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Bridge Health Monitoring System using IOT

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Abstract: *This research paper presents a The bridge is an important transportation infrastructure for the development of social and economic activities of a country. Indonesia has a lot of long-span bridges which need regular monitoring and maintenance. All of these bridges are managed and supervised by the Indonesia Ministry of Public Works. The fact, that the bridges are located in a remote area and provide difficulty in data management. Therefore, it need a system to monitor on the health of the bridges in real time and centralized in order to manage these bridges. Few of literature describing the structural health monitoring (SHM) system based on wireless sensor network (WSN) implementing for several bridges. In this project the system is designed for IOT based monitoring acceleration in 3 dimensions, tilt, variation in height and vibration. Thus this project can monitor bridges located on remote area by a single station with complete considerations including time efficiency, human resource efficiency and without risking human life.*

Keywords*:* Bridge health monitoring, IoT, Structural Health Monitoring, Wireless Sensor Network, Damage Detection

I. INTRODUCTION

Introduction Bridges are unarguably one key components of the transportation infrastructure in modern days. As stated in the 2008 Transportation Statistics Annual Report, total of 599,766 bridges are currently in use in the United States of America. To ensure the safety of the users,the Federal Highway Administration (FHWA) requires ail bridges to be inspected at a 2-year interval following the National Bridge Inspection Standards (NBIS). The NBIS represents the national standards for the proper safety inspection and evaluation of all highway bridges in accordance to the federal law of United Sates,23 U.S.C. 151. Statistics show that there is approximately 25nation's bridges have received ratings of either structurally deficient or functionally obsolete. NBIS suggests that the rating of functionally obsolete is used to describe a bridge that is no longer by design functionally adequate for its task while the rating of structurally deficient is used to describe a bridge that has one or more structural defects that require attention. Nonetheless, all bridges are susceptible to damages caused by road users, environmental impacts as well as aging process. The changes to structural properties of a bridge caused by damage will change the way the bridge responds to ambient motions. For an example, steel corrosion (damage) results in a reduction in the cross sectional area of a steel member and lead to a reduction in the stiffness(structural properties) of structural elements. The change in modal properties (i.e. modal frequency, damping ratio and mode shape) due to the change in stiffness can be captured through modal analysis of vibration response. Therefore with the vibration responses collected through sensor monitoring,modal properties can be extracted through the use of modal analysis algorithm and the structural condition of a bridge can be evaluated. oT The Internet of things (IoT) is the inter-networking of physical devices, vehicles (also referred to as "connected devices" and "smart devices"), buildings, and other it emsembedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data. The IoT allows objects to be sensed or controlled remotely across existing network infrastructure, creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit in addition to reduced human intervention. When IoT is augmented with sensors and actuators, the technology becomes an instance of the more general class of cyber physical systems, which also encompasses technologies such as smart grids, virtual power plants, smart homes, intelligent transportation and smart cities.

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II. LITERATURE REVIEW

BHM faces many challenges, such as fatigue and corrosion evaluation, scour effects, etc.

Rizzo, P.; Enshaeian, A. [1], requiring further research to propose better solutions. In this paper, we provide an overview of the research progress in BHM technology in recent years and summarize the research on the damage identification of bridge structures.Alwis, L.S.M. [2] Fiber optical sensors (FOS) have emerged as an excellent sensing technology due to their inherent advantages such as small size, light weight, strong anti-electromagnetic interference capability, corrosion resistance, and embeddabilityHou et al. [3] studied the method for accurately associating traffic load with bridge response. In their proposed framework, a computer vision approach based on DL was used to accurately identify trucks from field images. The framework was applied to a 20-mile highway corridor to verify the correlation between bridge response peak and measured truck weight, based on one year's measured data. In practice, the existing identification methods usually require prior information of the road to locate the traffic load, which is tricky in some cases.Ju et al. [4] introduced a recursive neural network when studying the temporal correlation of data, and built a framework for abnormal data recovery. The monitoring data of the Bund Bridge in Ningbo, China were used to verify the accuracy of their framework. Deng et al. [5] developed a platform based on Revit to realize visual warnings and the integrated management of monitoring information. They associated monitoring data with a BIM model through a virtual sensor system and then imported it into Revit. Xia et al. [6] used a GP metamodel to replace the 3D finite element model of the bridge for updating. They first studied the thermal effect mechanism of the bridge deck and established the relationship between the longitudinal boundary stiffness (LBS) and the structural temperature. The GP metamodel was then used to map the relationship between LBS and longitudinal displacement. Lin et al. [7] also used a GP model to replace FEM in a study of model updating methods based on influence lines. In a case study of a long-span suspension bridge, this substitution improved the efficiency of the iterative optimization of boundary condition estimates. Chen et al. [8] proposed a two-stage method for bridge FEMU. The proposed method combined a radial basis function (RBF) neural network and Bayesian theory. The feasibility of this method was verified by a series of numerical and laboratory experiments.

III. WORKING

Step 1:Sensing Vibrations A motion sensor ADXL345) is mounted on the bridge structure.It continuously detects vibrations, tilts, or acceleration caused by:Moving vehicles,Structural stress,Environmental conditions (e.g., wind, earthquake).

Step 2: Data Transmission via Node MCUThe sensor sends the data to a NodeMCU ESP8266, a microcontroller with built-in Wi-Fi.The I2C communication protocol is used to read sensor data (SDA and SCL pins).

Step 3: Wi-Fi Communication NodeMCU connects to a Wi-Fi network and pushes data to a cloud server or IoT platform like:Thingspeak,Blynk,Firebase,Google Sheets (via APIs).

Step 4: Web Interface or App DisplayThe user (engineer/authority) logs into a dashboard or app to:View live vibration/tilt graphs.Analyze historical data trends.Get alerts for critical values.

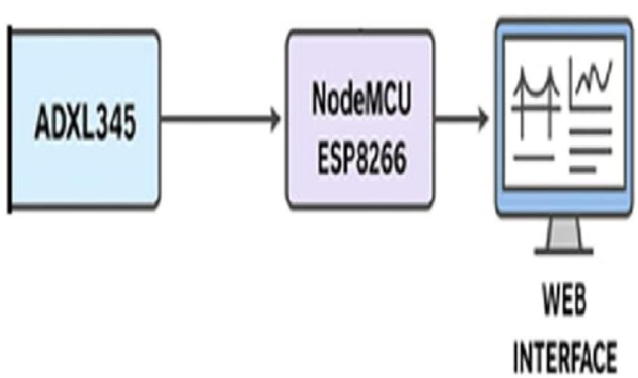

FIG. BLOCK DIAGRAM

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Block Diagram Components Explanation

ADXL345 (Accelerometer Sensor)

Function: Measures acceleration, vibration, and tilt. In this system, it's used to detect structural movements or vibrations in a bridge.

Type: 3-axis digital accelerometer.

Output: Sends motion data via I2C/SPI to the microcontroller.

NodeMCU (ESP8266)

Function: Acts as the main IoT controller.

Role:

Collects sensor data from the ADXL345.

Connects to Wi-Fi using the built-in ESP8266 module.

Transmits the data to a cloud server or web-based application.

Bonus: Supports web interface hosting and HTTP/MQTT protocols.

Wi-Fi

Function: Receives real-time data from NodeMCU.

Use: Can be a local web server, Google Firebase, Thingspeak, Blynk, or any IoT cloud platform.

Purpose: Enables remote monitoring, storage, and analysis of structural health data.

Web Interface

Function: Visualizes the real-time data.

Displayed Data: Vibration graphs, historical trends, alerts, or structural anomaly detection.

Users: Engineers, inspectors, or authorities who monitor bridge health remotely.

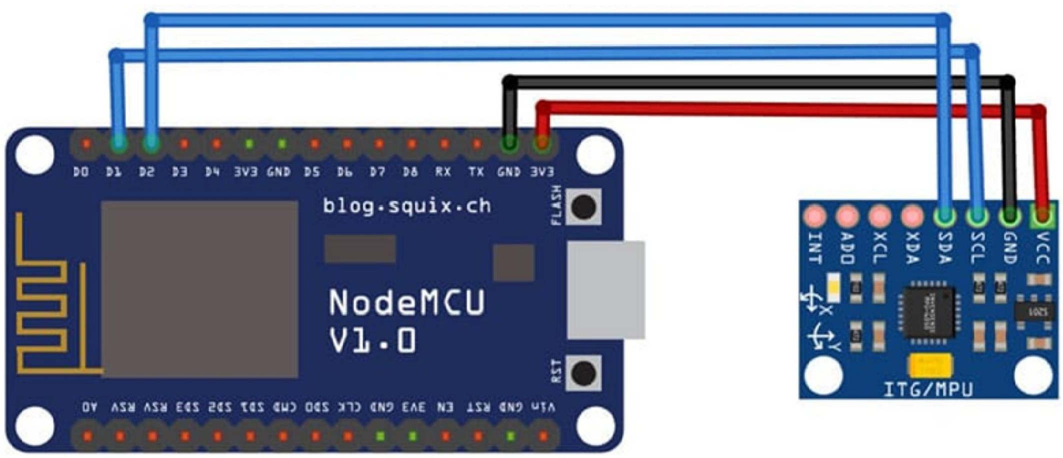

FIG. CIRCUIT DIAGRAM

Working Concept

The ADXL 345 senses any motion or vibration from the structure (e.g., a bridge).

It sends this motion data (acceleration and rotation) to the NodeMCU via I2C.

The NodeMCU can:

Display the data on a web dashboard.

Send it to a cloud platform like Thingspeak, Blynk, or Firebase.

Trigger alerts if motion exceeds safe thresholds

Wiring Connections

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MPU6050 Pin	Connected to NodeMCU Pin	Purpose
VCC	3V3	Power supply (+3.3V)
GND	GND	Ground connection
SCL	D1 (GPIO5)	I2C Clock line
SDA	D2 (GPIO4)	I2C Data line

Note:

The MPU6050 operates on 3.3V, which is why it's connected to the 3V3 pin, not 5V.

I2C communication requires only two wires: SDA and SCL, making it ideal for sensor communication in IoT projects.

IV. SYSTEM REQUIREMENT

The system requirements for the Bridge health monitoring system using iot System include both hardware and software components essential for its operation. On the hardware side, the setup consists of an PCB board, jumper wires, Accelerometer ADXL sensor for measure vibrations, tilt and acceleration, Nodemcu(ESP8266 for microcontroller with wifi for data p ESP8266 board and web server code processing and transmission For software requirement Arduino IDE ESP8266 and web server code.

V. HARDWARE REQUIREMENT

This chapter explains the key hardware components used in the Bridge health monitoring system using IoT. It covers each element's function, features, and specifications, forming the foundation for system design and software .Electronic Parts:

In this section, we will explore the key electronic components used in the development of our Bridge health monitoring system using IoT. Each component plays a crucial role in controlling, powering, and coordinating the various functions of the health monitoring to ensure accurate and efficient operation. [12:07 AM, 6/19/2025] Pranoti: hardware requirements for a Bridge Health Monitoring System using IoT in MPU6050 or ADXL345 Sensor: These are vibration and motion sensors that measure acceleration and tilt in three directions (X, Y, Z). NodeMCU (ESP8266): A microcontroller with built-in Wi-Fi that reads sensor data and sends it to the internet.. Power Supply: A battery or USB adapter to power the NodeMCU and sensor (usually 3.3V or 5V).Jumper Wires: Used to make connections between the sensor, NodeMCU, and power supply.

TABLE 1

Sr. No	Component name
1.	Accelerometer ADXL345
2.	NodeMCU
3.	PCB
4.	Arduino IDE
5.	Jumper wires
6.	Web Interface

SOFTWARE REQUIREMENT

This section covers the software tools that control the Bridge health monitoring system using IoT operations.

1. Arduino IDE

The Arduino Integrated Development Environment (IDE) is a free, open-source software platform used to write, compile, and upload code to Arduino boards.

Key Features of Arduino IDE

Code Editing Interface: Simple environment to write and edit C/C++ code.

Board and Port Selection: Allows easy selection of the target board (e.g., Arduino Mega 2560) and USB communication port.

Library Management: Provides a built-in library manager to include external packages.

Serial Monitor: Real-time communication with the board for
debugging and sending commands.Cross-Platform Support: Available for Windows, Linux, and macOS.

Steps to Use Arduino IDE
Download and Install Arduino IDE
Available from https://www.arduino.cc/en/software
Install the latest version and launch the IDE.
Install Board Support
Go to Tools > Board > Boards Manager.
Install support for ESP Boards (includes Node MCU ESP 8266).
Connect Node MCU
Plug in the Node MCU via USB.
Select Tools > Board >Node MCU.
Select the correct port under tools.

VI. CONCLUSION

Based on the potential combinations of different available sensors and systems, the range of applications is virtually endless. Application of structural health monitoring technologies to bridges has seen great increase in the past decade. Initial results from these applications have shown the capability of available IoT Based technologies in monitoring, analyzing, and understanding the health of the monitored bridges. Since most of case studies and applications are just in past recent years, it is necessary to examine their performance and results over a long time by continuous monitoring to determine the durability and reliability of these systems.

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