Towards Vehicular Sensor Networks with Android Smartphones for Road Surface Monitoring

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Abstract. Road surface monitoring, including automated pothole and bump detection, is essential for both drivers and road maintainers. This paper presents preliminary results from an ongoing experimental study with the central question: is a smartphone with Android operating system capable of performing road surface monitoring using participatory sensing approach? The test results with 3 Android models and several tracks are presented and demonstrate feasibility of the approach.

Keywords: road surface analysis, android smartphone, accelerometers, vehicular sensor network

1 Introduction

Although there exist pothole maps, such as, `potholes.co.uk` [3], the information collection is manual and based on individual reports. Manual approach tends to be irregular, not sustained and therefore of limited confidence. Automated solutions have been demonstrated, but they require specialized hardware [5].

Recently, a promising approach, called Participatory Sensing, emerged, using smartphones - a virtually ubiquitous and powerful class of participatory sensing hardware platform.

The collected information amounts would be enormous in terms of sensor sample count and geographic area coverage, should we get all the mobile phone users involved in a united data gathering task. Although participatory surface monitoring systems, such as Nericell [7], already exist, to the best of our knowledge, this is the first evaluation on the Android platform, with on-board accelerometers, requiring no external sensor modules. A couple of Android pothole detection applications exist in the Android market [2], however we were not able to assess their accuracy.

According to Gartner Press Release for November 10, 2010 [1], Android is one of the most popular smartphone platforms at the moment, and the popularity is even rising. Additionally, it is one of the most open and flexible platforms providing software developers easy access to phone hardware and rich software

API. We envision Android-based smartphones as a powerful and widely used participatory sensing platform in near future. In this paper we examine Android smartphones in the context of road surface quality monitoring.

We evaluated a set of pothole detection algorithms on Android phones with a sensing application while driving a car in urban environment. The results provide first insight into hardware differences between various smartphone models and suggestions for further investigation and optimization of the algorithm, sensor choices and signal processing.

2 Our approach

Our approach requires an Android smartphone with GPS, 3-axis accelerometer and communication channel (Cellular or WiFi), either fully charged or connected to a car-charger, as the sensing may consume a significant amount of energy on prolonged runs. The system consists of two applications: for the Android device and a data server (Figure 1).

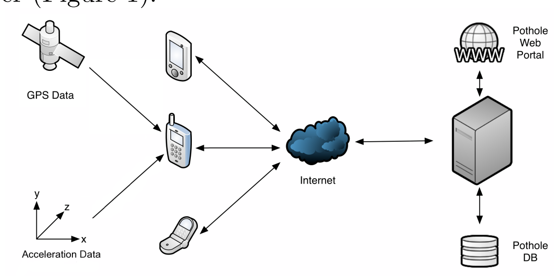


Fig. 1: System architecture

The Android device application has an event-driven architecture. The most important are sensor data availability, Internet connection availability and User interface (UI) events. The list of the used sensors includes GPS to detect the current location and accelerometer to detect potholes. After the sensor data is received, it is processed and stored in the database that is periodically synchronized with the main server's database so both have an up-to-date information. UI allows to start/stop sampling process and see debugging information. We envision the pothole detection system as a background service in the future, used by other applications, such as Waze [4], therefore we do not put strong emphasis on UI at the moment.

Server application on PC is a Java web-application with an SQL database based on Spring framework. It consists of application servlet, sensor data controller and user interface. User interface uses Google Maps API for pothole visualization.

3 Evaluation

Evaluation of our solution was performed in two real world experiments on the road, on January 25th and 28th, 2011. Each time a different vehicle (BMW 323 Touring and Mitsubishi Space Wagon) was used. Through such varied experiment time and technical equipment we anticipated to minimize impact of time and vehicle specifics to acquired sensor data. Although we have performed more test runs, we discovered that in certain winter weather conditions road surface may change over a short time, and it is hard to establish a ground thruth and repeated runs on the same track with consistently same conditions.

Experiments were carried out on test track identical to that used during our previous activities described in [6] but this time each experiment consisted of only three laps. In our opinion, it should be enough to get a proof-of-concept impression about observed events and recorded data. Data acquisition equipment set consisted of three mobile phones (Samsung i5700, HTC Desire, Samsung Galaxy S) with custom Android based data collection application installed described above.

The first goal was comparison of data, recorded using different equipment, during the same period of the time. As one could expect, we found that different hardware units with equal software have different accelerometer data acquisition rate and GPS accuracy and signal stability, see Table 1. This aspect should be considered in context of detected event position granularity.

Table 1: Acquired data characteristics among used Android devices. Averaged over 32 minute drive.

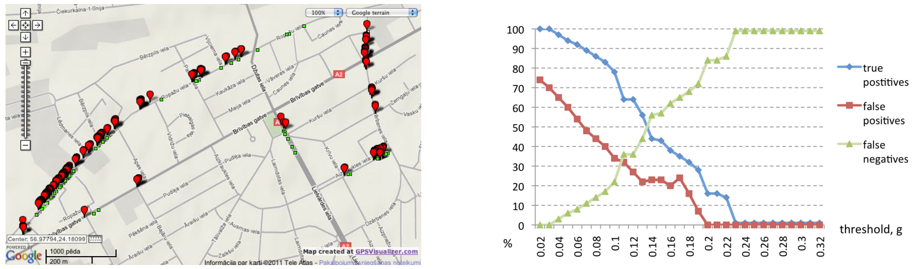
Device	**Accelerometer**		**GPS**		
	sampling rate, Hz	**Z-axis StdDev, g**	**accuracy, m**	**locations missing, %**	**visible satellites**
Samsung i5700	26	0.1128	-	5	5-9
HTC Desire	53	0.0753	6.31	0	4-13
Samsung Galaxy S	90	0.0507	6.27	0	5-8

After first data set acquisition we started with empirical event detection algorithms. We evaluated the following algorithms:

- STDEV(Z) - events are detected by thresholding standard deviation of Z-axis[3] acceleration. The lowest false positive rate, promising but additional research has to be done to find appropriate window size.
- Z-DIFF - thresholding differences of two consecutive Z-axis samples ($z_i - z_{i-1}$). Highly sensitive to noise.
- Z-THRESH - thresholding absolute value of Z-axis acceleration. The simplest approach. Highest false negative and positive rate, not usable individually.
- G-ZERO - detect events having Z-axis value close to zero g. Besides bumps and potholes also detects drifts, which have to be filtered by additional methods.

When comparing the events detected by methods in our previous work [6] (where thresholding of audio signal by amplitude was performed) and events detected by sensing application on Android smartphones (see Figure 2), they seem to share common trends. However, further study and additional test data is required to acquire a valid algorithm accuracy and stability assessment.

[3] Here we use the term Z axis to describe vertical axis, perpendicular to road surface



(a) Android (red balloons) and our previous methodology (green) [6] detected potholes, GPSVisualizer.com used

(b) Threshold impact on accuracy, value of 0.1g selected as optimal: 78% true positives, 34% false positives

Fig. 2: Comparison of STDEV(Z) on Android with our previous work on pothole detection by audio thresholding

4 Conclusion and Future Work

In this paper we describe our preliminary results from two test drives with three Android smartphones running pothole detection application, based on accelerometer data processing. Despite hardware differences in terms of GPS accuracy and accelerometer sampling rate and noise, we postulate, that pothole detection is possible. However, to assess our hypothesis, more in-depth evaluation must be performed, combination of multiple algorithms should be investigated, and a larger and more representative test data set must be collected.

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