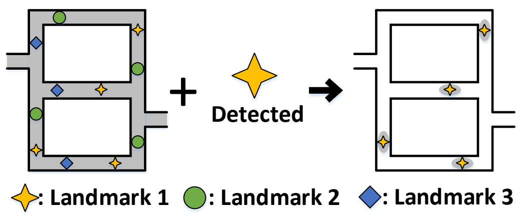
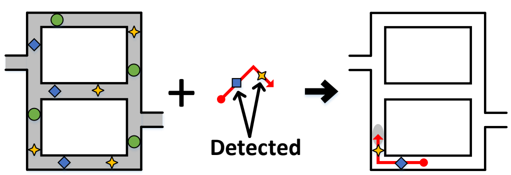


(a) Localization using constraints imposed by the map.



(b) Localization using detected landmarks.



(c) Localization using both map constraints and detected landmarks.

Figure 2. Intuition of localization. (a) trajectories can be used for localization since only a few paths on the map could accommodate the trajectory. (b) once a landmark is detected, only a few positions marked with the same kind of landmark are possible. (c) using both map constraints and detected landmark could narrow down the uncertainty more quickly.

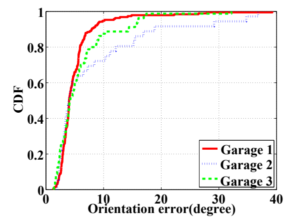
2 Experiments

We use smartphones to collect motion sensor readings on a vehicle in three underground parking lots, and their size are $250m \times 90m$, $80m \times 90m$, and $180m \times 50m$, respectively. Each parking lot has one entrance and one exit, and there are 298, 68, 79 parking spots, 19, 7, 12 bumps, 10, 14, 11 turns and 4, 2, 2 slopes in each parking lot, respectively. During experiments, we conduct 20 vehicle traces in each parking lot with 4 iPhones with different poses to simultaneously collect inertial sensor data during the driving.

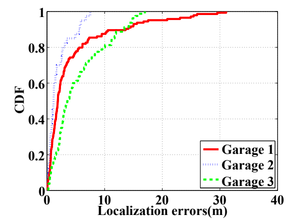
Evaluation of Pose Estimation. Here we evaluate the accuracy of estimated smartphone's pose inside vehicle.

Figure 3(a) illustrates that our algorithm works well in different parking lots, they all achieve 13 degrees accuracy at 90-percentile, and Parking lot 2 has the largest error of 16 degrees, due to its short straight road which we use to compute the vehicle's orientation.

Evaluation of Landmark Detection. Here we evaluate the performance of landmark detection using the precision and recall as metrics.



(a)



(b)

Figure 3. (a)Pose estimation error and (b)Vehicle localization errors in different parking lots.

Table 1 shows the recall and precision for different landmarks. We observe that turn detection has detected all the turns correctly. Bump detecion has the lowest precision of 87%, and recall of 83%.

Table 1. Landmark detection performance

	Bump	Turn	Slope
Precision	87%	100%	97%
Recall	83%	100%	95%

Localization performance. Finally, we evaluate the localization error of the whole system. Figure 3(b) shows the localization error in 3 parking lots, which are between $3-10m$ at 80-percentile, small enough for the driver to trigger a honk using the key.

3 Conclusion and Future Work

We describe VeLoc that can track the vehicle's movements and estimate the final parking location using the smartphone's inertial sensor data only. Experiments in three parking structures have shown that VeLoc can track the parking locations to a few parking spaces, which is enough for the driver to trigger a honk using the car key.

Currently VeLoc depends on accurate parking structure maps to reduce the uncertainty in the vehicle location. Since such maps are not always available, we plan to study how to obtain the map information [2], and track the vehicle when only incomplete and/or inaccurate map is available. This further extends VeLoc's capability in the real world.

4 Acknowledgments

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