University of Mumbai

Crowd sensing Road Surface Data with Geospatial Visualization for Augmenting Navigation and Telemetry of Ground Vehicles

Submitted at the end of Semester 8 in partial fulfillment of requirements

for the Degree of

Bachelor of Technology

by

Keyur Vinay Kulkarni (1913026)

Paras Jitendra Shah (1913036)

Jangala Sai Keerthana (1913083)

Guide

Prof. Chaitali Kulkarni

Department of Electronics and Telecommunication Engineering

K. J. Somaiya College of Engineering, Mumbai-77

(Autonomous College Affiliated to University of Mumbai)

Batch 2019 – 2023

Certificate

This is to certify that the dissertation report entitled **Crowd sensing Road Surface Data with Geospatial Visualization for Augmenting Navigation and Telemetry of Ground Vehicles** submitted by Keyur Vinay Kulkarni, Paras Jitendra Shah, Jangala Sai Keerthana at the end of Semester VIII of Fourth Year B.Tech is a bona fide record of partial fulfillment of requirements for the Degree of Bachelors in Technology in Electronics and Telecommunication Engineering of University of Mumbai.

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This project work is submitted at the end of Semester VIII in partial fulfillment of requirements for the Degree of Bachelors in Technology in Electronics and Telecommunication Engineering of University of Mumbai.

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Keyur Vinay Kulkarni **Roll no.: 1913026**	______________________
Paras Jitendra Shah **Roll no.: 1913036**	______________________
Jangala Sai Keerthana **Roll no.: 1913083**	______________________

Date:

Place: Mumbai-77

Abstract:

Among many Web / Smartphone applications belonging to the field of Geographic Information Systems (GIS), for providing navigation services, Google Maps service is used by most common people almost daily. Such mobile applications provide route(s) towards destination(s) and some information related to surrounding geography. However, data related to the condition of road surface, on which (all types of) vehicles, pedestrians might travel, is not available in as objective, precise format as data related to routes. Road surface conditions contribute significantly to decisions related to road travel in many cases. Common people, who travel on the given route for their purpose, Logistics businesses, that use Roadways for transporting cargo / freight, and Road-building corporations, who need to survey and maintain / repair the given road network, are few examples that will be benefitted by the Road surface condition data.

With this motivation, in our project, we attempt to measure road surface conditions using the vehicle's vibrations, curate a database of roads in our locality and visualize it in mobile application. We measure the vibrations of the vehicle using an accelerometer, analyze the reading, and store this information in the database service provided by Firebase Real-time Database. This is made possible with the help of NodeMCU microcontroller development board, which applies the Kalman Prediction Algorithm as the data is collected and connects to the database service via in built Wi-Fi capabilities and Wi-Fi hotspot from User's smartphone. Along with sensing the presence of pothole estimated using Kalman prediction algorithm, an HTTP request is made to a (secondary) mobile application (on User's smartphone) whose sole purpose is to respond with current GPS co-ordinates using the smartphone's sensors. Thus, the sensed pothole/irregularity estimated via Kalman prediction algorithm, and corresponding GPS co-ordinates are stored in the database, which is used by the (primary) main mobile application which uses MapmyIndia maps API for visualizing the road conditions along with routes' details.

Keywords: WSN, Accelerometer, GPS, Crowdsensing, Signal Processing, Data Analysis, Data Visualization, longitude, Latitude.

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Chapter 1

Introduction

This chapter explains the nature of the problem statement by stating the motivation and background as well as defines the scope of the project. Here, the void created by the problem is expressed followed by the necessity to address it.

1.1. Motivation

One important parameter that influences the route selection and the traveler's journey is the quality of road surface. The information related to quality of road surface is meagerly available to the users from popular media like apps, travel blogs, websites related to traveling / journey, description of other experienced people, etc.

Even if data related to the road surface quality may not reach to the people through popular applications/media, the importance and necessity of this data does not wane. Not only the pleasantness of the time invested by the travelers but also the health of the vehicle itself and the goods, if any, depend upon the road surface. The necessity of the data pertaining to road surface may escape the travelers while planning the journey because of less experience in encountering high variance in road surface quality and / or people adapting to the variance.

Since there is no definite and objective source for determining the road surface quality, people decide to experience the quality first-hand with the expectation that the purpose of travel will be achieved and the destination will be attained with tolerable variance in the required experience. Knowledge of road surface quality becomes vital when personal, commercial, governmental users have to confront variation intolerant situations.

It may be difficult for some people to realize that their current experience / situation of road travel is part of the problem that we are trying to tackle in this project, because they have adapted and become habitual to them. People will not realize that the conditions that they have adapted to are actually problems. People should identify the current practical conditions of traveling on the road, which they have adapted to deal with, as part of the problem. Then they may understand our project as a viable part of the solution.

1.2 Shortcomings of Existing Solutions

Reliable, comprehensive and easy-to-grasp information related to road surface quality of the desired road may be obtained from experienced people. However, that information is limited by the language, region and access to such community of people. Probably, the information delivered may not be understood because of lack of understanding and/or uncommon subtle assumptions of the communicating parties.

Besides verbal subjective description on blogs or websites related to the travel, resources conveying objective measures and accurate descriptions are uncommon and scarce to the public at large.

Popular applications like Google Maps (from Google Inc.), OpenStreetMap (from OpenStreetMap foundation), HERE WeGo (from HERE technologies), etc. have made the planning and route selection process very easy for travelers i.e., passengers and drivers. Such applications may be extrapolated to the domain of Geographical Information Systems which integrate concepts of geographic databases, mapping and navigation services, data from multiple positioning systems like GPS, GLONASS, IRNSS / NAViC, BeiDou, QZSS, etc. with the APIs, User applications and websites. The process of path selection and travel time estimation, that required decent cartographical and geographical understanding along with legible and updated maps printed (physical copies), can now be done very easily and effectively by anyone with smartphone within minutes. However, neither of the application platforms deliver road surface quality data to the users.

1.3 Potential use cases for the collected data

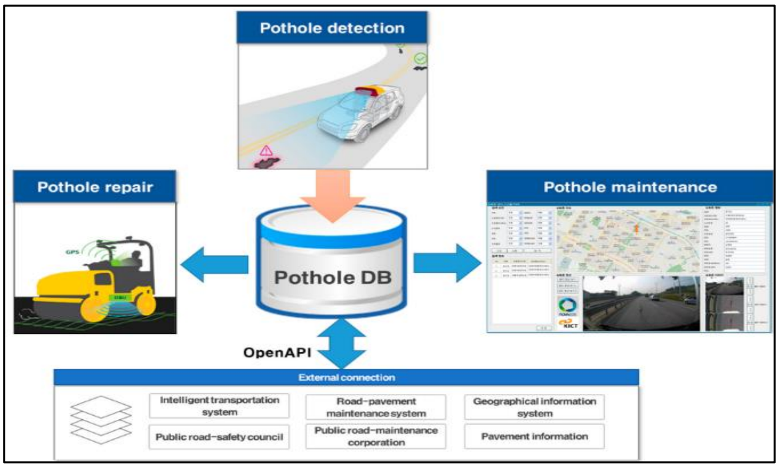


Fig (1.1) Graphic explaining applications of a pothole database, made from vehicle mounted sensors.

Out of all the travelers using the roadways, if information related to road surface was available beforehand then many travelers would find it helpful, and even critically essential. Road quality is the largest variable in the journey of most travelers.

The knowledge of road surface quality is essential for

- Government authorities, road building companies to know when and where road quality inspection and repairs need to be made so that the quality of road that is provided to the tax-payers is maintained,
- Logistics businesses; teams of people that are tasked to transport large quantities of goods (or, sometimes, when the size of the goods to be transported is itself large) to distant places with the help of large heavy vehicles,
- Private vehicles that carry passengers vulnerable to uncomfortable journey like pregnant women, infants, people with disabilities, senior citizens, etc.,
- Emergency vehicles like ambulance; although choosing the fastest route is required, but, if more stable route is beneficial for the purpose (e.g.: to the patient) without much compromise in speed, then it will serve the purpose well,
- Common people expecting more comfortable / pleasant experience of journey because along with their experience, the health of their vehicle is also affected due to unpredictable road surface quality,

Many benefits, like the ones mentioned above, can be derived for personal, commercial, governmental operations with the knowledge of road surface quality.

1.4 Scope of the Project

In this project, we strive to incorporate both, the hardware that shall be required for collecting the data as well as the software system required to deliver it to the users.

We plan to deploy an embedded system containing MEMS accelerometer sensor on a vehicle without inhibiting any function of the vehicle. Since data from the accelerometer sensor shall be is crucial for us, we need that embedded system to communicate that data to a data storage element, such as a database, over the internet. An application at the user side, shall fetch data as requested by the user and display it to the user.

In this part of our project, we have focused our efforts in building the data collection system so that it can be compact / portable and complete in view of the probable requirements of our information system.

The microcontroller development board, and other elements of the embedded system, shall be chosen as per fulfillment of expectation from embedded system, ease of interfacing the required sensors and our experience with them. Although delivering an optimal embedded system is not the focus of our project, achieving small form factor is what we strive for.

In our project, we do not consider the cases where the embedded system will not be connected to the internet, such as places with very limited / constrained connectivity. Simple logic involving buffering may be applied in such cases. However, routing the generated data to certain gateways (that are always connected to the internet) using principles of Wireless Sensor Networks (in this case Vehicular Sensor Networks) is not the goal.

Even though the application development aspect of the project is not focused in current efforts, only the required features of application shall be included in the design & development phase.

1.5 Organization of the report

In this report, the Introduction (Chapter 1) briefs the reader about the problem statement and the selected approach. We try to provide a general overview of what drives us to select the aims and goals that we set for ourselves in light of the project.

The Literature Survey (Chapter 2) elaborates on those vital documentations of projects, theses, reviews, etc. that justify the project design and approach / plan that we fulfill as part of the project.

The Project Design (Chapter 3) provides details of the plan derived from the literature survey.

The results from various experimentations and implementations are provided in Chapter 4.

Final conclusions & decisions following the implementations, which chart the way for further aspects of project, are iterated in Chapter 5.

The Appendix contains supplementary information needed to support the certain sub-sections in the chapter. The first one, A, provides the Code with reference to implementations mentioned in Chapter 4.

1.6 Summary

Having an understanding of the road surface quality is essential when dealing with situations that are intolerant of variation. This chapter describes the main aim of the project viz. why road quality data is important and how vehicles can be used to collect this data. With the help of a MEMS accelerometer sensor data can be collected. Data collected will be analyzed and wherever an irregularity is detected the GPS coordinates of that location will also and mapped onto an app, that will be provided to users so that they can take the decision. This project provides a transition from manual inspection to automatic inspection which not only reduces time but also reduces the labor cost. Logistics businesses and emergency vehicles like ambulances will benefit greatly from the project.

1.7 Outline of next chapter

In addition to the basic information and literature referred for determining the plausibility & practicality of the project, an in-depth review of the requirements and related topics is vital for deciding the execution plan towards the final goal.

Thus, the next chapter, chapter 2, Literature survey, shall explain the resources referred to arrive at the current understanding of the project.

Chapter 2

Literature Survey

This chapter covers the review of those resources, project papers, conference papers, research papers, educational websites i.e., literature which have been most influential for us. The contents from the paper are first condensed into key points and then analyzed to incorporate the learnings in our project.

2.1. Literature Survey

[1] Jakob Eriksson, Lewis Girod, Bret Hull, Ryan Newton, Samuel Madden, Hari Balakrishnan (MIT CSAIL), "The Pothole Patrol: Using a Mobile Sensor Network for Road Surface Monitoring", 2008

Summary

This paper proposes the importance of mobility in spatiotemporal coverage of Road Surface and implementation of delay-tolerant, reliable transmission scheme, dPipe. It also covers the analysis of possible positions for accelerometer placement and filtering techniques for acceleration data .It also recognizes features that represent the actual road anomalies.

[2] Guido Morgenthal, Jan Frederick Eick , Sebastian Rau and Jakob Taraben, "Wireless Sensor Networks Composed of Standard Microcomputers and Smartphones for Applications in Structural Health Monitoring", 2019

Summary

This paper demonstrates the feasibility of integrating smartphones as data acquisition nodes into the network, utilizing their internal sensors.The results of demonstration confirms the high performance of the measurement system in terms of stable sampling at high sampling rates up to 1 kHz. It also highlights limitations of cheap MEMS-based sensors.

[3] Thomas J. Matarazzo , Paolo Santi, Shamim N. Pakzad, Kristopher Carter, Carlo Ratti, Babak Moaveni, Chris Osgood, Nigel Jacob, "Crowdsensing Framework for Monitoring Bridge Vibrations Using Moving Smartphones", 2018

Summary

This paper describes about the condition monitoring and evaluation of civil structures using Mobile Sensor Networks as a scalable monitoring solution.

[4] Emanuele Massaro, Chaewon Ahn, Carlo Ratti, Paolo Santi, Rainer Stahlmann, Andreas Lamrecht, Martin Roehder, Markus Huber, “The Car as an Ambient Sensing Platform”, 2017

Summary

This paper describes how a car can be used as an urban sensing platform with respect to specific examples dealing with: weather and environmental sensing, road safety, driver behavior analysis.

[5] Suhas Mathur, Tong Jin, Nikhil Kasturirangan, Janani Chandrashekharan, Wenzhi Xue, Marco Gruteser, Wade Trappe, “ParkNet: Drive-by Sensing of Road-Side Parking Statistics”, 2010

Summary

This paper describes how various scenarios and events involved in the detection of parking space using mobile sensors.

2.2 Summary

Current technology provides us with many options of obtaining this data. Out of the many methods that we came across, the projects that influenced our decision-making were described above. This brings the choice of technology to be used with those that can prove one option / approach to be better than the rest. The preference of one option / approach is evaluated by its compatibility, suitability with humans that use them. Thus, it becomes a matter of subjective evaluation of the preference on one method over another. Hence, no distinct conclusion can be derived regarding the superiority of one approach / option over another. Nevertheless, the study of multiple approaches can greatly benefit us in formulating our own solution. The learnings we derive from this literature survey reflect in our Project Design.

2.3 Outline to next chapter

We have established the potential of road surface quality data and its scarcity in chapter 1. We understand the subjective description of road surface quality data with moderate difficulty and in a time-consuming manner. This is because the description is dependent on many factors, that vary from person to person, like language used, details explained, authenticity of description, non-verbal assumptions, etc. An objective description involves explanation involving numbers belonging to the mathematical method and/or scientific process followed to obtain them. Such objective data is better i.e., more universal and effective to communicate, than subjective description. In our project, the scientific process that we must engage in must extract data from the actual situation which, in this case, is portions of the road that reflects the changes in the road surface quality. This endeavor is explained in the next chapter.

Chapter 3
Project Design

This chapter explains the design choices made for formulating the project to solve the problem statement. It also explains the order of functioning of every segment of the project.

3.1 Background

Our approach is inspired from the quote, "Experience is the best teacher". Experiencing road surface quality of a certain region is the best way of knowing the road surface quality. The experience of road surface quality translates to the seemingly random, stochastic manner in which the vehicle moves / reacts which may be discomforting and unexpected to the passengers. The irregularities in the road surface are, usually, undesirable imperfections along an approximately smooth road. We know that this motion is limited to only that region where the road surface is not smooth. Tackling these problems forms the basis of the solution we present through our project.

3.2 Understanding behind the Project

Firstly, for recording and remembering the motion of the vehicle, we must be able to sense the motion and then store it locally or remotely. Speaking in terms of vehicle's motion, the magnitude of the motion is proportional to the severity of the road surface irregularities. MEMS accelerometers exhibit the techniques of measuring this motion based on advancements in microelectronics and VLSI domain. Owing to the trends of technological developments today, these accelerometers are portable, require low-power, easy to interface using popular microcontrollers and affordable. Thus, such accelerometers are required to measure the magnitude of motion of the vehicle. To aid our understanding of the accelerometer data, we must also know the location from which the data is gathered. Since, the accelerometer data is gathered by the virtue of the vehicle travelling from existing location to destination, the data may be of little use if the knowledge of position, location of the vehicle when the accelerometer data is collected is not known. The GPS service can be availed when the position and location data is needed. That means, for knowing the motion of vehicle, the accelerometer data, supported by the GPS data of vehicle, must be collected at multiple instances along the route of travel.

Secondly, in order to record this motion, we need these devices to move along with the vehicle itself. Hence, the scope of our project is limited to deploying these devices on minimum one vehicle for gathering and analyzing data. Even if deploying these devices on multiple vehicles is beyond the scope of our project, it may be considered as an extended goal in the future. Thus, in principle, we will be requiring some vehicle for sensing the road surface data and reporting it back for storage on secure place for developing further applications. The vehicle to be used for this project is hired for the sake of the project demonstration and it does not contain any modification for specially affecting the working of the embedded system.

After collecting the data, it is essential for us to suppress erroneous readings i.e., noise which is inherent to the sensor and / or the embedded system's working environment. For deriving useful information from the magnitude of motion of the vehicle, certain algorithms (belonging to signal processing and/or machine learning; based on physics behind motion of sensor, statistical nature of the readings reported by sensors, etc.) need to be applied. Based on the sensor readings, the algorithms shall be able to grade the road surface quality. Based upon the grade, at least, we shall be able to report whether the road surface is smooth or rough or pothole-ridden.

After forming a compact self-sufficient embedded system using the accelerometer if the embedded system is discreetly situated on the axle / shock-absorber of the vehicle, then data related to road surface quality can be generated ubiquitously. The analytical algorithms can be applied on the data with the help of the microcontroller development board that is used in the embedded system since that can be the best platform which can function as an edge computing element.

This is why we have chosen to use accelerometer-based embedded system deployed on actual moving vehicles for collecting road surface quality data.

3.3 Flow of Project's Operations

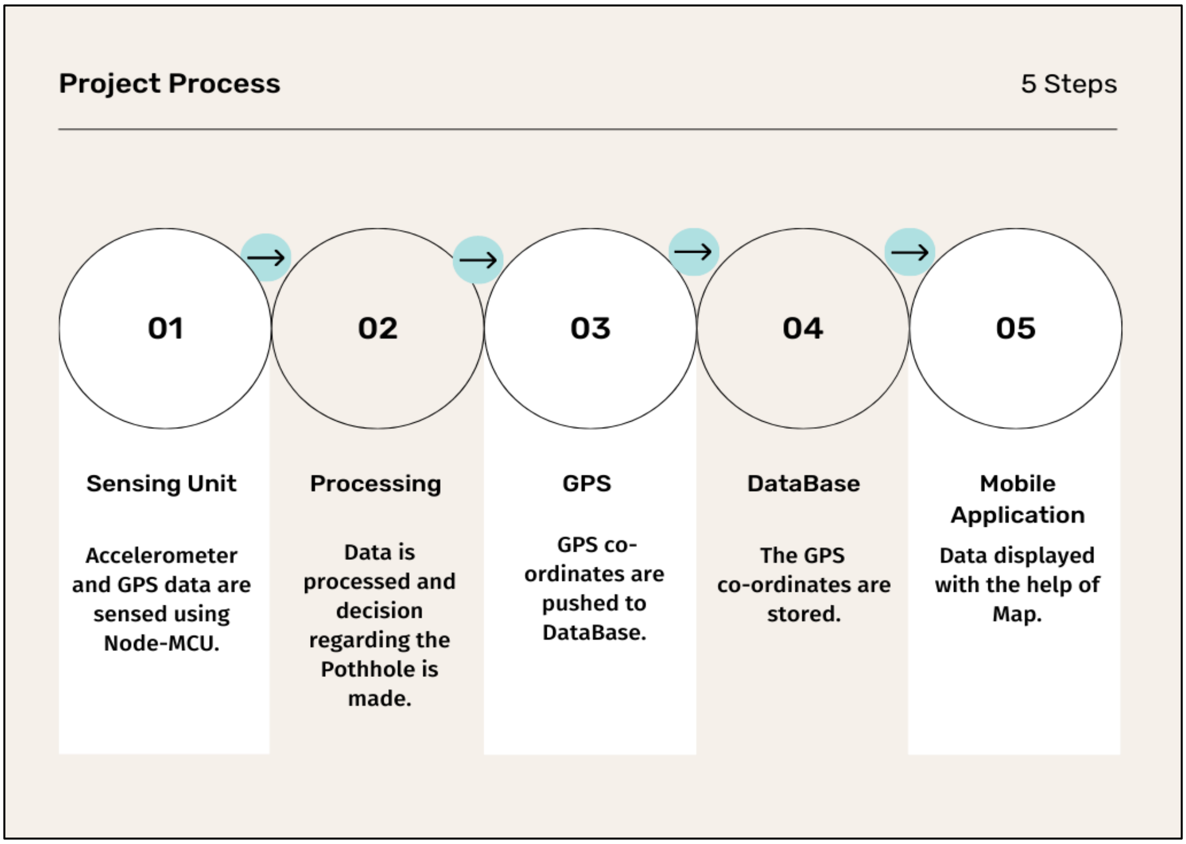


Fig (3.1). Flowchart of Project

- Digital accelerometers (3-axis) are responsible for sensing its own acceleration in 3 directions as per rectangular co-ordinates.

- Such accelerometers will be connected to NodeMCU, which is responsible for being connected to the internet (provided by internet-enabled cars or smartphone-hotspot of users in the car), receiving this data, temporary storage and processing it; powered by sufficient battery source.

- When placed (in compact form) along the suspension / wheel axle (at present, place of mounting is under study), this 'sensory node' will move as the vehicle moves / reacts to the road surface; thus, sensing the accelerations and generating that respective data.

- Once the data has been collected the controller will apply classifier algorithms for knowing whether the reported data corresponds to pothole-ridden road or rough road or smooth road based on the degree of severity

- Once the collected data has been processed the NodeMCU sends an request to the app for GPS coordinates and then this data is stored in the Firebase, a database which is responsible for storing values from all sensory nodes.

- Mobile application shall acquire such data from database, present engaging user interface & visualize the required data in a manner which is easily understood by all, thus realizing the purpose.

3.4 Hardware

The hardware components used in this project are responsible for the collection of data. Here the following hardware components used in the project

1.***ADXL345***: ADXL345 is a small, thin, low power, 3-axis accelerometer with high resolution (13-bit) measurement at up to ±16g. Digital output data is formatted as 16-bit twos complement and is accessible through either a SPI (3- or 4-wire) or I^2C digital interface. The ADXL345 is well suited for mobile device applications. It measures both dynamic accelerations resulting from motion or shock and static acceleration with a selectable measurement range of ±2 g, ±4 g, ±8 g, or ±16 g.

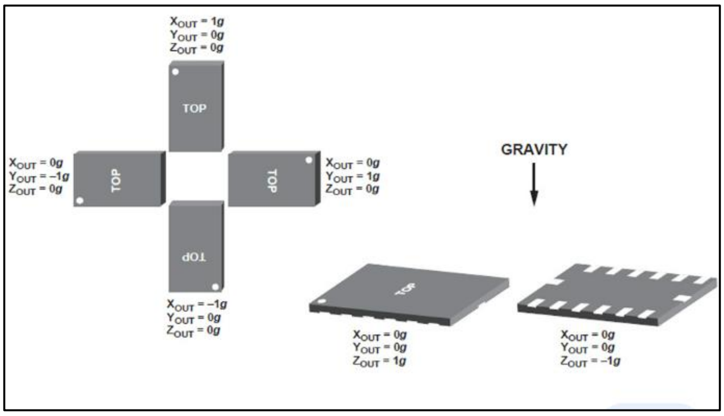


Fig (3.2) Orientation of accelerometer w.r.t 'g' notation of ADXL345 sensor

2.***NodeMCU:*** NodeMCU is an open-source firmware and development kit based on the ESP8266 Wi-Fi chip. The ESP8266 is a low-cost, low-power system-on-a-chip (SoC) that integrates a microcontroller unit (MCU) with a Wi-Fi radio, making it an ideal platform for Internet of Things (IoT) applications.

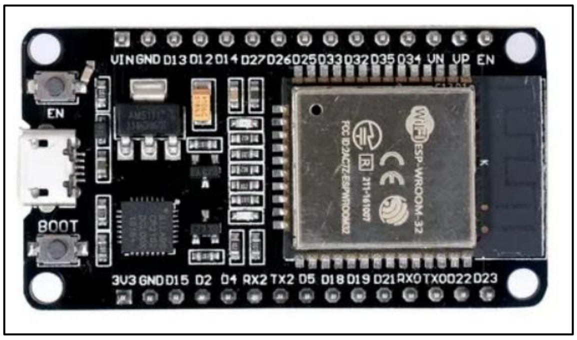


Fig (3.3) NodeMCU

3.***Zero PCB:*** Zero PCB used here is a general-purpose rigid copper board with pre drilled holes. With the help of Zero PCB all the hardware components are soldered together which eliminates the chances of loose connections, reduces the complexity, and reduces the size of the final product.

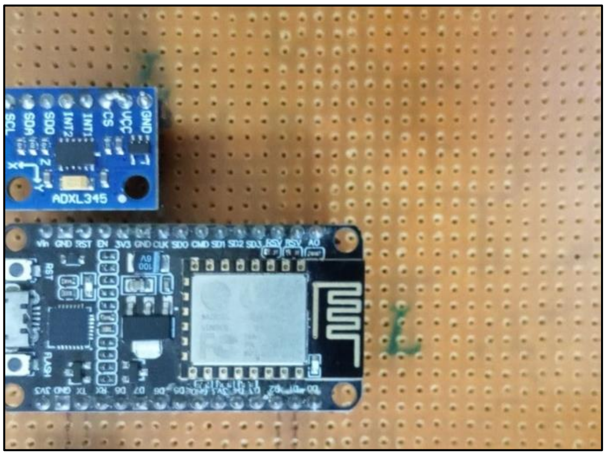
4. ***Female Header Pins:*** These pins are soldered on the Zero PCB, which allows ADXL345 and NodeMCU to be detachable from the Zero PCB. These pins are very helpful if replacement of any components is required.

Connections

The following table explains the connections between NodeMCU and ADXL345

ADXL345	***NodeMCU***
GND	GND
VCC	3V
CS	3V
SDO	GND
SDA	D2
SCL	D1

Table (3.1) Connections between NodeMCU and ADXL345



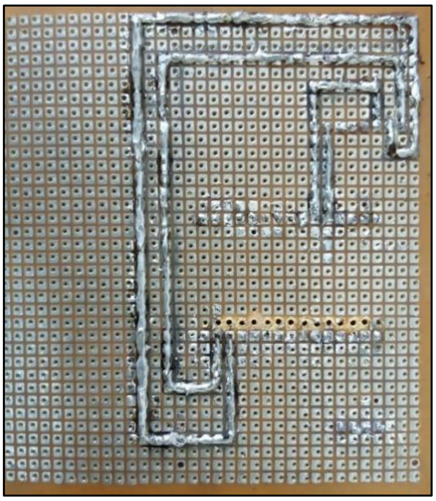


Fig (3.4) and (3.5) Front and back view of the final hardware setup used in project

With the above connections in mind, the components are soldered together, this process is called Soldering.

3.5 Processing

The recorded readings are used to differentiate whether the collected data corresponds to pothole-ridden road or smooth road. For the scope of this project, such binary classification is made for simplifying the performance analysis of system-level implementation. By using the accelerometer readings, classification is made between pothole-ridden road and smooth road. This classification is made with the help of Kalman prediction algorithm.

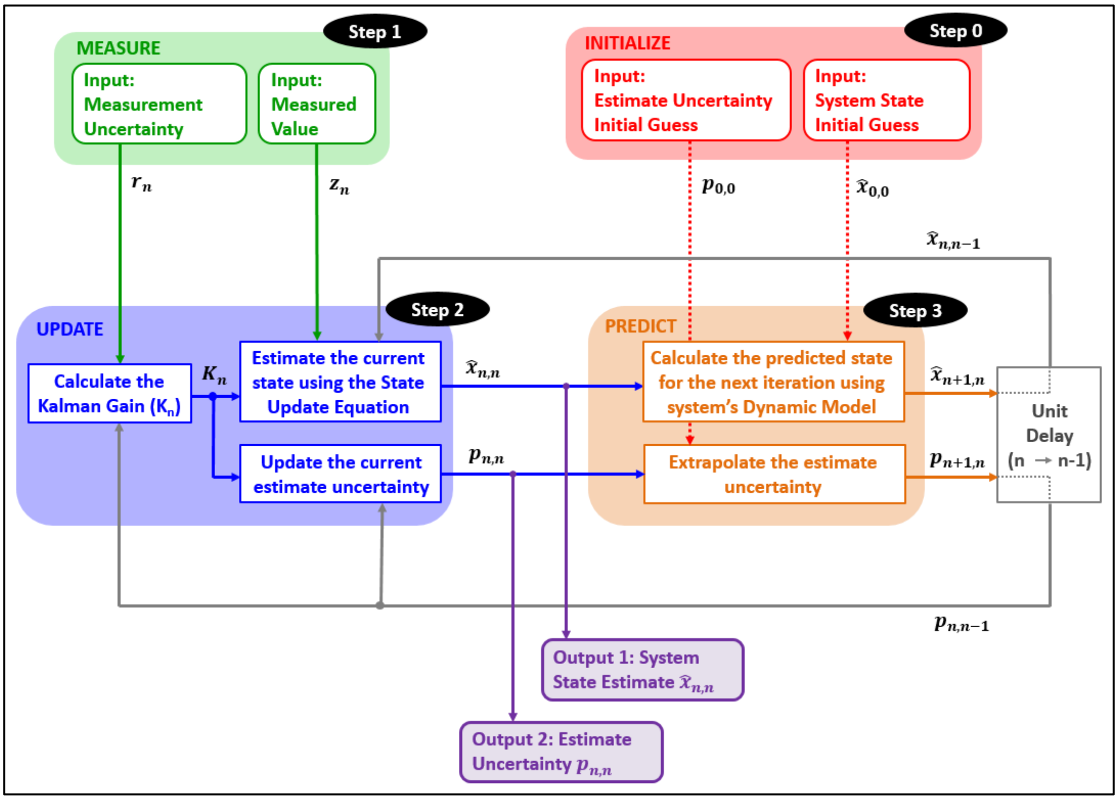


Fig (3.6) Flowchart of Kalman filter

The Kalman algorithm predicts consecutive accelerometer reading by accounting the past readings and the associated errors. If the new recorded reading differs from the predicted reading beyond a pre-defined threshold (static) deviation then that instance corresponds to pothole-ridden road, else it corresponds to smooth road.

An explanation of the Kalman prediction algorithm is mentioned in the above diagram.

Before iterating through the steps of the algorithm, error associated with measured and estimated value are arbitrarily initialized. The estimated value is arbitrarily chosen for initiating further steps of the algorithm. The value of the estimated value and initialized errors influences the time taken by the prediction algorithm to narrow down to a threshold value. This threshold value is the one with whom the actual (real-time) value is compared for making the required classification.

New accelerometer readings are recorded and tested for their compliance within the threshold. Correspondingly, after each iteration, based on the deviation of the actual (real-time) values w.r.t. predicted value, the estimated value and errors associated with the estimated value is updated.

The error associated with measured value is not updated because the uncertainty of the sensor to measure acceleration remains constant.

3.6 Software:

The following software's were used to interface with the hardware, process data, store it, and visualize it.

Arduino IDE: The Arduino Integrated Development Environment (IDE) is a software platform used to program and develop applications for Arduino microcontrollers. With the Arduino IDE, you can write code in the Arduino programming language, which is based on C, C++ and provides easy-to-use functions for interacting with the board's hardware.

Firebase Realtime Database: Google offers a cloud-based NoSQL database solution called Firebase Realtime Database. It enables programmers to create real-time apps that can sync and save data between clients and servers in real-time.The database may be accessed through Firebase's SDKs for a number of platforms and stores data as JSON objects. Firebase will automatically sync the data across all connected clients.

Visual Studio Code: Visual Studio Code is a free and open-source code editor developed by Microsoft. It is designed to be lightweight, fast, and customizable, with features that make it suitable for a wide range of programming tasks, including web development, machine learning, and game development.

Figma: Figma is a cloud-based design tool used for creating user interfaces, website designs, and mobile app designs. It allows designers to create, collaborate, and share designs with others in real-time.

Framework and Programming Languages:

Flutter:Flutter is a mobile app SDK (Software Development Kit) developed by Google for building high-performance, high-fidelity, apps for iOS, Android, and the web, all from a single codebase. It uses the Dart programming language and a reactive programming style, making it easy to build beautiful and responsive user interfaces.

CPP: C++ provides a wide range of libraries and frameworks that can be used to extend the functionality of an Arduino project. For example, developers can use the Arduino standard library to work with sensors, displays, and other peripherals, or they can use third-party libraries to add support for specific components or protocols.

Dart Programming Language: Dart is a general-purpose programming language developed by Google. It is primarily used for developing web, mobile, and desktop applications. Dart is an object-oriented language with a syntax that is similar to Java, C#, and JavaScript.

3.7 Outline to next chapter

The project's existing workflow yields appropriate and precise results. The project flow provides a detailed understanding of how the hardware and software components deployed throughout the project will be integrated. It is necessary to practically apply the theoretical knowledge discovered through the literature review. The practical application of our project flow is clearly explained in the following chapter. Through the experiments, we could examine our project's hardware components. Numerous trials have been carried out, and numerous problems that arose during the experimentation and implementation have been successfully resolved

Chapter 4
Implementation and Experimentation

This chapter provides a brief of our experimentation and tryouts with the options of components / constituents of our system. The results and observations that we obtain are crucial for selecting components in our final system design.

4.1 Hardware Implementation:

- Multiple trails were conducted to produce the most accurate results. Throughout the numerous trails, several things have been discarded and modified keeping in mind the practical limitations.

Procedure Followed:

- The first and foremost step is the manufacturing of the hardware system.
- All the hardware components are soldered via the Zero PCB with help of Female header pins.
- The CS and SD0 pins are soldered to VCC and ground, respectively, because we will be receiving sensor values in 2-wire mode via the sensor's I2C protocol.
- Since there are no internal pull-up/pull-down registers, the CS and SD0 pins are left floating. As a result, they must be soldered to their appropriate pins.
- According to the connections VCC is soldered to the 3v of NodeMCU and GND of ADXL345 is soldered to the GND of NodeMCU.
- Now SCL and SDA pins on ADXL are soldered to D1 and D2 on NodeMCU respectively.

Hardware Installation:

Fig (4.1) Hardware Setup

From the picture above, the sensor is interfaced with the Node-MCU
with the help of jumper wires. The battery provides power to the Node-MCU.

Fig (4.2) ADXL345 position on shock absorber

The shock absorber is the primary interface of the vehicle with the distresses of the road surface faced by the wheel axle. In order to mitigate the impulsive response of the vehicle to the distresses, the shock absorber is designed to not propagate or induce any motion in the vehicle caused by distress. Hence the accelerometer is placed on the shock absorber so that it records the reaction of the vehicle to road distress. ADXL345 is oriented w.r.t to the Z-axis.

4.2 Processing and Experimentation:

- After the successful assembly of hardware, collection storing and processing of data becomes the priority.
- The Kalman estimation algorithm is used by the NodeMCU to understand whether the surface of the road is pothole-ridden or smooth.
- If the real-time value of acceleration (in Z-direction; as per the orientation of the accelerometer mounted on the vehicle) differs beyond the acceptable limit around the estimated value, then it is inferred as pothole-ridden road, else it is inferred as
- The measurement error, estimation error and estimated value are arbitrarily initialized.
- The value of the estimated value and initialized errors influences the time taken by the prediction algorithm to narrow down to a threshold value.
- This threshold value is the one with whom the actual (real-time) value is compared for making the required classification.
- These influential values are incorporated in the parameter of Kalman Gain. The value of the gain determines the rate at which the error in estimated value decreases, and hence the estimated value narrows down to a certain average value.

Kalman Equations:

The equations of Kalman prediction algorithm at n^{th} iteration are as follows,

STEP 1 > $(\,Kalman\ Gain\,)_n =$

$$\frac{[\,(\,Error\ in\ Estimated\ Value\,)_{n-1}\,]}{[\,(\,Error\ in\ Estimated\ Value\,)_{n-1}\,] + [\,(\,Error\ in\ Measured\ Value\,)_{n-1}\,]}$$

STEP 2 > $(\,Estimated\ Value\,)_n = (\,Estimated\ Value\,)_{n-1} +$

$$[\,(\,Kalman\ Gain\,)_n\,] * [\,(\,Measured\ Value\,)_n - (\,Estimated\ Value\,)_{n-1}\,]$$

STEP 3 > $(\,Error\ in\ Estimated\ Value\,)_n =$

$$[1 - (\,Kalman\ Gain\,)_n\,] * (\,Error\ in\ Estimated\ Value\,)_{n-1}$$

STEP 4 > $(\,DELTA\,)_n = (\,Measured\ Value\,)_n - (\,Estimated\ Value\,)_n$

B	C	D	E	F	G	H
Iteration	Measured_value	Measurement_error	Estimated_value	Estimate_error	Kalman_Gain	Delta_Z
1	5.1	500	500	500	0.5	-494.9
2	8.35	500	252.55	250	0.333333333	-244.2
3	10.5	500	171.15	166.6666667	0.25	-160.65
4	12.25	500	130.9875	125	0.2	-118.74
5	13.75	500	107.24	100	0.166666667	-93.49
6	12.75	500	91.65833333	83.33333333	0.142857143	-78.908
7	9.75	500	80.38571429	71.42857143	0.125	-70.636
8	7.125	500	71.55625	62.5	0.111111111	-64.431
9	6.625	500	64.39722222	55.55555556	0.1	-57.772
10	9.875	500	58.62	50	0.090909091	-48.745
11	12.625	500	54.18863636	45.45454545	0.083333333	-41.564
12	13.5	500	50.725	41.66666667	0.076923077	-37.225
13	10.75	500	47.86153846	38.46153846	0.071428571	-37.112
14	5.25	500	45.21071429	35.71428571	0.066666667	-39.961
15	2.95	500	42.54666667	33.33333333	0.0625	-39.597
16	1.875	500	40.071875	31.25	0.058823529	-38.197
17	1.775	500	37.825	29.41176471	0.055555556	-36.05
18	2.15	500	35.82222222	27.77777778	0.052631579	-33.672
19	2.05	500	34.05	26.31578947	0.05	-32
20	1.95	500	32.45	25	0.047619048	-30.5
21	1.85	500	30.99761905	23.80952381	0.045454545	-29.148
22	1.475	500	29.67272727	22.72727273	0.043478261	-28.198
23	1.375	500	28.44673913	21.73913043	0.041666667	-27.072
24	1.275	500	27.31875	20.83333333	0.04	-26.044
25	1.175	500	26.277	20	0.038461538	-25.102
26	1.35	500	25.31153846	19.23076923	0.037037037	-23.962
27	1.25	500	24.42407407	18.51851852	0.035714286	-23.174
28	1.15	500	23.59642857	17.85714286	0.034482759	-22.446

Table (4.1) Excel Data Analysis

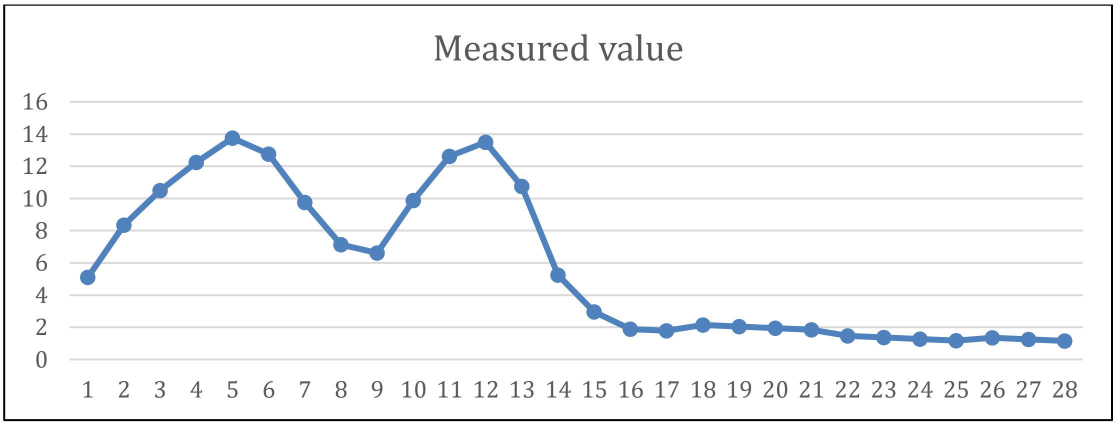


Fig (4.3) Measured value of Accelerometer z-axis

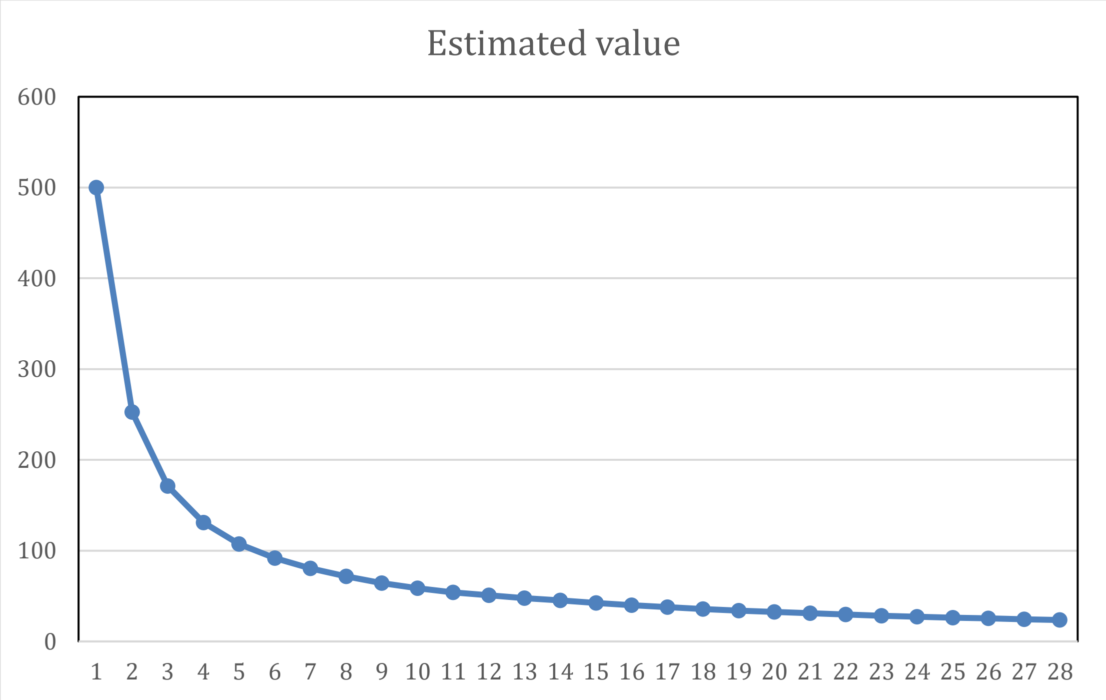


Fig (4.4) Graph of Estimated value of Accelerometer z-axis

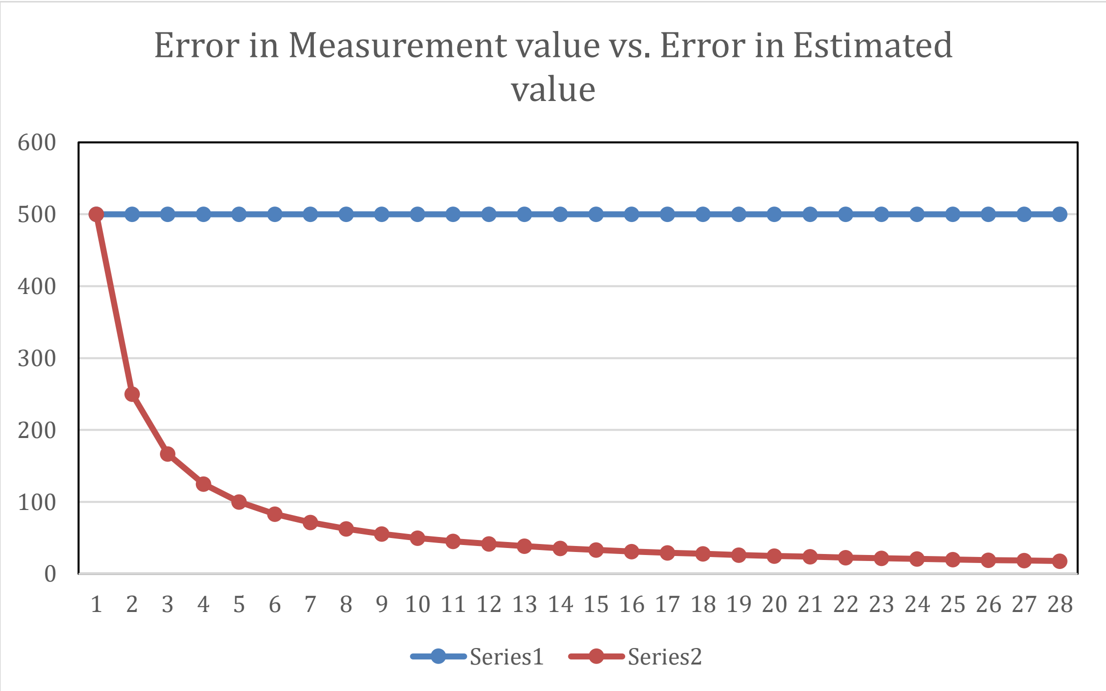


Fig (4.5) Graph of Measured value vs Error in Estimated value

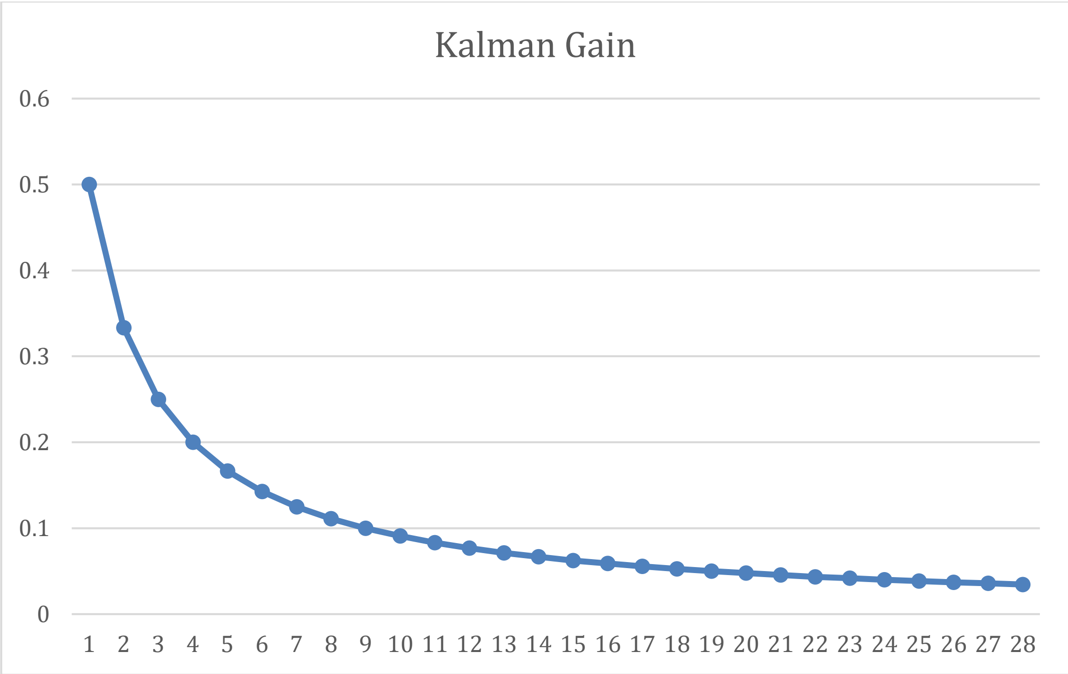


Fig (4.6) Graph of Kalman Gain

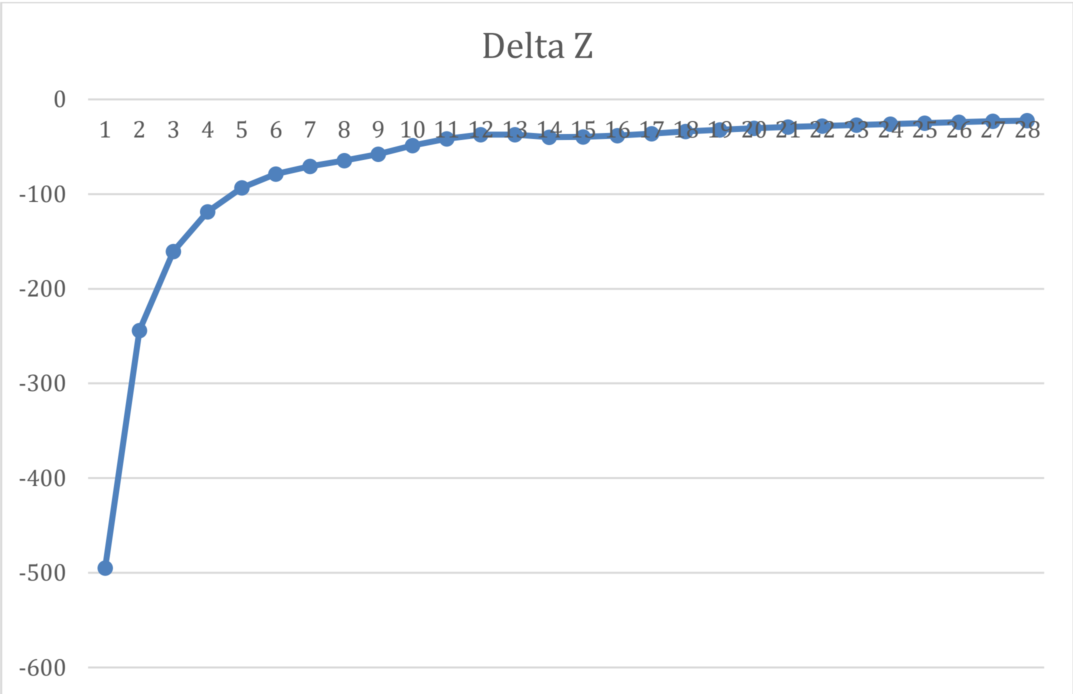


Fig (4.7) Graph of Delta Z

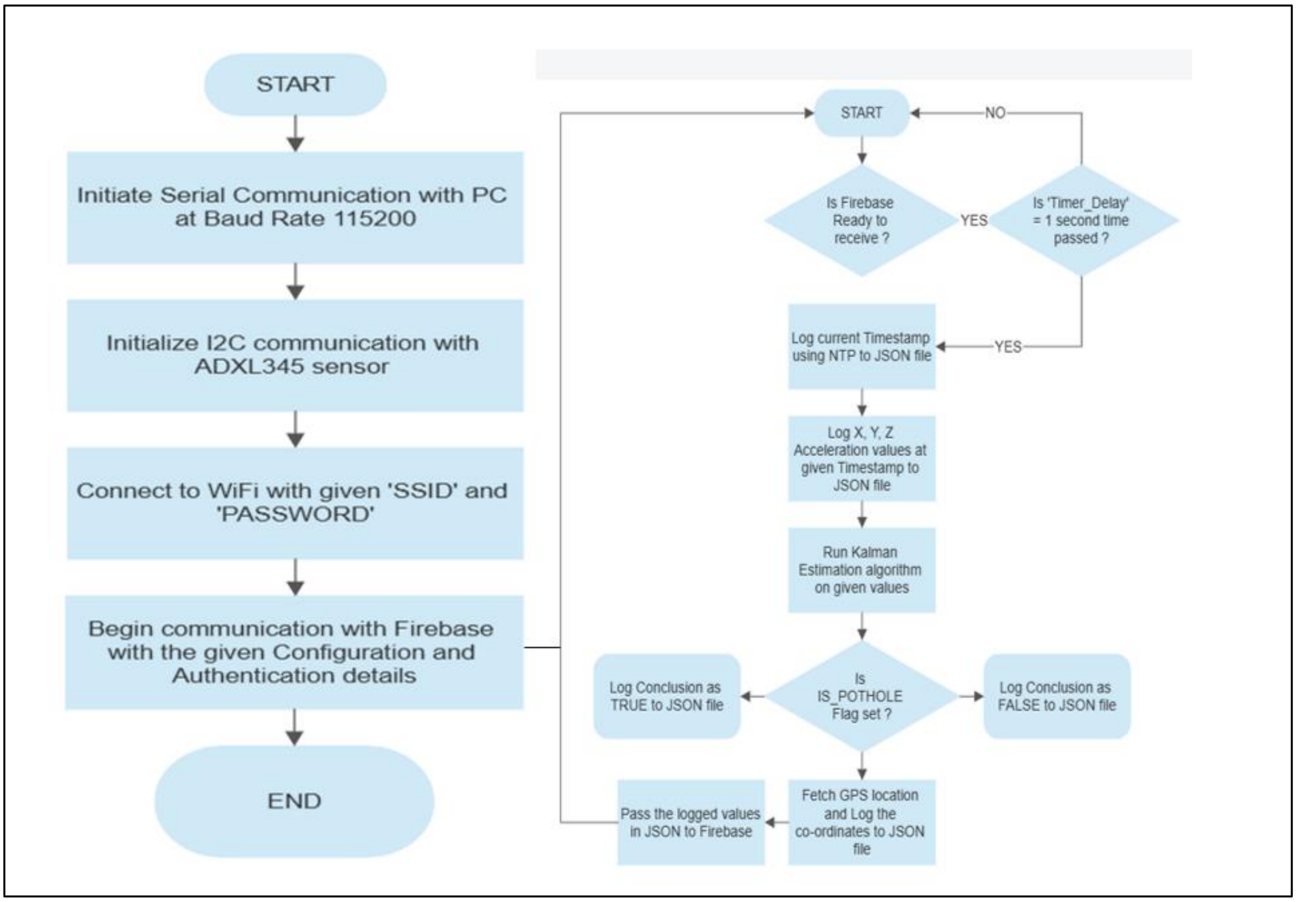


Fig (4.8) Processing Flowchart

4.3 Retrieval of GPS Coordinates:

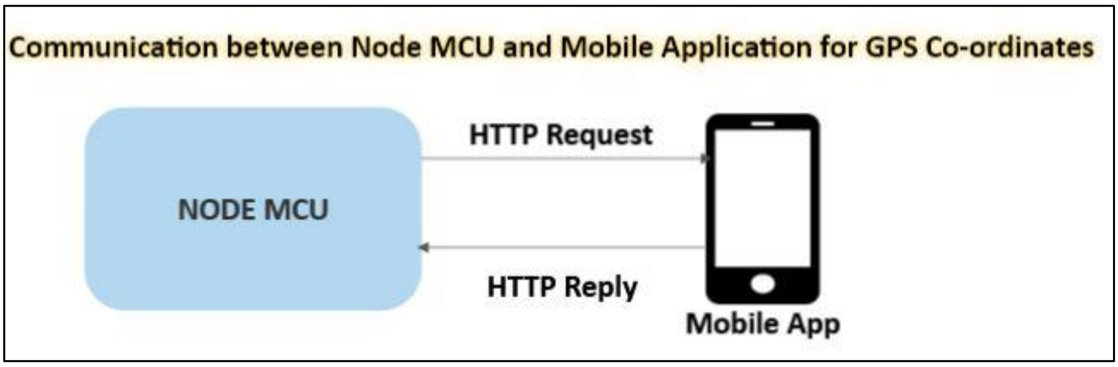


Fig (4.9) Interaction between Node-MCU and GPS locator Application.

The GPS coordinates are obtained with the coordination between the hardware and software. Once the processing part is accomplished the NodeMCU sends a request to the mobile application and the mobile applications replies with the latest GPS Coordinates.

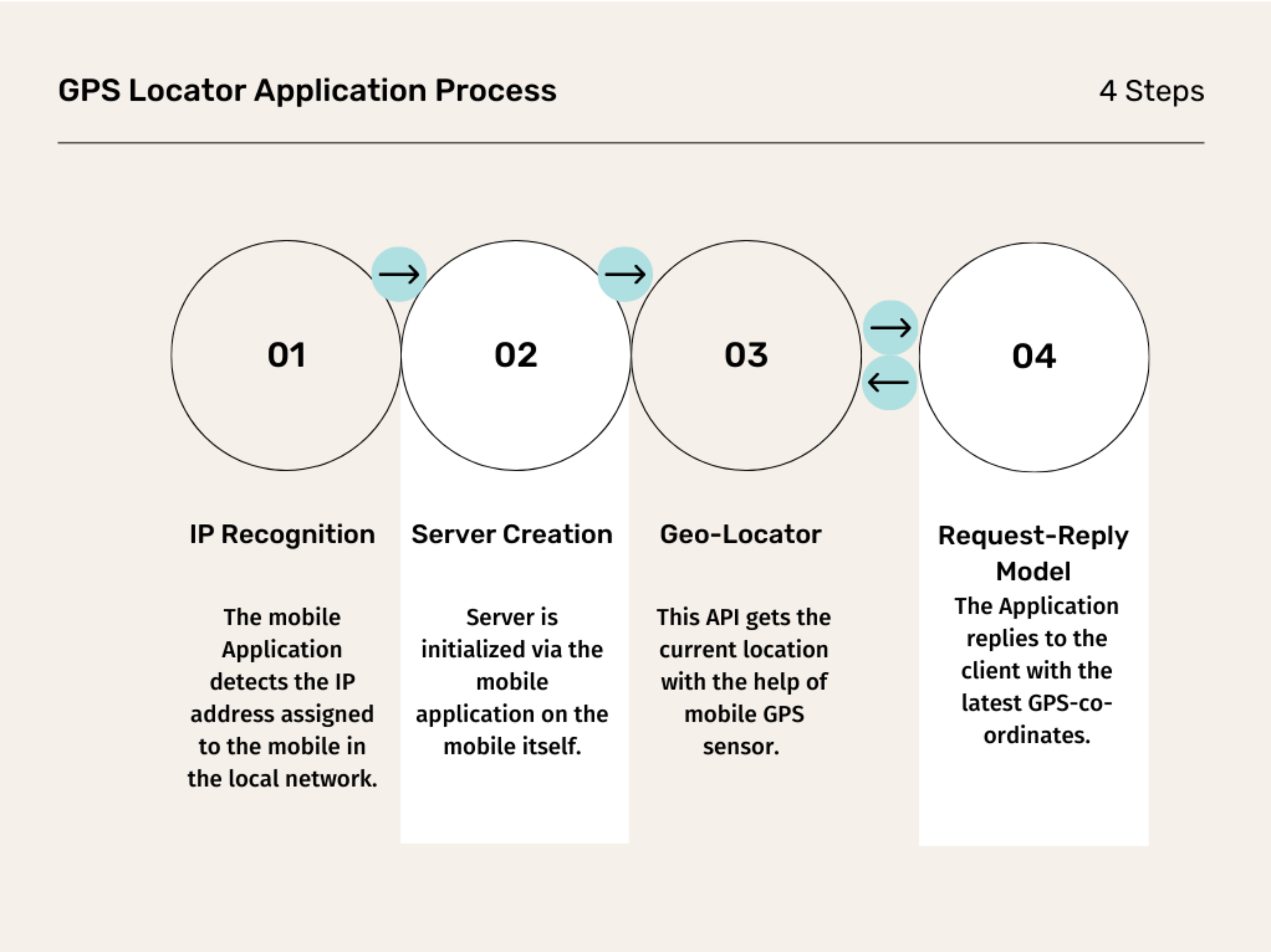
4.4 Software Implementation:

Multiple software applications were developed to aid in visualization and GPS retrieval purposes.

Procedure Followed:

GPS Locator Application

A flutter based mobile application that acts as a server which replies to the clients with last known GPS location fetched from the mobile GPS sensor.



Fig(4.10)Flowchart of GPS location Getter App

Utilization of multiple plugins and API's have been done for this application to work.

geolocator: A Flutter geolocation plugin which provides easy access to platform specific location services such as get the last known location, get the current location of the device;

mini_server: This package was developed to create a server while your flutter application is running. And following are the features: GET, POST, PUT, DELETE.

User Interface:

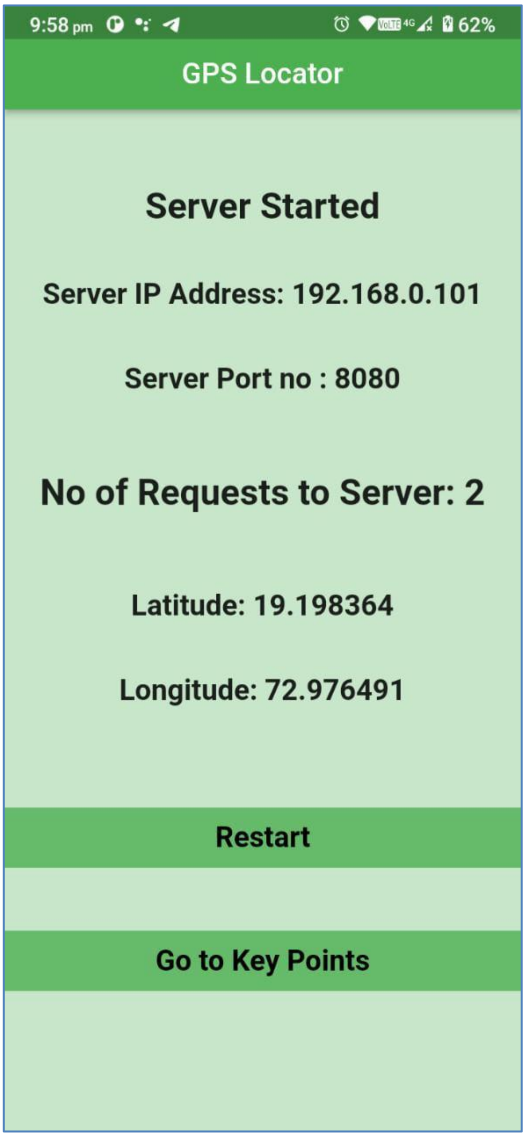


Fig (4.11) Graphical user interface using Android App for GPS locator

Parameters visible on the app:

Server IP Address: Shows the private IPv4 address of the mobile phone which is acting as the server.

Server Port No: 8080 which is the default for Hyper Text Transfer Protocol.

No of Requests to Server: shows the no of times the server is receiving requests from the client.

Latitude and Longitude: The latest GPS co-ordinates that the server has replied to the client.

Firebase Realtime Database:

Fig (4.12) Snapshot of Database

Attributes:

***Kalman_Conclusion*:** It is a Boolean parameter, i.e., if “True” then an irregularity exists and if “False” then no irregularity exists.

***X_accel*:** Acceleration in X axis.

***Y_accel*:** Acceleration in Y axis.

***Z_accel*:** Acceleration in Z axis.

***loc_latlong*:** It contains the GPS coordinates in the order of Latitude, Longitude.

timestamp: Unix timestamp.

Main User Application(K^2PR):

A Flutter based mobile application where the user can access the road surface quality with the help of map.

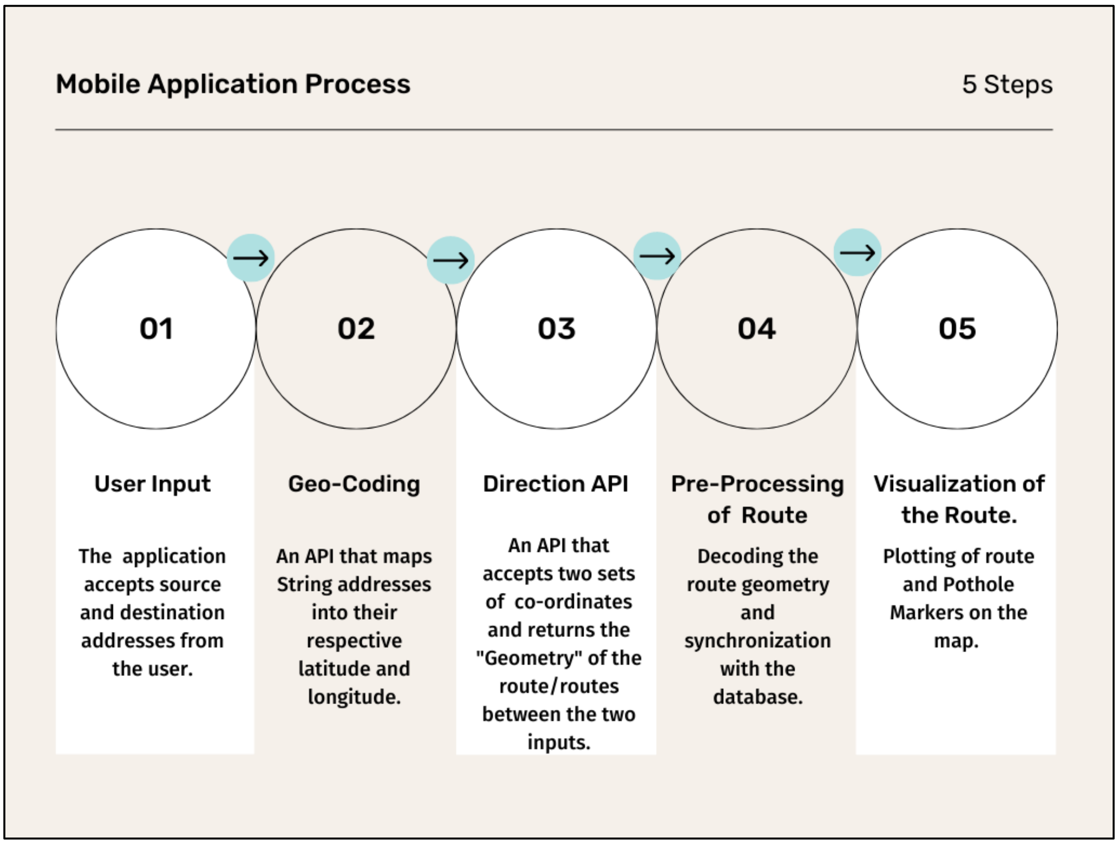


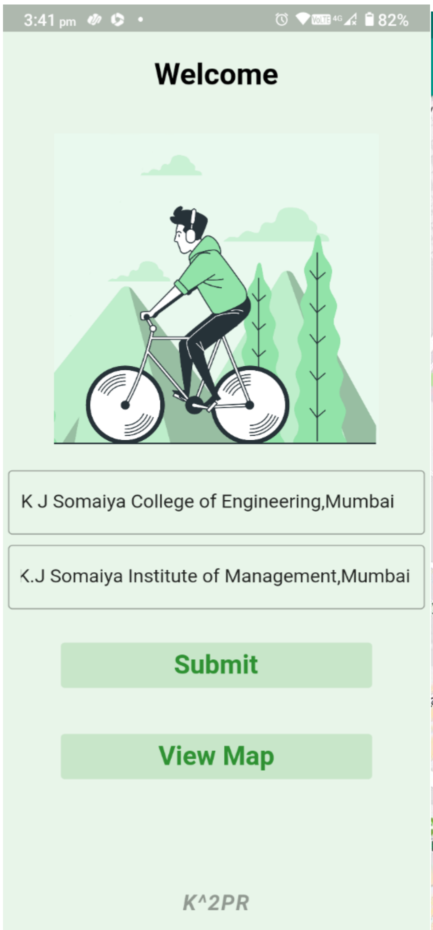
Fig (4.13) Flowchart of Main Application

Utilization of multiple plugins and API's have been done to visualize the map in accordance to the user input.

- **Flutter Geocoding Plugin**: Translate's an address into latitude and longitude coordinates.
- **mapmyindia_gl** : This Flutter plugin allows to show embedded interactive MapmyIndia maps inside a Flutter widget.
- **firebase_core**: A Flutter plugin to use the Firebase Core API, which enables connecting to multiple Firebase apps.
- **polyline_do**: Polyline encoding is a lossy compression algorithm that allows you to store a series of coordinates as a single string.

- **http:** This package contains a set of high-level functions and classes that make it easy to consume HTTP resources.
- **firebase_database:** A Flutter plugin to use the Firebase Database API.
- **latlong2:** LatLong provides a lightweight library for common latitude and longitude calculation.
- **Routing API for Passenger Vehicles**: This REST API calculates driving routes between specified locations including via points based on route calculation type (optimal or shortest).

User Interface:



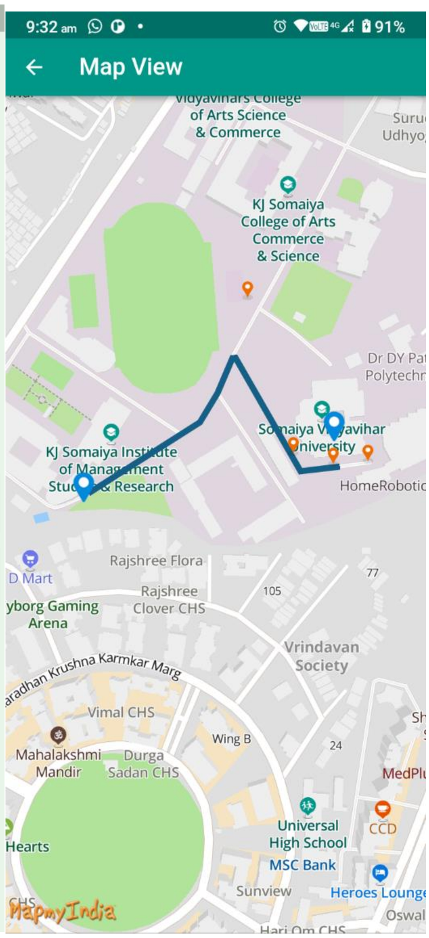


Fig (4.14) and (4.15) User Interface of Main Application

The user must follow the following steps when they open the app:

1.Address of Source

2.Address of Destination

3. Select "Submit"

4. Select "View Map"

With the aid of makers, a route on the map would be displayed with irregularities present between the two inputted addresses.

Chapter 5

Conclusions & Further Work

This chapter concludes the project and also gives us perspective regarding the scope for future work on the project.

5.1 Conclusion

The main goal of the project is to collect data related to road surface quality using location-aware accelerometers situated on vehicles, analyze the collected data and present it to the user in the form of an application.

The existence of the problem is the lack of objective and formal methods for knowing the road surface quality. So, there is a general necessity of such data / platform / reference that is usually ignored or taken for granted. Thus, the problem that is being tackled through this project has a practical effect in the daily life of people and businesses.

Many methods, projects and approaches were taken into consideration to solve the problem in the Literature Survey. It was understood that even though this approach using accelerometers is not the first initiative, it looks interesting enough to try and apply the multi-disciplinary knowledge that was gained during our B. Tech course, and promising enough to develop one such full-fledged solution.

5.2 Future Scope

- For processing the acceleration data, use FFT algorithm to evaluate the frequency of change of acceleration values.

- When possible, with FFT, can use DCT for better performance and energy compaction within the represented sinusoids (in frequency spectrum). Implementing DCT will also achieve compressive sensing methods in this project.

- Better arrangement of hardware components in dedicated PCB for robustness and compactness of application.

- Deployment on 4-wheeler vehicles and 2-wheeler vehicles in large numbers for aggregating as much data as possible.

- Evaluating multiple routes, between given location and destination, queried by the user, based on their quality, which is calculated using the length of the rough patches on them

5.3 Summary

We conclude this report in this chapter by summarizing our final stance that we put forth through our chapters. The introduction to problem statement in Chapter 1, justifying our approach through the literature / resources that we have referred in Chapter 2, the formulation of the design constraints for the project along with the detailed description of our path in Chapter 3, the project design and experiments we conducted to practically implement the project in Chapter 4.

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