Detecting Road Conditions with a Phone's Accelerometer

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Abstract

This project is designed to assess the feasibility of an application that uses real time data from smart phone accelerometers to generate a map of road conditions. The implementation of this service will provide users with valuable information about the conditions of roadways that will limit potential damage to the user's vehicle. This information can also be used to provide a valuable service to others such as bike riders. This service will differentiate itself from other existing services by providing a safe and simple interaction for the user. The most important factor to preserve user safety is to ensure that the user does not have to interact with their phone during the process.

Introduction

In 2012 an estimated 3 trillion miles were driven on the United States' 4 million miles of roads (Figure 1). With such a massive amount of stress put on such a vast road system it is no wonder why we encounter bumps, potholes and cracks on our daily commute. As we face this potentially hazardous issue every day, federal, state and local governments are faced with the daunting task of keeping the infrastructure safe and up-to-date. Maryland for example has 31,469 miles of public roads and 55% of those roads are in poor or mediocre conditions. What does this mean for drivers? In Maryland motorists spend on average $422 per year vehicle repairs due to bad roads (American Society of Civil Engineers, 2011). This leaves much room for improvement.

Our proposed solution is to develop an Android application which will ultimately work like the traffic overlay in Google Maps (Figure 2). For example, green would indicate good road conditions and red would indicate a road section in need of repair. We aim to create a simple user interface and provide seamless integration with a "cloud" that will collect data from every phone's accelerometer. This data will be shared between all users to provide the most complete information at all times while also limiting battery usage as much as possible. Another priority is safety - the user should not have to press any buttons while driving and we would like to see voice recognition of simple commands and voice responses as well. All of these things combined will be very useful and user friendly; however, our most difficult task will be something that the user will not even notice.

What we have learned from some of the competing applications is that the hardest part is developing an algorithm which will be able to differentiate between potholes and speed bumps, or a stiff suspension from a soft one (Street Bump 2012, Mednis, A. et al., 2009). Since we cannot assume anything about the driver's car or even their driving style. One person may drive slow over a bump, the next person may be fast and although those would give completely different readings we must be able to tell they both drove over the a bump. Based on results of previously done research we believe using our own implementation of the “Z-Diff” pothole detection algorithm as mentioned in “Real Time Pothole Detection using Android Smartphones with Accelerometers” to be our best solution as the researchers found this algorithm to be 92% effective in their tests (Mednis, A. et al., 2009).

Background/Review of Past Work

Every day, millions of people travel on US roadways for work, errands, or just a leisurely drive. Rarely do we stop to think about the problems we may encounter on our travels, instead we are more focused on an issue at work or what we need to get at the grocery store instead of an annoying pothole. But just how “annoying” can the common pothole be? According to the Independent Insurance Agents of America (IIAA) an estimated 500,000 auto insurance claims are filed each year for a total of about $5 billion dollars in damage (Aaa Press Release, 2010). Due to this enormous cost to drivers there have been attempts to remedy the problem. Since our focus is on developing an application for mobile phones we focused on researching competing “pothole-tracking” apps. These apps are readily available on the Google Play Store, and the Apple App Store.

One such app, called “Street Bump,” tracks bumps and potholes using the phone’s accelerometer, much like our app. However, this particular app struggles with speed bumps and manhole covers, and additionally (and most importantly) does not share aggregated recorded statistics with the users. Instead, the app sends the data to the local government’s road maintenance workers. These organizations will then use this information to fix problematic road conditions after “three or more bumps occur at the same location” (streetbump.org, 2012). This app is currently available on the Apple App store for free. However, this was the only app we found that used accelerometers to automatically record potholes in an area. Most apps, on the other hand required users to actually physically record poor road conditions that they experienced. One of these, “Potholes Hunter” is a pothole tracker (available on the Google Play store for free) intended to be used in Hungary. Users take photos and rank the “worst potholes in the country” (Potholes Hunter, 2013). The app also places these potholes on an overlay of a map, making the app function much like ours will.

Another app like this, “FillThatHole” focuses on bicyclists for its target user base (http://www.fillthathole.org.uk/iphone). Again, users must photograph and fill out forms about certain potholes on their own. However, much like “Potholes Hunter” usability of this app relies on its users taking time to actually record the potholes in their area. In Mumbai, a similar project failed miserably when users did not want to take the time to fill out pothole reports when they encountered one. In fact, only 340 people bothered “to download it and upload pictures of bad roads” (App for Mumbai’s potholes fails to deliver). This points out the most critical aspect of our project: making an app that will be user friendly, and simple. This will ensure that users actually *use* the app.

Several other web-based tools provide limited functionality to monitor road conditions. The website Here.com, a service implemented using the Google Maps API, provides a color coded map of what the traffic conditions are a road are like. It also provides basic indication of road hazards such as disabled vehicles and road work. However, it only has fours sets of icons that it uses to distinguish these conditions and they do not appear to be assigned with any consistency. In order to find out any further details you must put a mouse cursor over the icons. This is extremely distracting and unsafe for a travelers to use while they are driving. In addition, this service is based upon users uploading information about what they see and is therefore dependent upon direct user interaction. Another tool to track traffic and road conditions is the website of the Federal Highway Association. This tool does not house any information of its own. Instead, it provides references to the tools run by individual states. The most significant disadvantage of this is that there is no tool for someone who is travelling across state lines because the tools are run by individual states. This mean that a user traveling from Maryland to Virginia will have to first use the tool run by Maryland, return to the Federal Highway Association website and then go to a tool run by Virginia.

The city of Seattle is currently offering the “Find It, Fix It” app (http://www.seattle.gov/customer-service-bureau/find-it-fix-it-mobile-app, 2013) for city residents to report potholes, along with other items such as graffiti and abandoned vehicles. This is a promising idea and could be more widely used by other municipalities in the future. However, the app is not helpful to end user in planning routes. The reports go directly to the city, and then they are processed by the appropriate departments. There is no way for residents to see potholes others have submitted, so they know what areas to avoid.

In addition to several competing applications our research also provided us with an article titled “Real time pothole detection using android smartphones with accelerometers” which discusses and tests four possible algorithms used for pothole detection.The four algorithms discussed are Z-THRESH, Z-DIFF, STDEV(Z), G-ZERO (Figure 3A-D). For our application we will focus on developing our own implementation of Z-DIFF as it showed the most promising results by far with 92% accuracy. The other three scored much lower with around 75%-80% accuracy. The Z-DIFF algorithm detects quick changes in vertical acceleration data (Mednis, A. et al., 2009). And although we will use our own implementation of Z-DIFF for the project we want to go one step further and build on this algorithm by doing what the researchers suggested in the *Conclusion and Future Work* section of their article, develop a way for the algorithm to calibrate itself. This is extremely important if we want to develop an effective application for all users because we can not make assumptions about what phone and car the user have and even how they drive.

Target Users

There are a number of different types of users who might take advantage of the features of this application. The primary group we will be targeting for the initial application will be drivers. We chose to develop for this group since it will be the easiest to test.

Drivers

People looking for a road without potholes and road debris will use the application for finding a suitable travel path. This encompasses a number of different types of drivers with different motivations for finding a smooth road. First and foremost, drivers using a personal vehicle have an incentive to reduce potential damage to their vehicle. Repairing vehicle damage from bad road conditions could cost money out of pocket or raise insurance premiums.

Another group of drivers is those who are using a car owned by someone else, for example a taxi cab driver or a travelling salesman using a company car. In this case, vehicle damage would not only be costly, but time-consuming; having a vehicle be out of service could mean the person's livelihood is at risk.

Finally, another group of drivers that might use the application would be people driving expensive or exotic cars, for example bringing a rare car to a car show. Any damage to the car could be extremely expensive and time-consuming to repair, especially if the car is an antique.

Bicyclists

Finding a smooth road for an enjoyable bike ride can be difficult, especially after moving to a new area. A blown tire or damaged rim can be expensive to repair. Bicyclists can use the application for finding smooth roads in the area, and plan a trip or route using the application data. Alternatively, if the bicyclist feels like exploring, they can use the app to record where they've went and how the road conditions were. Next time, they will know which roads were good and which ones should be avoided.

Government officials

Governments on every level could use the application to monitor road conditions at a very fine level of detail, eliminating the need for costly road surveys and monitoring systems. The data collected would contain every single road in their municipality, since all drivers using the application would be collecting data everywhere. This is important since officials could compare the relative qualities of different roads. Most importantly, the data would be accurate and up-to-date. Armed with this data, officials can make informed decisions about where best to direct maintenance resources.

User Research

Observation

In order to see how different users handle roads with potholes, we observed several such road hazards and recorded how users interacted. This observation technique will allow us to analyze what techniques, if any, drivers have for dealing with potential road hazards.

This observation includes a total of 48 vehicles in a 30 minute period. This data sample also discounts any results where there were pedestrians walking in the street or vehicles coming from the other direction that may have affected the drivers behavior. The hazard observed represents a two inch depression around a steel plate (See Appendix B) . A driver is said to have gone “Into” the hazard if they remained in their lane as they traveled over it. A driver is said to have gone “around” the hazard if the vehicle’s front left tire entered the opposing lane.

Survey

In order to quantify the potential implications of our project we conducted a survey of the target users of the product, college students and those who own cars. This survey asked respondents several questions designed to assess the potential impact and reach of our product. We believe that this survey, in conjunction with our observation of how drivers interact with potential hazards, will provide us will valuable feedback about what drivers say they do and actually do when driving.

Our survey was conducted on 42 students who were asked to describe their behavior before, during and after their drive in regards to assessing road conditions. In order to ensure that this demographics of the survey matched the target audience for our product we asked our survey respondents to self identify if they owned a car as well as their gender, age and occupation. For a full set of respondents identification please see Appendix 3.

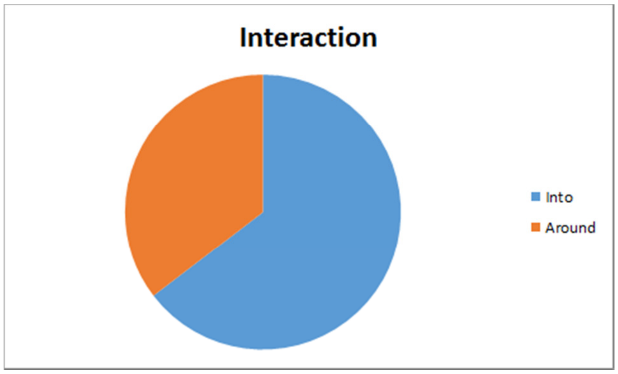
We conducted this survey by asking college students at the university via Facebook and Piazza to complete this survey. We then asked the respondents to self identify in order to ensure that their background was consistent with our target user.

The data we collected involved several questions to assess what a driver does before, during and after they drive. We asked drivers to quantify on a scale of 1 to 5 how often they check criteria such as weather, traffic and road conditions before they go for a drive where 1 represents 0% of the time and 5 represents 100%. We also asked respondents to identify the quality of roads that they drive on by asking questions about the number of potential road hazards they observed and the number of roads they see that are newly paved. The third major category of question we asked was how drivers handle potential road hazards such as potholes and poorly maintained rose. Finally we asked the participants to identify if their vehicle has ever been damaged by poorly maintained roads and how much it cost to repair.

Results

Observation of driver interaction with a potential hazard

During the course of this observation, we found that 17 out of 48 drivers choose to avoid the depression rather than go through it. These results tell us a significant number of users care about the safety of their vehicle. With this information it becomes apparent that there are drivers that value knowing where there are potential road hazards. The hazard that we observed was a relatively minor depression around a steel plate. If hazard where deeper, it is likely that more drivers would have tried to avoid it.



Road hazards exist and drivers try to avoid them. If we can successfully build an application that can notify a driver of such situations we can use this inform. It will be important to use this information to construct an interface that allows the driver to receive information in conjunction with when they are about to hit a hazard. If we notify the driver too early they may forget that they are approaching a hazard. In contrast, if we notify them too late they may hit the hazard instead.

Survey of Potential Users

Our findings about user behavior revealed several interesting figures. We found that on average drivers check the weather with a frequency of about 2.8 which would equal about 70% of the time. In contrast we found that driver check traffic with a frequency of about 2.4 or about 62% of the time. And finally users say they check road conditions with a frequency of 1.6 which would only represent about 40% of the time. This tells us that drivers assess road conditions much less frequently than they do weather conditions or traffic.

In addition we asked drivers to describe how often they avoid potholes on a scale of 1 to 5. The average came to be 4.095 which would equate to about 77% of the time. However this number is inconsistent with what we observed drivers doing. We observed only about 35% of drivers actively avoid potholes. This is a very surprising contrast between what drivers say they do and what they actually do. This suggests that drivers are unaware of the number of potholes that they hit despite the fact that they think that they actively try to avoid them.

From these results it becomes obvious that many people *say* that they tend to avoid poorly maintained roads outright. However, again, only 35% actively avoid potholes *right in front of them*. This means that we cannot fully trust that people actually think specifically about the conditions of the roads they will drive on in order to reach a destination. However, if we place the information on a map, and make it easy for users to observe the conditions of the roads they use at a glance, we can ensure that users will have the resources they need to avoid the nearly $2700 that the survey respondents reported as lost due to potholes.

Conclusion

After careful observation of both past products and current problems, it becomes clear that our product needs to differ itself from its competitors through two things: ease of use, and visibility. Despite there being several other apps that ostensibly do the same thing as ours, they are simply unwieldy. They put the onus on the user, and do not give incentive for the tedious, mundane task of cataloging potholes. One product, “Street Bump,” makes this simpler through the use of accelerometers and automatic detection, but the aggregated results of all data collected is not surfaced to the end user, making it useless for planning a route or avoiding severe damage. Therefore, we should move forward with automatic detection, but make certain that the results are at the fingertips of the user. Through our surveys, the desire for this functionality was made obvious. The people we surveyed mentioned checking road conditions and avoiding potholes, but in practice did no such thing. If, perhaps, this information was made more readily available (e.g. through our final product), they would be more likely to plan a route that will help them to avoid the serious damage that we both recorded and researched. The need for better driver-side tools is greater than ever due to ever increasing road usage. The power to avoid these terribly maintained roads needs to be put into the hands of the people using them every single day. We, as a group, must simply figure out *how* to do so.

With the need to provide easy to use software, and surface level information comes delicate design choice. We must be careful to research how we can make the app easy to use (for even the most inexperienced), yet instantly useful (for those who simply want the data). In the coming weeks, we will attempt to explore both the necessarily hidden (i.e. the accelerometer algorithm), and the inherently surfaced (i.e. the user interface).

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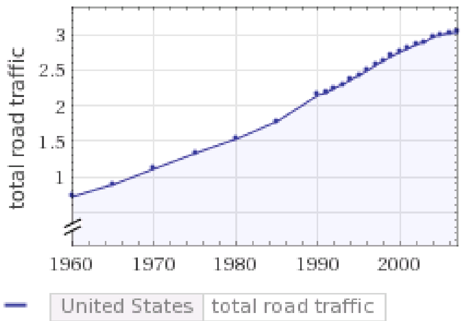
Appendix

A. Additional Figures

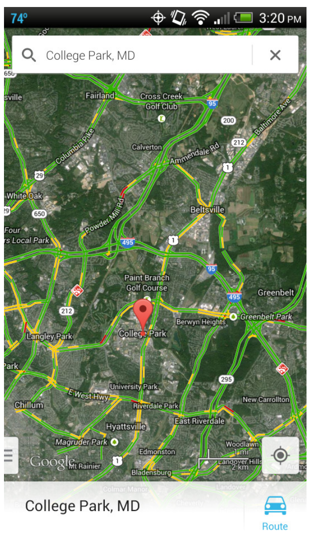
Figure 1 (from wolframalpha.com)



(from 1960 to 2007)

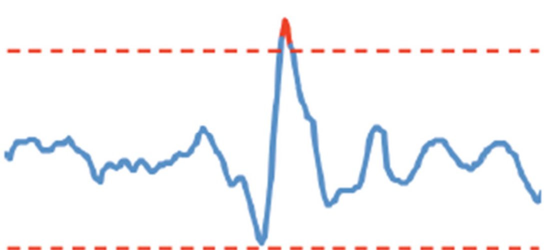
(in trillions of vehicle miles per year)

Figure 2 (from Google Maps application for Android Phones)



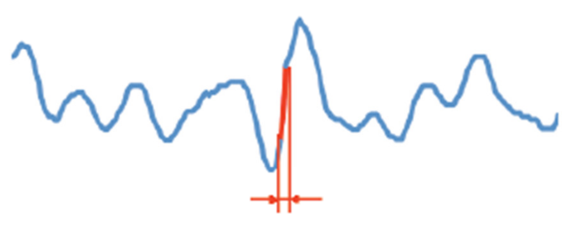
Green indicates little to no traffic
Yellow indicates moderate traffic
Red indicates heavy traffic

Figure 3A Z-THRESH*



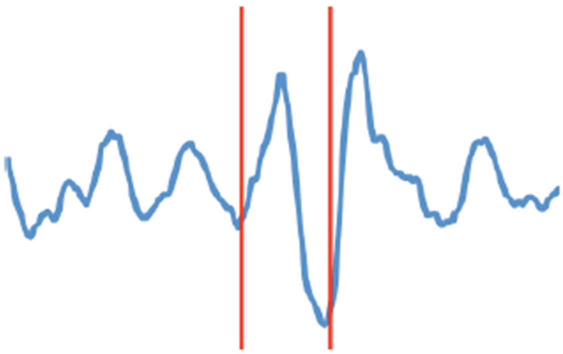
An event is considered a pothole if it goes above or below the threshold. The threshold can be calibrated to monitor for different events.

Figure 3B Z-DIFF*



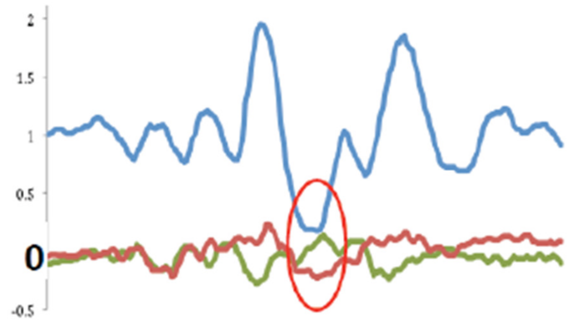
An event is considered a pothole if the value of the difference is beyond the threshold. Can also be calibrated.

Figure 3C STDEV(Z)*



Again an event is considered a pothole if it goes beyond a certain predetermined threshold.

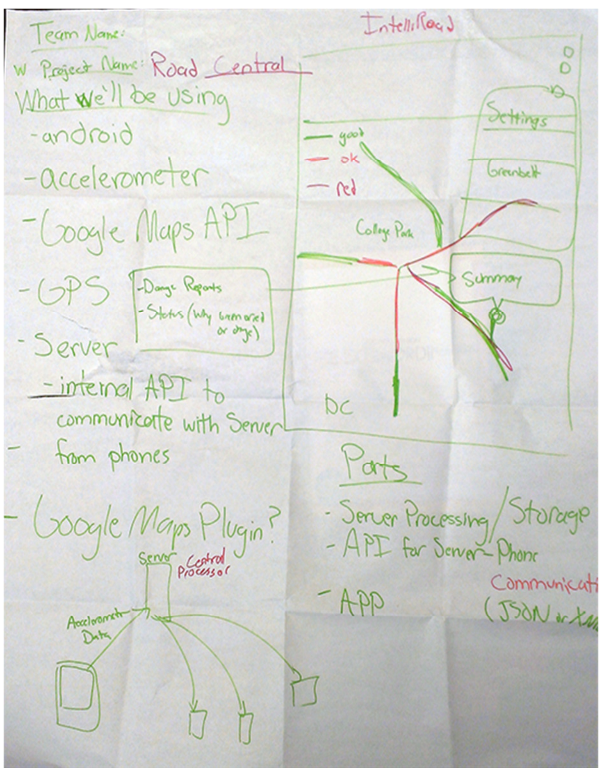
Figure 3D G-ZERO*

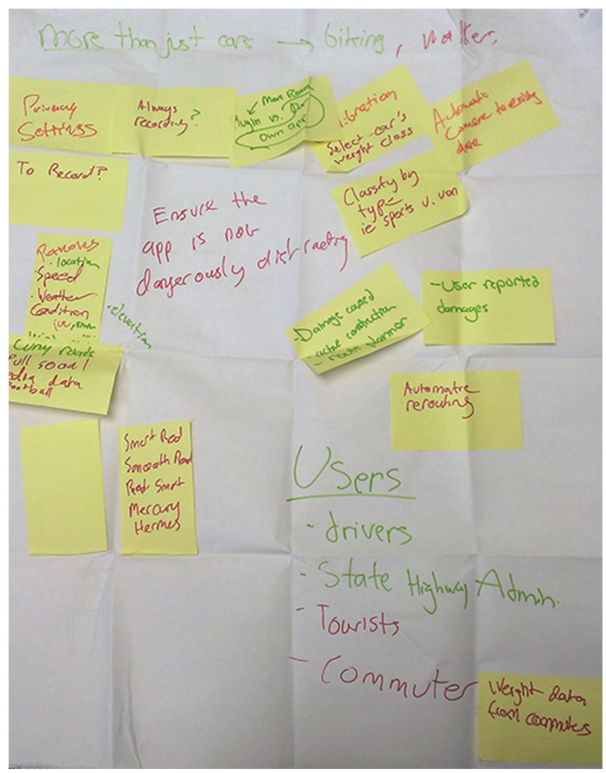


In the G-Zero algorithm an event is considered a pothole if all-three axis (X, Y, Z) are within a certain threshold.

*Figure 3 graphs and descriptions taken from Mednis, A. et al., 2009.

B. Original Brainstorm





C. Observation Notes

A compiled video of several of the vehciles interactions with the road hazard can be viewed at: http://www.youtube.com/watch?v=-As_70uq6C0

D. Survey Result Charts

How old are you?	Gender	What is your occupation?	Do you own a car?
21	Male	Student	No
49	Male	IT	Yes
51	Female	Insurance	Yes
18	Male	Student	No
22	Male	student	Yes
20	Male	Student	Yes
19	Male	Student	Yes
20	Female	student	No
21	Male	student	Yes
18	Male	student	No
20	Female	Student	Yes
21	Female	Student	Yes
21	Female	Student	Yes
21	Male	Broke college student	Yes
20	Male	Programmer	Yes
18	Male	Student	Yes
20	Male	Intern/student	Yes
19	Male	Student	Yes

19	Female	student	Yes
19	Female	student	Yes
20	Female	student	No
20	Male	Student	Yes
18	Male	student	No
19	Male	student	Yes
24	Female	Student	Yes
19	Female	Student	Yes
20	Male	Student	Yes
21	Female	Student	No
20	Male	student/wealth management	Yes
20	Male	Student	Yes
18	Female	student	No
20	Female	Student	Yes
21	Male	student	Yes
23	Female	student	No
20	Male	Student	Yes
21	Male	student	Yes
20	Female	student	Yes
21	Female	Student	Yes
21	Male	Student	Yes
20	Female	Student	Yes
22	Male	Consultant	Yes
22	Male	Student	Yes

E. Original Pitch

Using Mobile Phones Accelerometers to Track Road Conditions

There are over 3.9 million miles of roads in the United States that support over 2.7 trillion miles of travel by cars and trucks (1). With that kind of scope and use it makes it hard for every road to be monitored all the time. Also, this information isn't made readily available to the drivers. Local drivers will know of the bumps and potholes in the road by traveling drivers will not which makes this app most useful to them. Like google maps traffic overlay, an overlay for road conditions would also be useful to drivers. Drivers can avoid city streets with potholes in favor of a smoother route. Also, governments on every level could use this data to monitor problem spots in the road system. This would take some of the cost out of monitoring our transportation system's roads and also out of the user's pockets who need to spend money because of broken steering (2).

In the scope of this semester a prototype could be created which includes an overlay on a map using google maps api. Some data could be collected but the real benefit of using the app comes after the user base becomes larger. But to test its functionality only a few users would be needed.

References:

1) National Atlas. (January 14, 2013). Transportation of the United States. National Atlas: United States Department of the Interior. Retrieved from http://nationalatlas.gov/transportation.html

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