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**Boston University**

**Electrical & Computer Engineering**

**EC463 Capstone Senior Design Project**

**Problem Definition and Requirements Review**

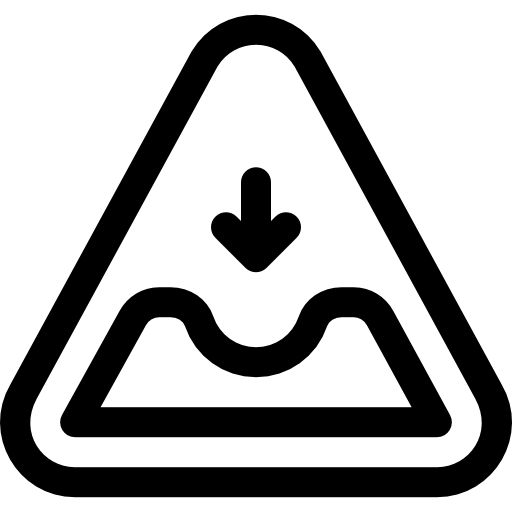
Road Roughness Mapping

Submitted to

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Submitted: October 14, 2022

**Customer Sign-Off \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

#### Road Roughness Mapping

#### Table of Contents

Project Summary 2

1 Need for this Project 3

2 Problem Statement and Deliverables 4

3 Visualization 5

4 Competing Technologies 6

5 Engineering Requirements 7

6 Appendix A - References 9

# Project Summary

Many roads in Boston are littered with potholes, remnants of poor repair work and generally rough surfaces. As a result, vehicle drivers are burdened with huge damage costs and the suspension/bumper of vehicles face significant damages. Vehicle drivers and pedestrians are injured and fatal accidents occur in some cases as well.

This calls for a smart system which can assess road roughness and display the locations of potholes on a clean user interface. The sensors in the smartphone (accelerometer, gyroscope) along with some external sensors (Lidar) collect pothole/location data and the aggregated data is uploaded to the cloud. Multiple machine learning models are trained on the collected data to predict the grade of roughness. The pothole information is displayed on our application integrated with Google Maps. Our system comprises an application, external sensors and a cloud service which work together to give the user a safe driving experience.

# Need for this Project

The city of Boston uses a reporting system for the location of potholes. With such a device, the citizen could theoretically bypass the report, and cities will automatically receive updated pothole location data while devices are in use. Both cities and consumers benefit from our device. Cities can more efficiently locate and repair potholes, and consumers will save money by having a smaller chance of having to repair vehicle damages caused by potholes.

The use of automobiles in society is something that makes transportation efficient and easy. It’s hard to imagine what the world would look like without it. Our cities are built around roads, and interstate highway systems interconnect the country on a massive scale. Automobile travel is such a necessity that 91.55% of households in the US have access to at least one vehicle. One of the biggest problems when it comes to automobile travel is road infrastructure. Especially in geographic locations with rapidly changing weather, potholes, cracks, divots, and otherwise roughness in roads are something drivers seemingly cannot avoid. These road conditions are detrimental to cars, with damages ranging from popped tires to a destroyed suspension system.

Damages from rough roads cause drivers in the US $3 billion annually. On top of that, the average repair bill associated with these damages is around $300, with one in three repairs costing up to $1000. It is clear that this problem is widespread and costly. The systems in place to prevent and repair road damages are insufficient. The city of Boston, in the heart of the bipolar-weather of New England, has some of the worst road conditions in the country. Even so, the systems in place for the prevention of rough roads are widely insufficient.

Boston uses a reporting system for locating unsatisfactory road conditions, which means that citizens need to make note of observed roughness, and manually input it on the internet. With the bustle of everyday life, this is inconvenient enough for most people to either forget or just simply not do at all. Other systems in place include an organized visual inspection of city roads once every *three* years.

This is simply not sufficient. Potholes are caused when moisture seeps under the road, freezes (causing expansion), and thaws, leaving a cavity underneath the pavement. It is therefore a seasonal occurrence, most likely to happen in the transition from winter to spring. This means that three cycles worth of potholes accrue in between the city’s visual inspections. The systems in place for rough road prevention are insufficient.

# Problem Statement and Deliverables

Given the poor road infrastructure and minimal upkeep done by the city, our team aims to develop a solution which will better map road roughness. We hope that our project will help Boston, and subsequently other cities, be able to better monitor the city’s road conditions, as well as provide everyday commuters a method to avoid areas with increased road roughness.

To do so, we plan to incorporate a user’s smartphone as the primary device, with additional sensors as support if necessary. The smartphone will run a mobile application, as well as collect acceleration data with the phone’s built-in accelerometer, image data with the phone’s camera, and finally GPS data with Google Maps which is incorporated with the smartphone. Users will then be able to upload their data to our cloud storage, and to ensure user safety, the data will be anonymized, aggregated, and the ability to limit data collection to the user’s own perimeter will also be implemented. If the accelerometer and camera of the smartphone are not sufficient in determining potholes, we plan on designing a rechargeable external sensor that can be easily attached and removed from the user’s car’s bumper.

Once the sensors and other components are completed, we plan to give faculty members at Boston University our device, and have them collect data with their own vehicles. The data collected by them will then be stored and analyzed by our algorithm. The algorithm aims to first determine if there actually is a pothole at a given location, and if so what the severity of the pothole is. It also will have the ability to factor in the make and model of the user’s vehicle, thereby ensuring that the height and suspension of various vehicle’s has no effect on the algorithm’s calculation of the location and severity of a pothole.

Once the algorithm has analyzed the given data, it will then update the mobile application, allowing users to visualize the data in which they helped to collect. As more and more data is collected, the goal is for our pothole data to function as a way for government officials to better understand both where potholes are and which ones are most harmful to commuters and should be given priority in repairs, as well as an additional layer onto GPS route calculations, thus enabling users to be provided with a route that not only takes the least amount of time, but also that avoids any harmful conditions which could cause potential damage to their vehicle.

# Visualization



*Figure 1.1 The mobile application contains the user interface. It will be using the onboard smartphone sensors in order to gather data as the user is driving. For privacy concerns, we will implement features that will allow the user to opt out sharing unwanted information. As of now, the external sensor might be useful in the case of insufficient or inaccurate smartphone sensors. Finally, a cloud service will be used to upload gathered data from the client side.*

# Competing Technologies

The condition of roads is an important factor in improving safety for passengers and reducing monetary damages/fatal accidents. Many people have developed systems to assess road roughness and mitigate the risks of accidents. Their goal is to create a product that will ensure a smooth and safe experience for vehicle drivers. We could not find a company aimed specifically at detecting potholes and analyzing road surface roughness. But, we came across multiple products that solved our problem and used a similar approach.

It is relevant to include some projects made by students. The pothole detector app created by Aniruddha Mysore detects potholes using the phone’s accelerometer/gyroscope, locates potholes on a map and uploads data to a cloud service. Similarly, students at George Mason University created a pothole detection system using ML and computer vision that detects potholes using a camera. They used the SSD algorithm to train a machine learning model. They did not collect data; rather they took pothole images from the internet and used an annotation tool to label the images for supervised machine learning.

A smart pothole detection and mapping system was developed by professor Rohan Borgalli at Shah and Anchor Kutchhi Engineering College. Ultrasonic sensors and a GPS module were used to collect pothole data. Pi-camera was used to collect pothole images. The data is processed by a deep learning framework to obtain the diameter or severity of the pothole. The severity and location of the potholes are then visualized on the Google Maps API of the application. The deep learning model was trained using 150 images with 568 pothole labels.

We also found a patent for pothole detection. This patent consists of a system which has a data collection unit and a pothole detector unit. The input interface receives sensor data (data from accelerometer, gyroscope, camera, engine, etc.). The pothole detector determines if the data corresponds to an actual pothole and stores the relevant information. A local processor determines if a set of data corresponds to a potential pothole. Then, the potential pothole data is sent to a server to determine the likelihood of the potential pothole being an actual pothole. The patent includes a pothole map to visualize pothole locations.

Even though a number of similar products exist, we strongly believe that our product has the edge. We are using some external sensors to complement and validate the data acquired through the smart phone’s in-built sensors. Privacy concerns must be addressed and our product asks for permission before collecting data. The user is in control of the data collection process. Moreover, the user can also input the region within which data collection must take place. The data is uploaded to the cloud and hence, we do not have to worry about storing information on a physical drive.

# Engineering Requirements

In terms of requirements, our final project should meet three major objectives: data collection, data analysis and data presentation. Considering the nature of this project, the objectives will be fulfilled on different platforms. In the matter of data collection, we are considering two different approaches. The first approach is a self-contained device. This device will have to satisfy the following five functional requirements: record the road roughness data, record the location data, process the recorded data, store the processed data, and finally transmit the stored data.

For road roughness, we decided to use sensors like accelerometer or gyroscope. With the combined inputs from both sensors, we will be able to distinguish between the “nice” roads and “inferior” roads. For location, the ideal choice would be to use a GPS chip which gives the highest fidelity data. However, there are privacy concerns associated with using a high-definition GPS, so alternatively, a Wi-Fi chip could also be used to produce a rougher locational datapoint. To process the recorded data, we could use a microcontroller, e.g. Arduino, Raspberry Pi, ESP-IDF, etc. On top of processing the data, the controller would also help coordinate the operation of the whole device. To store the processed data, the best functioning and low-costing option is a micro-SD card. Finally, to transmit the data, we could either use Wi-Fi to transmit the data directly to the cloud or use Bluetooth to transmit the data to the user’s smartphone first, and then pass it on using Wi-Fi or cellular.

The second approach regarding data collection is using smartphones. While a standalone data collection device is surely plausible, we don’t have to limit ourselves to the conventional solution. During the past two decades, the computing power and utility of smartphones have skyrocketed. Smartphones provide a clean interface to implement all of the functions listed above as modern smartphones have high-precision sensors. By using the user’s smartphones, we shift the center of the data collection process to mobile applications rather than microcontrollers. The main issue with this approach is again privacy and the users’ consent as it’s easier to convince people to use a standalone device than their own smartphones. However, we will not be giving up this approach just yet. A questionnaire will be sent out to our potential customers and their preference will decide our next step.

For the objective of data analysis, the data recorded on the collection device will be transported onto a computer and processed with machine learning algorithms and human supervision. The key challenge to conquer in this aspect is to make sense of the data coming from different cars. The difference in the make and model of these cars mean that with all other variables controlled, i.e. driving on the same roads with the same collection device, a deviation in the resultant data points is to be expected. To overcome this hurdle, we can use the trend of the data to define flexible thresholds which can lead to a consensus among different users.

Lastly, for data presentation, we will be aiming the final product towards two groups of people. First, our final analyzed data will be directed to drivers not unlike our test users in the form of a mobile app. For the ease of use, we may choose to overlay the roughness data on an existing map carrier’s platform. The outcome will look similar to when drivers turn on the real-time traffic layer. This will provide a better driving experience to the users of our app. Second, the final data can be presented in a visualized way to the city officials. With this data, the state of Boston’s roads will be displaced in a straightforward manner, helping the officials decide where to dedicate their attention first.

On top of the functions and objectives that we will try to fulfill with this project, there are also constraints that we need to consider during the design process. First of all, the device needs to be self-contained. This means that the set-up for the users should be minimal and intuitive. To meet this requirement, the device must be self-sustaining, i.e. it must contain a battery instead of requiring external connections. Moreover, as mentioned earlier, for a project that requires a huge amount of data, privacy should be on the top of the list of things we need to evaluate. The data collection process must be anonymized to achieve differential privacy, and full control of the device must be given to the user, i.e. when and where to start and end data collection. When choosing our test users, we will disclose the full functionality of our device and gain their consent before collecting any data.

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