IOT BASED AIR QUALITY AND HAZARDOUS EVENT DETECTION HELMET FOR THE MINING INDUSTRY

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ABSTRACT—In the area of mining technology, real-time monitor and control of mine hazard are more complex. Mine safety modules are configured to communicate to ground control or a central station. A real critical issue in mines is hazardous gases. Systems used in a mine can create intense vibrations and increase the level of hazardous gases such as CO, SO2, NO2 and particulate matter. The working conditions can be very noisy and miners don't watch each other constantly. The first hazardous event is defined as an event where miners are struck by an object against the head with a force exceeding a value of 1000 on the HIC (Head Injury Criteria). An accelerometer was used to measure the acceleration of the head and the HIC was calculated in software. The layout of the visualisation software was completed, however the implementation was unsuccessful. Tests were successfully done to calibrate the accelerometer. The second is the concentration level of the hazardous gases such as CO, SO2, NO2, and particulate matter. The third hazardous event was classified as a miner removing the mining helmet off their head. An IR sensor was developed unsuccessfully but an off-the shelf IR sensor was then used to successfully determine when the helmet is on the miner's head. PCB's that were designed and made included a breakout board and a prototype board. A whole software implementation was done based on Contiki operating system in order to do the control of the measuring of sensors and of calculations done with the measured values.

Keywords— hazardous gases, accelerometer, IR sensor, HIC.

1. INTRODUCTION

The problem addressed in this paper was the improvement of a mining helmet in order to ensure more safety awareness between miners. When working with noisy equipment, being aware of one's surroundings can sometimes be challenging [2]. In the mining industry miners tend to remove some of their safety gear because the gear is too heavy, warm or uncomfortable to work with. However, miners generally do not remove their helmets. Presently mining safety helmets only have the purpose of protecting the miner's head against potential hazardous bumps. The safety helmets do not have any technology added to it to let miners know when a fellow miner has encountered a hazardous event. Therefore the purpose of the project described in this paper was to modify an existing mining safety helmet to make the helmet even safer by adding a wireless sensor node network.

A mining helmet needs to be modified to improve miner safety by adding intelligence to the helmet. When a miner removes his helmet he needs to be warned. If an object falls on a miner even when wearing his helmet he can become unconscious or immobile. The system must determine whether or not a miner has sustained a life-threatening injury. These two events are defined as hazardous events. Thirdly, dangerous gases need to be detected and announced.

In the area of mining technology, real-time monitor and control of mine hazard are more complex. Mine safety modules are configured to communicate to ground control or a central station. A real critical issue in mines is hazardous gases. Systems used in a mine can create intense vibrations and increase the level of hazardous gases such as CO, SO2, NO2 and particulate matter. The working conditions can be very noisy and miners don't watch each other constantly. Miners tend to stay in groups and will be no more than 5 meters (m) from each other. A warning system needs to be incorporated that will warn miners within a 5 m radius that a miner is experiencing a hazardous event. This system needs to process and transmit the event within 1 second (s). These systems measure the environment around the miner with gas sensors and are then used to implement evacuations. These do not alert the miner at all or only alert the miner in an audible way. These systems warn miners, but when a miner is obstructed or injured, an external input is required from ground control.

1. SYSTEM OVERVIEW

As the helmet is the only safety gear miners tend to keep on, this is where the new safety equipment was added on to. Three sensors were used, an accelerometer, air quality and an Infra-red (IR) sensor. These were used either to detect if a miner has experienced a bump to the head or removed his helmet and surrounding air quality. The three sensors were connected to a ZigBee module. This module does all the processing and also controls the wireless communication between separate helmets through the Contiki operating system (OS). The whole system was analyzed throughout the design process in order to keep the power consumption to a minimum as the system is running on battery power. Different sensors were considered for each separate component in order to keep the power level as low as possible. In order to explain the entire system and the alternatives of each component, the system will be explained component by component. The system consists of six components, helmet remove sensor, collision sensor, air quality sensor, data processing unit, wireless transmission and alerting unit.

Fig 1:Smart helmet module device for mining safety.

2.1 collision sensor

In order to conclude that a bump is actually dangerous, the bump needs to exceed a certain threshold for a certain amount of time. According to the Federal Motor Vehicle Safety
Standard 208 (FMVSS 208) a Head Injury Criteria (HIC) should not exceed a value of more than 1000.

$$HIC = [(t2 - t1)[\frac{1}{t2-t1}\int_{t1}^{t2} a(t)dt]^{2.5}]_{max}$$

The variable t1 is starting time, t2 is the end time, a(t) is the acceleration over time. An accelerometer was needed to measure the acceleration of the system. The accelerometer needed to be able to measure at least 70 g in 3 axes. The ADXL377 accelerometer satisfied the specifications. There are a few limitations when using the HIC equation. The time interval t2-t1 should be limited to a maximum of only 36milliseconds (ms). The time limitation is to limit the equation to impacts and not sustained accelerations. It is also mentioned that the accelerometers can give inaccurate measurements due to scull deformation. To compensate and to over design, the accelerometer is placed on the helmet itself and not on the plastic harness holding the head. This will allow the accelerometer to reach acceleration experienced by the helmet that will be greater than the actual acceleration experienced by the miner's head.

2.2 air quality sensor

Air pollution from coal mines is mainly due to emissions of particulate matter and gases include methane (CH_4), sulphur dioxide (SO_2), and oxides of nitrogen (NO_2), as well as carbon monoxide (CO). From different studies, it is well known that when human being comes in contact these chemicals/pollutants it could have adverse effect on their health. These unbalanced ratios of air pollution gases, such as suspended particulate matter, increase respiratory diseases such as asthma, chronic bronchitis, and cardiovascular problems [13].In this article we have measured the CO, SO_2, and NO_2. Per the literature we have chosen the electrochemical gas sensor because of its accuracy and low power consumption in the development of air quality detectors. These sensors are also very selective to the target gas.

2.3 helmet removal sensor

For detecting the removal of the helmet a few different approaches were considered. The comparison, advantage, and disadvantage of the proposed approaches in the literature was reported . For this study, the IR beam based helmet remove sensor technique was considered better among other available techniques such as a switch, analogue distance sensor, and digital distance sensor. The IR beam can be designed to use low amounts of power. An off-the-shelf IR distance detector was used for this application. The IR sensor was designed to send a constant signal from the one side of the helmet to the other side.

2. RESULTS

3.1 wireless transmission test :

The purpose of this test was to determine whether or not the wireless transmission between the nodes meets the minimal requirement of transmitting data more than 5 m and how successful the data transmission. Placing the one node at distance 0 m (stationary point) configured to transmit every second continuously. The second node was placed at distances varying from 1 m to 13 m, 8 m further than specified. The second node was configured to receive and transmit the data through the USART. Connecting a computer and storing the first hundred seconds, of the system clock, that was received. The data of each distance was stored and analyzed. The test was done in an environment with people moving through the line of sight and the presence of a Wi-Fi network with the router situated in the middle of the transmission.

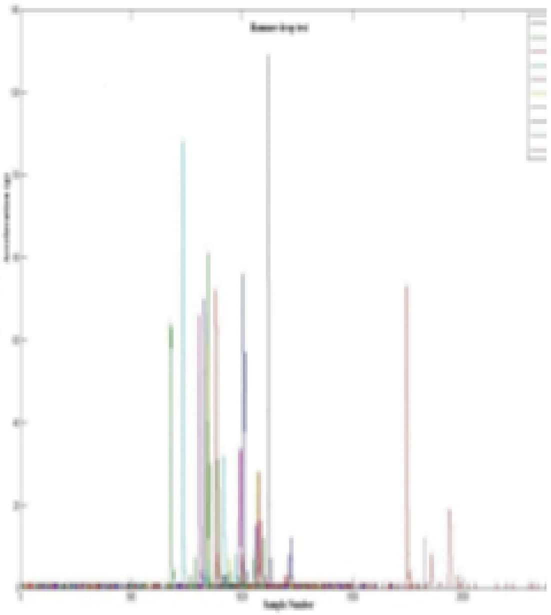

Fig 1.: Accelerometer measurements from impact test on helmet with hammer dropped.

3.2 Air Quality Test

In the air quality testing process, we have used the known gas concentration cylinder and follow the static chamber method for the development of the AQ sensor. An incubator is used for testing of the developed system. The incubator is simply a rectangular plastic box with a hole on the side to fit a pipe that is used to pump in gas. The sensor node is powered on and placed inside the incubator that is then closed. Gas cylinders were used to pump the gas into the incubator. The sensor node then takes measurements of the gas concentration. Off-the-shelf air quality monitoring devices are very expensive and thus there was nothing to compare the measurements to, however the concentration levels were estimated and the accuracy of the system was determined.

The IR sensor designed from first principles was working device. It was discovered, after the system was integrated, that the transmitted IR signals reflects off the dummy head and kept reflecting off the helmet's surface until it reached the receiver. The signal at the receiver side was close to the same amplitude as the signal received when the helmet was removed from thehead. The system can therefore not distinguish between

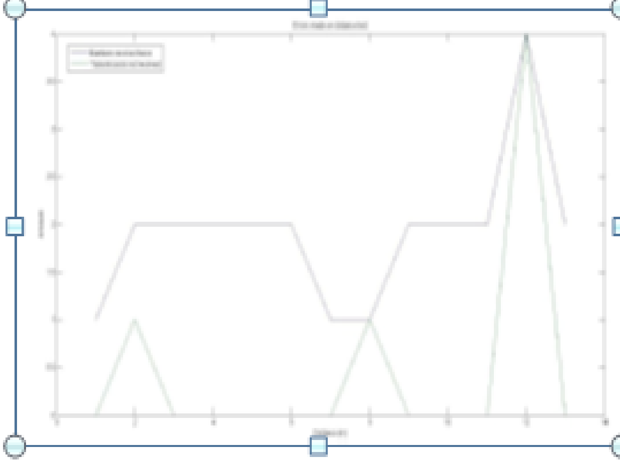

Fig 2: Distance test error, showing a transmission that was not received and transmission received more than ones.

The test was then done using an off-the-shelf IR sensor. It gave the results that were expected and needed for the test to be successful. The system successfully detected when the helmet is removed 10 cm off the dummy head with an average deviation of 0.3% too far. The effect of these results is that any miner will trigger the alert signal when removing the helmet completely off their head as it was specified. Fig. 5showed the consistent values between 81 g and 64 g with an average of 71 g. The results Fig. 6 show the first impact at an average of 56 g and the second more severe impact with an average of 85 g. The result showed that the output of the accelerometer was scaled inaccurately and that the accelerometer needed to be calibrated more accurately. The transmission was successful at distances more than double than were specified.

2. CONCLUSION

The hazardous events were classified as a miner removing the mining helmet off their head. An off-the-shelf IR sensor was then used to successfully determine when the helmet is on the miner's head. Another hazardous event is defined as an event where miners are struck by an object against the head with a force exceeding a value of 1000 on the HIC (Head Injury Criteria).An accelerometer was used to measure the acceleration of the head and the HIC was calculated in software. The layout of the visualization software was completed. Tests were successfully done to calibrate the accelerometer. PCB's that were designed and made included a breakout board and a prototype board. A whole software implementation was done based on Contiki OS in order to do the control of the measuring of sensors and of calculations done with the measured values. The system was extensively tested in order to determine whether or not the system works to the requirements. It was observed that the accelerometer should be placed on the inside of the helmet and not on the plastic harness inside the helmet to compensate for the weight difference. The accelerometer calibration was then modified to correctly calibrate the accelerometer. A few aspects of the system can be improved.

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