Journal of Artificial Intelligence and Engineering Applications

Website: https://ioinformatic.org/

15th October 2025. Vol. 5. No. 1; e-ISSN: 2808-4519

Design of an IoT-Based Road Condition Monitoring System Using NodeMCU, Ultrasonic Sensor, and Vibration Sensor

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Abstract

This study designs an Internet of Things (IoT)-based road condition monitoring system using NodeMCU ESP8266, the HC-SR04 ultrasonic sensor, and the SW-420 vibration sensor. The system is designed to detect road damage such as potholes and uneven surfaces by combining distance measurement and vibration detection, then transmitting the data in real time to the Blynk application. The research employs a prototyping method and is tested on a remote-controlled (RC) car equipped with sensors, which is operated on a simulated track with varying road surface conditions. The test results demonstrate that the system is capable of detecting changes in road surface elevation and vibrations with high accuracy, and transmitting the data to the Blynk application with a delay of less than two seconds. This system has proven effective as a fast, accurate, and integrated tool for monitoring road conditions to support road maintenance and improve road user safety.

Keywords: *IoT, NodeMCU ESP8266, Road Monitoring, Ultrasonic Sensor, Vibration Sensor*

1. Introductions

Good road conditions are an essential factor in supporting smooth transportation and ensuring the safety of road users. However, in many regions, road damage such as potholes, cracks, and uneven surfaces is still commonly found. Road condition monitoring is generally carried out manually by field officers, which is often inefficient and results in delays in the repair process[1].

he development of Internet of Things (IoT) technology provides opportunities to implement automated monitoring systems capable of detecting road conditions in real time. Previous studies have utilized IoT in various fields, such as building monitoring, air quality assessment, and intelligent parking systems.[2]. However, the utilization of IoT for detecting road conditions by combining ultrasonic and vibration sensors is still rarely explored [3].

This study aims to design and implement an IoT-based road condition monitoring system using NodeMCU ESP8266, an ultrasonic sensor, and a vibration sensor. [4]. The data obtained from the sensors are transmitted in real time to the Blynk application as a monitoring interface. The system is expected to detect variations in road conditions (good, moderately damaged, and severely damaged) with high accuracy, making it an effective solution to support road infrastructure maintenance[5].

2. Theoretical Fondation

2.1 Internet of Things (IoT)

IoT is a technological concept that enables physical devices to be interconnected through the internet to collect, transmit, and analyze data in real time. Its application in public infrastructure allows for automated and efficient monitoring, including on road networks[6].

2.2 NodeMCU ESP8266

NodeMCU ESP8266 is a Wi-Fi–based microcontroller module equipped with data processing and wireless communication capabilities. This device has become one of the most popular components in the development of IoT-based systems due to its small size, low power consumption, affordable cost, and flexible programming support through the Arduino IDE. NodeMCU not only functions to read data from sensors but also processes the data before transmitting it to cloud platforms or monitoring applications. In this study, NodeMCU serves as the central controller that connects the ultrasonic sensor and vibration sensor to the Blynk application.

2.3 HC-SR04 Ultrasonic Sensor

The HC-SR04 ultrasonic sensor is a distance sensor that operates based on the principle of ultrasonic wave reflection. The sensor emits high-frequency sound waves through the trigger pin and then measures the time taken for the reflected waves to return to the echo pin. From this time difference, the sensor is able to determine the distance between the sensor and an object. The HC-SR04 provides fairly good accuracy for measuring distances at short to medium ranges. In this study, the ultrasonic sensor is used to detect changes in road surface elevation, such as uneven surfaces or potholes.

2.4 SW-420 Vibration Sensor

The SW-420 vibration sensor is a digital sensor used to detect shocks or vibrations on an object. It operates by utilizing signal changes caused by mechanical movements received by the module. When the detected vibration exceeds a certain threshold, the sensor provides a digital output signal. This function is highly relevant for detecting uneven road conditions, as the resulting vibrations can serve as an additional indicator alongside elevation measurements. In this study, the SW-420 sensor is paired with the ultrasonic sensor to strengthen the classification of road conditions.[7].

2.5 Platform Blynk

Blynk is an Internet of Things (IoT) platform that enables users to develop monitoring and control applications for hardware devices via smartphones. It provides a simple yet interactive interface, allowing users to view sensor data in real time, receive notifications, and control devices. The platform supports various types of microcontrollers, including NodeMCU ESP8266. In this study, Blynk is used to display the readings from the ultrasonic and vibration sensors, allowing road conditions to be monitored directly through mobile devices by users.[8].

3. Analysis and Planning

3.1 Research Methodology

This study employs the prototyping method, a system development approach that emphasizes the creation of an initial model (prototype) that is tested iteratively. This method is chosen because it provides a direct illustration of the system's functionality and allows for early evaluation of the accuracy of the sensors used.[9].

3.2 System Components

The system is designed using several main components, namely NodeMCU ESP8266 as the central controller, the HC-SR04 ultrasonic sensor for distance measurement, the SW-420 vibration sensor for shock detection, the LM2596 voltage regulator for power regulation, the 18650 battery as the energy source, and the Blynk application as the monitoring interface. All components are integrated into a single circuit to function in a coordinated manner.

Table 1: Tools and Materials

ALAT	BAHAN
LAPTOP/HP	NodeMCU ESP8266
ARDUINO IDE	Sensor Ultrasonik HC-SR04
APLIKASI BLYNK	Sensor Getar(Vibration Sensor SW-420)
KABEL USB	Breadboard dan Kabel Jumper
OBENG	Power Bank/Baterai 18650
WIFI	Modul Regulator Tegangan
MULTIMETER	

3.3 System Block Diagram

The system design is illustrated through a block diagram that describes the workflow. The sensors read the road conditions, the NodeMCU processes the data, and the measurement results are then transmitted via Wi-Fi to the Blynk application, where they can be visualized in real time.

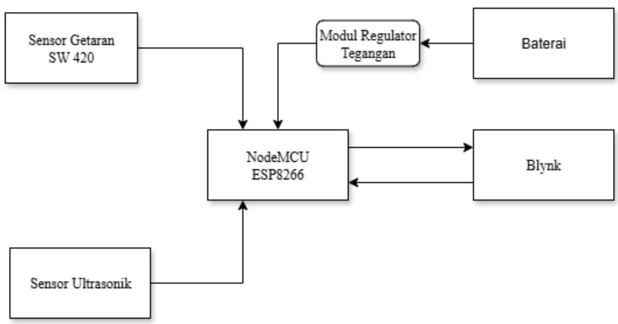

Fig. 1: System Block Diagram

3.4 Entire Range of Tools

This circuit functions to operate the system so that the device can work in accordance with the programmed specifications.

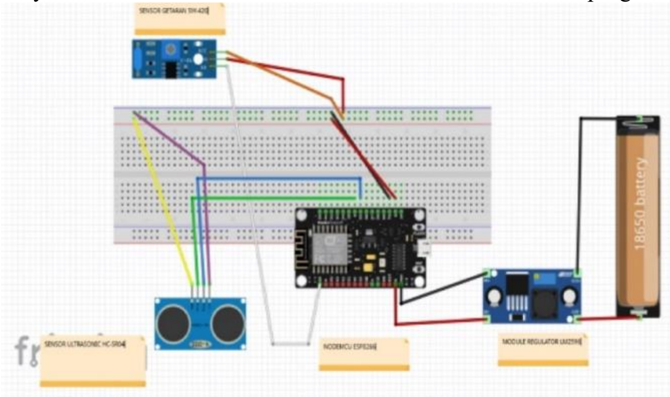

Fig. 2: System Schematic

3.5 Flowchart System

The system workflow is also described through a flowchart. The process begins with device initialization, followed by the NodeMCU connecting to Wi-Fi. After that, the sensors read distance and vibration data. The obtained data are classified into specific road conditions, and the system then sends the status and notifications to the Blynk application.

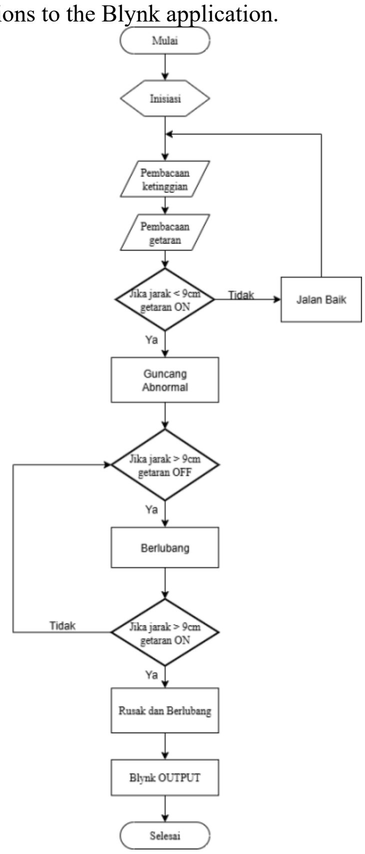

Fig. 3: Flowchart

4. Discussion and Implementation

This study produces an IoT-based road condition monitoring system that has been tested through the implementation of both hardware and software.

4.1 Hardware Implementation

The hardware is designed by placing the HC-SR04 ultrasonic sensor and the SW-420 vibration sensor on an RC car. The NodeMCU ESP8266 is used as the central controller, while the power supply is provided by a portable 18650 battery connected through a voltage regulator.

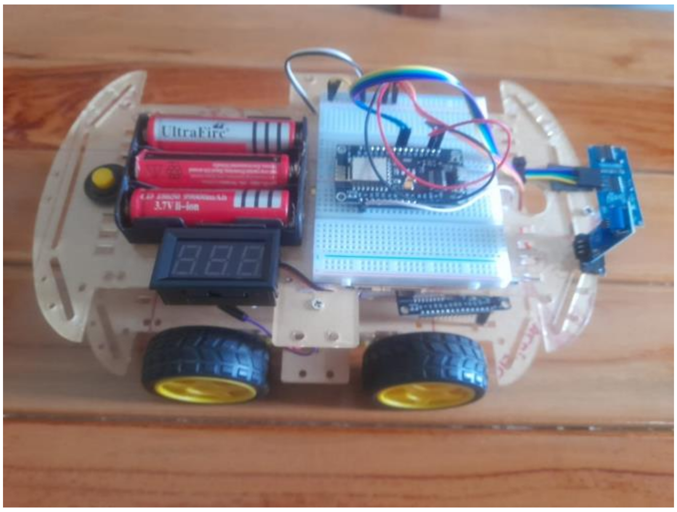

Fig. 4: The device is mounted on a toy car (RC)

4.2 Software Implementation

The system programming is carried out using the Arduino IDE. The NodeMCU is programmed to read data from the ultrasonic and vibration sensors, then process it into road condition status. The processed data are transmitted to the Blynk application via a Wi-Fi connection, allowing real-time monitoring.

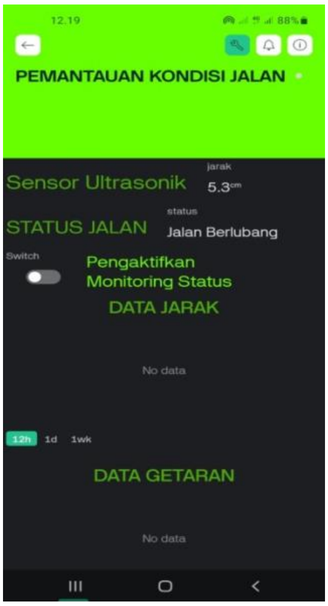

Fig. 5: Interface Appearance

4.3 System Testing

The testing was conducted by placing the entire circuit on a remote-controlled (RC) car. The car was operated on a simulated track with three different surface conditions: flat road, bumpy road, and pothole road. This testing aimed to evaluate the system's accuracy in directly detecting changes in road conditions.

Fig. 6: Reading data from sensors

4.4 Road Condition Testing Results
The testing was carried out on three types of road surfaces, namely:

Table 2: System Testing

No	Jenis Permukaan Jalan	Hasil Sensor Ultrasonik	Hasil Sensor Getaran	Status
1	Rata	1-9cm	On	Baik
2	Bergelombang/Lubang	>9cm	Off	Rusak(sedang)
3	Lubang Besar	>9cm	On	Rusak & Berlubang

4.5 System Performance
The system was tested in terms of the response time for transmitting data to the Blynk application. The results show that the data can be sent and displayed with a delay of less than two seconds, thereby supporting real-time road monitoring with consistent accuracy.

5. Conclusion
This study successfully designed and implemented an Internet of Things (IoT)-based road condition monitoring system using NodeMCU ESP8266 as the central controller, an ultrasonic sensor to detect changes in road surface elevation, and a vibration sensor to identify shocks. The experimental results demonstrate that the system is capable of detecting potholes and uneven road surfaces, and transmitting the data in real time to the Blynk application. The system's fast and accurate response proves that the design is effective as a tool for road condition monitoring, although it is still limited to a prototype scale with testing conducted using an RC car.

To make this system more optimal and applicable in real-world scenarios, several further developments are required. First, testing should be conducted using actual vehicles to better represent real road conditions. Second, integrating a GPS module is essential to provide accurate information on the location of road damage. Third, the addition of extra sensors such as cameras or LiDAR could enhance the detail of detection and classification of road conditions. Furthermore, the implementation of machine learning algorithms has the potential to strengthen the system's accuracy in automatically classifying road damage. Finally, further trials under varying weather conditions and different road surface types are necessary to ensure the system's reliability in diverse real-world situations.

With these developments, the IoT-based road monitoring system is expected to become a more comprehensive and effective solution in supporting road infrastructure maintenance and enhancing road user safety.

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