Gradient Profiling for Pedestrian Services

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ABSTRACT

Mobile systems have long been the cause of distraction to pedestrians. Motivated by the safety challenges this distraction poses, we aim to develop a sensing technology based on smartphones and wearable devices, for fine-grained location classification in urban environments. Particularly, we are using shoe mounted inertial sensors to sense the ground a pedestrian is walking on. To begin with, it seeks to detect transitions from sidewalk locations to in-street locations. This can be used for warning a distracted pedestrian or alerting an oncoming vehicle to the presence of a pedestrian in street. In addition, it can also be used for precise sidewalk-level localization in dense urban environments.

Categories and Subject Descriptors

H.4 [**Information Systems Applications**]: Miscellaneous

Keywords

Pedestrian Safety; Smartphone; Localization; Inertial Sensing; GPS; Accelerometer; Gyroscope

1. INTRODUCTION

Smartphones have caught our attention for a long time. Unfortunately, recently they have turned into a major distraction [1] and are having a negative impact on pedestrian safety. We envision to build smartphone and wearable systems based techniques to enable various services for pedestrians, primarily safety related. The challenge for these services, however, is to determine the pedestrian's precise location. Most importantly, this would require the ability to distinguish when a pedestrian is potentially at risk, particularly walking in street, to walking in relatively safe areas on a sidewalk. To this end, we developed a shoe sensing approach that can determine the gradient of the ground that a user is walking on. This helps us detect when a pedestrian transitions from sidewalk to street, by walking off ramps or stepping off curbs. In the future, we intend to communicate this information to oncoming vehicles. Furthermore, we are also looking at how gradient profiles can be used to precisely localize a pedestrian in dense urban environments where GPS positioning has large errors. In this abstract we present our progress so far, and discuss some potential techniques that we intend to build in the future.

Related Work. In prior work, the Walksafe project has presented preliminary results on using cameras on pedestrians' smartphones for detecting oncoming vehicles [2]. The energy consumption of continuous camera operation is likely to remain a challenge. None of the existing works have explored the potential of shoe-mounted sensors in outdoor environments. Robertson et al. [3] explore indoor localization for pedestrians using foot-mounted inertial sensors. Jimenez et al. [4] use ramp detection in indoor environments to provide drift correction in indoor locations. Many car producers [5] are now integrating night vision, active breaking and automatic steering solutions in their new models to reduce pedestrian accidents. Honda is developing a Vehicle-to-Pedestrian technology that is able to detect a pedestrian with a DSRC enabled smartphone [6].

2. SENSING SOLUTION

In our prior work [7, 8], we demonstrated the limitations of smartphone based GPS positioning for pedestrian risk detection, especially in urban environments. In this work, we address the pedestrian safety challenge through shoe-mounted inertial sensors. Our approach exploits the existing trend of shoe mounted exercise tracking devices. Since a pedestrian is usually safe when walking on the sidewalk, our approach is to identify pedestrians that are in the roadway. These pedestrians may be in the way of approaching vehicles and hence potentially at risk.

Crossing Detection Algorithm. In our recent work [9], we have proposed a crossing detection algorithm that can generate targeted electronic alerts. Our primary idea is to distinguish street and sidewalk locations of the pedestrian through inertial sensing of ground features, particularly by sensing the sidewalk design features that demarcate roadways and sidewalks. In urban environments, that follow consistent design guidelines, these features are primarily ramps and curbs. We leverage these design features and develop a sensing system that can automatically detect transitions from a sidewalk into the road. This includes stepping over a curb, which often occurs when crossing a street at midblock locations. More importantly, our solution can track the inclination of the ground and detect the sloped transitions (ramps) that are installed at many dedicated crossing to improve accessibility. We focus on ramps because they are common in urban environments; we believe that the smoother transition makes it more likely that a distracted pedestrian fails to recognize the transition into the street.

We have developed a prototype sensing system based on an inertial device affixed to a shoe to evaluate the effectiveness of this approach. This device comprises an accelerometer, gyroscope, magnetometer, battery and bluetooth. The algorithm extracts changes

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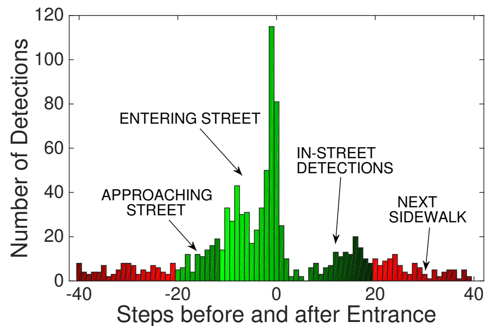

Figure 1: Performance of Crossing Detection Algorithm (Manhattan testbed).

in pitch, yaw and acceleration magnitude for each sample from the accelerometer and gyroscope measurements. Note, that the sensor orientation does not need to be precisely calibrated; small discrepancies can be tolerated since we only track changes in pitch, yaw, and magnitude from step to step. Pitch is the rotation of the foot along the sideways axis, which represents the inclination of the foot. Yaw is the change in rotation of the foot around the vertical (gravity) axis, and helps in detecting when a pedestrian turns. The magnitude of the acceleration helps us detect the event of stepping off a curb. The shoe-mounted sensor has the capability to measure foot inclination at any given point in time and reflects the slope of the ground when the foot is flat on the ground. Our algorithm algorithm recognizes the phases in a walking cycle, and extracts the pitch during the stance phase when the foot is flat on the ground. A sequence of these pitch readings (one at each step), is called a slope profile. At every step, the algorithm compares the current slope to the slope profile from the past few steps, to determine whether or not a person is entering the street. We analyzed the performance of the detection algorithms across pedestrian environments including major cities on two continents with different sidewalk designs (Manhattan, NY and Turin, Italy). The total distance walked during these experiments was 112.5 miles and this experimental dataset included 1670 street crossings. For safety applications, the timeliness of detected events is very important. The results for our New York City test paths are shown in Figure 1. Zero on the x axis marks the step when the pedestrian enters the street. We observe that the highest density of detected events lies in the steps before the entrance, depicted in fading shades of green to the left of zero. On either side of this window, the detections fall rapidly.

3. PROPOSED TECHNIQUES

In our future work, we plan to take advantage of the slope profiles obtained through gradient sensing, to design numerous other pedestrian services. Of these, we are dedicated to developing the following two.

Sidewalk-level localization. In addition to safety services, gradient sensing can also be used for the development of other pedestrian services, like precise localization and pedestrian navigation. Slope profiles can help us uniquely identify the sidewalk that a pedestrian is walking on. The smartphone's GPS provides us only a rough estimate of the user's position in urban environments, to a radius of approximately 20 meters. With this information, we can narrow down the approximate location to a set of 4 possible sidewalks, which are the sidewalks on either side of the current block and those on either side of the next block, towards which the user is heading. Our crossing detection approach allows us to know when a pedestrian enters the sidewalk and when he exits it. Such knowledge can enable our system to localize pedestrians in a set of sidewalks, leveraging slope traces and a profiling database. The profiling database contains, for each sidewalk, slope traces from different walkers. Using these traces we can profile each sidewalk uniquely. The profiling database for each pedestrian is constructed based on the rationale that a person may repeatedly walk the same path, e.g., a path to the office or a usual lunch place. We can compare a test trace to all the traces in the profiling database to find the best match. Once the sidewalk has been uniquely identified, outdoor pedestrian navigation becomes very precise and can aid turn-by-turn sidewalk level directions.

Driver Pedestrian Awareness. A major application of the crossing detection algorithm would be to announce the presence of a pedestrian to oncoming vehicles. Owing to the high density of pedestrians in urban environments, such announcements would need to be sent out only when the pedestrian is in the way of a moving vehicle. Therefore, this proposed system can use the capability of the crossing detection algorithm that can distinguish a pedestrian who is walking on a sidewalk to a pedestrian who is in the street. Additionally, these messages could be filtered at the vehicle. In addition to the crossing detection algorithm, we aim to build a reliable pedestrian-to-driver communication technique.

4. CONCLUSION

In this abstract we have described our existing work on pedestrian safety and potential applications of shoe-mounted inertial sensing for pedestrian navigation and precise localization. We aim to investigate these techniques over the following year to develop a robust platform for developing pedestrian services.

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