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Monitoring of bridges to alert accidents using Raspberry PI

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Abstract A serious problem has emerged in India in recent years, namely the occurrence of bridge collapse tragedies, which result in the loss of life and damage to properties. To address this issue, a bridge monitoring system has been developed. This system operates continuously, providing 24X7 monitoring of bridges, and takes into account various factors such as water overflow, earthquakes, scour depth, and the possibility of bridge collapse. In the event of an accident on a bridge, the monitoring system automatically closes the bridge and sends an alert message to the bridge users. This alert remains active until the issue is resolved. The implementation of this system relies on the utilization of Raspberry Pi and electronic sensors, ensuring a fully automated process.

Keywords: bridge collapse, bridge security, automation, bridge monitoring system, evaluating the condition of critical

1. Introduction

Transportation serves as the most convenient means of moving between different locations, with various modes available such as roads, waterways, and air travel. This article focuses specifically on road transport, particularly the bridges that span rivers and facilitate the connection of multiple roads. India's first sea bridge, the Pamban Bridge, was constructed in 1914 by the British, marking the beginning of bridge usage for transportation in the country.

Tragically, in Maharashtra, India, a bridge located on the Savitri River near the Mumbai-Goa expressway collapsed in 2016, resulting in the loss of nearly 40 lives. This incident caused significant disruptions in traffic flow, as the Mumbai-Goa highway plays a crucial role in the transportation and economic sectors of both Maharashtra and Goa. Consequently, a new bridge was constructed after a period of 10 months to restore transportation functionality.

Another incident occurred in Andheri, Mumbai, in 2018, when the Gokhale Bridge connecting the east and west sides of Andheri collapsed, resulting in two fatalities and three individuals being hospitalized. After almost a year, the government approved the reconstruction of the bridge, and within 10 months, it was successfully rebuilt. Both of these incidents caused severe transportation inconveniences for the affected population.

Bridges are constructed over rivers or in mountainous regions to alleviate heavy traffic congestion (Sousa et al 2016). However, when these bridges reach the end of their lifespan, they become hazardous and susceptible to collapse due to unfavorable natural or man-made conditions. Factors such as excessive water pressure caused by heavy rainfall or inadequate bridge maintenance contribute to these collapses (Sousa 2013). These incidents invite accidents and pose a significant threat to public safety. To prevent such disasters, continuous monitoring of bridges is imperative.

As a result, a bridge-monitoring system has been developed to ensure the constant surveillance of these structures, thereby safeguarding human lives and minimizing property losses.

2. Methodology

In recent years, there has been an increase in the number of bridge collapse incidents in India. Such failures can be attributed to two main factors. The first factor involves natural calamities, including floods, tsunamis, hurricanes, and scouring. The second factor relates to anthropogenic activities, such as the use of low-cost materials, lack of bridge inspections, and insufficient maintenance practices, among others.

It is important to note that there is currently no existing system capable of predicting bridge collapses (Robertson 2005). Therefore, this project focused on four key parameters: water overflow, earthquake detection, scour depth, and bridge collapse. Based on these parameters, appropriate sensors were selected for implementation.

I. The first parameter addressed the issue of water overflow on the bridge. During periods of heavy rainfall, the water level in the river rises, and if it exceeds a certain threshold, there is a risk of water flowing over the bridges. To prevent accidents in such conditions, it is essential to restrict user access to the bridge. As shown in Figure 1, the Real-Time working of the

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ultrasonic sensor was employed to measure the distance between the water and the bridge. These sensors were positioned on the bridge and programmed to detect when the water level surpassed a predetermined limit. In the event of potential overflow, the system activates alerts using buzzers, LEDs, and barriers.

Ultra-sonic sensor:

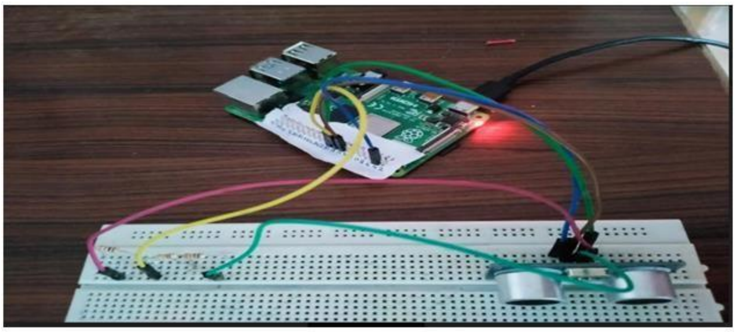


Figure 1 Real-Time working of the ultrasonic sensor.

II. The second parameter is scour depth (Richard 2010). When the measured scour depth exceeds the design value, it imposes additional stress on the pillars and the lower section of the jacket, thereby increasing the risk of platform failure. Ultrasonic and LDR sensors (Figure 2) are utilized to obtain readings of these parameters. By monitoring the scour level, the system can detect if it falls below the threshold level, indicating the need for maintenance or servicing.

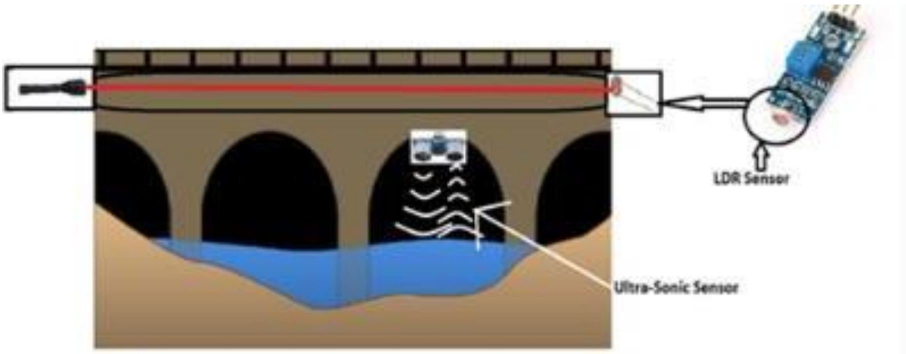


Figure 2 Ultrasonic and LDR sensor module.

III. The third parameter is earthquake detection. Often, we are unable to obtain timely information about earthquakes, which can result in major disasters. To mitigate this risk, in Figure 3, vibration sensors are employed. The system monitors for increased frequency vibrations and promptly alerts bridge users, providing crucial information to help ensure their safety.

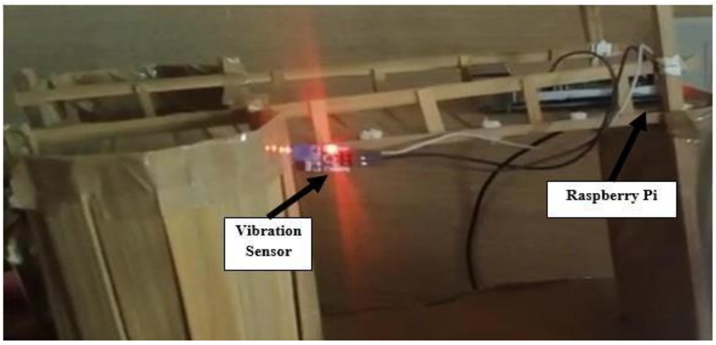


Figure 3 Real-Time working vibration sensor.

IV. The final parameter of focus is the collapsing of bridges. To detect bridge collapses, laser light detection sensors, as shown in Figure 4, are utilized. This technique involves covering the bridge with a pipe, through which light is transmitted from one end. If the light is received at the other end, it indicates that the bridge is in working condition. However, if the bridge has collapsed, the disturbance caused by the collapse will disrupt the position of the attached pipe, consequently interrupting the transmission of light. This disturbance is highly sensitive, as it prevents the reception of light intensity at the other end, triggering the generation of an alert message.

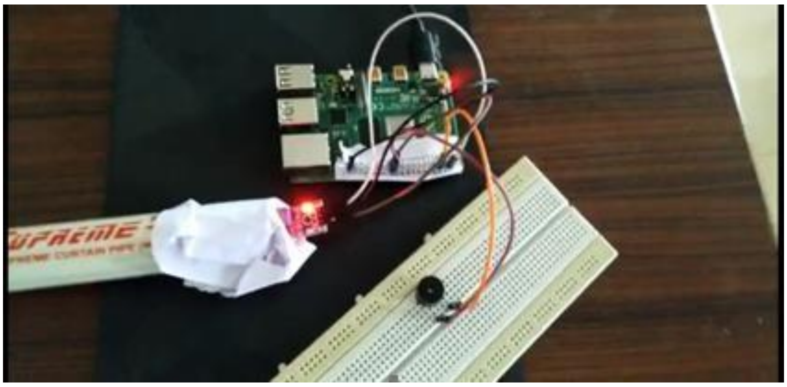


Figure 4 Real-Time working of LDR sensor.

In all of these cases, bridge barriers are utilized at the ends of bridges to halt vehicle traffic. An LED lamp is employed to indicate an alert regarding the bridge's condition, signaling that the bridge is temporarily inaccessible for transportation (Jin-Lian 2020).

I. HARDWARE

To manage and process the collected data, a Raspberry Pi is employed as the controlling unit (Figure 5).

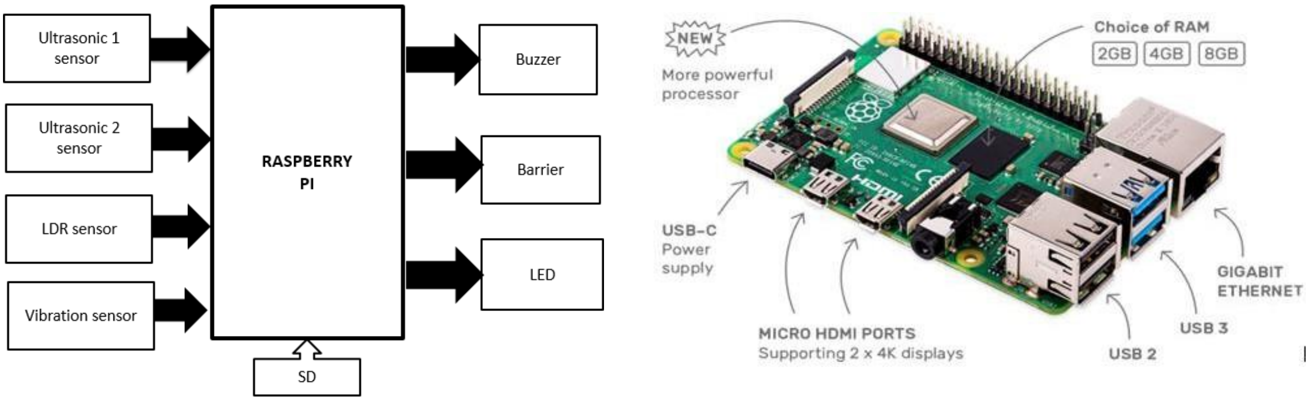


Figure 5 Raspberry Pi 4 model B.

The Raspberry Pi 4 model B, shown in Figure 5, is a compact computer, measuring 3 inches in width and 4 inches in height. It serves as a small-sized computing device that can be connected to a display, keyboard, and mouse. The Raspberry Pi offers a wide range of applications, including coding education, electronic gadget development, mathematical operations, gaming, multimedia applications, and internet-based functionalities (Shaikh 2019).

Specifications

- Broadcom BCM2711, Quad-core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz
- 2GB, 4GB, or 8GB LPDDR4-3200 SDRAM (depending on model)
- 2.4 GHz and 5.0 GHz IEEE 802.11ac wireless, Bluetooth 5.0
- Gigabit Ethernet
- USB 3.0 ports; 2 USB 2.0 ports.
- Raspberry Pi standard 40-pin GPIO header
- micro-HDMI ports
- 2-lane MIPI CSI camera port
- 4-pole stereo audio and composite video port
- OpenGL ES 3.0 graphics
- Micro-SD card slot for loading operating system and data storage
- 5V DC via USB-C connector (minimum 3A*)
- 5V DC via GPIO header (minimum 3A*)
- Power over Ethernet (PoE) enabled (requires separate PoE HAT)
- Operating temperature: 0 – 50 degrees C ambient

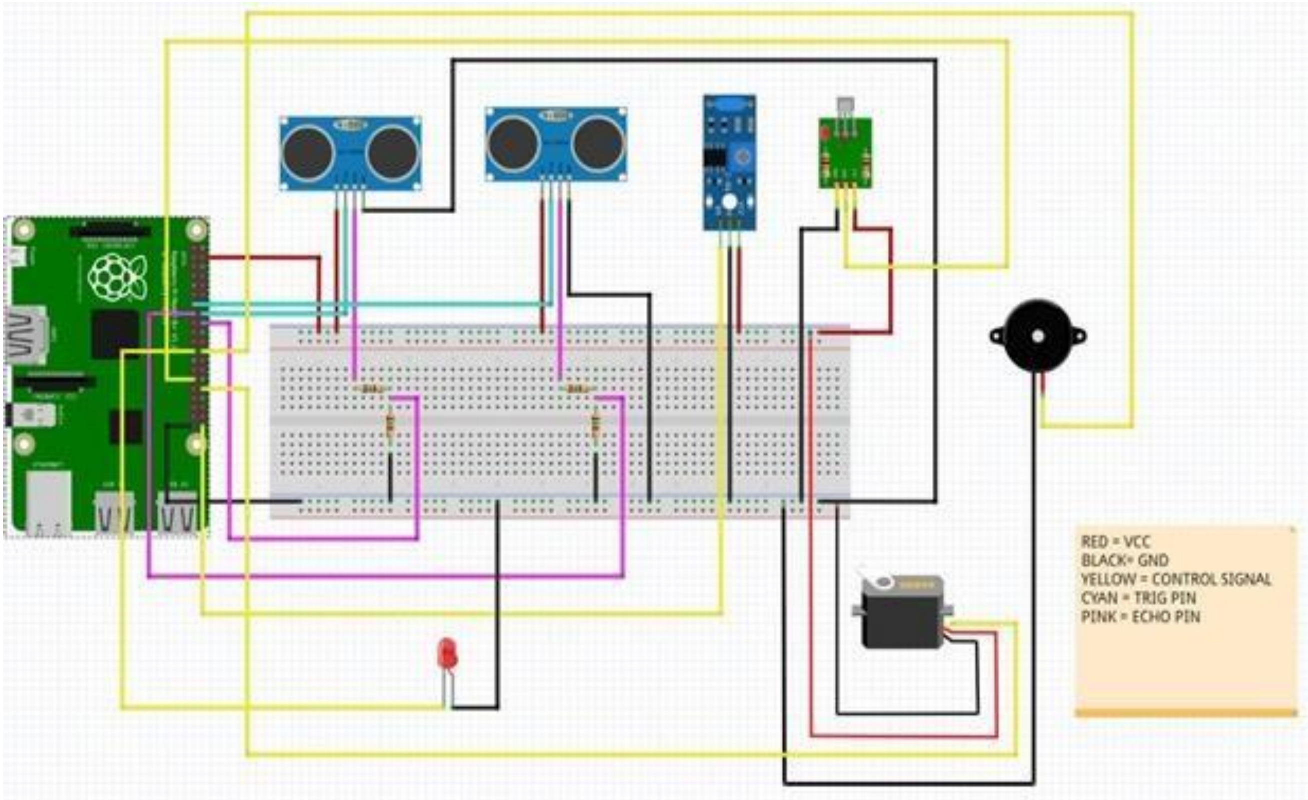


Figure 6 Schematic diagram of the system.

Circuit diagram:

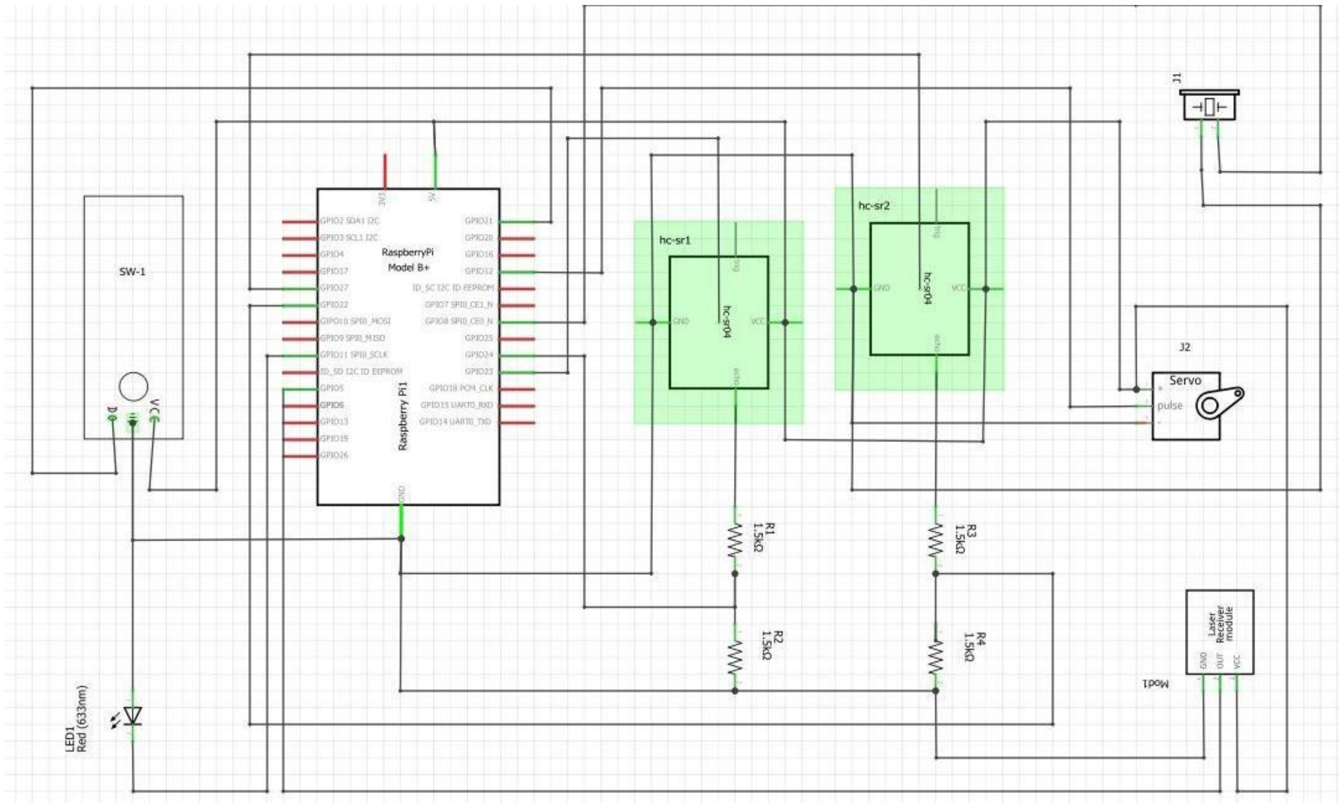
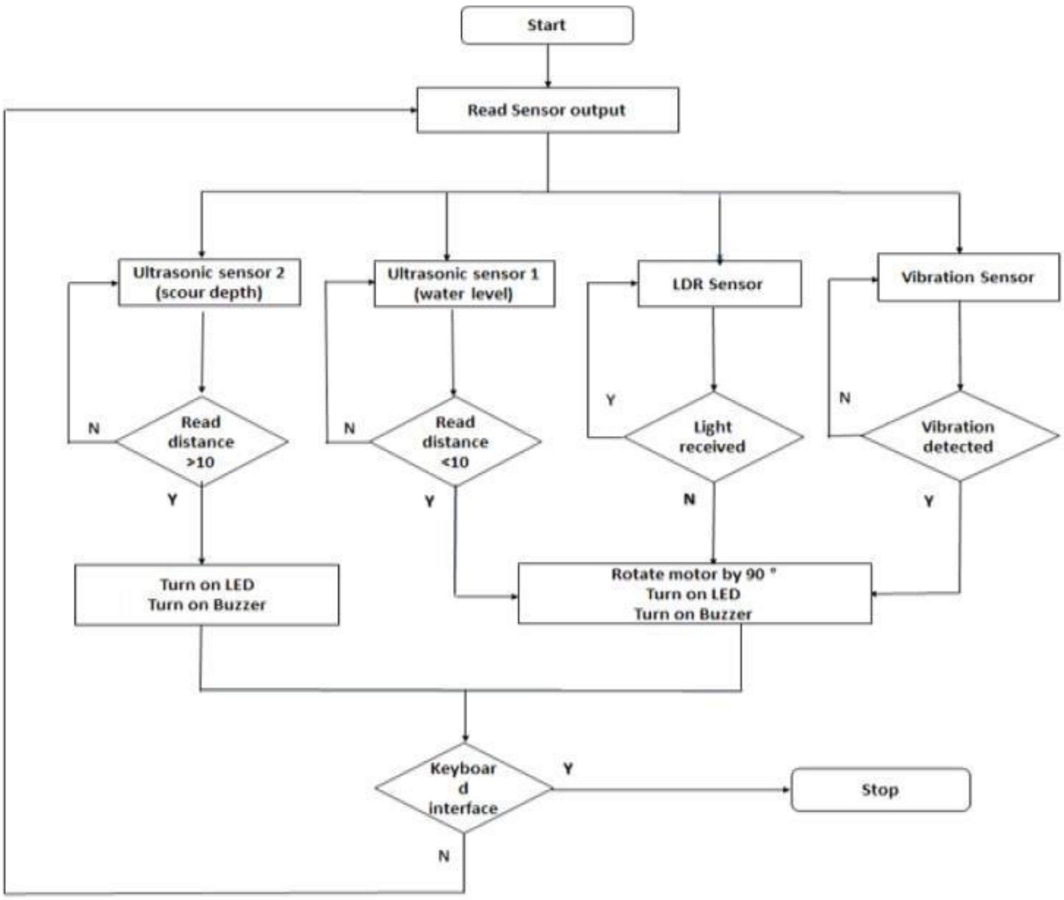


Figure 7 Circuit diagram of the system.

II. SOFTWARE:

Algorithm:
1. Start
2. Activate all the sensor
3. Read data from the sensor
   I. If the output of ultrasonic sensor 1 (for scour depth) is less than the predefined level, then:
   Go to step 4 else.
   Go to step 5.
   II. If the output of ultrasonic sensor 2 (for water level) is less than the predefined level, then:
   Go to step 4 else.
   Go to step 5.
   III. Read l dr data and check whether it sends light from one end or not, and if it reaches another end, then:
   Go to step no 5.
   IV. Read data of vibration if the output is high, then go to step 4; else, go to step 5.
4. Rotate the motor to activate the barrier (not in case of scour depth), and turn on the led and buzzer for alert indication
5. If the output of all sensors is low, then go to step 3.
6. Stop when the keyboard interface is.

Flowchart:



3. Results and discussion

During the project, it was confirmed that the sensor interfaces connected to the Raspberry Pi as shown in Figure 6 Schematic diagram of the system provided precise results. As per the circuit diagram shown in Figure 7, The detection of Scour Depth involved the utilization of the first ultrasonic sensor, which generated an alert if the measured distance fell below the predefined level. In the case of water level detection, the second ultrasonic sensor issued an alert and closed the barrier when the measured distance exceeded the predefined level. The LDR sensor accurately determined the condition of the bridge for collapse detection. Additionally, the vibration sensor detected seismic activity and triggered an alert, leading to the closure of the barrier for earthquake detection.

4. Conclusion

The implemented project represents in Figure 8 the Final prototype model is a fully automated system, eliminating the need for human intervention in sending alert messages to individuals in close proximity to the accident location. The working of the bridge monitoring system is shown in Figure 9. This approach significantly enhances the system's efficiency by providing real-time accident location information to relevant individuals. Moreover, machine learning techniques can be leveraged to further enhance the system's capabilities. By obtaining permission from the government and collaborating with Google, unsafe bridges can be incorporated into Google Maps, ultimately leading to the preservation of more human lives through the utilization of this system.

Figure 8 Final prototype model.

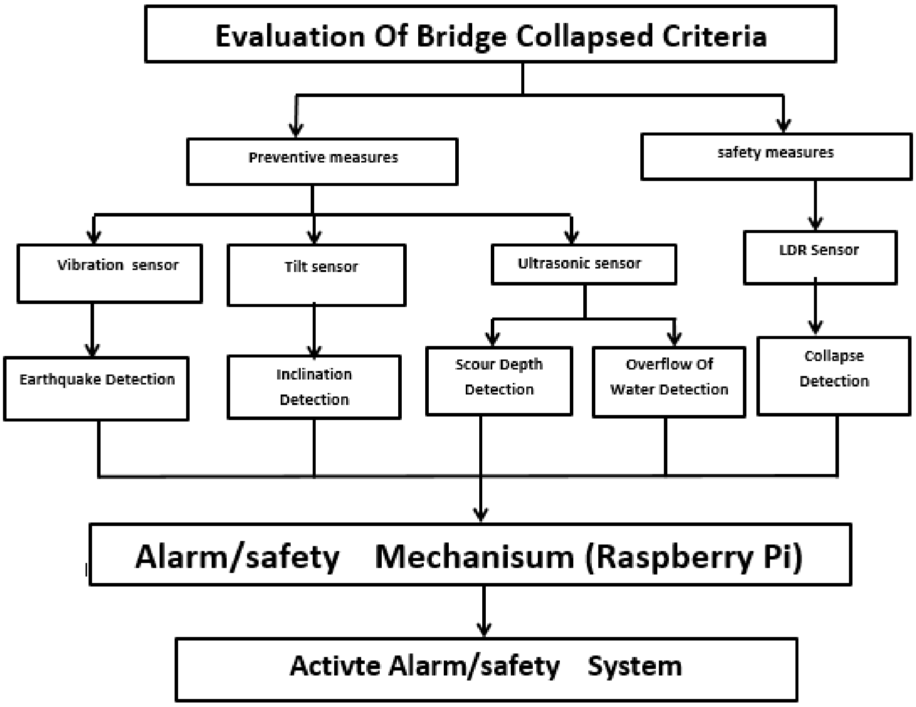


Figure 9 Working of the bridge monitoring system.

5. Patent Details

A patent has been published for the project titled "Monitoring of Bridges to Alert Accidents Using the Internet of Things (IoT)" under Application No. 202121011899 A. The filing date of the patent application is March 20, 2021. The patent has been published in the Patent Office Journal No. 38/2022, dated September 23, 2022, specifically on page number 61167.

Ethical considerations

Not applicable.

Conflict of Interest

The author declares no conflict of interest.

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