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Real-Time Monitoring of Building Cracks and Enhanced Vibrations through IoT

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Abstract

Building defects like cracks and vibrations also affects the daily routines, safety, emergency responses, public trust, and economics. Inhabitants face discomfort, and safety becomes a worry when the emergency responses are delayed, leading to an aberration in public opinion that affects both reputation and inhabitants' rate. The research addresses this complex scenario by employing low-cost sensors to detect cracks and vibrations in buildings, enhancing safety through emergency messages dispatched to mobile devices via the internet. Moreover, the research introduces real-time monitoring through an IoT platform, effectively tackling these challenges and mitigating their broad implications for buildings and communities. The manifold advantages of the approach include the cost-effective utilization of sensors, offering a financially feasible solution, while the real-time monitoring feature ensures swift action in response to emerging concerns. The entire process is orchestrated and managed by the NodeMCU microcontroller.

Keywords: Crack Detection, Flex Sensor, Piezoelectric Sensor, IoT, Blynk server, vibration detection

1. Introduction

In the realm of structural integrity and building safety, the imperative to develop innovative solutions has gained significant momentum. Addressing concerns that transcend superficial appearances, this research delves into a comprehensive approach aimed at the

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detection of pivotal building issues – cracks and vibrations[7-10]. Anchored with advanced technological principles, the work revolves around the deployment of specialized sensors – flex sensors for crack detection and piezoelectric sensors for vibration measurement. Guiding this intricate orchestration is the ESP8266 microcontroller, more commonly recognized as NodeMcu, which functions as the linchpin for efficient control and synchronization. When the vibration exceeds the threshold or if a crack is detected, it promptly sends notifications. Through the seamless integration of the Blynk server, the prospect of real-time monitoring of the building's structural health materializes, and in critical situations, prompt notifications are instantaneously dispatched via the same server. This amalgamation of components and systems yields a paradigm characterized by its cost-effectiveness and energy efficiency, amplifying not only the standards of safety but also instilling a novel era of proactive structural preservation[11-14].

2. Related Work

[1] The work discusses early detection of building collapse using IoT, with notable contributions from Niranjan.D.K and N. Rakesh, as discussed in ICIRCA-2020 Proceedings. [2] The 2022 study in the IEEE Sensors Journal unveils a flexible sensor tag utilizing split ring resonator (SRR) technology to detect cracks on curved metal surfaces. The tag uses resonance frequency shifts to detect cracks with remarkable sensitivity, offering potential for precise surface crack detection in curved metals. [3] Abdelrahman Khalil et al. (2023) proposed a method for early crack localization in flexible structures using outputonly measurements. The method constructs transmissibility operators from the output measurements, which are then used to predict the output at other locations on the structure. Any deviation from the predicted output can be used to indicate the presence of a crack. [4] Presented at the 2018 Workshop on Metrology for Industry 4.0 and IoT, the study authored by F. Lamonaca, C. Scuro, P.F. Sciammarella, D.L. Carnì, and R.S. Olivito discusses "Internet of Things for Structural Health Monitoring." [5] At the 2019 International Multitopic Conference (INMIC), the collaborative work of Haroon Malik, Khurram S. Khattak, Tousiq Wiqar, Zawar H. Khan, and Ahmed B. Altamimi was featured. Their study, titled "Low Cost Internet of Things Platform for Structural Health Monitoring," introduces an economical IoT platform designed for efficient structural health monitoring applications. [6] The "Concrete

Smart Sensors for Structural Health Monitoring – A Review" was discussed by Sneha M Varghese, Sajeeb R, and M. C. Philipose during the International Conference on Circuits and Systems in Digital Enterprise Technology (ICCSDET) in 2018.

3. Proposed Work

The proposed work will use a combination of flex sensors and piezoelectric sensors to detect building cracks and vibrations. Flex sensors are a type of sensor that measures the amount of bending or stretching that occurs in a material. The sensors are commonly made from materials such as piezoresistive or capacitive materials. Flex sensors can be used to detect cracks in materials by measuring the change in resistance or capacitance that occurs when the material is cracked. The Piezoelectric sensors are a type of sensor that produces an electrical signal in response to mechanical stress. Sensors are commonly made from materials such as quartz or barium titanate. Piezoelectric sensors can be used to detect cracks in materials by measuring the change in voltage that occurs when the material is cracked. The data from the sensors will be collected by a microcontroller and sent to a cloud-based platform. The microcontroller is a small computer that can be programmed to collect data from sensors and send it to a cloud-based platform. The cloudbased platform is a remote server that stores data and provides access to it over the internet. The cloud-based platform will be used to store the data and generate alerts when cracks or vibrations are detected. The data will be stored in a database and can be accessed by users over the internet. The cloud-based platform will also be used to generate alerts when cracks or vibrations are detected. These alerts can be sent to users via email, text message, or push notification.

3.1. Components

3.1.1 Flex Sensor: A flex sensor is a type of sensor that measures the amount of bending or flexing that occurs in a material. Flex sensors are commonly made from materials such as piezoresistive or capacitive materials. Flex sensors can be used to detect cracks in materials by measuring the change in resistance or capacitance that occurs when the material is cracked.

3.1.2. Piezoelectric Sensor: A piezoelectric sensor is a type of sensor that produces an electrical signal in response to mechanical stress. Piezoelectric sensors are commonly made from materials such as quartz or barium titanate. Piezoelectric sensors can be used to detect cracks in materials by measuring the change in voltage that occurs when the material is cracked.

3.1.3. NodeMCU: A NodeMCU is a development board that is based on the ESP8266 microcontroller. NodeMCUs are commonly used to create Internet of Things (IoT) devices. NodeMCUs can be programmed using the Arduino IDE.

3.1.4. Blynk Server: A Blynk server is a cloud-based platform that allows users to control IoT devices using a mobile app or web browser. Blynk servers provide a variety of features that make it easy to create and manage IoT devices.

3.2 Methodology

The technical workflow of the research begins with powering on the system, which activates the NodeMCU microcontroller. Upon initialization, the necessary libraries are configured from the Arduino library manager, and the NodeMCU establishes a WiFi connection. With a stable connection, the NodeMCU is ready to operate. The real-time signals from the sensors, namely the piezoelectric sensor and the flex sensor, are acquired by the NodeMCU.

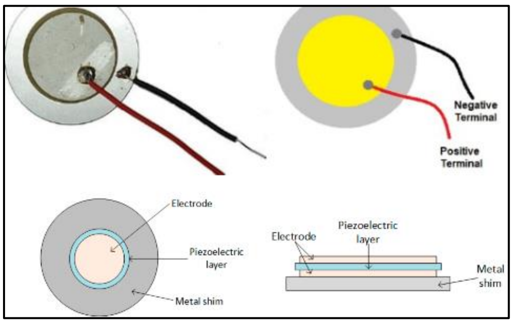

Figure 1. Construction of Piezoelectric Sensor

For the construction of piezoelectric sensor shown in Fig.1, vibrations are detected based on the principle of piezoelectricity, where mechanical stress generates electrical charges. When vibrations exceed a predefined threshold, the sensor responds by producing an electrical signal. This signal is then transmitted to the NodeMCU for processing. Simultaneously, the flex sensor monitors the building's structural integrity. When a crack occurs, the flex sensor undergoes physical deformation, leading to a change in its electrical properties. The construction of flex sensor can show in Fig.2.

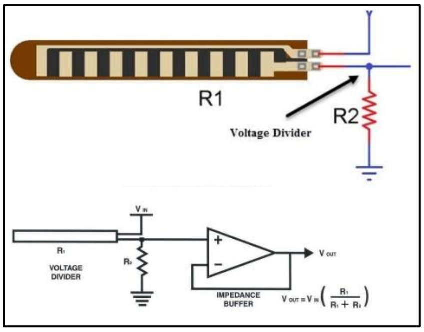

Figure 2. Construction of Flex Sensor [15]

The sensor registers this change and sends a corresponding signal to the NodeMCU. The NodeMCU processes the received signals through an Analog-to-Digital Converter (ADC) to convert analog data into digital format. Subsequently, the NodeMCU establishes a connection with the Blynk cloud server. The real-time sensor data, now in digital form, is transmitted to the Blynk server for monitoring and analysis. The Blynk server provides a user-friendly interface that displays the real-time condition of the building, showing vibration levels and crack status. When the piezoelectric sensor detects heightened vibrations beyond the threshold, it triggers an electrical response due to the piezoelectric effect. The NodeMCU interprets this response and promptly sends an emergency alert signal to mobile devices through the Blynk server. Similarly, in the event of a crack, the flex sensor reacts to the structural change by altering its electrical properties. This change is detected by the NodeMCU, which then initiates a notification process. The NodeMCU promptly sends a message to mobile devices via the Blynk server, indicating that a crack has been detected.

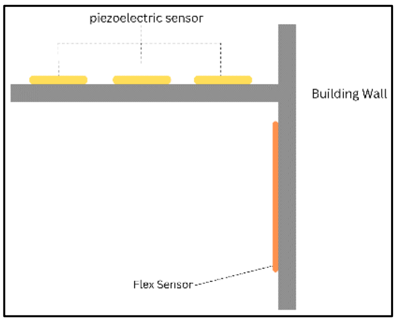

Figure 3. Placement of Sensors

Position the flex sensor and piezoelectric sensor on the building structure, placement of sensor is shown in Fig.3, as depicted in the previous diagram. The technical workflow commences with sensor data acquisition, followed by signal processing by the NodeMCU. The Blynk server facilitates real-time monitoring and alerts, ensuring that heightened vibrations and cracks are promptly detected and communicated to stakeholders.

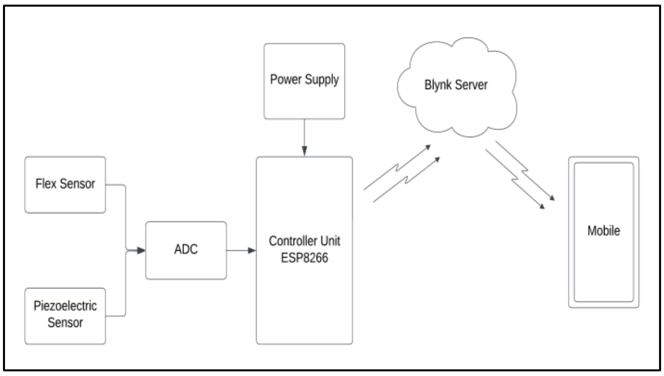

Figure 4. Block Diagram

3.3. Flowchart

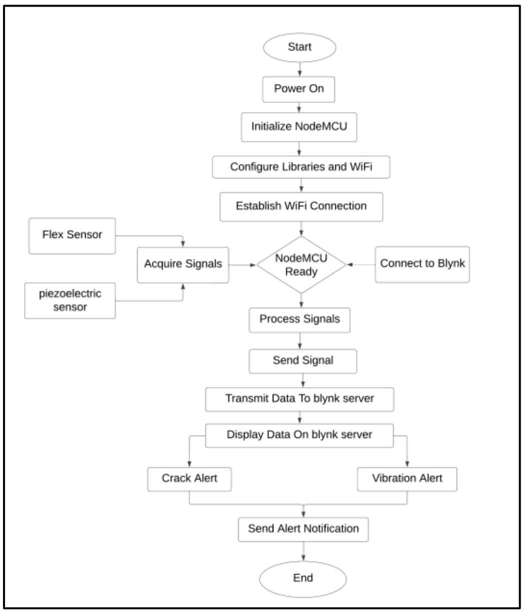

Figure 5. Flowchart of the Proposed Process

4. Discussion and Future Direction

The research implementation will be carried out in the future. The implementation will showcase the successful realization of an early detection system for building cracks and vibrations. Through the integration of flex and piezoelectric sensors, the ESP8266 microcontroller, and the Blynk cloud server, Blynk cloud interface shown in Fig.7, the system is capable of to monitoring the structural integrity effectively.

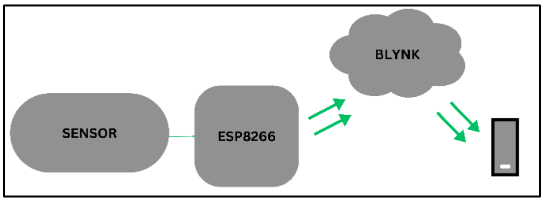

Figure 6. Workflow

The seamless interaction between these components, aided by the NodeMCU, ensured accurate data collection and processing. The integration of the Blynk cloud server would enable real-time data transmission and visualization on the user's mobile device. An interface will be designed in future to provide live information's on the level of vibration and the detection of cracks,. Emergency alerts triggered by the system further highlights its potential for enhancing the building safety.

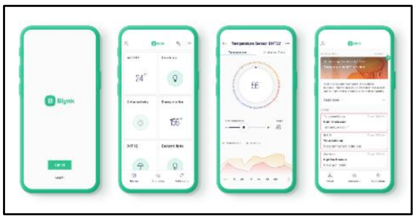

Figure 7. Blynk Mobile Interface [16]

In summary, the research's successful integration of sensors, microcontroller technology, cloud connectivity, and mobile interfaces emphasizes its significance in improving the building safety. By offering timely alerts and insights, the system contributes to more proactive and resilient urban infrastructure, aligning with the trajectory of smart city development.

5. Conclusion

In conclusion, the research showcases the potential of a comprehensive system for early detection of building cracks and heightened vibrations. By integrating flex and piezoelectric sensors, the ESP8266 microcontroller, and the Blynk cloud server, the research has laid the groundwork for an efficient real-time monitoring solution. The seamless interaction among these components underscores the significance of proactive building safety measures. In future the research work would be further enhanced by developing a prototype of the proposed model and the mobile interface for the same in order to give live information's to the users on the crack and the vibration detection.

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Author's biography

Hasan Basari A, born on December 24, 2002, in Trichy, Tamil Nadu, is a dedicated writer deeply influenced by his cultural heritage. In 2018, Hasan achieved a remarkable 96% distinction in Electronics and Communication Engineering, showcasing his dedication to the field. Currently pursuing a Bachelor of Engineering in the same department, his academic pursuits not only enhance his technical acumen but also provide unique perspectives that enrich his writing. With a solid foundation in academic excellence and a distinctive outlook on life, Hasan Basari A is poised for a promising literary journey, promising to captivate readers and make a lasting mark on the literary landscape.

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