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A Participatory System to Sense the Road Conditions

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Abstract

The monitoring of road conditions and surface anomalies such as potholes, bumps etc., has shown a great importance in the safety and comfort of road users from pedestrian to drivers. Detection and identification of such road anomalies not only reduces the causes of road accidents but also avoid vehicle damages. This can provision the management authorities to keep a track of road conditions along with maintenance of roads. Monitoring the road conditions is a challenging task and potholes detection plays an important role in the repairing of asphalt road surface. Many approaches exist to collect data about road surface conditions, however most of these approaches are low-speed human visual inspection or approaches that uses advanced and costly measuring equipments. Therefore, there is a need to develop a cost effective system that can manages these kind of issues. In this paper, a Participatory Sensing system based on raspberry pi is designed and developed to detect and record road surface anomalies that are measured by the inertial measurement unit (IMU) and GPS sensor. An android application is also designed and developed to alert the user from an upcoming high-intensity rough area on the road. Message Queuing Telemetry Transport (MQTT) protocol is used to publish and subscribe data from raspberry pi to data servers.

Index Terms: Raspberry Pi, MQTT, Potholes, GPS, IMU, Participatory, Android.

1. Introduction

A well maintained network of roads is must for the development and well-being of any country. It is a challenging task to maintain road conditions and fulfill the requirements of transportation. In Pakistan, according to data provided by Pakistan Bureau of Statistics (PBS) since 2011, almost 9000 road accidents happen every year killing an average of 4500 people [3]. The following graph illustrates the situation and presents the total number of road accidents occur from 2004 to 2013 [2].

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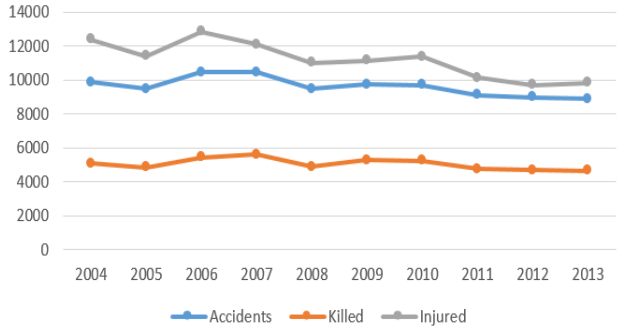

Fig.1. Pakistan Road Accidents (2004 to 2013)

However, there could be many unreported road accidents due to the bad roads conditions and remains unconsidered by the management authorities [3]. Thus bad road conditions could also be the major cause of many road accidents that occur. The detection and occurrence of road surface anomalies and their correct localization play a major role in improving driver's safety and for the optimization of road maintenance. Road quality contributes a lot to make the transportation system safer, efficient and comfortable. A major type of road anomaly that seems to occur everywhere is a pothole. It is defined as bowl-shaped surface failure having a minimum dimension of 150 mm [1]. A pothole occurs when water seeps into the soil beneath the asphalt structure, as it happen water weakens the soil structure supporting asphalt pavement and then the traffic over the affected area breaks the weak asphalt surface [14]. A continues flow of traffic damages both asphalt and the underlying soil structure to create a hole in the pavement. Potholes can generate some serious damage to a vehicle as well. If a vehicle hits a major pothole in the road, then not only the misalignment of steering system can occur but also a tire puncture or in many cases bent rims can occur too. While a road surface monitoring system can save money and all those mention damages, if the system itself is costly it does not fulfill the purpose. This work focus on developing a cost effective solution suitable for developing countries.

The purpose of this monitoring system is to develop the ability to automate the detection and identification of bad road surfaces based on IMU data analyzed by raspberry pi and to alert the user from upcoming high-intensity bumps or potholes. The use of this system can be a vital support for manual human inspection for the measurement of road quality. For collecting data from accelerometer and gyroscope, we use an IMU sensor that can measure accelerations and angular velocities along all 3-axis. By using these sensors road surface condition can be measured [5]. For example, when a vehicle drives over either a rough patch of road, pothole or bump a significant change in the Z-axis of the acceleration and gyroscope can be observed. By measuring the amount of change we can assign an intensity value to that pothole. Once the data is collected it can be analyzed and simplified using simple statistical techniques. Hence, that simplified data is then further used for fulfilling the system functionality.

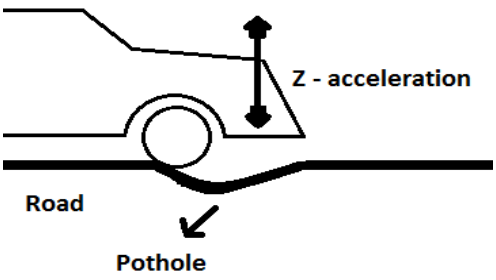

Fig.2. A Vehicle over Pothole

The paper is organized as follows: system components are briefly described in section 2. Previous work is reviewed in section 3. In section 4, the motivation of the work is described. The proposed a solution is presented in section 5. In section 6, experiment and results are discussed. A brief conclusion and future work is described in section 7.

2. System Components

2.1. Raspberry pi 2 Model B

The Raspberry Pi 2 is a small, powerful and easy to use credit card–sized quad core computer developed by the Raspberry Pi Foundation [4]. Few of its specifications include A quad-core CPU with each core having a clock rate of 900MHz with 1GB RAM, 40 General purpose input output (GPIO) pins along with 4 USB ports, Ethernet port, audio/video jack and HDMI port.

Fig.3. Raspberry Pi 2 Model B

2.2. UBLOX GPS Receiver Neo 6m

The NEO-6mGPS sensor module belongs to a series high performance and stand-alone u-blox6 positioning engine. Data is collected from it by using UART(Rx/Tx) interface.

Fig.4. GPS Module

2.3. IMU (Accelerometer and gyroscope)

The MPU-9250 sensor module is a 9-axis Motion capturing device that consists of a 3-axis gyroscope, accelerometer, and magnetometer. Data is collected from it by using I2C interface.

Fig.5. IMU Module

The software suit used for Raspberry – Pi is LAMP (Linux, Apache, MySQL, and PHP) and the programming language that is used is Python, It is a high level programming language which allows us to express the concept by using built-in libraries. Android studio is used for the development of user side application. The official IDE for the designing and development of Android applications is Android Studio [6].

3. Previous Work

Detecting road condition have been studied by different researchers. In [7] authors developed a system and explores the multiple features and provide relationships between acceleration data, collected by using smartphones sensors. Authors also provide a technique to measure and calculate the road roughness and its conditions. However, they have presented a solution for the road surface monitoring that is completely dependent on smartphone hardware such as built in accelerometer sensor and GPS sensor. Another study [8] has designed and developed a smartphone application that detect and analyze pothole and marks potholes on the map. Once this application is started, it automatically starts collecting data by using smartphone hardware such as built-in accelerometer sensor and GPS sensor The authors presented and compared some interesting algorithms regarding road surface monitoring [9]. These algorithms include Z-THRESH,Z-DIFF,G-ZERO, STDEV (Z), and also discussed concepts likes International Roughness Index (IRI). Another system is designed and developed to detect and analyze potholes and analyzed algorithm to monitor the civil infrastructure. They have used sensors like vibration sensor and GPS sensor to gather data and then analyzed the data to assess the road surface conditions [10]. A smart phone based system developed that utilized accelerometer and gyroscope sensor of mobile phones to measure and detect the road anomalies [11]. Another system was developed by using multiple smart phones where each smart phone is running a pothole detection algorithm and collecting data from accelerometer and GPS. Authors also simplified and de-noise data coming from accelerometer sensor [12].

4. Motivation

Several studies of road surface anomalies have proved that the assessment and evaluation of road paths and drive comfort depends upon the road surface quality [7] [8] [9] [10] [11] [12].But most of the studies uses smartphone sensors [8] [11] [12] to gather the data, hence we discover that there is a need to make an independent system of sensors that works on smaller cheaper unit other than smartphones and computers to measure and analyze data. A system that also have the ability to be connected with android applications so that data can be presented to its users with best the interaction possible. Thus, a system is designed and developed completely using a raspberry pi and android application.

5. Proposed Solution

The system is divided into three units as shown in Fig 6. The first unit called *client* is a sensing unit, it measures and locate the rough patch of the road by using GPS and IMU. Second, called *Server* is a

communication and data server unit which handles all the incoming information and acts as a bridge between Raspberry pi and android application to transfer information. The third unit consist of an android application to alert users or drivers for upcoming high intensity road bumps or potholes.

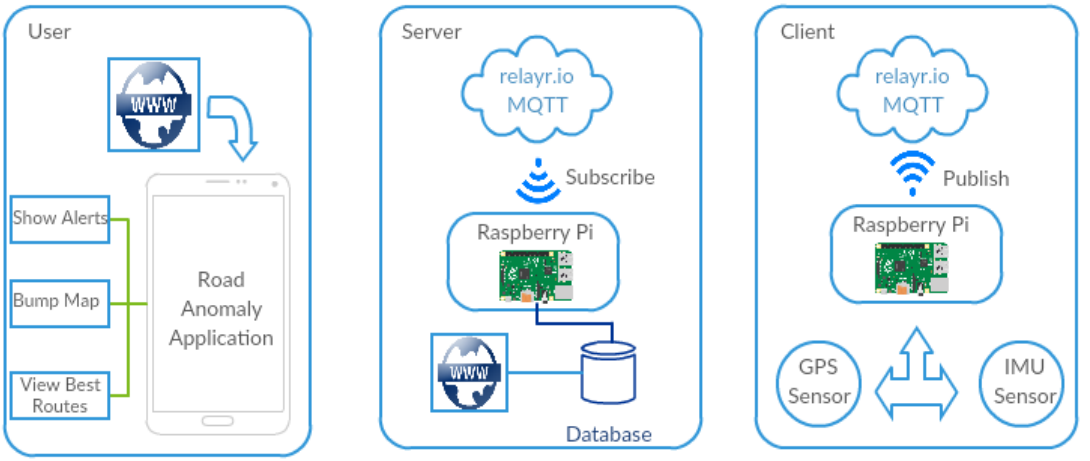

Fig.6. System Architecture

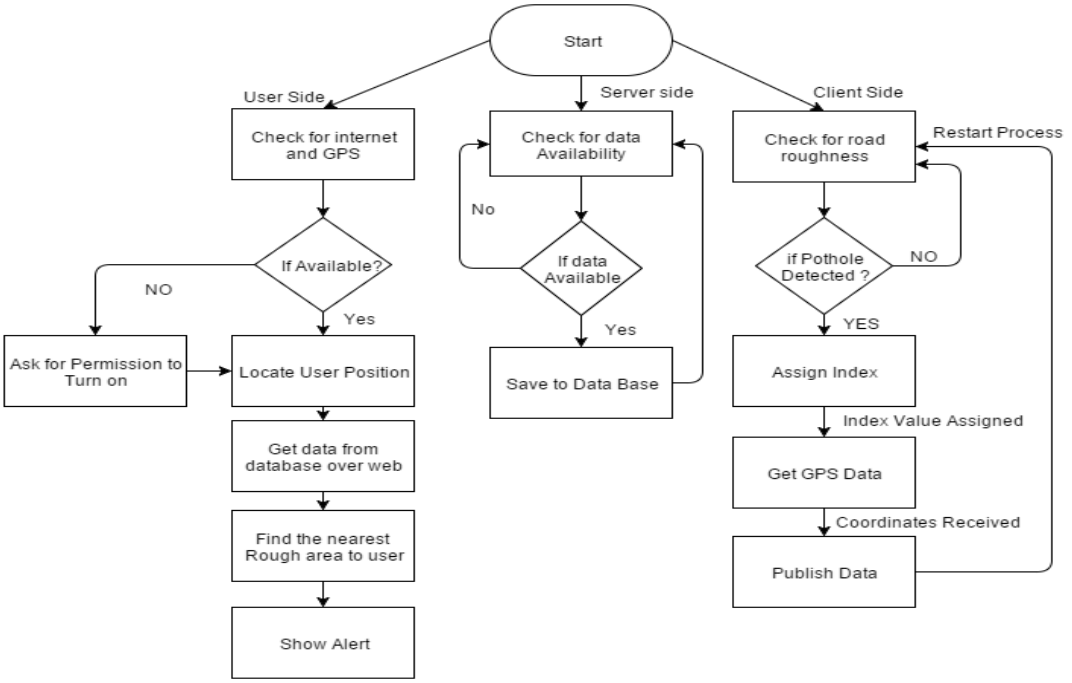

Fig.7. System Workflow

6. Experiments and Results

We have conducted few real life experiments and collected data samples using the Raspberry Pi system. Later, the collected data is de-noised and simplified using a simple algorithm. After normalizing the data, it is published to the data server which records the data into its database from where our android application can fetch the data over HTTP and shows the nearest incoming bump or pothole location with respect to the user location.

6.1. Data collection setup

The system is placed under the rear window of the car. The data is collected from accelerometer and gyroscope sensor attached to the raspberry pi. The values of Z-axis from an accelerometer and gyroscopic sensor are collected at time intervals of 100ms (10 readings per second). The following Fig 8 illustrate the axis orientation and polarity for the IMU sensor.

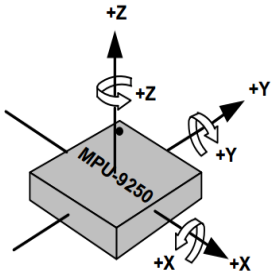

Fig.8. IMU Orientation and polarity [13]

6.2. Data sampling

Data is collected from both accelerometer and gyroscope sensor but gyroscope sensor shows more reliable values with respect to accelerometer sensor. As earth's gravity affect the values of accelerometer sensor but it does not affect the value of gyroscope sensor. Below is a sample data that is collected from both sensors at the same time.

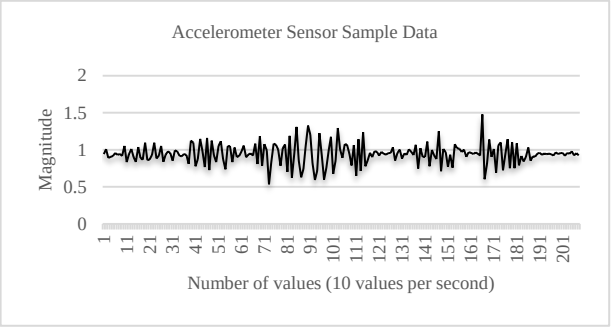

Fig.9. Accelerometer Sample Data

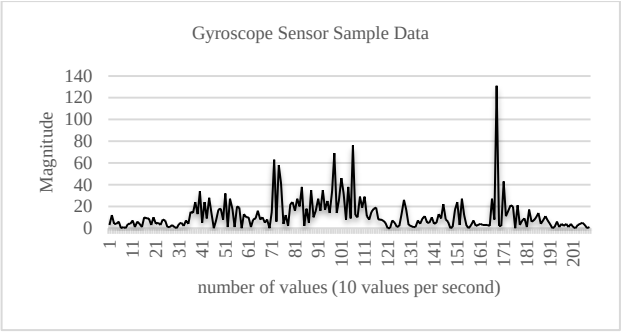

Fig.10. Gyroscope Sample Data

6.3. De-Noising data

To filter the sensed data moving average algorithm is applied. The algorithm works by taking N samples of inputs at a time and then by taking average of samples it produces a single output point. It is a simple way to remove noise from the data.

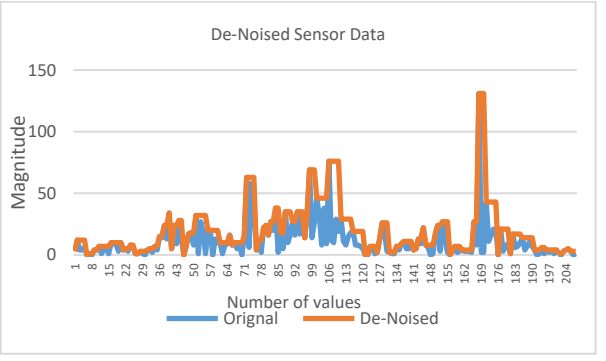

Fig.11. De-Noised Data

As shown in Fig 11 de-noised data (orange line) is obtained which smoothen sensor values for further analysis.

6.4. Roughness index

Once the data is filtered, a roughness index is assigned to each data point based on the acceleration of the vehicle. Each data point is analyzed by pothole detection algorithm running on raspberry pi to detect and categorize bumps or potholes based on acceleration data.

6.5. Publishing data

Once the index is assigned the process of localizing bump or pothole on the map is started. For this GPS data is obtained, then the combined data of coordinates and roughness index is published over MQTT to relayr.io cloud services. This completes the work of first unit of the system.

6.6. Subscribing data

Second unit of the system is raspberry pi based data server that subscribes data from relayr.io and record data into its database and shows results on Google map. A sample of data is obtained by the system is shown in following Fig 12. Each data point can be further classified either as a Pothole or Bump based on variation in z-axis acceleration.

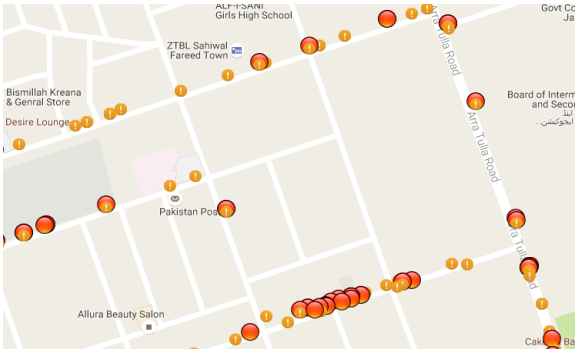

Fig.12. System Generated Pothole Map

- Yellow dots shows high roughness
- Orange dots shows Extreme roughness

6.7. User Alert Application

The third and the final part of the system is user alerting system that fetches data from the server and finds the nearest high intensity data point with respect to user's location. It then analyze and classify this data point either as Bump or Pothole then shows a notification to the user. A screenshot of application showing the alert notification is shown in Fig 13. The current user location is shown by red location marker and bump is shown by exclamatory icon.

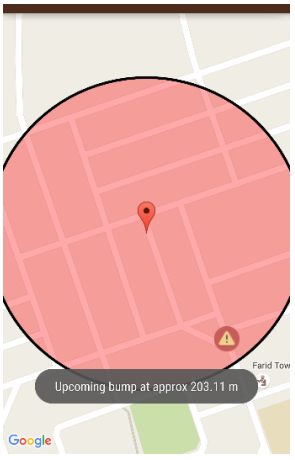

Fig.13. Bump or Pothole Alert

7. Conclusion and Future Work

In this paper, a Raspberry Pi and Android base participatory system is developed that can detect, measure and record road surface roughness occurred due to bumps or potholes and shows alert to android users for upcoming high intensity bumps or potholes. A simple algorithm is designed that simplifies the sensor data and assigns roughness index to the incoming data. For future work, we would like to extend the functionality of the system to sense traffic conditions as well and install the devices to the vehicles to participate and collect data on a larger scale to develop a system for smart cities.

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Authors' Profiles

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Muhammad Asif has received PhD in Computer Science from the Department of Computer and Information Science (IDI), Norwegian University of Science and Technology (NTNU), Norway. He has done his master degrees in Information system engineering from the Department of Computer and Information Science (IDI), Norwegian University of Science and Technology (NTNU), Norway. He is currently working as Assistant Professor in University of Lahore, Pakistan. His research interests are Internet of Things, Mobile and Pervasive Computing.

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