IOT Project Report

Bridge collapsing detection

A Project Report Submitted

in Partial Fulfillment of the Requirements for the Degree of

Bachelor of Technology

In

Computer Science Department

By

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CSE-4

3rd year

BML MUNJAL UNIVERSITY™

SCHOOL OF ENGINEERING AND

TECHNOLOGY BML MUNJAL UNIVERSITY

GURGAON

November,2020

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Provide a brief descriptive title of your project:

Bridge collapsing detection

Even after frequent inspections, bridges might collapse causing fatal deaths. An IoT based bridge monitoring system can replace the Manual inspections and can also serve as a last-minute emergency alerting system. A Bridge Monitoring system, monitoring the bridge every time senses the load on bridge, vibrations of bridge, cracks in concrete of bridge and water level below the bridge. Based on the information gathered from the sensors, if any value is exceeding the expected value then it sends the detected errors to associated officers and if these values were exceptionally high then alerting system starts sounding buzzers, closes the entry on to the bridge and provides cautious notice to the traveling vehicles.

Problem statement and motivation:

Every Construction has a limit on its lifetime which is based on its structure, design, materials used for its construction, the place it is constructed. Bridges which fall in the same category are also limited for 60-70 years but should be inspected frequently. Even after these inspections, few bridges collapsed due to unexpected climatic variations or sudden variation of the pressure/load on the bridge. to avoid such mishaps and frequent inspections, a collapse detection system monitoring the health of bridges can be used.

List the specific problem which your project is solving:

After construction of bridges, they are manually being inspected. This inspection usually occurs every 20-30 days based on the topography in which bridges are checked, load carried by the bridge and the climatic conditions there. This is a robust and error prone job for human beings. Human negligence during construction or inspection may lead to huge disasters. These tasks can be replaced by the Bridge Monitoring system where it constantly senses the data and sends it for analysis.

Last minute emergencies like sudden increase of water flow beneath, wind, sudden increase or decrease of loads etc where there would be no time for humans to caution others, the Bridge collapse detection system activates and alerts people on the bridge.

Provide a detailed explanation of how this project solves the problem(s). In your description, include links to relevant online documents or figures including at least one drawing, All the description of the drawing with numbering must be mentioned in the detail.

The aim of the design is to collect some crucial information from the bridge and then analysing the data and if any data is recorded with extraordinary difference than expected then alerting system should be activated.

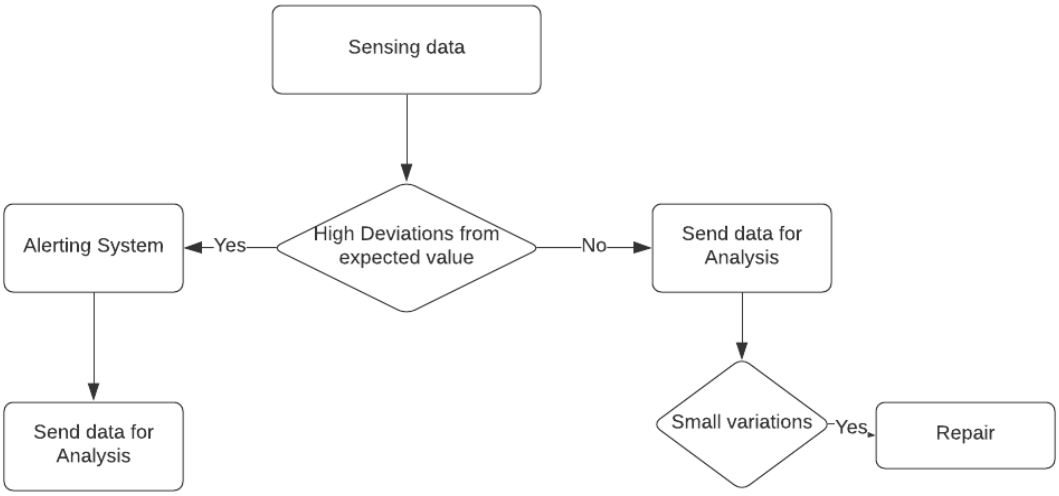


Fig 1: Basic Functionality of Project

Sensing Data:
The most common causes for bridge failure are Structural or design failures, Extraordinary loads on bridge or high force on bridge due to water flow beneath, concrete material failure, vibrations due to synchronous resonance with wind or vehicles etc. the data corresponding the mentioned failures are to be collected constantly. So different sensors are to be used.

Type	**Sensor to tackle**
Structural failure and Heavy loads	Load sensor
Concrete material failure (Cracks)	Ultrasonic sensor
High Vibrations	Vibration sensor
High pressure due to water beneath	Water level sensor

Concrete Material Failure: Matter expands with rise in temperature and contracts with lower temperature. Even concrete materials are not exceptions of this basic law. The concrete material which was used to construct the bridge gets contracted in colder times and expands if the temperature is high. So cracks occur due to expansion and compression of particles. These cracks affect the worst if not taken care. So ultrasonic sensors are placed. They work based on the echo. Here we are using low frequency sensors frequency ranged from 3 – 80Hz. This sensor sends the echo of frequency 20Hz and this echo get reflected back with some frequency. The returned frequency will be bounced back with increase in frequency if there are any cracks. If it identifies any crack then corresponding data is sent to Arduino.

Heavy Loads: Every construction is constructed in such a way that it can with stand with dead load and live load on the bridge with many times greater than the actual real time loads. collapse due to extraordinary loads is not frequent but gets impacted when any other kind of failure occurs. So, Load on the bridge must be calculated continuously. If an exceptionally higher or lower value of load gets recorded, then alerting system should be switched on

instantaneously. We are using SEN0160 weight sensor module which is based on HX711 (ADC). HX711 is a precision 24-bit analogy-to-digital converter. For measuring and converting it uses 2.6 to 5.5V power supply.

High vibrations: Under the right wind conditions, any bridge would be driven at its resonant frequency, causing it to oscillate and twist uncontrollably. Studies show that the bridge collapse when vibrated at certain frequency or loaded with extraordinary weight before getting collapsed. Vibration sensor (SW 420) records the vibrations on the bridge. The maximum frequency the bridge can hold is 20KHz. When there is any occurrence of collapsion, the vibrations starts from the frequency of 8KHz. If the vibrations are beyond the frequency 8KHz then alerting system must be switched on else the data can be send to analytics via Arduino.

High pressure due to water beneath: When the river passes under a bridge, the high-water level smashes the debris into the bridge. If the impact doesn't destroy the bridge immediately, the weight of the piled up combined with the force of the flowing water pushing on it can bring the bridge down. So measuring water level is much important which is used later in analysis.

Each sensor mentioned above, senses information and sends it to arduino UNO through wired connections as they are not much apart. Here basic analysis of data is done at arduino i.e., if any extraordinary variations of the values occur then it could be considered as an emergency and alerting system is activated.

This Monitoring system is continuously operational and senses the information at every instant. This sensed data is sent to arduino UNO which is in turn connected to Database server through Wi-fi module. The data in the database is analysed and stored for future reference. In the analysis if the value from any sensor is frequently fluctuating or increasing with constant rate or decreasing at constant rate, then repair or through manual inspection should be done.

Storage and analysis of data:

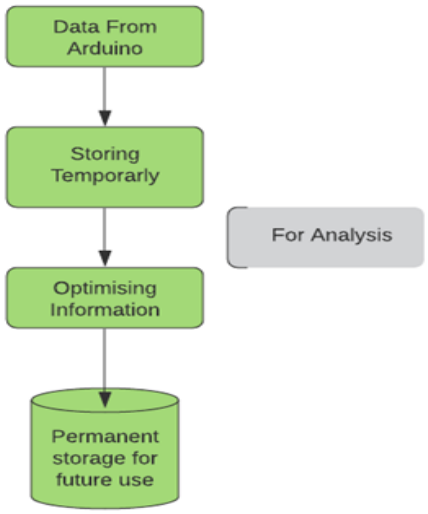


Fig 2: Flow of data in Analysis

Arduino UNO is connected to the internet with Node MCU. Node MCU (ESP8266) is the extension used to connect and pass data over the internet. After hosting a website and creating a database, Node MCU can send data to the website and database. The data is stored temporarily in a database which will be extracted for analysis. The data is analysed after extracting from the database. In most of the cases the sensors sense normal expected values. Storing data of every second over years which are just expected and normal is useless and effect storage space. So to avoid the high usage of storage space, the data after analysis is found recurring and close to expected values, then they are omitted and data if few instances of day is stored. In cases of climatic changes and other effective conditions, then data is stored at more frequently than usual conditions. This permanently stored data over years is used to draw conclusions on each effective parameters of the bridge. When the analyst realize that the data collected over last few years is changing continuously (i.e. Constant rate of increase or decrease) then repair works are done accordingly.

Alerting System:

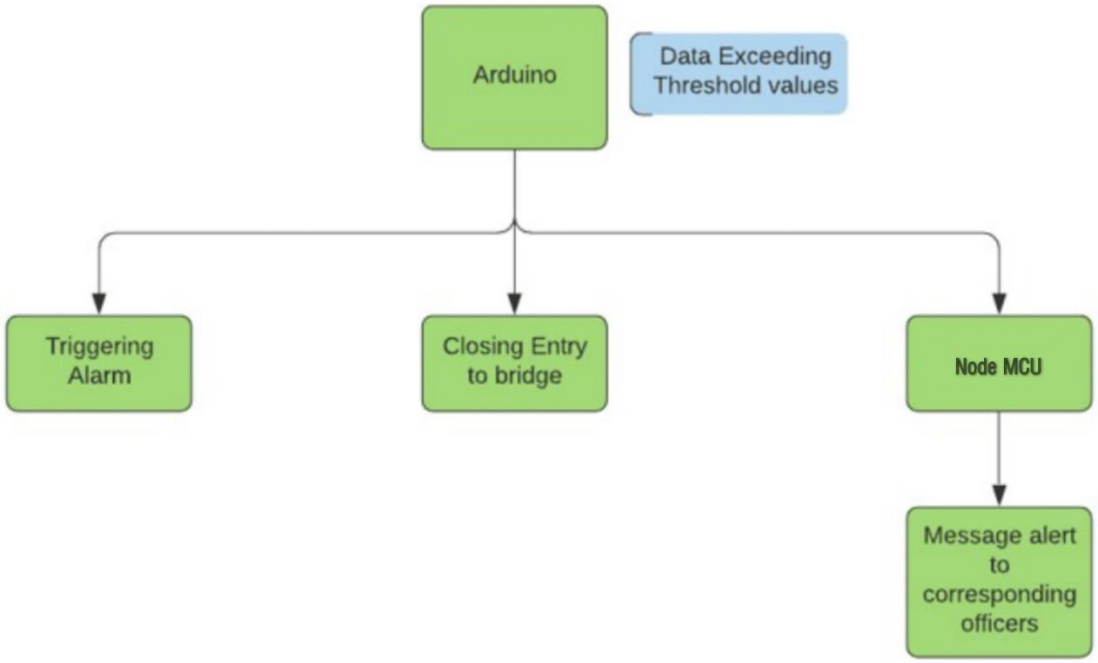


Fig 3: Flow Chart of Alerting system

Whenever extraordinary values highly deviating from expected values are recorded then it could be considered as the emergency case and the initial and most important task to be done during those emergency situations is to alert passengers travelling on the bridges. So alerting system which is attached to the monitoring system alerts the travellers. The Arduino is connected to piezo buzzer (Buzzer or sounding element), which will be sounded based on instructions of Arduino. When this alarm sound then, travellers get to know about the bridge is in faulty condition and takes precautionary measures. In emergency, entry to the bridge is restricted. entry gates are closed by the motors associated with it, which is operated from the instructions of Arduino. After alerting the passengers on the bridge, the corresponding officers, nearby hospitals are to be alerted. Node MCU attached to Arduino is also used to send alerting messages to them. So, the corresponding officers and ambulances could be available instantaneously.

Existing state-of-the-art: (Brief background of the existing knowledge):

CN106442720B: The present invention provides a kind of acoustic shock type track bridge health monitoring device, system and method, monitoring device includes sound collection equipment and Communication processing equipment, where the sound collection equipment is used for transmission sound spectrum for acquiring generated sound spectrum, Communication processing equipment when wheel driving source vibratory impulse track bridge.

US9036861B2: Spatially Integrated Small-Format Aerial Photography (SISFAP) is another present invention. It is a low-cost Solution for bridge Surface imaging and is a remote bridge inspection technique to Supplement current bridge visual inspection. The aircraft flying at about 1000 feet above ground level (AGL) can allow visualization of large cracks and joint openings on bridge. An Onboard Global Positioning System geo-references the images collected, therefore the integration and automated damage detection. A deck condition rating technique based on large crack detection is used to quantify the condition of the existing bridge decks.

Intelligent measuring system using network wireless sensors for structural diagnostics: designed a system that monitors Structural Tension under external environmental load. The proposed System is a reliable system for measurement and diagnostics to predict structural failures through non-destructive diagnostic procedures. A wireless sensor network is implemented based on smart sensors with built in microprocessors and wireless communication. The system makes use of lamb waves and piezo-wafer active sensors. It integrates Structural Diagnostics and Analysis with non-destructive testing methods and Measurement Systems, Intelligent Materials, Data Transmission and Signal Processing.

List out the known ways about how others have tried to solve the same or similar problems? Indicate the disadvantages of these approaches. In addition, please identify any prior art documentation or other material that explains or provides examples of such prior art efforts.

S No.	Existing State of the Art	Drawbacks in existing state of art	Overcome
1	**CN106442720B:**The present invention provides a kind of acoustic shock type track bridge health monitoring device, system and method, monitoring device includes sound collection equipment and Communication processing equipment, where the sound collection equipment is used for transmission sound spectrum for acquiring generated sound spectrum, Communication processing equipment when wheel driving source vibratory impulse track bridge.	This project uses sound spectrum to identify the deformation or cracks in bridges, this will not give an efficient output because small cracks will not produce different sound when compared to an healthy bridge. These errors may cause large property damage.	This patent only focuses on the cracks in the concrete material of bridge or some other deformations. our project also uses structural failures, extraordinary loads, pressure due to water at bottom to predict the bridge failure.
2	**US9036861B2:** Spatially Integrated Small-Format Aerial Photography (SISFAP) is another present invention. It is a low-cost Solution for bridge Surface imaging and is a remote bridge inspection technique to Supplement current bridge visual inspection. The aircraft flying at about 1000 feet above ground level (AGL) can allow visualization of large cracks and joint openings on bridge. An Onboard Global Positioning System geo-references the images collected, therefore the integration and automated damage detection. A deck condition rating technique based on large crack detection is used to quantify the condition of the existing bridge decks	It can only detect large cracks because the images are taken from a very altitude. in this case we will not able to detect small cracks which may lead in heavy damage.	Only large cracks can be detected with this technology but our project also uses structural failures, extraordinary loads, pressure due to water at bottom to predict the bridge failure.
3	**Intelligent measuring system using network wireless sensors for structural diagnostics".** A wireless sensor network is implemented based on smart sensors with built in microprocessors and wireless communication. The system makes use of lamb waves and piezo-wafer active sensors (PWASs). It integrates Structural Diagnostics and Analysis with non-destructive testing methods and Measurement Systems, Intelligent Materials, Data Transmission and Signal Processing	Could not predict the disaster if the structural failure occurs and could not analyse the data from past few years.	Interfacing the components to Arduino board, Motor Driver, Node MCU with web-based application connected to database

List the Technical features and Elements of the project.

Technical elements of Project:

Sensor Layer:

1. Structural Failure (Load sensor)
2. Extraordinary loads (Load Sensor)
3. High Vibrations (Vibration Sensor)
4. Concrete material Failure (Ultrasonic sensor detecting cracks)
5. High pressure due to water beneath (Water level Sensor)

Arduino board and its Shields:

1. Arduino Board (Collecting information, initiating transformation of information, controlling Alerting system)
2. Node MCU (Transmitting data over internet to database and Sending SMS to Hospitals, Rescue team and corresponding officers)

Actuators layer:

1. Alarm (Piezo Buzzer)
2. Restricting entry on to bridge (DC Motors and closing gates)

Draw the block diagram of your project

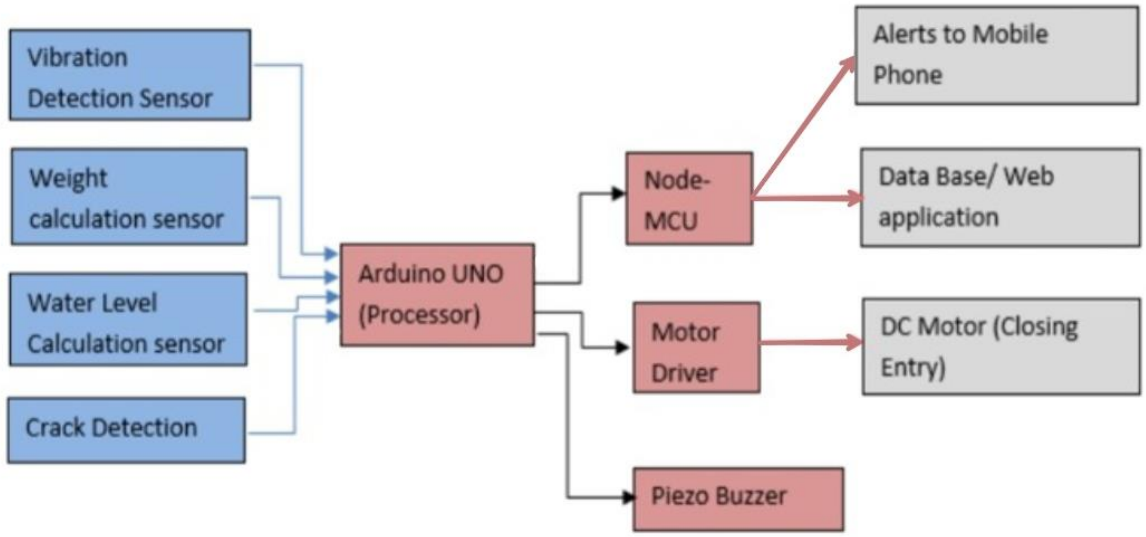


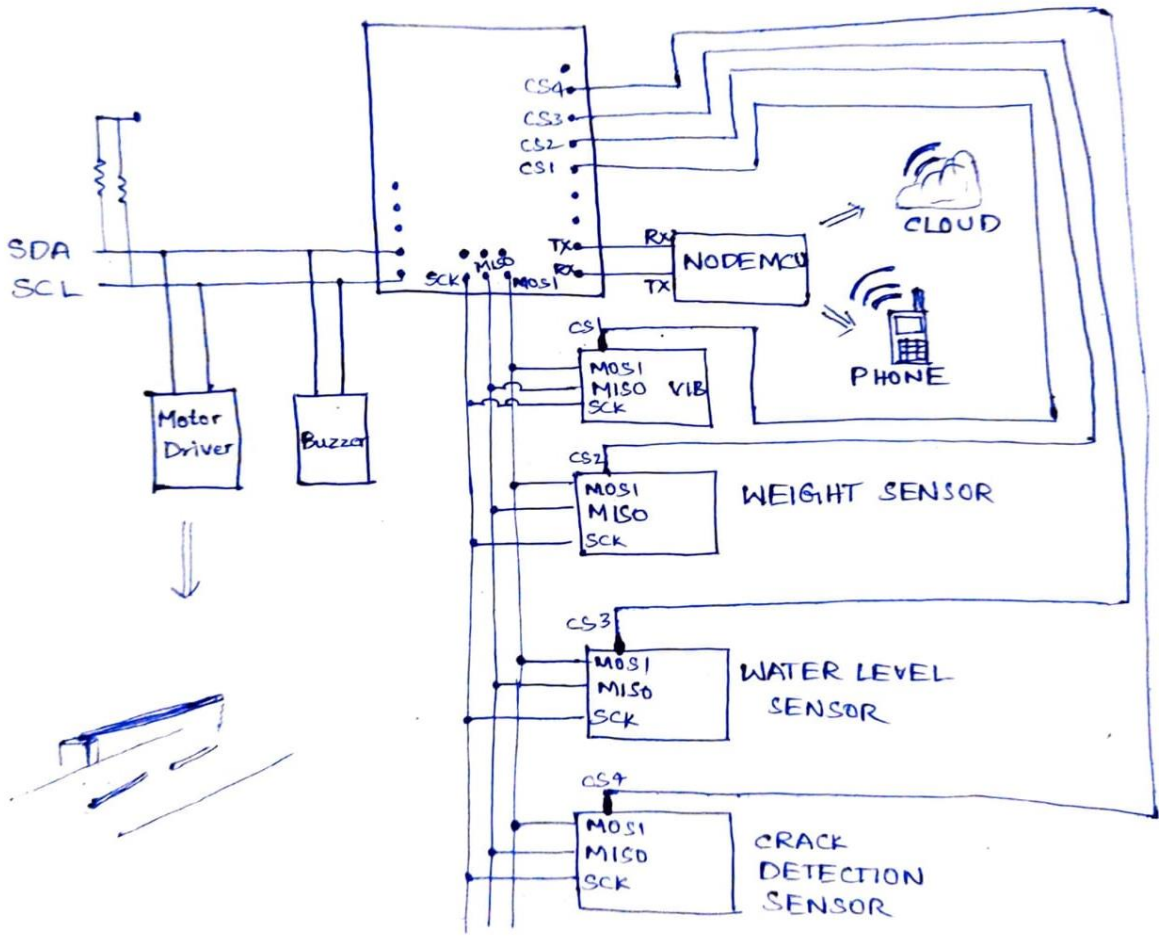
Fig 4: Block Diagram of the project with sensors, processor, shields and actuators

Communication between:

Vibration Detection Sensor and Arduino UNO: like other sensors, Vibration sensor is connected to Arduino UNO with SPI (Serial Peripheral Interface) communication. SDI (selective dissemination of information) pin is connected to MOSI (Master Out Slave In) pin on ICSP (In-circuit serial programming) header of Arduino. SCK (Serial Clock) pin from sensor is connected to SCK pin in Arduino. SDO pin is connected to MISO (Master in Slave Out) pin of Arduino. Chip Select pin is connected to digital pin of Arduino.

Weight calculation sensor and Arduino UNO: connected with SPI communication. SDI pin connected to MOSI pin, SDO pin is connected to MISO pin, SCK pin is connected to SCK pin. Chip Select pin is connected to digital pin of Arduino.
Similarly, Water level sensor, crack detection sensors, relate to SPI communication like the above. Only Chip select pin is connected to different digital pins of Arduino.
Arduino With Motor Driver and Piezo Buzzer: The alerting system is connected to Arduino through I2C communication. Motor Driver, Piezo Buzzer are part of Alerting system. Arduino acts as master and Motor Driver, Piezo Buzzer acts as slaves. All the elements on the transmitting wire are addressed by the Arduino UNO with their address and would pass message to them individually but on the same line.
Arduino With Node MCU: UART communication protocol is used to communicate the Arduino with Node MCU (Wi-Fi Module). As the communication between them is one to one and data is transferred always irrespective of time and situation, a separate protocol other than the above mentioned to be used. So UART is used in the communication.

Circuit diagram:



List all the components (hardware and software used in your project)

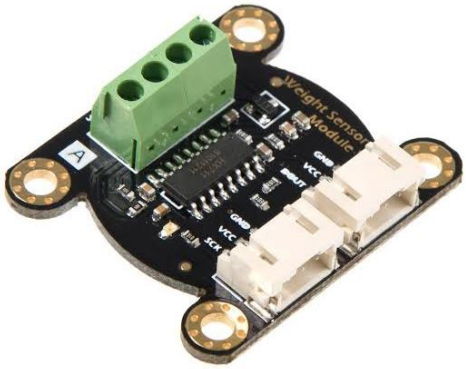
Arduino UNO: It is an open source hardware and software combined USB board that connects to the system with a USB cable. For our project it is the heart of the system where all the sensors are connected to the Arduino and are operated in a synchronized manner.

SW 420 (Vibration Sensor): The vibration sensor is used here in order to detect the vibrations of the bridge which are compulsory during any bridge collapse. This Vibration Sensor Module consists of an SW-420 Vibration Sensor, resistors, capacitor, potentiometer, comparator LM393 IC, Power, and status LED in an integrated circuit. During no vibration, the sensor provides Logic Low and when the vibration is detected, the sensor provides Logic High.

Ultrasonic water level Sensor:
There are a number of different types of liquid level sensor used to detect the point level of a liquid. Some types use a magnetic float, which rise and fall with the liquid in the container. Once the liquid, and by extension, the magnet, reach a certain level, a reed magnetic switch is activated.
The WL705 uses the latest ultrasonic distance measuring technology for accurate non-contact water level monitoring. The sensors contain a rugged transducer in a stainless steel sealed housing for long life and provides an industry standard 4-20 MA output. There are three ranges available including 3 ft, 12 ft, and 48 ft to meet a wide variety of applications. The unique 3 ft range sensor is ideal for measuring flow in small flumes and weirs. The 12 ft and 48 ft ranges are best for measuring river, lake and tank levels and for measuring open channel flow in larger flumes. Installation is simple and requires no programming or calibration. No maintenance is required.
//float height = map(analogRead(sensorPin), 102, 1023, 40, 1440) / 10.0;

Crack detection sensor:
We are using Ultrasonic sensor for crack detection. Ultrasonic sensor is used to detect the crack on the bridge by not receiving the echo from the bridge; if the echo sound is received then no crack is detected on the road. The output of the ultrasonic sensor is given to the microcontroller, which is connected to the GPS, Node MCU and motor driver IC. Below shown is Maxbotix MB1240 XL-MaxSonar-EZ4 High Performance Ultrasonic Sensor

Weight Sensors:
The SEN0160 weight sensor module is based on HX711 ADC. HX711 is a precision 24-bit analog to-digital converter (ADC) designed for weigh scales and industrial control applications to interface directly with a bridge sensor. The input multiplexer selects either Channel A or B differential input to the low-noise programmable gain amplifier (PGA). Channel A can be programmed with a gain of 128 or 64, when a 5V supply is connected to AVDD analogy power supply pin. Channel B has a fixed gain of 32. Onchip power supply regulator eliminates the need for an external supply regulator to provide analog power for the ADC and the sensor. HX711 includes basic functions and also some features like a quick response, high integration, immunity, etc. This chip reduces the cost of electronic scale as well as improves the reliability and performance.



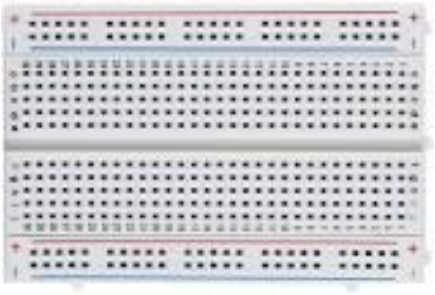
WIFI MODULE (NODE MCU):
Wifi Module enables low-power consumption modes, such as hibernate with real-time clock (RTC) mode. A module may offer an integrated antenna or provide an RF connector for an external antenna.

Motor Driver:
Motor drivers acts as an interface between the motors and the control circuits. Motor require high amount of current whereas the controller circuit works on low current signals.
the function of motor drivers is to take a low-current control signal and then turn it into a higher-current signal that can drive a motor.

Servo Motors:
The entry to the bridge is to be denied if any destruction is predicted. Gates are opened and closed accordingly with the help of servo motors which are also controlled by Arduino UNO.

Buzzer:
A "piezo buzzer" is basically a tiny speaker that you can connect directly to an Arduino. "Piezoelectricity" is an effect where certain crystals will change shape when you apply electricity to them. From the Arduino, you can make sounds with a buzzer.

Breadboard:
A breadboard is a construction base for prototyping of electronics. Originally the word referred to a literal bread board, a polished piece of wood used for slicing bread.



Jumper wires:
A jump wire is an electrical wire, or group of them in a cable, with a connector or pin at each end, which is normally used to interconnect the components of a breadboard

Software Component:

Arduino IDE:

The Arduino Integrated Development Environment is a cross- platform application that is written in functions from C and C++. It is used to write and upload programs to Arduino compatible boards, but al with the help of third-party cores, other vendor development boards.

List out the features of your project which are believed to be new and distinguish them over the closest technology.

The present day models which are used in real time, avails only few of the sensors thus restricted to collect only limited types of data or detecting only few kinds of faults. Few Models present in market now:

1. model collecting data only about cracks with the help optical cables detecting crack when ever found.
2. Health monitoring System of bridge monitoring only loads on the bridge or pressure on the bridge due to water level.
3. Sensors detecting only the vibration of the bridge.
4. Alerting system on human instructions.

Thus our model edges over all the above mentioned technologies and detects all the required information using IoT(transmitting the data from bridges to the analysis centre without human intervention) and Data analysis are believed to be new in our project.

Are there alternative ways of implementing your project that is different from what you have disclosed? Specifically, if someone knew of your solution to the problem you solved (Question 3), would it be easy for them to come up with an alternative solution to the same problem that did not include details of your project? Please explain:

Convolution neural Network (CNN) is a kind of artificial neural network system with deep learning ability. Concrete cracking which is one of the factors that reduce the service life of structures. There are different types of cracks in concrete structures.so the treatment methods of different types of cracks are different. We will find the type of crack in structure by dividing the bridge cracks into three categories: small cracks, large cracks, serious cracks, using MATLAB to enhance the image, denoising, and segmentation, and then using convolution neural network models to classify the types of fractures. The process starts with 'Image Preprocessing in which there are three sub parts

a. Image Enhancement
b. Wavelet Image Denoising
c. Image Segmentation

Next we will establish a 'Convolution Neural Network Model'. This method can be used to identify cracks and classify them into different types of cracks. In this method we need to build an efficient model to get correct output. This is a difficult task to do and connecting this model to the arduino needs many changes to be done in the programming. This will not be an easy way to solve the problem.

Status of your project: been built or tested or implemented? If please provide the particulars of the first time it was successfully built or implemented (when, where, by whom, and evidence of this event including written or on-line pointers to documentary evidence):

We are currently building a prototype for which we have the components and are in the developing process of the project which includes programming, setting up components etc. The model which we are currently building is a cluster of various other projects. we are considering this as the first model. Al we are setting up various test cases to verify its accuracy through the values obtained.

Briefly state when and how you first conceived this idea?

We came up with this idea because last year a small bridge collapsed in my village due to heavy rainfall. Three people died while crossing it. Mostly this situation happens because of floods and heavy load on it. I read in an article that there will be some vibrations for a few seconds on edges before it collapses. We are planning to fix five sensors to build this model better.
Our idea is to fix the gates at the edges (like railway gates) which are controlled by vibration sensors. When the shaking occurs, the sensors will get a beep sound for a few seconds and closes the gates and stops the people from crossing the bridge. This model can be used for old bridges.

Conclusion:

The model in this project monitors the health of the bridge, detects the collapse and could alert the travellers on the bridge. the frequent manual inspections, constant evaluation of its working could be replaced by the model. In this model, sensors sense the required information and pass it to the database, where it is analysed and optimized for storing. Whenever the values are exceptionally variated or above threshold value then alerting system is activated where alarms are sounded and entry to the bridge is restricted. Thus, the model provides reliable information about the bridge condition, provides availability for analysis of data and a reliable alerting system which makes the model functionable in real time.

References:

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2) **"Application of Internet of Things Technology and Convolutional Neural Network Model in Bridge Crack Detection" -** LIYAN ZHANG, GUANCHEN ZHOU, YANG HAN, HONGLEI LIN, AND YUYING WU Laboratory of Engineering Computing, North China University of Science and Technology, Tangshan 063000, China

3) "**SMART IoT BASED BRIDGE MONITORING AND DAMAGE DETECTION USING ANDROID APP**" - Jatin Chaudhari, Gaurav Musale, Vaibhav Dudhare, Prof. Archana B. Uphade *Dept. of Computer Engineering Loknete Gopinathji Munde Institute of Engineering and Research Center, Nashik, Maharashtra, India.*

4) **"IoT Based Bridge Health Smart Monitoring System" -** AKSHATA DHURI, SNEHAL KADAM, PRATIKSHA JOGALE, LATIKA KAWADE PROF. SHUSHMA KORE Department f Electronics and Telecommunication K.C. College of Engineering & Management studies & Research, Kopri, Thane (E)-400 603, India.

5) **"Bridge Monitoring and Alert Generation System Using IOT" -** Varsha Kusal, Amrita Argade, Sanika Chiplunkar, Rohini Kumbhar, Swati A. Khodke Department of Computer Engineering Bhivarabai Sawant Institute of Technology and Research, Pune, Maharashtra

6) **"Survey on IoT based Bridge Health Monitoring Systems" -** Vaishali Hirlekar, Parth Doshi, Viraj Shetty, Ajinkya Tungare Department of Computer Engineering, Shah & Anchor Kutchhi Engineering College, Mumbai, India