IOT based Bridge Safety Monitoring System

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***Abstract*—Advancements in sensor technology have brought the automated real-time bridge health monitoring system. Our system is composed of (i) Monitoring devices installed in the bridge environment. (ii)Communication devices connecting the bridge monitoring system and cloud based server. (iii)A dynamic database that stores bridge condition data. (iv)A cloud based server that calculates and analyses data transmitted from the monitoring devices. This system can monitor and analyse real time condition of bridge and its environment.**

***Index Terms*—Bridge safety Monitoring, Internet of Things (IoT), Flood Conditions, Monitoring Centre, TCP/IP, WI-FI Module, Sensors, Data Analysis.**

I. Introduction

Transport plays an important role in today's life. Bridges are one of the important transport infrastructure. Now a day it is very essential to monitor, the bridges as there were incidences happen earlier. The reason behind these incidents are as there is no such type of system, which will give information to the peoples if the bridge is not in good condition when sudden situations may occur like flood, earthquake. It shows that the safety of bridge is at threat. When it happens, bridge collapses and human deaths and accidents occur.

Zig-Bee technology is used in existing system. It is cost and time consuming, but this system used the TCP/IP protocol which is suited for all types of bridges. In this study, WSN and smart building technologies are adopted to solve the various problems of bridge safety system. This is achieved by developing an IOT based bridge safety monitoring system capable of monitoring the environmental data of a bridge and transmitting the data to the mobile devices of bridge safety management staff for reference and documentation. The water level is checked manually through water level sensor. So for this the system is being developing an application in which everything is automated so less human efforts are required.

A. Problem Statement

To develop a pervasive system to monitor and sense the conditions of bridge and share this information with admin to generate the alert.

B. Objectives of the Bridge Monitoring System

- To provide safety for bridges.
- To avoid accidents during heavy rainfall.
- To improve the bridge efficiency.
- To overcome the technical and cost obstacles.
- To overcome the difficulties in manual monitoring of bridges.
- Alert during the unsafe conditions, saves the life of people.

II. Literature Survey

1) A new cable-stayed bridge is currently under construction across the River Yamuna in Wazirabad, Delhi. The bridge is provided with bridge health monitoring system, supplied by a joint venture of Mageba India, Mageba Switzerland and Vienna Consulting Engineers. The paper describes the purpose of the system and the requirements it will fulfill, and presents the general system layout, a description of the equipment and the technical solution for data transfer. A special focus is given to the subject of data management, which includes the archiving, analysis and presentation of the recorded data.
2) With Japan facing the recent social infrastructure issue of aging infrastructure, NTT DATA developed a solution which remotely monitors bridges which provides valuable information for maintaining bridge safety. NTT DATA implemented the bridge monitoring system-BRIMOS with the support of ODA (Official Development Assistance). The Cau Can Tho Bridge is a newly constructed bridge built over the Mekong Delta basin where the foundation is naturally very soft.
3) The grant, entitled "A Remote Bridge Health Monitoring System Using Computational Simulation and GPS Sensor Data" is collaborative effort with Cranfield University, Railtrack, W S Atkins and Pell Freischman. The work focuses on using kinematic GPS to create and validate finite element models of bridges, allowing vibrations of the structures to be analyzed for any movements. The paper details the progress of the work to date, including the way in which the field data gathered and analyzed by the Nottingham group is used by the Cranfied Group in order to assess the quality of structures.

III. Existing methods

1) Jin-Linn Lee explained IoT-based bridge safety monitoring system is developed using the ZigBee technology. This system is composed of: monitoring devices installed in the bridge environment; communication devices connecting the bridge monitoring devices and the cloud-based server; a dynamic database that stores bridge condition data; and a cloud-based server that calculates and analyses data transmitted from the monitoring devices.
2) Shivan Haran, et al. discusses the monitoring of bridges using Wireless Sensor Network. As a testbed, a heterogeneous network of WSN and conventional P2P together with a combination of sensing devices is to be used on a bridge model. Issues related to condition assessment of the bridge for situations including faults, overloads, etc., as well as analysis of network and system performance is discussed.
3) Ren-Guey Lee et al. provides backup scheme for bridge monitoring system by using the WSN which is efficient and reliable. By collecting the environment parameters transmitting the numerical data to the gateway through the multiple-hop relay, and then it further stores data in the back-end database for the specialized monitoring staffs to analyse and study. This system can able to improve the inconvenience to add or remove sensor nodes in an existing wired bridge monitoring network.
4) A. R. Pawar explained the Structural health monitoring system is used to measuring the key parameter of the environmental and structural conditions in a regular base in real-time. Purposes of SHM are safety, disaster mitigation, detect structure damage etc. Wireless sensors are used to monitor environmental and physical condition like level of water, pressure, acceleration etc. For bridges and dam's application, wireless sensor measures the acceleration, tilting angle of bridge pillar and water level. The wireless sensor network is used in industry, urban terrain tracking and civil structure monitoring, security and surveillance, smart buildings etc.
5) Chae, M. J. Ph. D., P.E. gives the Advancements in sensor technology have brought the automated real-time bridge health monitoring system. Many bridges in Japan and Korea have adopted this structure health monitoring system. However, current system uses complicated and high cost wired network amongst sensors in the bridge and high cost optical cable between IOT Based Bridge Safety Monitoring System ICEM, Department of Computer Engineering 2018-2019 4 the bridge and the management centre, which increases the overall cost of installation and maintenance cost of health monitoring system. This paper presents the development of a cyber-physical system that monitors the environmental conditions or the ambient conditions in indoor spaces at remote locations. The communication between the system's components is performed using the existent wireless infrastructure based on the IEEE 802.11 b/g standards.

IV. Proposed Method

The WI-FI module itself act as sever through which status of condition of bridge is transmitted to the monitoring Centre. The Monitoring devices like water level sensor, vibration sensor and weight sensor are continuously monitoring the structural health of bridge. If water level is increased or weight is too high and if bridge is being vibrated then barriers with servomotor will close. The status of bridge is directed to the monitoring Management Centre.

It has a technology called MBM (Monitoring Based Maintenance) that enables maintenance engineers to monitor the condition of the bridge in real time. The System includes the web application which is useful for the engineers working in the bridge department to monitor the current position of bridge.

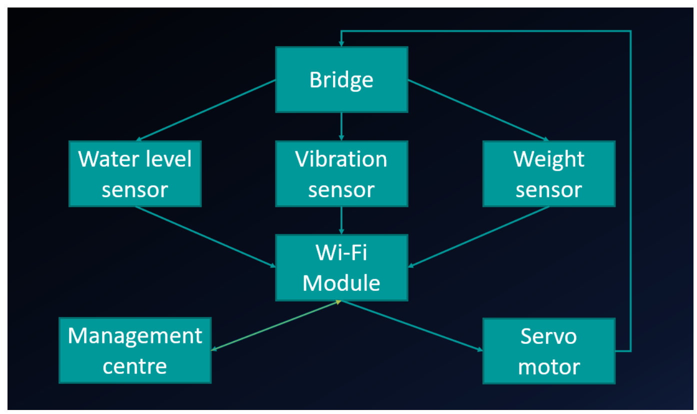

Fig. 1. Dataflow Diagram

V. Design

The methodology implemented includes:

- Structural Design Components
- WI-FI Module & TCP/IP protocol
- IoT Components
- Experimental Setup

A. *Structural Design Components*

- Design of Vibration sensor, weight sensor and Water level sensor which is the Assembly of communicating devices.
- Ultrasonic sensor senses the water level.
- Vibration sensor detect the motion of bridge in case of Heavy wind and environmental parameters.
- Weight sensor detect the load of the bridge.
- The output value or status is collected on ESP8266.

B. *WI-FI Module & TCP/IP protocol*

- WI-FI module itself act as a server which is connected to the Nodemcu.
- The WI-FI module transmits the status or condition of bridge to the monitoring Centre. This transmission is done through TCP/IP protocol in the form of packets.

- TCP/IP protocol is the transmission control protocol and internet protocol through which the transmission of data is easily possible without any interruption.

C. IoT Components

- Sensor layer:
  The sensor layer leads to detect or collect all kind of necessary information from physical world like physical, identification, audio, video data.
- Network layer:
  The network layer mainly responsible for transmitting data reliably and safely through wider and faster networks connections like TCP/IP.
- Application layer:
  Application layer performs the function to support information coordination, sharing and interconnection across monitoring center and bridge.

D. Experimental Setup

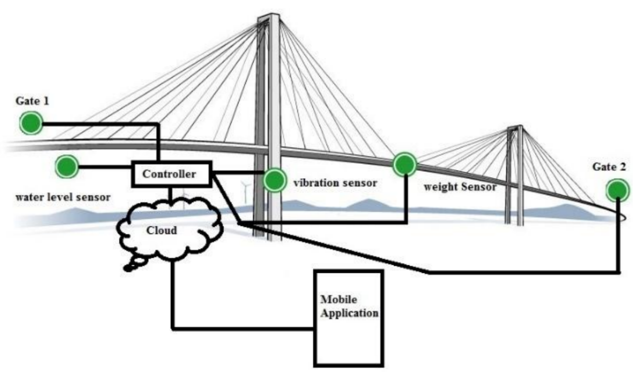

Fig. 2. System Setup

E. Mathematical Notation

The distance can be measured using:

$$Speed\ of\ ultrasonic = 0.034\ cm/\mu s$$
$$Distance = time \cdot speed$$
$$Distance = (duration/2) \cdot 0.034$$

The safety condition can be measured using:

$$f(x) = \begin{cases} 'Safe' & \text{if } d < \theta_1\ \&\ w < \theta_2\ \&\ \alpha < \theta_3 \\ 'Unsafe' & \text{if } otherwise \end{cases}$$

$$\begin{aligned} where, \\ d &= Distance(cm), \\ w &= Weight(Newton), \\ \alpha &= Tilt(^\circ), \\ \theta_1, \theta_2, \theta_3 &= Thresholdvalues \end{aligned}$$

VI. Implementation

A. Hardware required

1) ESP8266 Nodemcu: The ESP8266 is a micro controller which have the Inbuilt Wi-Fi module to Connect the device to internet. Esp8266 have 1 analog pin and 11 data pins to connect many sensors in a single system.

2) Water Level Sensor: Ultrasonic Sensors use to detect the level of substances that can flow. These kinds of substances include liquids, slurries, granular material and powders. These measurements can be used to determine the number of materials within a closed container or the flow of water in open channels.

3) Vibration Sensor: Vibration sensor is use for measuring, displaying, and analyzing linear velocity, displacement and proximity, or acceleration.

4) Weight sensor: The HX711 Load Cell Amplifier Module is uses 24 high-precision ADC converter chip hx711, is meant for high-precision electronic scale and style, with two analog input channels, the interior programmable gain amplifier was integrated with multiplier 128.HX711 uses a two-wire interface (Clock and Data) for communication.

5) Servomotor: A servomotor may be a simple motor, controlled with the assistance of servomechanism. the motor as a controlled device, related to servo mechanism is DC motor, then it's commonly referred to as a DC Servo Motor. If AC operates the controlled motor, it's referred to as an AC Servo Motor.

B. Algorithm

- Declare the variables Loads and Vibration and waterLevel as input.
- Declare stepper as output.
- Initialize ESP8266 Nodemcu.
- Initialize GSM.
- If maximum load is detected using weight sensor then stepper motor should close the gate.
- If the vibration sensor reaches the maximum threshold then send message to monitor house. The gate is closed and opened once we get message from the monitor house.
- Water level sensor senses water level and once the water level crossed the maximum threshold then the gate is closed.
- The readings are sent to database and update in web application.
- Notify required authorities.

VII. Simulation

A. Components

- Arduino Uno R3
- Breadboard
- Resistors

- Jumper Wires
- Tilt Sensor
- Force Sensor
- Ultrasonic Distance Sensor
- Buzzer
- DC Motor
- LCD 16 x 2
- Green and red LED

B. Circuit Design

The initial setup is as shown below. The ultrasonic distance sensor (Water Level Sensor) is used to monitor the water level under the bridge. Force Sensor is used to monitor the weight on the bridge. Tilt Sensor measures any aberrations along the bridge. LCD Screen is used to display useful information about bridge safety to nearby peoples. Gate is used to close entry and exit point of bridge and LED is the traffic signal and buzzer alarm's when gate is being opened or closed.

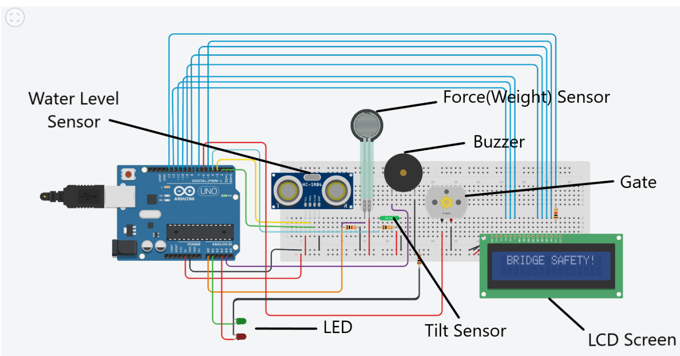

Fig. 3. Circuit Design of simulation in Autodesk Tinkercad

C. Code

```
#include <LiquidCrystal.h>

#define echoPin 2
#define trigPin 3
#define fsrpin A0
#define tilt 4
#define motor 6
#define backLight 13
#define safe A1
#define close A3
#define buzzer A4

int fsrreading; //weight
long duration;
int distance; //water level
int tiltreading; //1 if no tilt, 0
    otherwise
int gateclosed = 0;

LiquidCrystal lcd(12, 11, 10, 9, 8, 7,
    5);
```

```
void setup() {
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  pinMode(tilt, INPUT);
  pinMode(fsrpin, INPUT);
  pinMode(motor,OUTPUT);
  pinMode(backLight, OUTPUT);
  digitalWrite(backLight, HIGH);
  lcd.begin(16,2);
  lcd.clear();

  lcd.setCursor(1,0);
  lcd.print("BRIDGE SAFETY!");
  Serial.begin(9600);
  delay(1000);
}

void loop() {
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(2);
  digitalWrite(trigPin, LOW);
  duration = pulseIn(echoPin, HIGH);
  distance = duration * 0.034 / 2;

  fsrreading = analogRead(fsrpin);

  tiltreading = digitalRead(tilt);

  if(gateclosed == 0 && (distance < 150
      || fsrreading > 300 || tiltreading
      ==0)){
    analogWrite(safe,0);
    analogWrite(close,255);
    lcd.clear();
    lcd.setCursor(0,0);
    lcd.print("EVACUATE BRIDGE!");
    lcd.setCursor(0,1);
    tone(buzzer,500);
    digitalWrite(motor,HIGH);
    delay(4000);
    digitalWrite(motor,LOW);
    gateclosed = 1;
    noTone(buzzer);
  }

  if(gateclosed == 1 && (distance > 150
      && fsrreading < 300 && tiltreading
      ==1)){
    tone(buzzer,500);
    digitalWrite(motor,HIGH);
    delay(4000);
    digitalWrite(motor,LOW);
    noTone(buzzer);
```

```
      gateclosed = 0;
      lcd.clear();
      lcd.setCursor(3,0);
      lcd.print("SAFE␣TO␣USE");
      analogWrite(safe,255);
      analogWrite(close,0);
      lcd.display();
    }
    delay(1000);
    Serial.println(distance);
}
```

VIII. Results

A. Simulation Results

When the bridge is safe, Gate will be open and green LED glows and “Safe” message is displayed in screen. It can be seen in below figure:

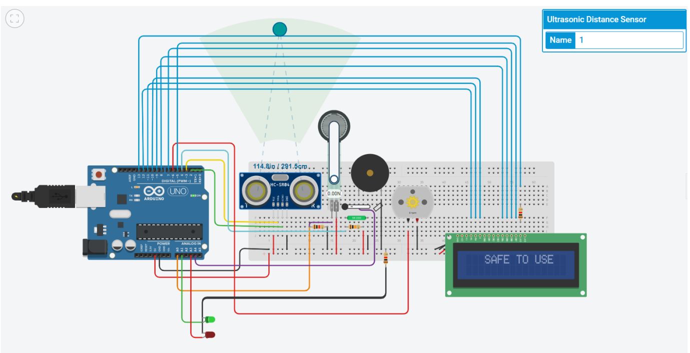

Fig. 4. Safe Condition

Even when multiple measurements are below threshold, the LED red glows and the Gate closes while the buzzer is beeping. Bridge safety information is showed in the LCD screen. This condition can be seen in below figures:

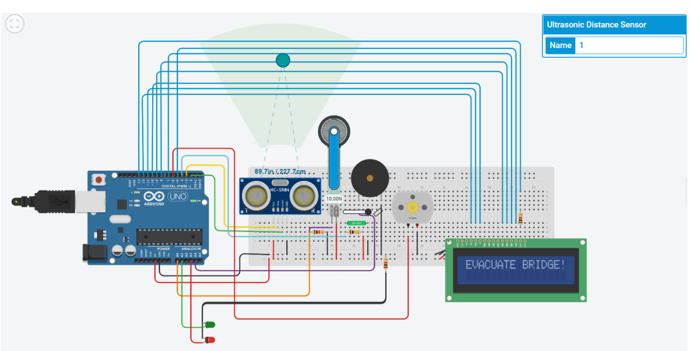

Fig. 5. Unsafe Condition

B. Graph Result

- Graph is used for show the analysis of data based on time wise analysis, Day wise analysis, and area wise analysis.
- Graph is the simplest data structure to show the analysis data.

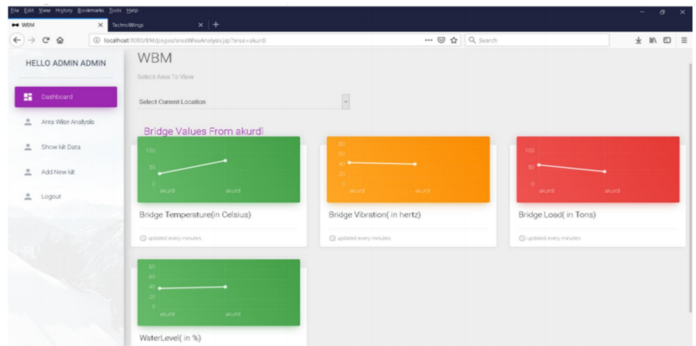

Fig. 6. Web Application and Graph Results

C. Web Application

- Web Application is built to show the real time bridge monitoring system analysis of data.
- Web Application added area wise analysis, add new kit, show kit data.

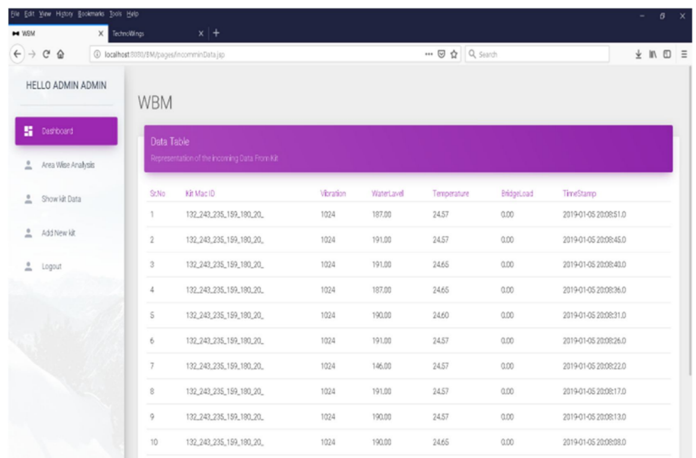

Fig. 7. Web Application and Real-time Readings

IX. Future Enhancement

In future, this system can perform additional activities. These include recording vibrations at the foot of the bridge using ses70 sensor. This results in better measurement for earthquake detection near the bridge. We can use tilt sensor along the bridge and warn if there is any aberration. We can use anemometer to measure wind speed and warn about hurricane or typhoon. Implementation of LCD projection on the bridge can be used to indicate critical conditions for people near the bridge. Further improvements can be done in underlying TCP/IP and use high precision sensors for better reading of environments.

Conclusion

A popular issue is bridge health condition monitoring in real time. The sensor technology is continuously advancing and condition monitoring has never been accurate and easier before. This system checks the water level and the position of bridge for safety purpose. In the emergency conditions like earthquake, flood, etc. broadcasting the message is added. This System is unique in its ability to monitor the bridge environment, it transmits environmental data through wireless communication and sends alerts to the bridge management staff. The system judges whether the bridge is safe or not for traveling by continuously monitoring. The main aim of Bridge Monitoring System is to save the lives of the people, to protect from accident.

Acknowledgment

Through this paper we learnt about bridge safety monitoring using IOT and how IOT can intervene and improve the existing technique's performance. The techniques can be improved in terms of cost and efficiency with IOT application under this area. We would like to thank Manjula ma'am for this opportunity and her encouragement to take up the project.

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