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Development of an IoT Based Blast Induced Ground Vibration Monitoring System

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ABSTRACT

Blasting is the cost-effective and quick operation in mining to obtain the rock fragmentation. Usage of explosives in blasting not only fracture and displace the rock butalso have some detrimental consequences on the adjacent structures, which may lead to their demolition. To sense, record, and monitor the ground vibrations, modern technologies like InstantelMinimate plus, Micromate, Blastmate-II are employed. The key drawbacks of this conventional systems are wire-based, expensive, and tedious process. To alleviate these limitations, this research proposed a low-cost IoT based wireless monitoring system for blast induced ground vibrations. The developed prototype uses SW-420 vibration sensor, Arduino based microcontroller and other indicating devices. This paper also focuses on the significance of IoT in the mining sector for optimizing production, profit, and safety.

KEYWORDS:Blasting, Ground Vibration, IoT, WSN,SW-420 Vibration Sensor.

1. INTRODUCTION

Mining plays a vital role in the economic development of any nation. Mining provides employment, generates tax, stabilize the economy, and contribute to the nation's GDP. Mining operations can be carried out in a variety of ways. In the mining sector, the most common rock fragmentation excavation methods are Drilling and Blasting. Blasting is a more cost-effective method of mining rock excavation. However, blasting pose risk to both humans and environment. According to the studies, only 1/4th of the explosive energy is used to fracture and displace the rock mass, while the remainingenergy is lost as ground vibrations, fly rock, noise, backbreak, air over pressure, and other forms of energy loss [1-5].

Ground vibration is a prominent issue among all the negative consequences [1].Ground vibrations are an inherent feature of rock blasting process, and they cannot be avoided but can be minimized to some extent [6]. Vibrations from the blast inflict substantial damage to the nearby structures and buildings as shown in Figure 1. So, it is necessary to sense, record and monitor the ground vibrations to know the permissible limits and ensure safety in mine. To monitor ground vibrations, current technologies such as InstantelMinimate plus, Micromate, Blastmate-II are commonly employed. Existingground vibration monitoring systems rely on wires to collect and transmit data in the field. Furthermore, wire-based prototypes can only be used in a restricted region, and the systems become inoperable if the wires are damaged, which happens frequently. Purchase and repair of existing devices are too expensive. As a result, it is important to develop a low-priced IoT based wireless monitoring system for Blast Induced Ground Vibrations (BIGV) [3,6].

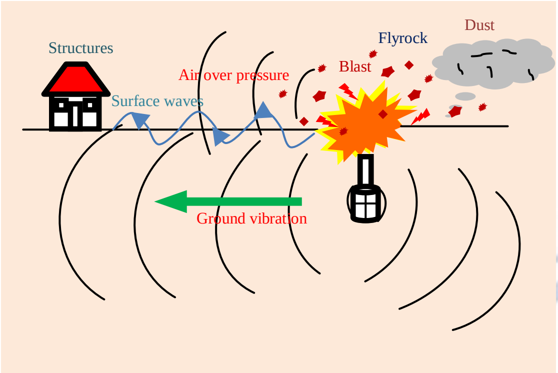


Figure 1: Environmental effects of blasting

Limitations of existing systems:

- Vulnerable to failure due to wire breakage.
- No real time data communication is possible.
- Existing systems are expensive.
- Operation requires an expert.
- The procedure is monotonous and time consuming.
- Storage memory is finite [7].

Tomitigate the above-mentioned limitations, it is necessary to develop an IoT based wireless blast induced ground vibration monitoring system. The model developed in this paper is reliable, fully optimised, cost saving and can be used by unskilled workers.

Ground vibration:

Groundvibration is defined as a time-changing displacement, velocity, or acceleration at a particular point in the ground. When blast ground vibrations propagate through the surface to a certain magnitude, they may cause damage to nearby structures [6,8].

The following are various kinds of wave motion of ground vibration:

- Primary waves.
- Secondary waves.
- Tertiarywaves [9].

2. REALATED WORK

Many researchers carried out their extensive work related to blast induced ground vibrations and monitoring them using IoT based systems. Jitendra Pramanik et al. (2018) developed an internet accessed mine monitoring system for monitoring blast induced ground vibration and discussed the role of IoT for production optimization, profit, and safety in mines [1]. Ragam Prashanth and Nimaje D.S (2019) discussed the adverse consequences of blasting and developed a wireless prototype having an accelerometer, Radio frequency module, and microcontroller unit and obtained vibration values in terms of PPV [2]. Nimaje D. S and Ragam Prashanth (2018) employed low-cost Wireless Sensor Network (WSN) and predicted PPV using an Artificial Neural Network (ANN) and they also utilised Zigbee technology for data transmission [3]. Karthik Guntha, SingamJayanthu, and Ragam Prashanth (2016) developed a WSN for vibration monitoring to mitigate the limitations of existing high-cost conventional wired systems [6]. Yoga Priyana, FolkesLaumal, and Emir Husni (2018) proposed an early warning system for detecting earthquake vibrations using ADXL 335 accelerometer sensor [10].

3. PROPOSED WORK

It is important to know about IoT and WSN to develop the prototype. The prototype developed utilizes the modern technology to suit the site conditions.

3.1 INTERNET OF THINGS (IoT)

The Internet of Things (IoT) is a network that consists of things or objects in physical form and integrated with electronics, sensors, and connectivity to make sure the network gain value and service by interchanging data with the maker, operator, and other connected devices. It is worth noting that the internet of things has been described from a variety of perspectives, resulting in a plethora of definitions in the literature. It is possible that the IoT definitions apparent ambiguity stems from the fact that it is made up of two words: the internet and things. The first word encourages a networked perspective, whereas the second favours generic objects[11].

3.2 IoT IN THE MINING INDUSTRY

IoT is utilised in the mining industry to optimise cost and production, improve safety measures, and create artificial intelligence demands. Many significant mining businesses are planning and analysing strategies to begin their virtual journey and digitization in the mining industry to oversee daily mining operations, owing to the multiple benefits it delivers. Consider the following scenario:

- **Cost optimization and increased productivity** can be achieved by using sensorsand devices that surveil the equipment's performance.
- **To assure the safety of workers and equipment** inside underground mines by using IoT to track blasting, ventilation, and toxicity levels in real time.
- **Maintenance isshifting from preventive to predictive.**
- **Improved speed of decision-making**. Emergency situations occur virtually every hour in the mining industry, with a high level of unpredictability.

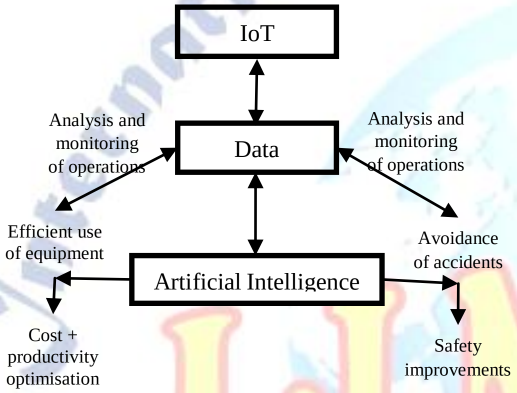


Figure 2:Flowchart of IoT in mining

3.3 Wireless Sensor Network in IoT framework:

WSN is a network of several spatially distributed autonomous nodes that covers a specific region, collects data about it, and distributes it. Thousands of wireless sensor nodes exist, each with a finite amount of compute power, memory, bandwidth, and sensing capability. They collect and store environmental data before sending it to a sink or base station to be processed and analysed. Radio signals can be used by the sensor nodes to communicate with one another[12].

WSN is a network of sensor and routing nodes that may be used to anticipate physical circumstances such as wind, temperature, vibration, and many more. These networks take data from minute nodes, process it, and then send it to the operators[13].

3.4 DEVELOPMENT OF WIRELESS SENSOR SYSTEM

The prototype consists of SW-420 vibration sensor, Arduino Uno microcontroller and other indicating devices.The SW-420 vibration sensor detects vibrations from different perspectives. When the sensor does not perceive vibrations, the sensor'scomponents act as a switch and close. Meanwhile when the sensor detects a vibration or shock, the switch will open and close at the vibration's transfer rate. This module combines an adjustable potentiometer, a vibration sensor, and an LM393 comparator chip to provide a varyingvirtual output based on the intensity of vibration. The sensitivity of the potentiometer can be altered to the pertinent level by regulating the potentiometer [14].

Table 1: Specifications of SW-420 vibration sensor

S. No	Parameters	Specifications
1	Voltage	3.3V DC – 5V DC
2	Output	Digital (0 and 1)
3	Sensor size	3.2 cm × 1.4 cm
4	Detecting distance	760nm – 1100nm
5	Detecting angle	60°
6	Signal	15mA

Arduino is a microcontroller-based open-source hardware and software platform that is extremely user-friendly. Arduino is a low-cost control board that can connect to a wide range of hardware and is simple to programme. Anyone working on a project can use it. Arduino senses its surroundings and influences them by accepting input from a variety of sensors [15].

The connections given for the prototype is given below:

A. SW-420 vibration sensor: The three pins of sensor VCC, GND, DO are connected to three ports of the Arduino board 3.3V, GND, PIN 9 respectively.

B. Buzzer: The positive and negative terminals of the buzzer are connected to PIN 3 and GND respectively.

C. LED lights: The negative terminals of the Green, Yellow, and Red LED lights are connected to GND, and positive terminals are connected to PIN 10, PIN 12, PIN 13 respectively.

D. USB port of the Arduino board is connected to laptop to get both power supply and to serial monitor the readings. A 9V battery may also be used for the power supply.

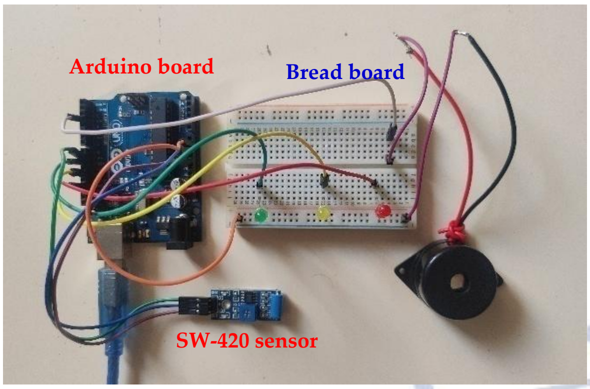


Figure 3: Developed prototype

Figure 5: Data displayed in the serial monitor

3.5 FLOWCHART OF THE MONITORING SYSTEM FOR SENSOR UNIT:

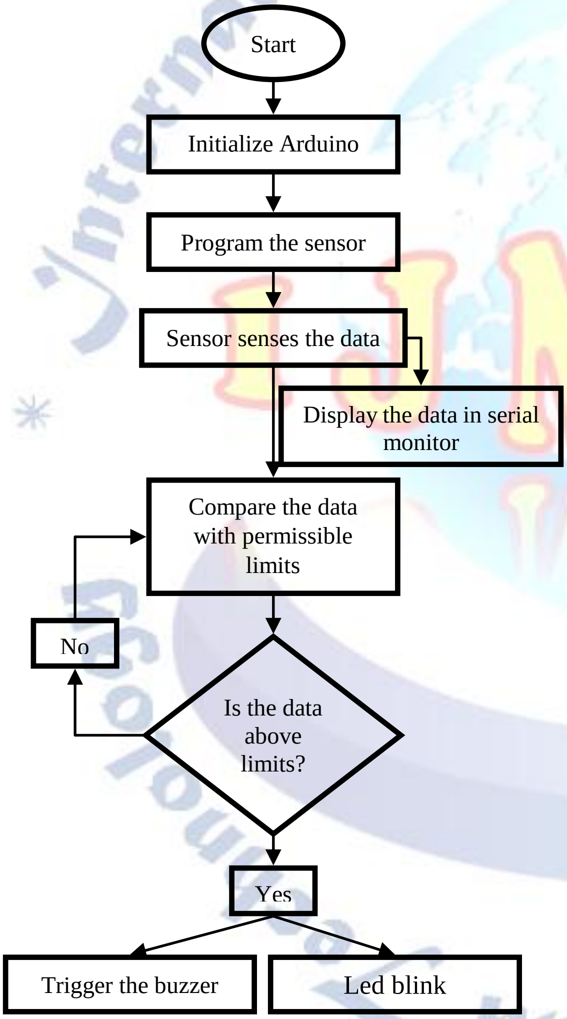
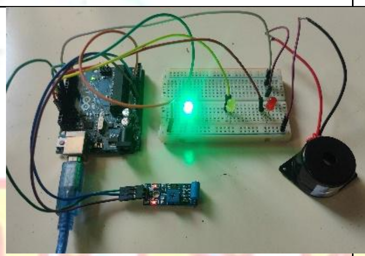
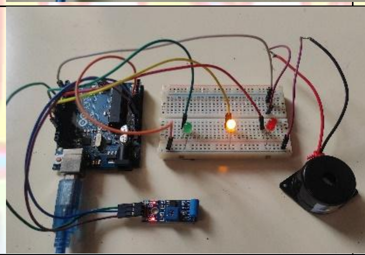
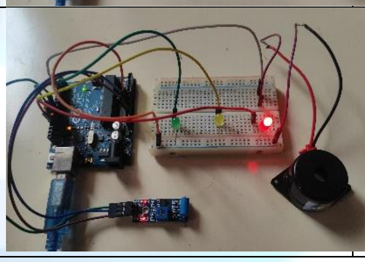


Figure 4: Flowchart of the monitoring system

Table 2: Measurement of vibrations and their indication

S. No	Visual Indication	Serial Monitor
1		measurement= 95 low vibrations in Hz green led on
2		measurement= 555 medium vibrations in Hz yellow led
3		measurement= 1255 high range vibrations in Hz red led

4. RESULTS

The data transmitted from sensor to microcontroller is analysed and evaluated as follows.

The SW-420 vibration sensor transfers the data to the microcontroller which analyses the data and display the data in the serial monitor. The prototype is composed of LED lights and buzzer to give the physical indication. The data obtained in the serial monitor is shown in Table2.

The range of vibrations is given in the code, so that the indicating devices act according to it. From Table 3, if the vibrations are low then Green LED blink. If the vibrations are in medium range, then Yellow LED blink and if the vibrations are high then Red LED blink and a Buzzer is triggered to give audible sound indicating danger.These physical indicators are employed to make the unskilled workers know about the safe and danger conditions of the site.

5. CONCLUSION

In this paper, a prototype is developed using IoT for monitoring the ground vibrations. SW-420 vibration sensor is employed as sensing device and the data transmission to the software is done by the Arduino microcontroller. The sensor records the values of vibrations and transfers them to the Arduino IDE software which displays the values in the serial monitor. The LED lights blink and buzzer ring when the vibrations fall within the range of sensor. The objectives of the paper are fully established, and the prototype developed islow-cost, reliable, and optimized. As the system is used as an alternative for the conventional systems, it is appreciable to adapt the IoT and WSN in the mining industry to ensure safety, optimize production and increase profits.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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