Analysis of Real Time Road Surface and Acoustic Data Processing for Minimizing the Accident Rate Using Feed Forward Neural Network

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Abstract: Simplified road condition monitoring is essential to maintaining road safety and maximizing transportation efficiency in smart cities. Effective road surface detection has been significantly improved by the use of artificial intelligence (AI). Issues with asphalt pavement are the main concern of both developed and emerging countries for the efficient functioning of everyday commutes. The identification of potholes, which are dangerous to cars and people and can result in an accident, has been the subject of several research. In order to identify potholes on edge devices, this study aims to explore the possibilities of deep learning models and use three outstanding deep learning models. This article proposes a low-cost technology for detecting the surface qualities of road pavement in real-time. The time-frequency domain processing of the inertial signals given by on-car sensors is done in order to get information about the condition of the road surface. The effectiveness of the suggested approach in determining the kind and existence of distress is demonstrated by the high categorization rates. Following data collection from the road surfaces, machine learning methods like Multi-Layer Perceptron (MLP) are used for analysis. The outcomes show how well the suggested approach can distinguish between various road conditions. These findings showed that the MLP had a higher accuracy of 98.98% when evaluating road conditions. In order to give safe transportation services in smart cities, the study offers important insights into the creation of a more effective and dependable road condition monitoring system.

1 INTRODUCTION

A pothole, one of the types of asphalt pavement failures that occur due to water in the supporting soil structure and traffic over the used area. First, when the underlying soil structure is hydrated and water is added, the supporting soil softens. Traffic wears and breaks up the poorly-supported wearing pavement in the affected area. It causes the asphalt and dust particles underneath to come out and sink, leaving an empty area in the road due to continuous driving activity.

Figure 1: A deep pothole.

1.1 Formation of Pothole

Pothole primer A public administrator's guide to an understanding and handling of the pothole problem, U.S. Army Corps of Engineers (Eaton et al.), says it takes two conditions to make a pothole: water and traffic. Water weakens the soil under the pavement, or the pressure of traffic applies stresses to the pavement that make it crack. Potholes do not form overnight, but rather start as a sign of fatigue within the surface of the road. Pavement that breaks up in this way between fatigue cracks is finally released in the form of a pothole when progressive fatigue leaves it unvoiced by adjacent surface stresses, and it is plucked or driven out of the surface by ongoing tire stresses. In areas that experience freeze and thaw, this type of freeze and thaw can damage a pavement and leave openings for water to enter. The process, made more acute than ever this year by spring thaw which saturates and weakens the supporting soil happens

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when the upper parts of a pavement's soil structure cannot melt past lower, still-frozen layers. Though they rarely exceed a few inches in depth, potholes can stretch out to several feet in width. If large enough as shown in figure 2 and figure 3, they are likely to cause damage to tires, wheels and even car suspensions. On-road implications. This can lead directly to serious traffic accidents especially on freeways with high speeds.

Figure 2: Condition of roads with potholes.

Figure 3: Road surface defects.

As illustrated in the figure, pavement distresses for asphalt sections are primarily divided into eight categories, as per the Texas Department of Transportation's (TxDOT) Pavement Management Information System Rater's Manual: rutting, patching, block, alligator, longitudinal and transverse cracking, ravelling, and potholes. Regular road surface monitoring and maintenance is crucial since it may extend a road's lifespan from 15 to over 30 years. The goal of this project is to create a road classification system that can evaluate the infrastructure in real time. The creation of novel artificial intelligence methods that can learn on their own from acoustic data obtained through an integrated system is the main goal of this article. The algorithm is implemented on an electronic board that is fixed to a car's rim flange. It is connected to a microphone that is placed within the tire hollow and has components for transmitting Low Energy (LE) data with web monitoring that is based on the Internet of Things.

2 LITERATURE SURVEY

Moazzam et al. (2013) may provide a pavement distress detection technique that mainly focuses on detecting and analyzing potholes and cracks generated due to road damage. The study addresses the essential issue of accurately predicting the volume of filler material required to repair a pothole to avoid any shortages and wastage. The idea is to extract road surface depth images from a Concrete and Asphalt roadway using an inexpensive Kinect sensor. These photographs are rendered in a way to generate meshes that facilitate the identification of potholes.

S.S. Rode et al. Pot-hole avoidance system for vehicles. (2009) propose a unique architecture for a pothole detection and warning system which is Wi-Fi based. As Wi-Fi-enabled cars drive through the area covered by the access points, they will receive the data broadcasted by the access points along the roadway. Additionally, acknowledgments responses may be transmitted by front-end nodes (cars) to the access points where they are dispatched to the back-end servers.

H. Youquan et al. proposed a method of efficient detection of the 3D sectional area of pavement potholes. (2011). The optical imaging principle of three-dimensional projection transformation is adopted to take pictures of the cross-section of potholes during detection. It involves a variety of digital image processing techniques like error analysis and compensation, image preprocessing, binarization, thinning, and 3D reconstruction. These experiment observations indicate that this method outperforms traditional methods in many aspects and enhances pothole detecting accuracy and performance.

Different from the more common investigation on crack detection in pavement distress (J. Lin et al. (2010) focus on the less studied area of pothole identification. The paper proposed a pothole detection method which uses histogram to extract the textural features that refers to a region of an image. A non-linear support vector machine (SVM) is then used to classify if the specified target region is indeed a pothole. Based on experimental data, the proposed algorithm offers an effective approach for detecting potholes on pavements, attaining a significantly high identification rate.

A DNN model for identifying the speaker was presented by F. Ye et al. (2021). Published in the journal of Applied Sciences, these researchers outlined a strategy to effectively and efficiently increase the accuracy of speaker identification systems using deep learning methods**. By using speech characteristics to identify specific speakers, the model offers a reliable solution for use cases such as voice-activated systems and security. Experimental findings demonstrate that the model achieves good recognition performance for tasks like speaker identification.

3 EXISTING SYSTEM

The current pothole-maintenance system has a black-box camera-based pothole detector. The pothole-detection system uses the camera to gather pothole information, including size, position, and appearance. The pothole-maintenance server utilizes the gathered data for intelligent pothole maintenance, which is kept in the pothole database. Based on our prior pothole database system, we created new software for the pothole-maintenance server, as seen in Figure 1 on the right. A variety of information about potholes is provided by this software, including video clips, images, regions, road authorities, road number, driving direction, lane number, road type, latitude, longitude, collectors, date of collection, pavement type, location, shape, size, and comments. With the help of the gathered GPS data, the pothole's position is displayed on a digital map. As a result, viewers can observe the pothole distribution with ease. Additionally, pothole maintenance expenses in the chosen region are precisely estimated by the program. In this manner, the program makes it simple and precise for transportation officials to create road-maintenance rules and strategies. Then, potholes can be intelligently fixed using a pothole-maintenance system, like our intelligent asphalt repair systems, and pothole data can be shared with other users and services through Open API and external connections. Pothole-maintenance system (Figure 1). Insofar as the current approach for detecting potholes only employs one black-box camera. It is possible to swiftly collect data over a large region and construct a variety of survey vehicles for pothole identification at a reasonable cost. Actually, because current pothole-maintenance methods do not offer reliable pothole information, the Korean government is unable to budget for yearly road repair expenses with any degree of accuracy. This initiative aims to identify and track road conditions and raise awareness of anomalies on the road, which is likely to occur in nations like India.

4 PROPOSED SYSTEM

The goal of this project is to create a road classification system that can evaluate the infrastructure in real time. The creation of novel artificial intelligence methods that can learn on their own from visual and inertial data obtained through an integrated system is the main goal of this research. The algorithm is implemented on an electronic board that is positioned on the dashboard or onboard unit of a car. It is connected to a camera and sensors that are placed within the suspension cavity and has WiFi or Internet of Things data transmission components. Three stages of the system's evaluation were conducted. First, the two CNNs were trained, and their outputs were compared. After that, the model with the best performance was chosen and quantified. Additionally, as a last comparison, the model accuracy for both the quantized and floating-point models was computed. Finally, the classifier was included into the embedded firmware, and an Arduino NANO board was used to evaluate its operation. To evaluate the application's performance on actual hardware, it was then installed on the specially made board. The development of a new dataset comprising the inertial data resulting from the contact between the wheel and road surfaces is a significant proposal of this project. The data collection was created in part through data augmentation and mostly through many measurement efforts.

5 PROPOSED DESCRIPTION

One really interesting and valuable project to detect road quality is to build a road surface analyser with Arduino Nano, MPU6050 accelerometer, HC-SR04 ultrasonic sensor, and limit switch. Below is step-by-step instructions to implement this system:

The aim of this project is to check road condition based on surface roughness, potholes and bumps. The limit switch can also serve to discern specific trigger events (for example, did the wheel hit something, or when the system is moving), while the accelerometer will pick up vibration and bumps of the ground, and the ultrasonic could be used to measure the distance to the road surface.

- Inertial sensors: not least accelerometers form the foundation of the cheapest road surface estimation systems. This project aims to develop a road classification system that can assess the infrastructure in real time.

- New low-cost AI based on on-device and GPS based on real time location and identification of problem areas based on MEMS signals
- AI embedded architectures consider constraints that an Internet of Things (IoT) device must operate within memory and embedded systems execution limits.

5.1 Data Processing

1. Accelerometer Data: To identify sudden changes that point to bumps, potholes, or uneven spots, use the accelerometer data, particularly along the Z-axis.

2. Ultrasonic Distance: Track variations in distance, which might reveal imperfections in the road surface.

3. Limit Switch: To initiate particular actions, such as recording data only when the system is in motion or a wheel strikes an obstruction, use the limit switch.

5.2 Data Analysis

As the machine moves across various road surfaces, gather and record data over time. Examine trends in ultrasonic and accelerometer data to identify particular kinds of anomalies in the road. For a more sophisticated system, think about wirelessly sending data for distant monitoring and analysis as well as recording it on a PC for surface study.

5.3 Fine-Tuning and Calibration

Adapt thresholds to the driving conditions and the accelerometer's sensitivity. To concentrate on more important occurrences that probably point to poor road condition, filter away little vibrations.

6 HARDWARE

6.1 Power Supplies

An apparatus or system that provides electrical or other forms of energy to an output load or collection of loads is called a power supply (sometimes referred to as a power supply unit or PSU). Electrical energy sources are most frequently referred to by this phrase, followed by mechanical ones and, seldom, others. When working with digital circuits, this circuit's tiny +5V power supply is helpful. Any supermarket or electronics store will sell small, low-cost wall transformers with changeable output voltage. Although such transformers are readily accessible, they often have extremely poor voltage regulation, which limits their usefulness for digital circuit experimenters until a better regulation can be found. The solution to the issue is the circuit that follows.

6.2 Transformer

A transformer is an apparatus that transfers electrical energy between two (or more) circuits through inductively coupled wires. The changing current in main circuit creates a changing magnetic field, which also induces an alternating voltage in secondary circuit. Current can be flowed in the transformer which allows energy to transfer from one circuit to another or a load applied to the secondary circuit. One factor (n) which is (or rather should be) equal to the number of wires turns in each of them, here is employed to dilute the secondary induced voltage (VS) from the primary VP: Therefore, a transformer can step up an alternating voltage if NS > NP or step it down if NS < NP by selection of number of turns carefully. A key application of transformers is lowering the current before transmitting electrical energy over long distances through wires. Due to their resistance, the vast majority of wires dissipate electrical energy as a function of the square of the amount of current passing through them. Transformers enable long-distance electricity transmission, where electrical power is converted to a high-voltage, and therefore low-current, state for transmission and then back again. As a result, transformers have spread through the electrical supply industry covertly implanting the general concept of generating far away from demand. By the time it finally reaches the user, nearly all of the electrical power in the World has passed through a series of transformers. Some enormous units are capable of transmitting 99.75 percent of their input power to their output, making transformers some of the most efficient electrical "machines." Transformers vary in size from tiny coupling transformers tucked inside backstage microphones to giant gigavolt-ampere rated pieces of gear used to connect sections of national power grids. There are many different designs for various functions, both home and industry, but they all operate on the same basic principles:

7 SOFTWARE

7.1 Arduino

Arduino is an open-source electronics platform based on simple software and hardware. Arduino boards receive an input, the light on a sensor, a finger over a button, a tweet, and they create an output in the form of blinking an LED, activating a motor and posting something online. The microcontroller of your board can be commanded to perform some actions by feeding instructions you may refer to as a Program. This is done using the Arduino software (IDE) shown in figure 4, which is built on Processing, and the Arduino programming language, which is built on Wiring. Whether for more simple everyday items or more complex scientific devices, Arduino is still the brain behind millions of projects every year. This open-source platform has borne from it a global hive of makers (students, hobbyists, artists, programmers and professionals) sharing knowledge creating an insane reservoir of useful information well suited for beginners and experts alike. Arduino was invented as a simple prototyping tool in the Ivrea Interaction Design Institute so students without any electronics or programming background could prototype quickly. The moment that the Arduino board became widely adopted, it began to be evolved to tackle new needs and challenges, from basic 8-bit boards to choices for wearables to those for embedded environments to 3D printing and Internet of Things/IoT applications. All Arduino boards are fully open-source, so you can solder them together yourself and then modify according to your requirements. The program is public and continually builds through donations from people all over the world.

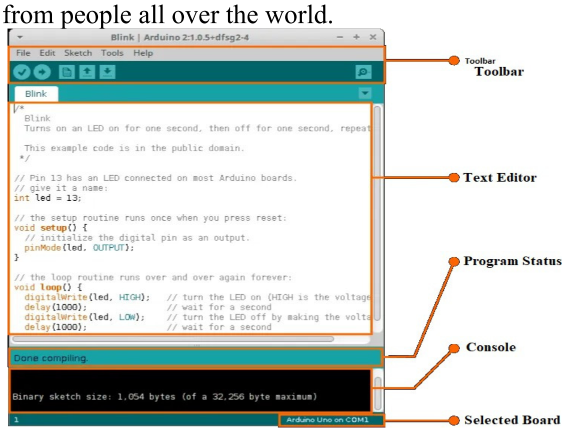

Figure 4: Arduino IDE.

7.2 Arduino Software

The Arduino Integrated Development Environment (IDE), also known as the Arduino Software, includes a text editor for writing code, a message box, a text terminal, a toolbar with buttons for commonly used tasks, and several menus. It connects to the Arduino hardware to upload programs and interact with the hardware.

8 RESULT

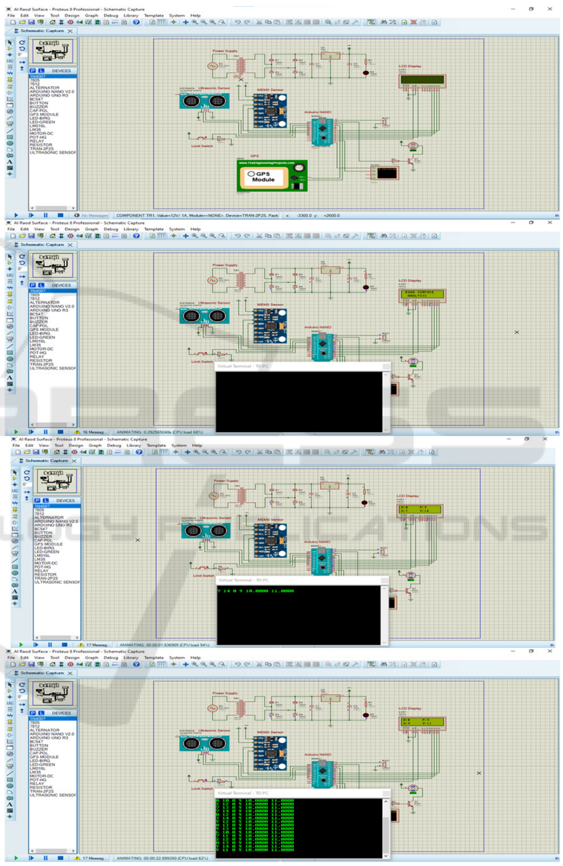

Figure 5: Real-time road hazard detection and risk mapping system.

Predicted Risk Level: "High Risk" (based on data from a road segment exhibiting uneven auditory signals and potholes that may indicate tire sliding).
Notice: "Warning: Hazardous Road conditions detected, slow down immediately."
The report on accuracy states, "Model accuracy: 92%, Precision: 89%, Recall: 91%."
Visual Representation: Figure 5 shows the city map with areas coloured according to the neural network's

rating (green for safe, yellow for intermediate risk, and red for high danger).

9 CONCLUSIONS

In this study, we have introduced an AI-based real-time road surface monitoring application. The program is intended to be used on a microcontroller board that has a microphone installed to record noises within a tire's cavity. According to preliminary test findings, the gadget can identify the asphalt's quality on the test set with 91% accuracy. This illustrates how well the suggested Tiny architecture works for this use case and how the Mel-inspired spectrogram can be used as an input to identify the condition of the road. The suggested strategy makes use of cutting-edge methods. Actually, the implementation of AI systems on embedded systems is a state-of-the-art technology that is the subject of a lot of ongoing study.

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