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Autonomous sensor nodes for Structural Health Monitoring of bridges

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Abstract - *In today's modern world, development is at an all-time high. Thousands of new buildings, tunnels, bridges, expressways, and other challenging and complicated structures are being built every day to meet the growing requirements of people as a result of increased growth. The evolution can also be seen in the new materials and building techniques utilised. Because of the increased building of large structures, structural analysis has become a key task, as maintaining the structure's integrity is critical. Traditional methods of structure analysis aren't very useful and don't go far enough. Structural health monitoring (SHM) is a significant advancement in the examination of structures for damage detection and determining the presence of fractures and flaws. The SHM system increases the structure's safety and reliability while also lowering maintenance costs and increasing the structure's usable life. In India, practical uses of this technology are relatively uncommon and lag behind in the civil sector.*

***Key Words*: Arduino; ESP32; IoT; Wi-Fi, Android App;**

1. INTRODUCTION

Continuous structural health monitoring (SHM) systems for aeronautical, mechanical, and civil structures have a lot of promise to become a big part of the damage detection, life assessment, and failure prediction fields. For manufacturers, maintenance teams, and operators, knowing the integrity of in-service structures in real time is critical. SHM is a rising topic of study that merits new and novel techniques. Continuous monitoring necessitates the collecting of data from sensors fixed or implanted in the structure on a regular basis. The collected data is then examined to find any potential defects; also, the monitored system's remaining life can be forecasted.

Wireless Sensor Networks (WSNs) have evolved as a powerful low-cost platform for linking huge networks of sensors over the last decade. Commercial, health, military, and industrial settings have all used these networks. Structural Health Monitoring (SHM) is an example of this type of application, in which sensors are placed throughout a structure to measure its health. SHM systems have traditionally been built on wired sensor networks, but the great dependability and inexpensive installation and maintenance costs of WSNs have made them a tempting alternative platform. Wired sensor networks are often only practicable for long-term SHM applications where the structure's health is crucial due to their high installation costs.

The huge cost savings from deploying WSNs for SHM would allow them to be used in critical public and private infrastructure, as well as for applications like short-term structural monitoring. Such systems have the potential to increase the lifespan of many structures by allowing for earlier diagnosis of damage, reducing the expense of routine inspections, and, most importantly, improving public safety.

2. RELATED WORK

[1] The author has developed an integrated bridge health monitoring system based on WSN for bridge SHM. This system is comprehensive and practical because it combines a low-level data acquisition platform with a high-level data acquisition data analysis software.

The platform uses very little power, is flexible and shows scalability to all kind of sensors such as acceleration, temperature, and strain sensor.

The network topology uses up to 4 hops of multihop in the experiment. The software enables analysis of multiple types of dynamic response parameters including vibration, acceleration, dynamic displacements and loads or continuous bridge condition monitoring.

[2] The main objective of this study is to design and implement a new integrated WSN for impedance SHM system, under which communication and damage detection algorithms have been properly integrated with sensors, microcontrollers and wireless transceivers available on the market.

There are two main contributions to wireless SHM system, including from hardware to graphical interface. The first is the DAQ method, which is independent of the ADC sampling rate and yields a method of determining damage made by a simple comparison between RMS voltage variations obtained from piezoelectric response signals. This allows the development of systems with simpler hardware and software.

The second contributor is the WSU with its low range coverage and ability to scale to a large number of nodes that can be monitored worldwide. Therefore, a dense sensor grid operating on real-world structures becomes possible.

[3] The presented monitoring system has been successfully implemented and tested via real time deployment. The deployment showed that cable stay force monitoring parameters based on wireless sensor networks is feasible and that appropriate algorithms and strategies can be implemented which fit the limited memory and computation resources of the motes and provide reasonably accurate results.

The feasibility is basically based on the integration of four methods for reducing energy consumption. Those methods are ultra low power hardware components, multi hop communication, low duty cycle operation and data reduction.

The latter method, which achieves a significant reduction of transmitted data by decentralized data processing, is a major aspect which enables a long node lifetime. There are various software tools which have been developed to allow the monitoring system to access the aggregated data and configure the network and monitoring tasks in a suitable way.

[4]Characteristics of dynamic loads and their interactions with wind turbine towers is very important for future development technologically. Wireless sensor networks provide an inexpensive and easy-to-install platform for collecting data needed to build these necessary models.

In addition, wireless sensors, with their inherent on-board data processing capabilities, can be used to automate monitoring and damage detection in large-scale wind turbines in a cost-effective way. By demonstrating the effectiveness of wireless networks sensors in wind turbine environments to collect data and the construction of dynamic models of the structure, this study shows the first stage of the implementation improve the design and economic viability of wind energy technology.

3. MOTIVATION AND PROBLEM STATEMENT

There are many old heritage sites and structures in India, which are either owned by the state government or by individuals. Despite the passage of time and the effects of the climate, these historic structures are still surviving. It's a remarkable evidence of trustworthiness. Despite these old structures, high-rise buildings and other sophisticated structures are being constructed in India on a daily basis. Because big structures, such as large monuments, retail malls, hospitals, and schools, attract large crowds, it is critical to keep an eye on their safety and health. Hundreds of people will be harmed if one of these structures fails. Dams are also huge complex structures which involve various complex design, construction, maintenance process. Failure in these dams would cause a great amount of loss to economy and also to thousands of peoples. So monitoring the health conditions of dams is utmost important.

4. OBJECTIVES

1: Detecting the existence of the damage on the structure using WSN sensors.

2: Locating the damage in the structure

3: Identifying the type of damage

4: Quantifying the severity of the damage

5. TOOLS USED

5.1 HARDWARE COMPONENTS:

1. **ESP32 Microcontroller Board -** The ESP32 is a low-cost System-on-Chip (SoC) microcontroller that can function as a complete standalone system or as a slave device to a host MCU, reducing communication overhead on the main application processor. ESP32 can be connected to other systems to provide WiFi and Bluetooth functionality via its SPI/SDIO or I2C/UART interfaces.

2. **Temperature Sensor (DHT-11) -** DHT11 is a low-cost humidity and temperature sensor. The temperature range of DHT11 is from 0 to 50 degrees Celsius with +-2 degrees accuracy.

3. **Vibration sensor -** It is used in variety of shocks triggering, theft alarm, smart car, an earthquake alarm, motorcycle alarm. Vibration detection thresholds are dependent on stimulation frequency because they are mediated by different sensory receptors. According to the human psychophysical tuning curve, thresholds lie between ~20 nm to ~4.5 pm.

Specifications:

Operating voltage 3.3V / 5V

Interface Digital

Size L: 40mm W: 20mm H: 10mm

Weight 4.3g

Gross Weight 10g

4. **Pressure sensor -** Measure how hard or soft someone presses on a surface with this FSR (Force Sensitive Resistor).

- Pressure sensor is used here for measuring the pressure or the force on the bridge.
- The pressure sensor used in our project has a force sensitivity range of (100g - 10kg).
- It has a pressure sensitivity range of (0.1kg/cm^2 - 10 kg /cm^2).
- Operates within the range (30-60 degrees celsius).
- Overall length of the sensor is around 4.5 cm while the overall width of the sensor is around 0.7 cm.

5. **Water level sensor -** The purpose of a float switch is to open or close a circuit as the level of a liquid rises or falls.

Water sensor specifications:

Maximum Load: 50 W

Minimum Voltage: 250V DC

Max Load Current: 1.0 A

Max Switching Voltage: 100V DC

Max Contact Resistance: 0.4 Ω

Temp Rating: -20~ 80 degree

5.2 SOFTWARE:

1. **Arduino IDE -**The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus.

It connects to the Arduino hardware to upload programs and communicate with them.

2. **Thingspeak-**It is an open data platform for the Internet of Things.

Our device or application can communicate with ThingSpeak. You can either keep your data private, alternatively, make it public.

It provides users with free time-series data storage in channels.

6. BLOCK DIAGRAM

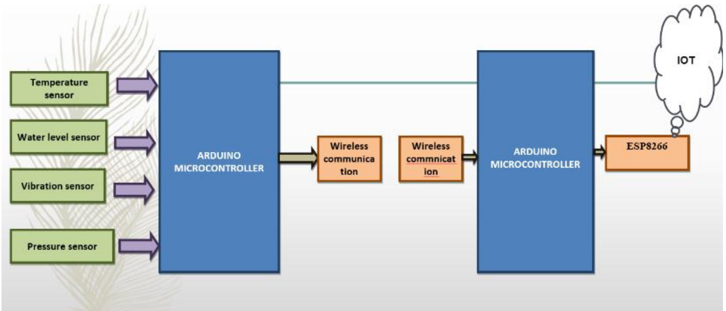


Fig-1: WSN communication

7. METHODOLOGY

- Arduino UNO is used as the backbone of this project all the sensors are interfaced with this microcontroller.
- Temperature sensor is used for checking the environmental temperature.
- Water level sensor is used to know the level of water in the bridge.
- Vibration sensor is used to know the vibration level that indicates there is any vibration of earthquake in the surroundings.
- Pressure sensor is used to know pressure or the force from the vehicle on the bridge.

The bridge health monitoring system composed of:

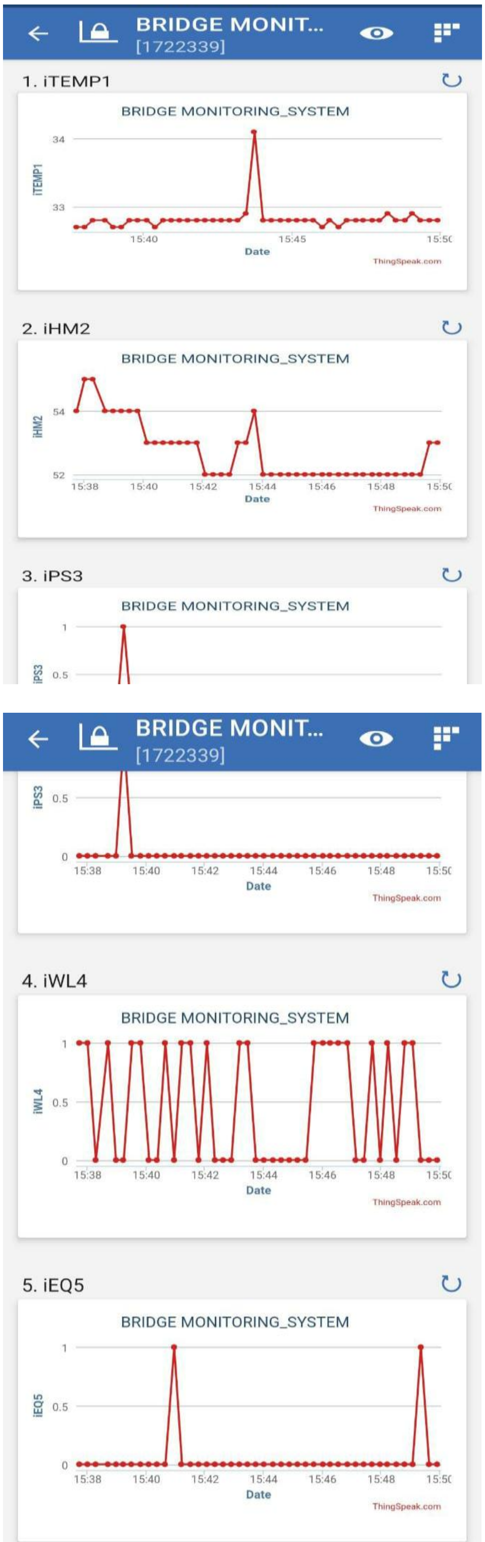
(1) Monitoring devices installed in the bridge environment.

(2) Communication devices connecting the bridge monitoring system and cloud based server.

(3) Creating a dynamic database that stores bridge condition data.

The detected data are transmitted to the server and database for the users to have real time monitoring of the bridge conditions via mobile telecommunication devices.

8. RESULTS



9. CONCLUSIONS

A durable and effective system requires an efficient design of a sensor network for application in structural health monitoring. A successful design must consider a variety of factors, including the sort of measurement necessary, the type of sensor used, and the number and location of sensors. Furthermore, the sensors' energy supply is critical because it affects their operation, as well as the amount of data acquired. While providing a continuous source of electricity would allow for continuous data collecting, the vast volume of data produced could pose significant transmission and storage issues. In a network, redundant sensors may improve the system's robustness, but this is predicted to increase the cost.

10. REFERENCES

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