A framework for pavement crack detection and classification

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Abstract. Pavement damage detection is indeed a very important process for the management of roads. Nowadays, scholars are focusing on finding a simple and accurate way to detect road cracks aiming to increase its life span and improve its safety and quality. However, due to some factors including cost of implementation and level of experiences required small communities and developing countries are yet unable to adapt this idea. Therefore, developing a feasible method is becoming extremely important for improving the quality and safety of pavements. Thus, this study is intended to propose a framework for pavement crack detection and classification through the use of inexpensive set of sensors and the applications of artificial neural networks. As part of the project, difficulties that are going to be faced by local agencies in small communities will be highlighted and possible solutions will be suggested. In general, this framework is expected to be helpful to government entities in developing plans and taking actions toward providing a suitable pavement distress mitigation strategy.

1. Introduction

Deterioration of the pavement is the system through which distresses develop under the combined impacts of road traffic and environmental factors. Serviceability, security and road quality are significantly affected by deterioration of pavements. Because of its extensive use, roads deteriorate with time and must, therefore, be maintained to ensure that safety, efficiency and durability requirements are met. Common deterioration of pavement involves cracking, surface defects, deformation and structural failure [1]. The most common types of cracking are fatigue cracking, longitudinal cracking, transverse cracking, block cracking, slippage cracking, reflective cracking and edge cracking [2]. The combination of fatigue and cracking block may be regarded as alligator cracking. These cracks are mainly caused by high load applied or excess moisture. Therefore, it is important to continuously check the pavement condition in order to provide a solid data for a pavement management system [3]. However, local governments in small cities often lack experienced staff for effectively using a fully implemented pavement management system [3]. Furthermore, available techniques for pavement crack detection are considered to be very expensive especially for small countries such as the case of Turkish Republic of North Cyprus (TRNC). For this reason, finding a way to reduce this cost and complexity is essentially towards an effective management of pavements.

Thus, the aim of this paper is to propose a framework empowered by a low-cost tool that can be used by small communities and to highlight the main difficulties and their solution that might be faced during the implementing of this methods.
2. Materials and methods

In this section, components of the framework for pavement damage detection empowered by a low-cost tool is going to be discussed.

2.1. Data collection

In this study a data collection circuit will be developed based on the use of Raspberry Pi Zero, Figure 1, as the main computer that works for data acquisition and data storing. An acceleration sensor MPU6050, Figure 2, with a data sampling rate of 60 Hz and range of ±8g will be used for measuring the vibration in the vertical direction. Furthermore, a Global Positioning System (GPS) GY-NEO6MV2 sensor, Figure 3, will be used for defining the location of the crack. In general, the total cost of the circuit and the sensors is considered low-cost system which allows small communities to get benefit of this method even at small budgets.

In order to collect the data, the device must be mounted on any vehicle or bicycle. Thereafter, the Raspberry Pi Zero will work as a data acquisition system through a python coded program that will read the output of the sensors and will store it in the memory card.

![Figure 1. Raspberry Pi Zero](image1)

![Figure 2. Chip of the MPU 6050 sensor](image2)

![Figure 3. Chip of the GY-NEO6MV2 GPS sensor](image3)

2.2. Data Pre-Processing

In fact, the recorded data must undergo a pre-processing stage to reduce their noise emerged from the uncontrollable environment in the pavement. The suggested method in this study is called the moving average filter which is composed of taking the average of a certain number of outputs and subtract that value from the readings of the sensor [4]. In addition, to removing the surrounding noise the suggested method will also remove the readings caused by the Earth’s gravity as the observed accelerations are in vertical direction.
2.3. Data processing

This stage includes both the crack detection and classification. At the beginning, the collected data mainly the vibration one will be divided into number of cases in which each case will represent a sudden change in the vibration input. This is going to be done by selecting all the values that cross a specified acceleration limit such as 10 m/s². Thereafter, 15 readings before and 15 readings after each of these values will be defined as a crack that will be classified separately.

Classifying each crack is going to be undertaken through the use of Artificial Neural Network (ANN) Figure 4 because of its capability to learn and capture the functional relationships among the hard description of data [5]. In order to develop the ANN system part of the recorded data will be used to train the system and rest will be to verify and test it.

In fact, the use of an accelerometer provides an easy way for identifying the vibration behavior of each change in the pavement texture such as cracks or speed humps. Furthermore, using a reliable ANN system can help in classifying each of the texture changes into the correct crack type. Table 1 shows examples of different types of changes in the pavement surface. It is clear that each one has unique characteristics. For example, the alligator crack can be defined by consecutive fluctuation of a similar peak values. On the other hand, the pothole can be observed by a sudden change in the vibration behavior that have a single peak value, while the speed hump is identified by a negative peak directly followed by a high value of a positive peak and its long duration. Using the same procedure, it is possible to specify the characteristics of each crack. These characteristics can be the duration of the fluctuation in vibration, the standard deviation in of the vibrations, and the number of positive and negative peak values.

![Figure 4. An artificial neural network [6].](image-url)
Table 1. Vibration behavior of various pavement texture changes.

| Type            | Photo               | Vibration Behavior |
|-----------------|---------------------|--------------------|
| Alligator Crack | ![Image of Alligator Crack](image1) | ![Graph of Alligator Crack Vibration](image2) |
| Pothole Crack   | ![Image of Pothole Crack](image3) | ![Graph of Pothole Crack Vibration](image4) |
| Speed Humps     | ![Image of Speed Humps](image5) | ![Graph of Speed Humps Vibration](image6) |

2.4. GIS Database

The importance of any GIS is its capability in data modelling, which is a set of constructs for describing and representing selected aspects of the real world in computer [7]. It is a procedure of designing and developing a data system by taking all the information that would be needed to support various business processes of the organisation [8]. Data model is created to depict the structure of the data handled in information systems that is demonstrated in entity-relationship diagrams (ERD). Three basic styles of data modelling, Figure 5, are generally used in practice today [9]:

- Conceptual data models: the process of constructing a model of the data, creation of ERD, used in organization and independent of all physical considerations.
- Logical data models: the method of representing data architecture and organization in a graphical way, mapping ERD to tables, without any regard to the physical data storage device.
- Physical data models: the internal schema database design.
In this stage, each crack will be defined by its type and location on a designed geodatabase that composed of a digitized roads network such as the one shown in Figure 7.

![Diagram showing levels of abstraction in data modelling](image)

**Figure 5.** Levels of abstraction in data modelling [10]

![Image of a digital road network](image)

**Figure 6.** An example of a digital road network

3. **Proposed Framework**

3.1. **Pavement Crack Detection and Classification Framework**

As mentioned previously, this paper is proposing a framework that can be used for pavement crack detection and classification.

The framework proposed in this study, as depicted in Figure 7, is composed of four main stages which are data collection, their pre-processing and processing and storing them in a GIS database for possible mitigation plans.
3.2. Challenges for Small Communities

In fact, the major difficulty that is expected to be faced by small communities is the lack of an accurate GIS database. Previous study [11] have illustrated how a GIS map can be collected, edited, and verified from other map sources such as locally maintained road ones. Furthermore, another challenge would be the cost of continuous data collection which can be overcome by licensing local agencies who run vehicle or bicycle renting services to work as a data provider for the government by introducing this low-cost device to their business.

4. Conclusion

This study contributes to the pavement damage detection and classification in small communities with the developed framework. As a part of this study, a proposed framework that can be implemented with a low-cost tool mounted to a vehicle or a bike was discussed. Furthermore, some of the challenges that are expected to be faced by these communities were mentioned and possible solutions were suggested.

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