IoT Based Safety and Health Monitoring for Construction Workers

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***Abstract*- Safety is a major problem in construction works. There is no proper solution to solve the problem. People's safety is not ensured in the construction works. In most of the cases, the problem occurs due to work stress or poor health conditions. Some of the accidents occur where people fall down from heights and left unnoticed which leads to death due to lack of medical attention. According to the international report almost 48000 workers die every year due to workplace accidents and the construction site tops the list with 24.20 percent. However, most deaths occurred were preventable. This project aims to develop smart wearable devices such as band and helmet using various sensors that will help in monitoring the health and safety of workers. The devices constructed using IoT help in detecting the fall of any workers and sends SMS notification for immediate aid. Moreover, the workers vitals such as heart rate and temperature are also monitored and warned regarding abnormal health conditions. The project aims to provide a secure and safer working environment for worker thus reducing the number of deaths happening in construction sites. The prototype developed was tested on various conditions and showed high accuracy in the performance.**

Keywords- IoT, Arduino, Sensors.

I. INTRODUCTION

The number of fatal deaths happening in the construction sites is soaring up every year. The safety and health of people is not ensured in construction sites. The workers face a lot of struggles and difficulties in the workplace due to the improper balance between work and their safety. Besides affecting them physically, they are affected mentally as well. Among all the other industries the building industry stands as the leading contributor of fatalities. According to the recent report from the Bureau of Labour Statistics (BLS), there happen around 150000 construction injuries every year and a major proportion of it is contributed by falls or slips from heights. Even with the tremendous development in technology there are no proper devices developed for the safety of worker. Hence, this paper works to build wearable devices such as smart band and helmet for monitoring the construction workers and to provide them a safer and secure working environment. The devices help in keeping track of the pulse, and body temperature of the worker. Moreover, care is also taken to provide emergency alert during any slip or fall of the worker (Both in-house and out-house fall). The rest of the paper provides a detailed study about the proposed system.

II. BACKGROUND

Falls are the second largest cause for the accidental or unintentional injury deaths around the globe. Each year over 7 million people die from fall injury and 80% are in low- and middle-income countries. Old aged people are more prone to fatal falls. [1] In many cases the people working in the construction site were also affected due to fatal or non-fatal injuries. As per the National Safety Council

Magazine, the data analysed by the researchers between 1982 and 2015 concluded that 42% of the fatalities involved falls. [2] Many of the cases of non-fatal injuries but due to lack of timely response the situation becomes worse. In some cases, if the fall is unexpected and unavoidable, then it is impossible to stop it. But giving medical attention on time can avoid the fatal injuries. The proper medical attention should be given to victims of minor injuries in order to elude critical health problems. Health issues such as stress, fever and pain are also a problem for construction workers. According to the study conducted by the Harvard School of Public Health, construction workers struggle with pain and stress from injuries and often fail to seek help, putting themselves at risk for more injuries and mental health issues like depression and suicide. [3] In this case, the injuries may happen due to mental health issues and thus the stress and body temperature of the workers can be monitored to identify the stress of the workers. Lot of devices was found to detect the fall but in many cases the range was limited as Bluetooth was used for the communication. Lot of developments with new devices have come now to improve the range limit that can be used to detect and alert the fall. It can be used in the case of old age people and also for construction workers. Stress can be detected by knowing the heart beat per minute and also the sensors in the thermometer helps in knowing the body temperature of the workers. In some cases, the readings were approximate but it can be improved with future technical advancements as the safety of the workers is our primary concern.

III. THE PROPOSED SYSTEM

The Technological development has led to lot of inventions and innovations. However, until today there are not any proper devices to ensure the safety of the construction worker or identify any fall of the worker. The existing system does not contain any safety measures for the workers to warn them regarding their health conditions. Due to the excessive work burden the construction industry is facing tremendous elevation in the death rate every year. Therefore, the paper proposes smart devices to ensure the safety and health of the construction worker.

The proposed system comprises of two primary components. One is the wearable devices such as a smart band and helmet which is built using sensors and other electronic elements. And the other component is the cell phone. The GSM module enables communication between the two components as described in the figure. On wearing these devices, the health and safety of the worker is continuously monitored and during any detection of abnormal health conditions or activities such as fall or slip of the worker, the respective supervisor is alerted in order to provide immediate aid to the worker. In, addition to avoid confusion on false alerts a button is provided, which he can click and stop the notification from being sent if he is alright. These wearable devices along with the application work together on complete monitoring of the workers thus providing a safe and secure working environment to the workers.

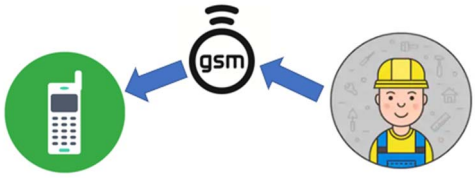


Figure 1 Alert system

IV. SYSTEM DESIGN

System design is one of the crucial phases in system development. There are various factors to be examined while designing the proposed system for seamless functioning of the device. These include 1) Comfortability 2) Portability 3) Reliability.

Comfortability- Constructions workers are prone to performing lots of physical activities. Lots of wires hanging around may cause interruptions while working. Hence the wearable devices developed should be designed in such a way that it is comfortable for the worker.

Portability- The size of the equipment should be compact and easily portable to all locations.

Reliability- Reliability is the primary aspect of every safety device. It should work fault-free under all conditions.

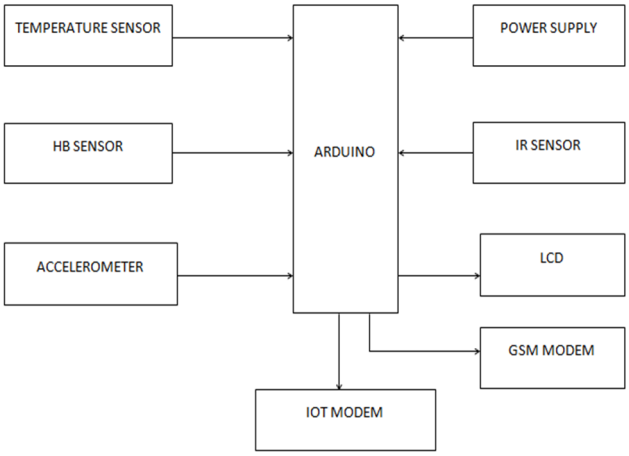


Figure 2 Block Diagram

The figure 2 illustrates the system design for the device. It comprises of two modules 1) Health monitoring 2) safety monitoring.

i. Health Monitoring

The functions of the health monitoring module is to track the pulse and body temperature of the worker. On wearing the health device -smart band, the respective heartbeat sensor, and temperature sensor monitors the vitals of the worker and updates it in a cloud database controlled by the supervisor.

Heart Beat sensor- The Heartbeat sensor measures the pulse rate of the person with a pair of LED and LDR and microcontroller. The basic working principle behind this sensor is optoelectronics. Infrared rays emitted by IR led strikes the surface and is reflected back. The Quantity of ray reflected varies based on the surface reflectivity. This light reflected strikes on the reversely biased IR sensor which results in reverse leakage current. Volume of quasi particles (electron -hole pairs) produced varies according to the magnitude of incident IR radiation. Higher intense radiation leads to increased reverse leakage current which is later passed into a resistor to produce an equivalent voltage. Thus with the ray intensity, the voltage varies accordingly.

Temperature sensor- The LM35 are highly precise temperature sensors having output voltage linearly proportionate to Centigrade temperature. Any type of calibration or trimming is not required in LM35 series sensor to provide accuracy of ±1/4°C at room temperature and ± 3/4°Cover a full -55 to +150 °C temperature range. The LM35's linear output, low output impedance and accurate calibration make control circuitry easy. The LM35 is rated to operate over a -55 ° to +150 °C temperature range, while the LM35C is rated for a -40 ° to +110 °C range (-10 ° with improved accuracy)

ii. Safety Monitoring

It develops a smart helmet for the safety of the worker for detecting any fall or slip of the worker and to provide immediate first aid. The helmet embedded with accelerometer sensor identifies the fall with the help of body acceleration.

Tri-Axis Accelerometer- The accelerometer sensor works based on the acceleration, threshold value and tri-axial position of the object. When an object strikes the ground there will be a zenith value at the total acceleration which has a magnitude.

$$|a| = \sqrt{a_x^2+a_y^2+a_z^2} \quad \text{----- (1)}$$

Where a_x, a_y, a_z represent the accelerometer values of three axis x,y and z.

$$\theta = \tan^{-1}\left(\frac{a_x}{\sqrt{a_x^2+a_z^2}}\right) \quad \text{----- (2)}$$

$$\psi = \tan^{-1}\left(\frac{a_y}{\sqrt{a_x^2+a_z^2}}\right) \quad \text{------ (3)}$$

$$\varphi = \tan^{-1}\left(\frac{a_z}{\sqrt{a_x^2+a_y^2}}\right) \quad \text{------ (4)}$$

The three angles of fall can be obtained by substituting the acceleration value a_x, a_y, a_z in the equation (2), (3) and (4). Futher, with the derived three angles, the orientation of the fallen body can be predicted.

V. IMPLEMEMTATION

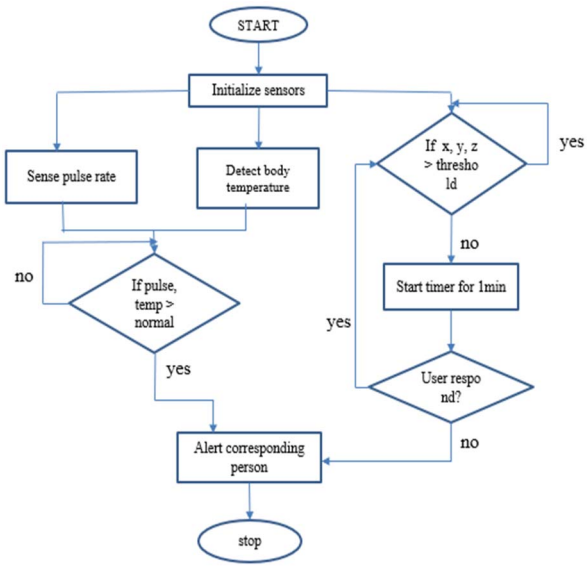


Figure 3 Working Algorithm

The figure 3 depicts the general working algorithm of the system.

1)The first step is to initialize and activate the sensors in the devices. 2) Then a connection is established between the mobile and the devices by inserting a sim card. 3) On wearing the equipment's, the Heart beat sensor, temperature sensor, accelerometer and IR sensor start tracking the vitals of the worker. 4) Once any abnormal health values are identified, an alert message is sent to the

considered supervisor through the GSM Module for organising the work burden. 5) Similarly, if the axis values of the accelerometer sensor exceed the normal threshold value the fall detection algorithm predicts the fall of worker. The system provides one min time for the worker to respond else it sends notification to the supervisor for immediate aid.

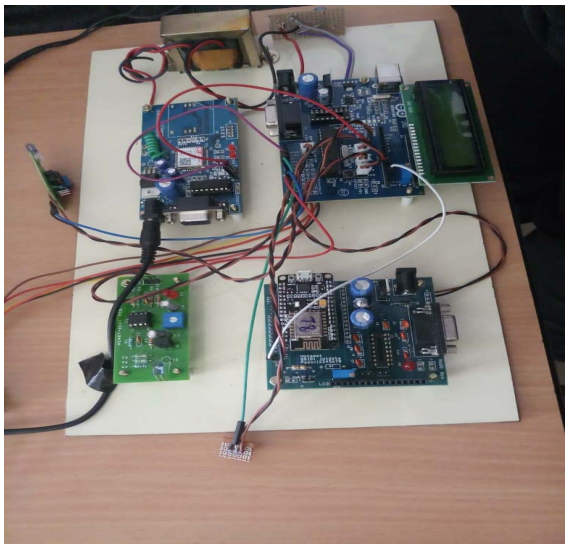


Figure 4 Prototype

The prototype displayed in Figure 4 was implemented using a Arduino Uno Microcontroller, WiFi-serial IoT, GSM/GPRS modem, Heart Beat sensor, Temperature sensor and accelerometer sensor. The three sensors connected to digital I/O pin J18, J19, J20 in Arduino Uno retrieves the vitals detected by the respective sensors and displays it in Micro controller. Furthermore, for the supervisor to monitor the worker, a connection is established between Arduino serial transmit pin (TX) and Wi-Fi receiver pin (RX) which enables passing of Health data from the micro controller and to a third-party cloud maintained by the supervisor. Similarly, the fall details are transmitted from the microcontroller by TX, that is and received sent as a SMS by the GSM module through pin RX.

VI. RESULT

Flawless functioning of any device is determined based on its accuracy of output. In other words, the Equipment should provide guaranteed result under any circumstances. Therefore, to study the accuracy of the proposed prototype, we tested the device in various conditions.

CASE 1 Heart beat and temperature sensor

The heartbeat of a person fluctuates under various

Figure 5 Device displaying Heart rate and temperature

conditions. The table 1 illustrates the average heart-rate that a person should have per minute under normal condition and after any doing intensive exercise.

Table 1 Expected range of BPM for a healthy person in different age groups

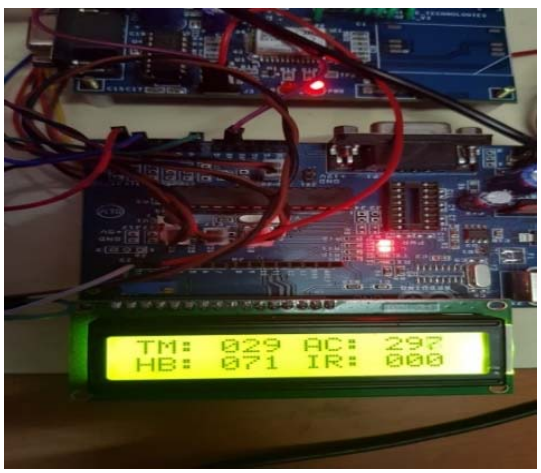
Age	Normal Heart rate	Heart rate After cardio
20-29	68-100	120-180
30-39	68-85	114-168
40-49	65-85	108-162
50-59	60-80	102-150
60-69	60-80	96-144
70+	60-75	90-132

Based on table 1, we tested our prototype on person of different age group and the percentage of accuracy of the heart rate sensor was determined. Table 2 displays the values produced by our prototype when examined on a person.

Table 2 Tested result

Age	Normal rate	After exercise
21	72	135
34	73	119
48	68	94
Accuracy	100%	67%

As per the testing, it was concluded that the heart beat sensor produces 100% accurate results in normal condition. However, in the other case (after exercise) the displayed output had a slight variation than the expected result. The beats displayed for a person with age 48 was 94, that is 14 beats less than that expected, thus reducing the accuracy to 67% in this category. Secondly, for the temperature sensor, as per medical knowledge, the normal body temperature for a person ranges from 36- 39 degree Celsius. However, the surrounding environment has



an effect on the temperature sensor. The surrounding temperature will have effect on the sensor which may increase or decrease the data slightly.

The figure 5 shows the heart rate of a person and the room temperature displayed on the LCD.

Case 2 Fall detection

For the Accelerometer sensor, the acceleration threshold value set up ranges between 295 -450. The device was tested by giving a sudden jerk to the accelerometer. This sudden movement triggered the threshold value to exceed 450 and a notification of fall detection was sent to the supervisor to his phone requesting for immediate aid.

Figure 6 Fall Alert Notification

VII. FUTURE SCOPE

The proposed system ensures the good fall detection taking into account of the complex conditions to provide safety of the workers and to monitor their health. The proposed system overcomes all the issues of the existing system which is in need of providing medical attention to the workers in the case of injuries. The system will detect the fall efficiently and alert the responsible person to provide medical attention. The system will be developed as a prototype now and in future it will be made in a compact size to be embedded into the wearable gadgets. In the future GPS system can also be integrated which can indicate the place of fall and thus making the approach faster and better.

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