IRoads: Smartphone-Based Road Condition Monitoring

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Abstract

Measuring and monitoring road conditions are essential to ensure public and vehicle safety, prompt maintenance, as well as fuel and time savings. While developed countries use sophisticated devices installed on specialized vehicles to measure and monitor the road conditions, it is cost prohibitive for countries like Sri Lanka. Moreover, the diversity of road types and non-standard physical properties, make it impractical for specialized vehicles to travel on roads in Sri Lanka and many other countries. Therefore, a system that is low cost and practically usable on roads with non-standard physical properties will be a useful solution for road condition monitoring.

Sensors such as 3-axis accelerometer, gyroscope, GPS, and magnetometer in most smartphones could be used to detect potholes and bumps, as well as to estimate International Roughness Index (IRI) at a much lower cost. Related work has shown that acceleration data from smartphones have a linear relationship with road roughness. Hence, it opens the way to the development of a system to measure the road roughness using smartphone sensors. While the accuracy of such a solution is relatively low, with the increasing number of motorists with smartphones, crowdsourcing could be used to collect data at a high spatial and temporal resolution that has been hitherto impossible. Such a massive volume of data collected through crowdsourcing could be processed using machine-learning and signal processing algorithms, such that the limitations and low accuracy of a single smartphone could be overcome by data analytics of the same road condition again and again.

A crowd sourced mobile app is proposed, to measure the road conditions such as potholes, bumps, speed breakers, and estimate IRI at a high spatial and temporal granularity. The proposed solution collects data over a broadband connection to a cloud-computing-based backend where machine-learning and signal processing algorithms are used to determine different road conditions and estimate IRI. Moreover, the solution provides visualization of this information using a map-based dashboard.

3-axis accelerometer is used as the main source for road profile monitoring. However, in a crowd sourced model, many practical problems need to be solved in addition to technical problems, as motorists may use vastly different types of smartphones with varying features and accuracy. For example, they may mount the smartphone in various orientations or orientation may change as the trip progresses. Therefore, a reorientation mechanism is essential to convert accelerometer data from any arbitrary smartphone position to the vehicle's axis. The solution implements two reorientation mechanisms. The first mechanism is using Euler angle-based algorithm. The second mechanism uses magnetometer and GPS bearing readings to reorient the acceleration vectors of the mobile device. Signal processing techniques are used to filter out the sensor noise for more accurate data gathering. Moreover, the magnitude of sensor reading tends to correlate with

acceleration and deceleration of the vehicle. Thus, vehicle speed data are also needed to capture road conditions accurately. Therefore, the proposed app connects to an OBD2 (On-Board Diagnostic) ELM327 adapter to collect vehicular data such as fuel consumption and speed of the vehicle. OBD2-based vehicle speed estimation is more effective than GPS-based estimation due to the low resolutions and slow sampling in GPS.

Random-forest algorithm is used in the backend to detect road anomalies (e.g., pothole or bump), while pulse calculating algorithm is designed for estimating IRI values. Road segments are classified based on IRI and a map is annotated based on the IRI values. Due to varying accelerometer accuracy levels, as well as low resolution and slow sampling in GPS, it is difficult to estimate the exact location of the road anomaly. Therefore, a clustering algorithm is used to identify the location of an anomaly by clustering GPS locations estimated from different trip data provided by users. Moreover, vehicular data will be used in the future to estimate the relationship between fuel consumption and IRI of Sri Lankan roads. Furthermore, the visualization of bad road segments could provide insights to drivers to bypass bad road segments while the authorities could use the dashboard to prioritize maintenance and policy marking.

An Android-based mobile app, namely iRoads, is developed and already used with a few data collection trails. The research currently focuses on calibrating the mobile app and related algorithms to accurately estimate IRI and detect road anomalies. For example, efforts are currently underway to calibrate estimated IRI values with the IRI readings from a ROMDAS Bump Integrator. The goal is to improve the accuracy to such a level that iRoads could measure roughness like a class-3 road profiling instrument. Another app is also developed to label road anomalies on the go, such that a large, labelled training dataset could be gathered for training and evaluation of machine-learning and signal processing algorithms. Based on this, dataset model parameters are to be tuned to more accurately estimate road anomalies.

Keywords: IRI, road anomaly, accelerometer, signal processing, machine learning

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