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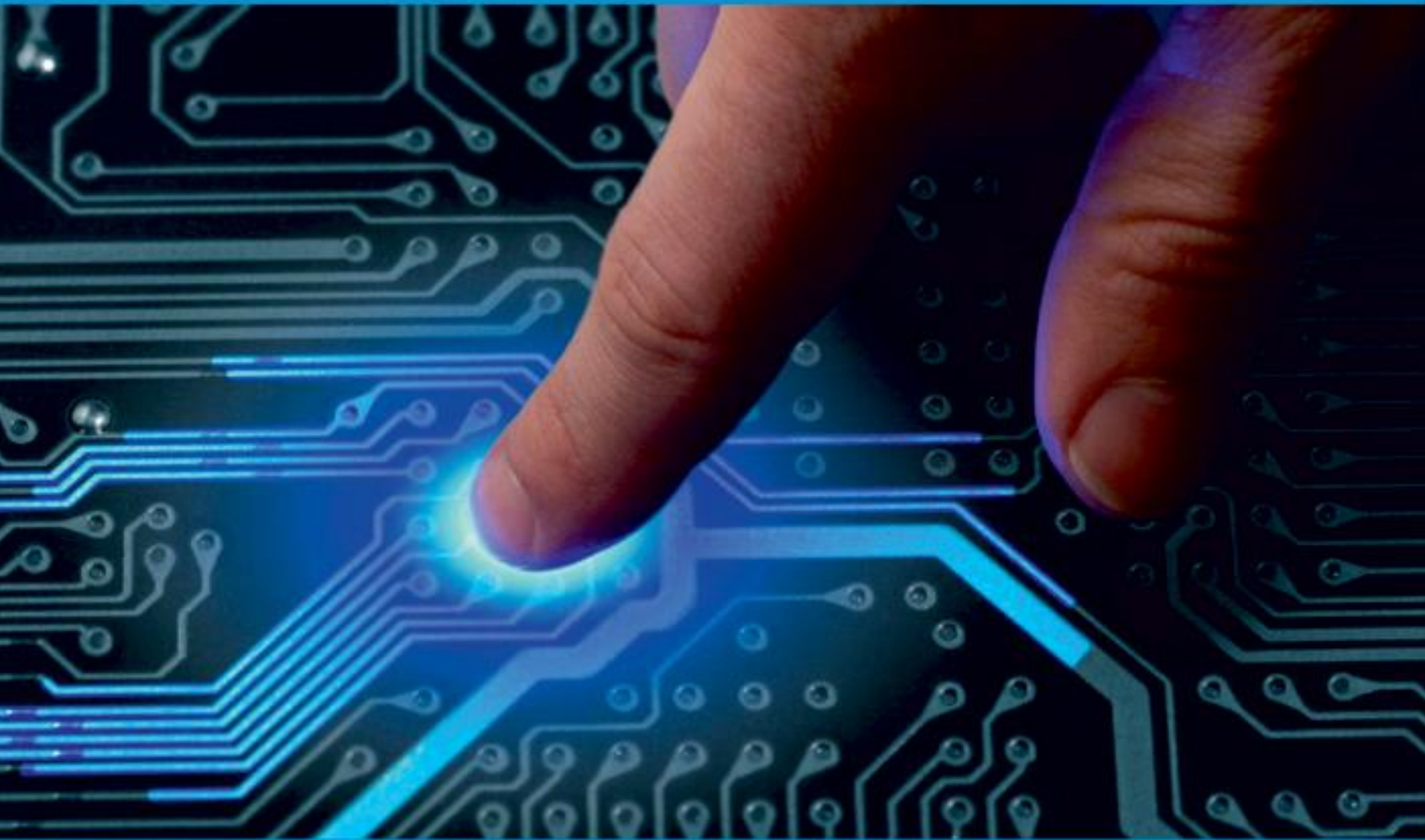

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Dhaanish Ahmed Institute of Technology, KG Chavadi, Coimbatore, Tamilnadu, India

An Ai Based Real-Time Road Analysis SystemUsing Mems Data with IOT Application

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ABSTRACT: Potholes and other asphalt pavement distresses must be addressed if safe and effective worldwide transportation is to be ensured. This research provides a revolutionary real-time pothole detection method based on deep learning models installed on edge devices. Throughvibrational patterns and surface imperfections, our system can accurately identify road surface conditions, including potholes, by evaluating MEMS data from on-car sensors in the time– frequency domain. The system's excellentaccuracy in identifying and categorizing different forms of pavement distress is demonstrated by experimental findings, which enhance road safety and upkeep. This study provides an affordable solution designed to improve commuterexperiences around the globe.

KEYWORDS: MEMS, GPS,Sensor, IoT , Asphalt pavement, Real-time data

I. INTRODUCTION

A. ROAD ANALYSIS

Asphalt pavement constitutes a fundamental component of transportation infrastructure, providing essential attributes such as smoothness, traction, load- bearing capacity, and minimal noise generation. However, the continuous exposure to vehicular traffic,weather elements, and other environmental factors subjects these surfaces to wear and deterioration, necessitating regular maintenance to uphold their functionality and structural integrity. The challenge of preserving high-quality road surfaces is a universal concern for governments globally, as deteriorating pavements pose various risks, including increased accident rates, degraded driving experiences, and heightened environmental noise levels.

The detrimental impacts of poor road conditions extend beyond immediate safety concerns to encompass broader societal and economic implications. For instance, traffic noise has been identified as a significant public health issue by organizations such as the World Health Organization, highlighting the need for effective pavement management strategies. Moreover, the presence of distresses such as potholes, rutting, cracking, and patching not only compromises road safety but also imposes financial burdens on governments and individuals through increased vehicle maintenance costsand potential legal liabilities.

To address these challenges, there is a growing recognition of the importance of proactive monitoring and maintenance practices. The Department of Transportation Pavement Management Information System Rater's Manual categorizes asphalt pavement distresses into eight primary types, including rutting, patching, block, alligator cracking, longitudinal and transverse cracking, raveling, and potholes. These distresses necessitate tailored maintenance approaches to mitigate their impacts and extend the service life of roadways.

In this context, leveraging advanced monitoring techniques such as deep learning models holds promise for enhancing pavement management practices. By enabling real-time detection and classification ofdistresses, these technologies empower transportation agencies to prioritize maintenance activities, allocate resources efficiently, and ultimately enhance road safety and longevity. Through collaborative research and innovation, stakeholders can collectively address the multifaceted challenges associated with maintaining high-quality road surfaces, thereby fostering safer, moresustainable transportation networks.

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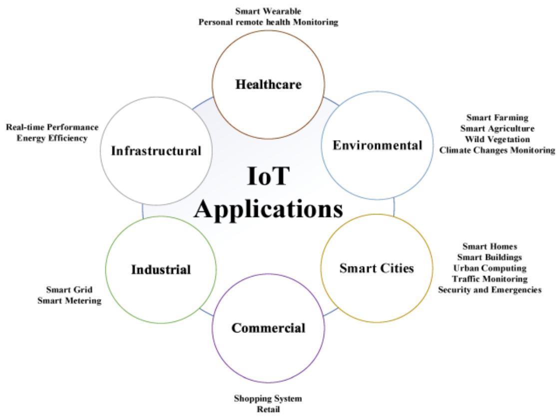
B. INTERNET OF THINGS (IOT)

Pavement management systems that use Internet of Things (IoT) technology are a paradigm change in the way we monitor and maintain road infrastructure. The conventional method of managing pavements mostly depends on manual data gathering and recurring inspections, which frequently causes ineffective resource allocation and a delay in responding to new problems. However, IoT provides real-time pavement condition monitoring, supporting proactive maintenance methods and boosting overall system resilience by integrating sensors and communication devices into road surfaces, vehicles, and infrastructure elements.

There are a number of clear benefits to pavement management systems that come with IoT integration. First of all, it makes it possible to remotely and continuously monitor important variables like temperature, moisture content, and structural integrity. This gives transportation organizations a thorough understanding of how well their road networks are doing. With the use of this real-time data, possible distresses may be identified early and promptly addressed to stop further degradation and reduce safety concerns.

IoT-enabled pavement management systems can also support predictive maintenance strategies by using machine learning algorithms to estimate future pavement conditions based on analysis of past data. Transportation authorities can maximize the lifespan of road infrastructure assets, manage maintenance schedules, and prioritize expenditures by recognizing patterns and trends in pavement deterioration.
Moreover, improved connection and interoperability provided by IoT technologies allow for easy integration with other smart city systems and transportation networks. Urban mobility solutions become more comprehensive and effective as a result of the synergies that are fostered across various infrastructure components, including public transportation networks, traffic management systems, and environmental monitoring platforms.
We examine how IoT may transform pavement management techniques in this research study, emphasizing how real-time monitoring, predictive maintenance, and system integration can benefit from its use. We intend to show the effectiveness of IoT-enabled pavement management systems in improving traffic safety, maximizing resource allocation, and fostering sustainable urban growth through case studies, experimental validation, and real-world demonstrations.



C. IOT IN ROAD ANALYSIS

The Internet of Things' (IoT) applications in road infrastructure have drawn emphasis due to its rapid advancement. The long-term real-time monitoring of pavements is hampered by issues with front-end sensor durability, sensor embedding causing harm to the pavement, and the redundancy of a large volume of real-time data. These issues are present when using IoT to road infrastructure monitoring.In order to overcome these obstacles, our research created an IoT-based self-powered distributed intelligent pavement monitoring system that includes a communication network, sensor network, cloud platform, and power supply system.

An integrated paving technique was developed that integrates embedded sensors with pavement material structures, taking into account the unique properties of slipform paving for cement concrete pavements. In orderto provide data support for pavement design,maintenance, and vehicle-road synergy applications, thesystem actively gathers and analyzes a variety of data types through on-site engineering monitoring, including system energy consumption, temperature and humidity, environmental noise, wind speed and direction, and pavement structural vibrations. The use of IoT technology in traffic safety, digital road maintenance, and optimum pavement material structure design will all be promoted in the future.

II. RELATED WORKS

Smart sensing of pavement temperature based onlow-cost sensors and V2I communications

Road network preservation, upkeep, rehabilitation, and enhancement are major difficulties (J Godoy, R Haber, JJ Muñoz, F Matía, Á García). In order to enable the modelling and analysis of road features, databases that are enriched with real-time data from monitoring devices must be created. Environmental factors such as temperature and humidity have a major influence on pavement quality. Information and communication technology, in particular wireless sensor networks and computational intelligence methods, is enabling the development of novel monitoring systems. The principal aim of this endeavour is to develop a pavement monitoring system for the purpose of measuring the temperature at internal layers.

The recommended approach is based on a neural network-based pavement temperature forecast model, durable and reasonably cost temperature sensors, and car-to-infrastructure links that enable the direct transfer of data from probes to a mobile auscultation vehicle. User requirements inform the design of probes, which produce a modular device that is low-cost, easy to install, and low-energy consuming. The test and validation experiment findings, which also reveal a reduction in routine test length and an increase in accuracy, illustrate the advantages and feasibility of the proposed system. Finally, data collected over a 12-month period is used to assess the predictive power of the suggested neural network and BELLS3 models for pavement temperature. In terms of mean absolute error and the dynamic behaviour of the predicted temperature, the neural network-based model performs better than the BELL3 model, suggesting that the pavement monitoring systemthat has been provided is suitable.

IoT-enhanced smart road infrastructure systems forcomprehensive real-time monitoring

Fei Yang a, Pengpeng Li a, Zhoujing Ye a, Ya Wei b, Songli Yang a, Biyu Yang c d, Linbing Wang e , Due to its rapid growth, Internet of Things (IoT) technology has drawn interest in its applications in road infrastructure. Nevertheless, there are still problems with deploying IoT to monitor road infrastructure. Theseproblems include the short lifespan of front-end sensors, pavement damage from sensor embedding, and the redundancy of a high number of real-time data, which makes long-term pavement real-time monitoring challenging.To solve these problems, this study developed an Internet of Things (IoT)-based self-powered distributed intelligent pavement monitoring system that consists of a power supply system, sensor network, cloud platform, and communication network. Taking into consideration the special characteristics of slipform paving for cement concrete pavements, an integrated paving technique was developed that merges embedded sensors with pavement material structures.The system actively collects and analyses a range of data types through on-site engineering monitoring, including system energy consumption, temperature and humidity, environmental noise, wind speed and direction, and pavement structural vibrations, to provide data support for pavement design, maintenance, and vehicle-road synergy applications. In the upcoming years, there will be a push for the application of IoT technology in traffic safety, digital road maintenance, and optimised pavement material structure design.

The Artificial Intelligence of Things Sensing Systemof Real-Time Bridge Scour Monitoring for Early Warning during Floods by Yung-Bin Lin [1],Fong-Zuo Lee [2],Kuo-Chun Chang [3],Jihn-Sung Lai [2,*],Shi-Wei Lo [4],Jyh-HorngWu [4] and Tzu-Kang Lin [5]

Still, scour surrounding bridge piers is the most frequent cause of bridge failure during flooding. Floods and excessive rain damage riverbeds and bridge structures, which increases the risk of bridge collapse and endangers people's lives and property. To protect drivers, it is imperative to monitor bridge safety capacity reductions under flood conditions. In this work, an artificial intelligence (AI) and Internet of Things (IoT) scour monitoring system with vibration-based arrayed sensors is developed and put into operation to get real-time scour depth readings.To withstand the extreme conditions during floods, these vibration-based micro-electro- mechanical systems (MEMS) sensors are housed in a watertight stainless steel ball inside a rebar cage.The Mask R-CNN deep learning model tracks variations in floodwater levels at the bridge pier by analysing live CCTV data. The hydrodynamic model with the chosen local scour formulas and the sediment transport equationis used to simulate the scour-depth evolution.The outcomes of measurements taken in the field and in the lab demonstrated that the early warning system could track the development of bridge scour depth in real time.

Nericell: Rich monitoring of road and traffic conditions using mobile smartphones by PrashanthMohan, Venkata N. Padbanabhan, Ramachandran ramjee

We analyse the difficulty of monitoring traffic and roadconditions in urban areas. Research in this area in the pasthas required service providers to track mobile phones orto put specialised sensors on vehicles, lorries, or the sideof the road. Furthermore, because of its relatively simpletraffic flow patterns, the industrialised world has been the focus of most prior studies. Actually, a lot of the world'sdeveloping nations have cities with chaotic traffic—lotsof braking and honking—a heterogeneous mix of vehicles—cars, buses, motorcycles, and two-wheelers—as well as varying road conditions—potholes, for instance.

We offer a solution called Neri cell to keep an eye on traffic and road conditions in situations like this. By using smartphones that consumers typically carry with them, it is able to undertake rich sensing. In this work, we mainly focus on the sensing aspect of these phones, which can use the accelerometer, microphone, GSM radio, and/or GPS sensors to detect obstacles such potholes, bumps, brakes, and horns.Nericell addresses a variety of problems, including the use of energy-efficient methods for localization and honk identification as wellas the ability to digitally realign a phone's accelerometer at any angle. We also go over the idea of triggered sensing, which conserves energy by utilising a variety ofsensors in concert with one another. Using promising results from studies conducted on Bangalore's highways, we evaluate the effectiveness of Nericell's sensing functions.

Road surface prediction from acoustical measurements in the tire cavity using support vectormachine
Johannes Masino [a 1], Julien Pinay [a 1], Markus Reischl [b],Frank Gauterin [a]

Traffic noise ruins people's enjoyment of their quality oflife and is a major source of speech disruptions, sleep disturbances, and general discomfort when it comes to areas near highways. Because it drives up the cost of noise abatement and depresses the value of homes closeto large road transit hubs, it also affects the economy. However, the existing methods for identifying tyre and road noise are difficult to use, expensive, and do not permit precise assessment.We present a novel method and an exploitation model that uses tyre cavity soundcaptured during routine driving to forecast different typesof road surfaces. With the use of the road surface data, other metrics such as rolling resistance, tire/road noise, and tire/road friction can be estimated. Our method is widely applicable and low-cost.

Our measuring equipment can be installed in regular cars,and unlike special measurement vehicles that include laser profilometers, our technology can interpret the data automatically. This makes it feasible to keep an eye on the road infrastructure all the time rather than just once everythree to four years.To test our classifier, we used data thathad not been used for training. After post-processing, ourfinal classifier achieves 91.8% accuracy with 95.1 and 90.6% average precision and recall, respectively. Utilising additional variables, such weather data, our model's output may create a digital map that would automaticallyidentify dangerous regions or noisy roads with low tyre road friction. This might be an essential part of advanceddriver assistance systems. A suitable vehicle speed restriction could be achieved in accordance with the recognised road hazards. Road infrastructure operators and civil engineering departments could use this application to maintain the complete road infrastructure more efficiently.

III. METHODOLOGY

A. Existing System

The existing systems is road surfaces based on going inthe direction of detection using cameras with smartphone cameras.Use a mobile Android device to perform real-time detection of anomalies, e.g., potholesand cracks.

Close Proximity method (CPX) is the name of a methodology based on test-tyre rolling on the road withmeasuring microphones located close to the tyre surface.Tyre-road noise is mainly due to the combination of airborne noise and structure-borne noise.However, this methodology has some drawbacks,Influence of bad weather, shadow, and

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light variations on the results.

That it requires a very complicated hardware and software setup with low final performance. Many studies are available about the correlation between roadsurface quality and tyre-road noise.

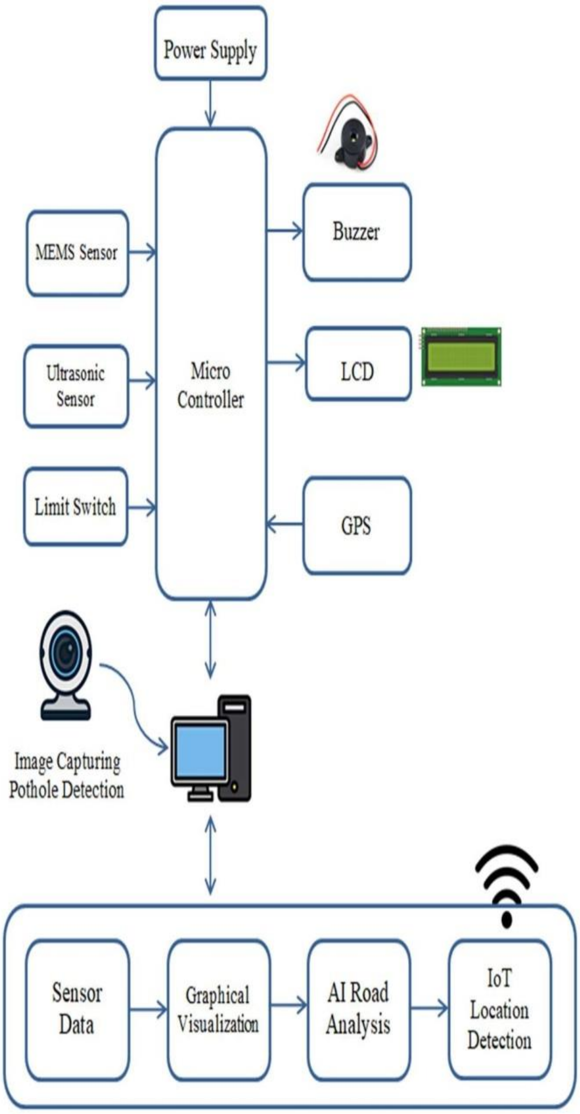
B. Proposed System

A modified sensor placed inside vehicle achieving aperfect insulation from external noise and weather condition.

Design of different architectures taking into account the memory footprint and execution constraints required by the embedded system.

By observing the classifier prediction on mocked data input, it was possible to verify the reliability of the final model on the real hardware. As was foreseeable,the board processes the data and simultaneously detects the correct class of the received input vectors.In addition, we checked the functionality of sensor data.

C. Proposed Block Diagram



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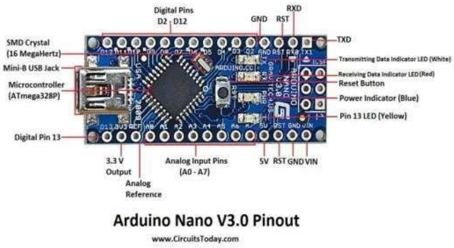
Hardware Description(i)Arduino Nano



Arduino Nano V3.0 Pinout

Arduino is an open source platform for prototyping based on user-friendly software. It provides a flexible base for engineers to experiment on designing interactive environments.

Its main components are,
1. 14 digital input/output pins(6 can be used as PWMoutputs)
2. 6 analog inputs(can also be used for digital I/O so atotal of 20 digital I/O's)
3. 16 MHz crystal oscillator
4. USB connection
5. Reset button

Although it comes in a different package, Arduino Nano shares many of the same features as Arduino Duemilanove. Similar to the Arduino UNO, the Nano is built with an ATmega328P microprocessor. The primary distinction between the two is that the Nano is offered in a TQFP (plastic quad flat pack) configuration with 32 pins, while the UNO board is supplied in a PDIP (Plastic Dual-In-line Package) shape with 30 pins. While the Arduino Nano has eight ADC ports compared to the UNO's six, the extra two pins on the Nano are used for ADC functions. Unlike other Arduino boards, the Nano board contains a mini-USB connector in place of a DC power jack. Both serial monitoring and programming are done on this port.

Accelerometer

The world's first Motion Tracking components, the MPU- 6050TM parts are made to meet the low power, low cost, and high performance needs of wearable sensors. The complete 6-axis motion tracking device is the MPU6050 sensor module. It is a compact kit that includes a 3-axis Gyroscope, a 3-axis Accelerometer, and a Digital Motion Processor. It also includes an on-chip temperature sensor as an extra feature. It can communicate with the microcontrollers thanks to its I2C bus interface.

1. Vehicle Dynamics Analysis: Vehicles equipped with accelerators are able to gauge the acceleration forces they encounter while driving. Engineers are able to evaluate a vehicle's handling qualities, stability, and general performance on various road conditions by examining these acceleration patterns. Road design engineers, safety researchers, and automakers can all benefit from this data.

2. Road Roughness Estimation: Accelerometers measure vibrations transferred to the vehicle's chassis, which can be used to determine road roughness. Vibration intensity can help authorities prioritise maintenance and enhancement projects by revealing theroughness of the road surface.

3. Pothole Detection: Vehicle jolts and collisions can be detected by accelerometers, which might reveal potholes or other surface flaws in the road. Potholes can be found and repairs can be scheduled by authorities using accelerometer data from several vehicles.

4. Tire-Track Analysis: Accelerometers can also be used to analyze tire-track patterns left by vehicles on the road surface. This information can be used to study tire- road interaction, assess tire performance, and understand how different road conditions affect tire wear and traction.

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5. **Road Load Data Collection:** Accelerometers can collect road load data, including vertical, lateral, and longitudinal forces acting on vehicles. This data is essential for evaluating road infrastructure durability, designing pavement structures, and ensuring roads canwithstand the stresses imposed by traffic.

6. **Vehicle Speed Monitoring:**In addition to analyzing vehicle dynamics, accelerometers can measure vehicle speed accurately. This data is useful for traffic management, speed enforcement, and analyzing vehicle behavior in different road conditions.

Ultrasonic Sensor
Ultrasonic sensors can be valuable tools for road surface analysis due to their ability to measure distances accurately and detect objects in their vicinity.

Here are some ways ultrasonic sensors can be used in road surface analysis:**Pavement Quality Assessment:** Ultrasonic sensors can be used to measure the thickness of road pavement layers. By analyzing the thickness of each layer (such asasphalt, base, and sub-base), engineers can assess the quality of the road surface and identify areas that may require maintenance or repair.

1. **Surface Roughness Measurement:** Ultrasonicsensors can also be used to measure the roughness of road surfaces. By analyzing the time it takes for ultrasonic waves to bounce back from the road surface, engineers can calculate surface roughness values. This information is crucial for evaluating ride comfort and safety, especially on highways and high-speed roads.

2. **Crack Detection:** Ultrasonic sensors can detect cracks and defects in road surfaces by sending ultrasonic waves and analyzing the reflections. This helps in identifying areas where cracks are forming or have already developed, allowing authorities to take proactive maintenance measures.

3. **Traffic Monitoring:** In addition to surface analysis, ultrasonic sensors can be used for traffic monitoring purposes. They can measure vehicle speeds, count traffic flow, and detect vehicles in specific lanes. This data is valuable for traffic management and planning road maintenance activities.

4. **Winter Road Condition Monitoring:** Ultrasonic sensors can also be used to monitor road conditions during winter, such as detecting the presence of ice or snow on the road surface. This information can be usedto alert drivers and authorities about potentiallyhazardous conditions.

Push buttons: Electrical actuators called push button switches, also called pushbutton switches, are designed to close or open the electrical circuits to whichthey are connected when pressed. Many different electronic devices can be controlled by them. Typically,these switches resemble buttons or keys.

Buzzers: An audio signalling device, often known as a buzzer or beeper, can be piezoelectric, electromechanical, or mechanical. Buzzers and beepersare frequently used in alarm systems, timers, training systems, and as a means of verifying user input, such as mouse clicks and keystrokes.

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(ii) LCD (LIQUID CRYSTAL DISPLAY)

LCD Display

LCD (Liquid Crystal Display) screens have a wide range of applications across various industries and projects. Inthe context of road surface analysis, LCD displays can be used in several ways:

1. **Real-Time Data Display:** LCD displays can show real-time data collected from sensors installed on roads. This data can include information about road conditions such as temperature, moisture levels, and surface roughness. Displaying real-time data allows engineers and authorities to monitor road conditions continuously.

2. **Data Visualization:** LCD displays can present data in graphical formats such as charts, graphs, and maps. This visualization helps in analyzing trends, patterns, and anomalies in road surface data. For example, displaying a graph of road roughness measurements over time canhelp identify areas that need maintenance.

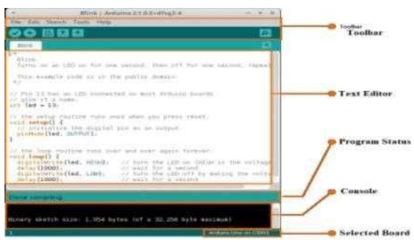
3. **Alerts and Warnings:** LCD displays can be used todisplay alerts and warnings regarding road hazards or abnormal conditions. For instance, if a section of the road becomes icy or develops a pothole, the display can alert drivers and authorities to take necessary actions.

4. **Traffic Information**: LCD displays can show traffic- related information such as speed limits, traffic congestion, and road closures/diversions. This information is helpful for drivers to make informed decisions while navigating roads.

5. **Interactive Interfaces:** LCD displays can serve asinteractive interfaces for users to input data or select options. For example, users can input specific locations for analyzing road conditions or select different parameters for data collection.

6. **Maintenance Scheduling:** LCD displays can be usedto schedule and display maintenance activities related toroad surfaces. This includes information about upcomingmaintenance tasks, schedules, and progress updates.

7. **Public Information Displays:** In public areas, LCD displays can provide information about road constructionprojects, detours, and safety tips for drivers andpedestrians.



8. **Remote Monitoring:** LCD displays can be part of remote monitoring systems, allowing engineers and authorities to monitor road conditions from a central location. This enables quick responses to changing road conditions and improves overall road safety.Overall, LCD displays play a crucial role in road surface analysis by providing visual information, alerts, and interactive interfaces for monitoring and managing road conditions effectively.

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Power Supplies

A power supply, often known as a power supply unit, or PSU, is a piece of machinery or a system that supplies electricity or another type of energy to one or more output loads. The most common usage of the phrase is in relation to electrical energy sources; mentions of mechanical andother sources are less common. This circuit's modest +5V power supply is a useful tool for digital electronics experiments.You can easily find small, low-cost wall transformers with a changeable output voltage at any grocery or electronics store.

Arduino IDE:

Utilising the Arduino IDE (Integrated Development Environment), one may programme the Arduino board software. It can be found on the internetas an open source.

Bootloader:

The bootloader is the programme that is loaded onto the ATmega 328 to allow programming of the ATmega 328 through the Arduino IDE. The Bootloader is loaded when the board is first turned on or reset. It writes to the microcontroller's programme memory via serial connection when it receives a signal from the IDE that a new programme needs to be uploaded.

Python IDE

Python is a broad-application programming language that is high-level and interpreted. Guido van Rossum developed Python, which was first released in 1991. Its design philosophy heavily utilises whitespace and places a high priority on readability of the code. It provides building elements for both little and large programming that are easy to understand. In July 2018, Van Rossum announced his resignation as leader of the linguistic community. Python features a dynamic type system andautomated memory management.

It supports several different programming paradigms, including imperative, functional, procedural, and object-oriented programming, and has a large and comprehensive standard library. Numerous operating systems have Python interpreters available. C The standard implementation of Python, like nearly all of its other implementations, is free software with a community-based development methodology. Python and C Python are governed by the nonprofit Python Software Foundation. Not all of Python's functionality was intended to be incorporated into it; rather, it was designed to be readily extensible.

IV. RESULT AND DISCUSSION

In conclusion, this research presents a novel approach using deep learning models deployed on edge devices to address the critical issue of pothole detectionin asphalt pavement. By leveraging MEMS signals from on-car sensors and processing data in the time- frequency domain, the proposed system demonstrates promising capabilities in accurately identifying and classifying various types of pavement distress, with a specific focus on potholes.The experimental results highlight the effectiveness of the system in real-time detection and classification of road pavement surface conditions, showcasing notableclassification rates and contributing to enhancing roadway safety and maintenance efforts. This cost- effective and efficient system has the potential to significantly improve road infrastructure management, leading to smoother and safer commuting experiences for all road users, both in developed and underdevelopednations.

V. CONCLUSION

Our expectations for the next phases are high thanks to the experiments that have been completed. With the intended device, new acquisition campaigns are specifically planned. This will allow the membership categories to be expanded and the model's resilience to be increased.

Our hopes for the next phases are high thanks to the experiments that have been completed. With the intended device, new acquisition campaigns are specifically planned. This will allow the membership categories to be expanded and the model's resilience to be increased. The algorithm operates as anticipated, executing real-time processing, classification, and PC communication, yielding extremely encouraging initial results.

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