CS-684-2016 Final Report

Road i/o

Measuring, Monitoring & Mapping Road Quality

Umang Chhaparia - 13D070054
Shalaka Kulkarni - 140070010
Mustafa Lokhandwala - 13D070043

Contents

1 Introduction

"One accurate measurement is worth a thousand expert opinions."

- Grace Hopper

In a developing country like India, the problem of poor road quality profoundly affects urban transportation efficiency. We aim to address this challenge by creating **Road i/o** - a road quality measuring, monitoring and mapping solution which will afford urban commuters the knowledge of road quality by location in order to plan their journey for a better travel experience. Moreover, the huge database of information accumulated on the road quality map could be provided to civic authorities to make them aware of a precise need for improvement in infrastructure.

2 Problem Statement

To design and build a device that collects data about road quality parameters such as uniformity, presence and size of craters, water logging etc. and analyses this data to obtain a road quality map of the city.

3 Requirements

3.1 Functional Requirements

1. Hardware Requirements
   (a) Ultrasonic Distance Sensor
   (b) Accelerometer
   (c) GPS module
   (d) SD card
   (e) TIVA C Series microcontroller TM4C123GH6PM
   (f) 9V Battery
   (g) PCB and soldering apparatus
2. Software Requirements
   (a) TI Code Composer Studio (CCS)

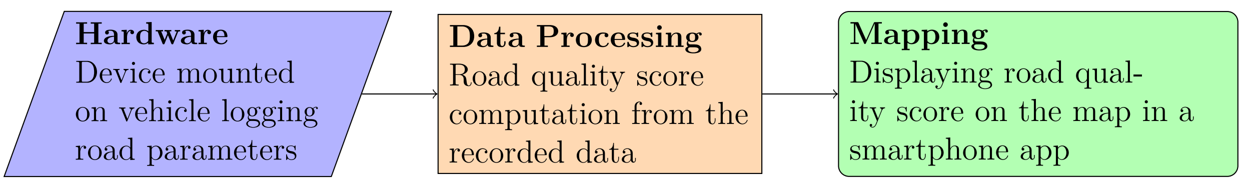
(b) Android Studio

(c) EAGLE 6.5.0

3.2 Non-functional Requirements

1. PVC container to encase the device
2. Drills, tape, insulation and other instruments and materials for prototyping
3. Clamps, screws and bolts to mount on a vehicle
4. Cycle to mount the device for testing

4 System Design



The device is mounted on the undersurface of a vehicle as shown in figure 1. It consists an ultrasonic sensor to measure distance from the road surface, an accelerometer to record changes in the car's motion such as jerks due to bumps or craters, and a GPS module to store the location corresponding to every dataset of the road profile. This data is then processed and analysed to assign a single numerical score (from 0 to 10) to represent the road quality at that point. These scores are then mapped onto an app on the user's smartphone to create a road quality map of the city. The app points out the user's location and depicts surrounding road quality.

4.1 Hardware

All the hardware components were first interfaced and tested separately, verifying the accuracy of their readings.

Figure 1: An example of the device mounted on the undersurface of a car

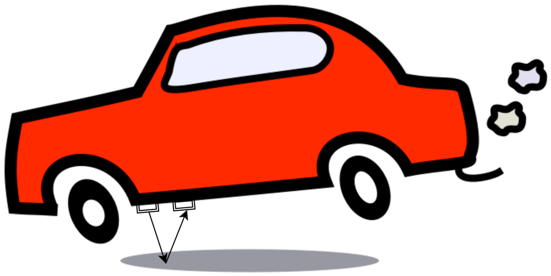
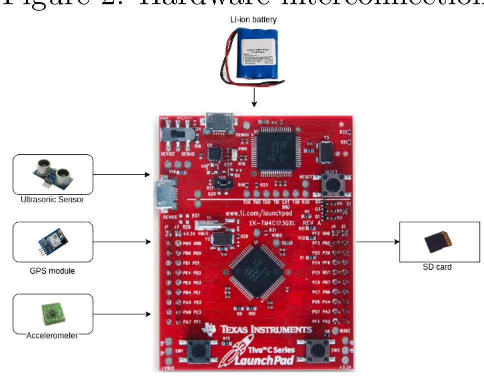


Figure 2: Hardware interconnections



4.1.1 Ultrasonic Sensor

The ultrasonic sensor is connected to port E of TIVA on PE.0 and PE.1 and makes use of TIMER0 and TIMER2 peripherals onboard TIVA.

4.1.2 GPS Module

The GPS module used is MT3333, an all-in-one multi-GNSS (Global Navigation Satellite System) from MediaTek (MT3333 Datasheet). We use the GPRMC string to extract latitude and longitude coordinates of the location, as well as speed over ground. The chip provides a UART interface over which data is transmitted to the microcontroller. It is interfaced with port B where Tx and Rx pins are connected to PB.0 and PB.1 respectively.

4.1.3 Accelerometer

The accelerometer is a part of the MPU-9250 Nine-Axis (Gyro + Accelerometer + Compass) from InvenSense. The datasheet of this device can be accessed here. This chip supports SPI (Serial Peripheral Interface) and I^2C (Inter-Integrated Circuit) serial interfaces for reading out the register values. We use the latter protocol since it requires only two lines of communication between the IC and the microcontroller as opposed to four lines needed by SPI. MPU-9250 is interfaced to port D of TIVA which has the SCL and SDA pin functions on PD.0 and PD.1 respectively.

4.1.4 SD Card

An 8 GB micro-SD card is used for recording the sensor data in real time. SD cards have an SPI mode, which allows read/write of data from a microcontroller. TIVA has SSI (Synchronous Serial Interface) peripheral which can be utilised for SPI communication as well. SSI0 peripheral is used to connect the SD card pins, PA.2 as SCLK, PA.3 as $\bar{\text{S}}\text{S}$, PA.4 as MISO and PA.5 as MOSI.

4.1.5 Voltage Regulator

The whole assembly (TIVA, sensors and SD card) is powered by a 9 V battery. But, the TIVA, ultrasonic sensor and SD card need a 5 V supply whereas accelerometer and GPS module require a 3.3 V supply. 9 V from the battery can be brought down to 5 V and then the 3.3 V output can be used from TIVA. 7805 is a 1 Ampere Voltage Regulator which gives an output of 5 V for input voltages from 7 V to 25 V. The datasheet is available here.

4.1.6 PCB

A BoosterPack™ is made to put together all the sensors, SD card module and voltage regulator circuit onto a PCB.

After soldering and inserting the individual modules on the PCB, the assembly was enclosed in a plastic box with a switch provided outside to start and finish the data recording.

Figure 3: All the modules populated on the PCB and connected to the battery (SD card not inserted)

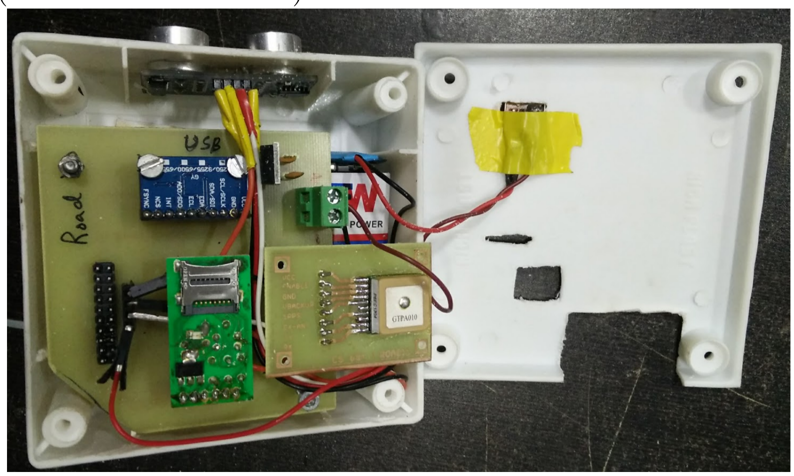
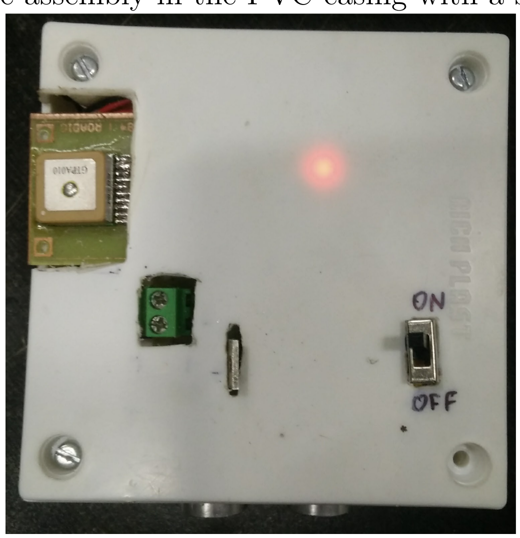


Figure 4: The assembly in the PVC casing with a switch outside



4.2 Data Processing

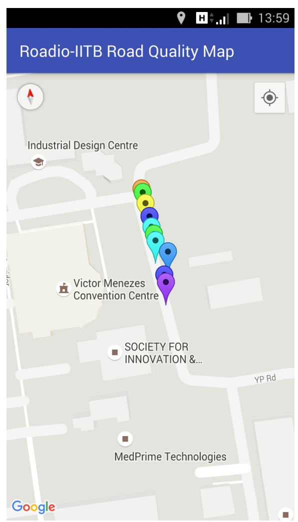
A moving average filter of window length 10 is applied on the readings of the ultrasonic sensor.

4.3 Mapping

The data obtained from the post-processing pipeline is stored in a file as latitude and longitude coordinates mapped to a road quality score, a real number in the range 0 to 10. This file is read by the Roadio-IITB Android app which extracts the location-mapped data and plots it on a Google map. Different coloured markers are used to depict different road scores, with violet being the best (10) and red the worst (0). On allowing location access, the current user location is also displayed on the map so that the road quality-marked area can be viewed relative to user position.

An example of the application screen is shown in figure 5 for sample data plotted on a road behind the Victor Menzes Convention Centre, IITB.

Figure 5: The different coloured markers indicating road quality



5 Test Results

To collect data and validate our concept, we mounted the device on a bicycle and collected data from rough patches and bumpers on patchy roads in the IIT.

Figure 6: The device fixed to a bicycle

5.1 Speed Breaker

The bicycle was riden over a speed breaker and the measured data from the ultrasonic sensor was processed and plotted.

Figure 7: Speed breaker

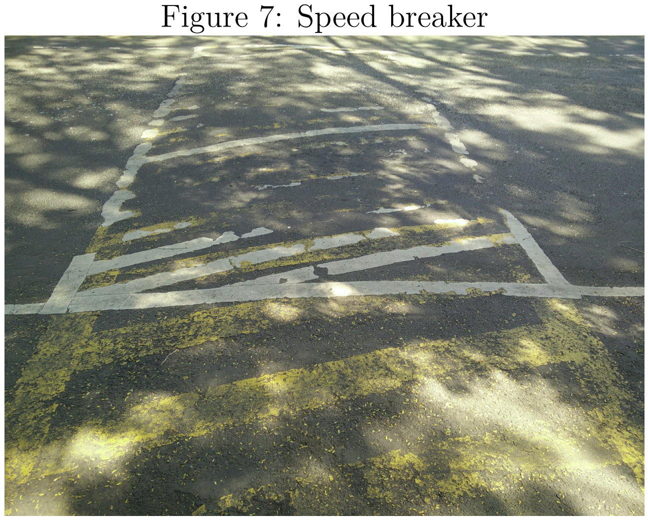
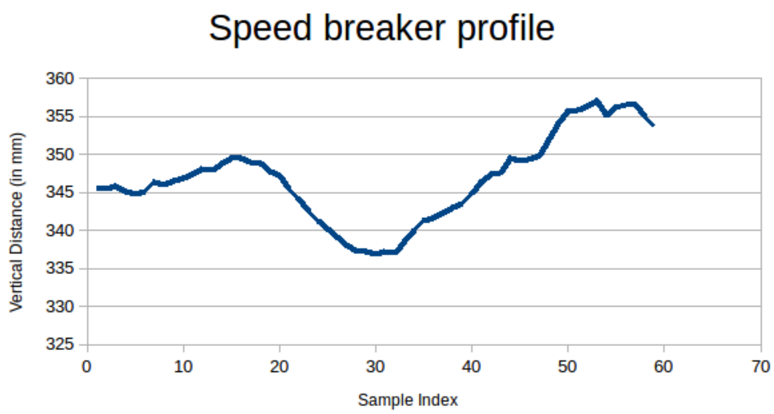


Figure 8: Distance profile of speed breaker

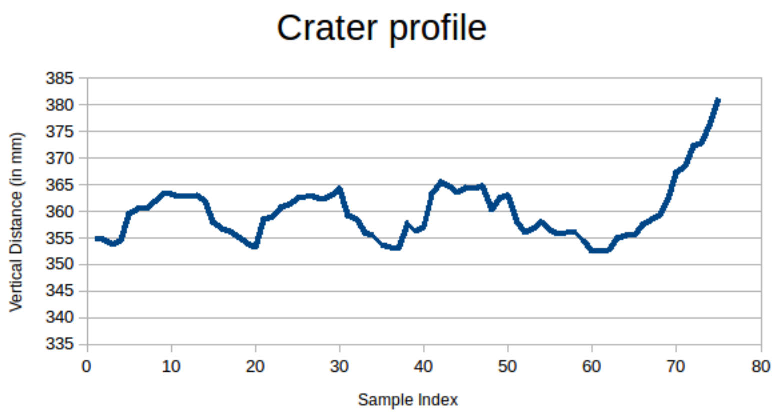


5.2 Craters

Similarly, after riding the bicycle over a few craters, we got the following graph of verticle distance.

Figure 9: Craters

Figure 10: Distance profile of craters



6 Discussion

From the testing data, it is evident that it is possible to measure and characterize road quality using the hardware created. The accuracy and granularity of the final output can be improved via the use of advanced signal processing techniques.

The interfacing of various modules with TIVA viz. ultrasonic, accelerometer, GPS module and SD card are independent i.e. each of them utilizes a different port and peripheral. So, the TIVA code can be used to interface individual modules as well.

7 Future Work

- There is lot of potential work that can be done at the data processing end i.e. in employing denoising techniques or sensor fusion algorithms, even with this device being mounted on a bicycle.
- Bluetooth can be interfaced on the device to transfer data wirelessly to the smartphone.
- Hardware can be made sleek by just including the necessary components and embedding them on a PCB. For example, the necessary part from the TIVA LanchPad is just the TM4C123GH6PM IC.

8 Conclusion

We are looking forward to develop this as a full fledged product and actually go ahead in making a difference. This has the potential of creating a whole new realm of transparency and accountability in the way the road infrastructure will be managed.

References

[1] Road i/o: Road quality measurement, monitoring and mapping solution - https://github.com/shalaka-kulkarni/2016-cs684-roadio

[2] Pavement Interactive (August 16, 2007) Roughness - http://www.pavementinteractive.org/article/roughness/

[3] Bill Slawski (07/05/2015) Google To Map The Quality Of Roads? - http://www.seobythesea.com/2015/07/googletomapthequalityofroads/

[4] United States Patent (August 18, 2015) Systems and methods for monitoring and reporting road quality

[5] Ultrasonic Ranging Module HC - SR04 http://www.micropik.com/PDF/HCSR04.pdf

[6] Google Maps for Android API