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Bumpy Roads Project: crowdsource monitoring of road roughness

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Abstract

Road condition monitoring plays a key role in ensuring safety and comfort to various road users, from pedestrians to drivers. Having information on infrastructure quality guarantees road managers an adequate maintenance on time. While professional road profilers equipment based laser scanners, image, and video cameras exist, they are usually associated with high purchase, operation, or maintenance costs that not always fit the budget from a small city or village. We believe that road users can contribute to monitor the pavement quality simply by using their own smartphone while driving. The Bumpy Road projects tries therefore to develop a collaborative application where data collected with the help of the drivers can be aggregated and analyzed, allowing a fast and low-cost surveillance on the roads conditions.

1 Introduction

The roughness of a road is a crucial factor that determines both the comfort and safety of road users and collaborates with the economic prosperity, productivity, and well-being of a region. Road bumps can have a considerable impact on tire wear, fuel consumption, and, ultimately, the economy and the environment. In some cases, the effects can be even more far-reaching. Providing road roughness data can prove immensely useful for road authorities to take effective control and maintenance measures. Additionally, it can help other civil users make informed decisions when selecting suitable routes.

Within urban infrastructure, local streets and highways are crucial transportation conduits. Developed countries possess millions of kilometers of road network that mainly consist of asphalt or concrete, varying in surface condition, age, and performance. Unfortunately, several countries have reported issues with the current state of their networks. For example, the American Society of Civil Engineers gave the country's network a D grade (A being the best) due to its poor condition [2]. Business organizations, which have a direct interest in road conditions, often express concerns and dissatisfaction, and almost 50% of UK citizens also feel the urgency of changing the way roads are maintained [3]. In France, the maintenance of several roads has been delegated to regional or local authorities since 2004, including routes that cross most cities [1].

One way to determine a road's quality is by measuring its roughness. Roughness is defined as the variation in surface elevation along a road that causes vibrations in traversing vehicles [8]. Since the 1960s, several works have been done on this subject, and different measuring equipment and techniques have been developed. For automated data collection, specialized vehicles equipped with several sensors, such as laser scanners, road profilers, accelerometers, image and video cameras, and positioning systems are used [4]. However, due to the complexity of these vehicles, the cost to purchase, operation, and maintenance are high. For these reasons, their usage is often restricted to important roads or performed sparsely over the years.

With the rapid widespread of smartphones that come embedded with a variety of sensors (e.g., gyroscope, accelerometer, and GPS), users now hold powerful devices that can be used as personal sensing [6]. Mobile devices can act as super sensors that are readily deployed and can be used to dynamically collect intelligence about cities [10]. This information can complement existing monitoring protocols and provide up-to-date information on the evolution of the road's conditions.

2 The Bumpy Roads Project

The Bumpy Roads project aims to develop a road roughness monitoring tool based on the crowdsourcing paradigm. Volunteer users collect data during their car rides, helping to evaluate most of the road network and keeping the information updated over time. The project is therefore split into two parts: data gathering on a mobile device and a companion website for data visualization and analysis.

2.1 Data Gathering

Data gathering is mainly performed by a smartphone application that collects vertical vibration using the phone's IMU sensors. For this, we use the vertical acceleration index that indicates the acceleration force along a given axis (in m/s^2). A prototype application was developed for Android smartphones, recording both the vibration suffered by the car or bicycle [7] on a ride and its relative GPS location.

Due to the simplicity of the required equipment, data gathering can also be implemented on dedicated devices such as Arduino-like ICUs, which can be directly installed in a car or truck [9]. Such a solution is adapted to deploying a fleet of vehicles, for example on public transportation buses, post-office cars, or garbage collection trucks. Furthermore, using a fleet of vehicles allows for regular updates, while smartphone updates depend on the user good will to use the application.

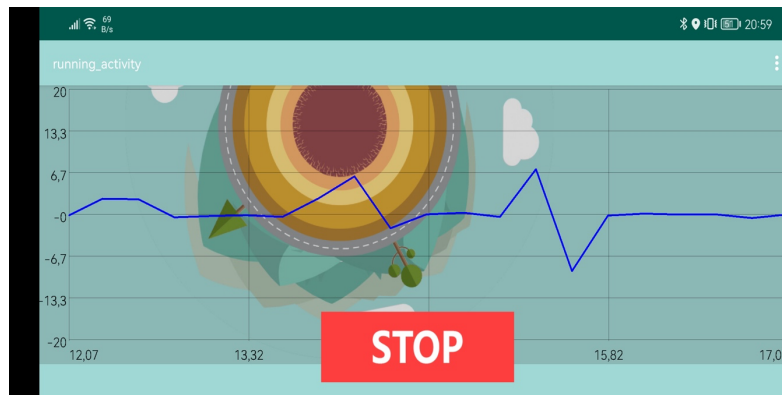


Figure 1: Data gathering application interface.

Concerning the data, raw vertical acceleration is a good indicator of the pavement quality, at least when qualitatively comparing two road segments. If more professional metrics are required, there are works such as [9] and [11] that describe how to convert IMU acceleration data into International Roughness Index (IRI), a metric used by professional equipment.

More advanced insights can be obtained by filtering and processing this data. Hence, filtering can be used to differentiate potholes from speedbumps, as illustrated by [6], or to account for the influence of driving speed on the recorded vibrations.

2.2 Companion Website

The data collected by the users is anonymously transmitted to a server, which stores the data in a database and allows the visualization and exploration of the road status. Currently, we implemented a Google Maps overlay that shows raw data as measurement points, as presented in Figure 2.

To improve the presentation, we are now working on different methods to aggregate measures from several users and to display the average score of a road segment. By aggregating data, we may also apply a fading factor to highlight more up-to-date measures. Also, artificial intelligence can be used to detect rapid deterioration of the pavement (roughness does not always means pavement deterioration), sending alerts to authorities.

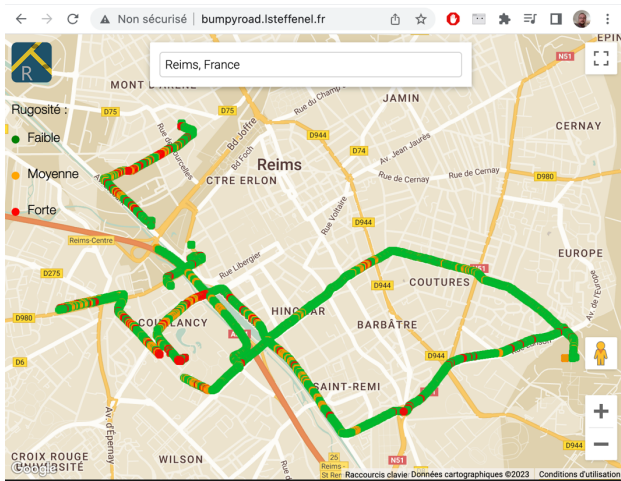


Figure 2: Road conditions monitoring on the website.



Figure 3: Speedbump interpreted as a road problem (red).

3 Conclusion and Future Directions

The Bumpy Roads project is a crowdsourcing-inspired application where drivers collaborate to monitor road conditions and therefore contribute to better road network coverage, all while allowing a fast response in case of pavement deterioration problems. While the data from the sensors do not achieve the same accuracy as professional devices, they may be used as a cost-saving alternative for cities. Also, due to its collaborative nature, users contributing to the application may feel more concerned about the maintenance of the traffic network, therefore participating in the local or regional decisions.

This project was started as a student's project in 2019, but due to COVID-19, it remained only at the prototype stage. We recently reopened the project and expect an improved interface by Summer 2023 (with a more efficient smartphone application and most of the improvements discussed in section 2.2). The source code will be published on GitHub for interested users, villages, cities, or towns.

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