IoT BASED AIR QUALITY MONITORING AND CONTROLLING IN UNDERGROUND MINES

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ABSTRACT

Working in a heavy-duty and harsh air environment especially in the underground is not easy to practice especially with its huge risks. In fact, the mining type of work makes it more complicated and has to be sophisticated to overcome those hazards. Where, there are various risks and threats in the underground environment that face the mine workers and machineries such as varying oxygen gas concentration, toxic gases, flammable gases, heat, and humidity. In fact, the variation and sudden changes of those factors have effects on both cases such as increased or decreased and exist on the human as workers, machines, and materials. On the other side, this paper adopts various concepts such as Wireless Sensor Network (WSN) and Internet of Things (IoT). In the implementation perspective, this paper is implemented in Arduino UNO along with the various sensors for desired parameters and using ESP8266-01 as a WIFI module to provide a communication to the internet (IoT platform). In fact, the used IoT platform here is the ThingSpeak platform to perform as an observing dashboard and controlling channel. The paper is considered as four nodes, where two nodes are used for data collection and others are used for controlling the devices. The first two nodes collect data such as Oxygen gas (O_2), Methane (CH_4) deficiency in air, Carbon Monoxide (CO) deficiency in air, temperature, and humidity of the air. On the other side, the last two nodes are used to control the ventilation and siren systems of the mine.

INTRODUCTION:

The industrial sector has developed and advanced rapidly in the last decades within the twenty-first century, where that reflects the fourth industrial revolution. As well, with the continuous progress of the industry and the use of materials, which leads the nowadays technologies to reach the advanced technology industries. In the manner of rapid development, material consumption reaches its peak as per the current time development demands. That reflects the progress of the materials and minerals finding and exploration. In this way, the industrial environment of exploring the materials and minerals faces several risks. Furthermore, among the types of exploration materials is underground mining, which contains more dangerous factors and challenges. The underground mines are a closed and bounded environment which makes the air trapped underground. As in underground mines, the air quality is varying with many unexpected actions and risks that may happen such as low oxygen concentration, high temperature, high humidity, toxic and flammable gases. All the previous risks will obviously affect the mines workers health. Besides the worker's health, having a flammable environment is a high risk as well. From this perspective, this paper aims to ensure safety in the underground mines through monitoring and observing the oxygen concentration and detect other toxic and flammable gases, control the ventilation system of the mine, and the siren in emergency situations.

BACKGROUND:

Working in an industrial environment is risky especially in the underground. Also, the mining type of working makes it more complicated. There are various risks and threats in the underground environment such as varying oxygen gas concentration, toxic gases, flammable gases, heat, and humidity (Howden n.d.). The variation of those factors has effects on both cases such as increased or decreased and exist (detected) on the human as workers, machines, and materials (Ozmen and Aksoy 2015). As the first factor, the rising of oxygen concentration causes different threats like toxic air for breathing, increase rust probability on metal material in the mines, and lastly having an extraordinary flammable environment (Ozmen and Aksoy 2015). Likewise, having a low concentration of oxygen concentration cases difficulty breathing for workers and an unreliable environment for sensors readings and machines. The second factor is toxic gases, where there are different toxic gases that are trapped in underground and between soils such as carbon monoxide and hydrogen sulfide, and other rear toxic gases (Howden n.d.). These types of gases should be monitored for any detection in the different underground places and obviously the toxic gases cases death for mining workers. The third factor is flammable gases, where there are various available flammable gases that are trapped underground and between the soil such as carbon monoxide, hydrogen sulfide, and methane (natural gas) as mainly (alkanes molecules) (Howden n.d.). In fact, most of those gases were high explosive gases.

Underground mines are a closed and bounded environment which makes the air trapped underground. As in this type of mines, the air quality is varying as there are many unexpected actions and risks such as low oxygen concentration, high temperature, high humidity, natural gas, carbon dioxide, and other toxic and flammable gases (Howden n.d.). All the previous risks will obviously affect the mines workers health. Besides the worker health, having a flammable environment is a big risk as well, where this increases the probability of having an explosion of that mine (Adams 2019), which makes the working environment is too risky to work in.

LITERATURE REVIEW:

In this part, various articles and patents of projects have been reviewed and studied to make an understanding for implementation and made this paper possible through comparing what have been done in these projects and how it has been used. Also, this chapter will include research papers which have similar ideas, concepts, appropriate solutions, approaches, or components to this paper. Besides, it includes a comparison between these papers and make an evaluation of each research paper respectively. The next table summarizes the reviewed papers here with a discussion on the relations and differences.

Title, Author, Year	Concepts, approach, methods, and analysis,	Inconsistencies, gaps, contradictions, differences	Improvements
An Internet of Things System for Underground Mine Air Quality Pollutant Prediction Based on Azure Machine Learning, Jo and Khan, 2018	An air quality monitor for undergrounds mines using Arduino with different sensors. Implement IoT, machine learning concept and wireless sensor network	Almost the same but without the machine learning concept and Zigbee communication system. Also, it has no oxygen concentration monitor and this has ventilation and siren alarm control.	- Use LCD display in the device for observation.
Design and Development of E-Sense: IoT based Environment Monitoring System, Pujara and Kukreja, 2020	Air quality monitor for outdoor uses as for cities pollution measurement. Built on Arduino with few sensors and it adopts the IoT concept.	The main gap is on the purpose of the project and the used parameter measured. Used due lack of papers on air quality in mines	- Have more nodes in the distrusted in the city for an accurate reading.
IoT and WSN Based Air Quality Monitoring and Energy Saving System in Smart City Project, Raj and Simitha, 2019	A device used for measuring the air qualities and pollution in smart cities. Built on Arduino with few sensors and it adopts the wireless sensor network and IoT concept.	The main gap between this and the main is the purpose of the project and the used parameter measured. Used due lack of papers on air quality in mines	- Have a sealed prototype.

Real-time Environment Monitoring System using ESP8266 and ThingSpeak on Internet of Things Platform, Parida and Nada, 2019	A device used to monitor and measure the air quality and pollution in cities. Built on NodeMCU with few sensors and it adopts the IoT concept.	The key gap is on the purpose of the project and the used parameter measured. Used due lack of papers on air quality in mines	- Have more nodes in the distrusted in the city. - Use LCD display in the device for observation.

Table 1. Summarization of reviewed articles on this paper

METHODOLOGY:

The methodology is an important thing to consider in designing a project such as this which gave a clear path to the main purpose of the project. Also, considering a useful and beneficial methodology to follow will illustrate the plan and the progress through this paper. The applied methodology in this paper is the V methodology is the most likely suitable for programming and hardware projects in designing and implementation which is why it has been used here. Also, it's used in this paper for its easiness and flawless in usage and implementing it which corresponds with the paper procedure if any mistake happened. The V methodology has good flexibility in case of phase fails, which is an advance for this paper especially as it is in the design part in which having different opinions and concepts at the same time along with the paper's implementation ideas and limitations of the existed components.

The used V methodology of this paper consists of seven phases. The main and first phase is on defining a concept and its specification as making the parameters which to be considered and follow. The second phase integrates the first phase where this phase is on identifying the concept's system structure and the components which are planned to use to build in that specific concept. The third phase integrates both previous phases on designing the desired paper's concept with the considering the parameters and components of previous phases. The fourth phase is on coding the desired and planned concept from previous stages and code the other units of concept as well. The fifth phase is on simulating the finished concept from previous phases in simulation programs to check the validity of codes and the paper's concept. The sixth phase is on testing the concept's system and units, where in reality it is to check the validity and the functionality. The last phase which is the seventh phase is in the implementation of the concept idea in its planned shape and consider it as approved and the maintenance. Overall, in case of having any fails or having drawbacks in any phase itself, it is possible to went back to the matched phase and re-done the work through changing the drawback itself. The next diagram shows the planned to implement and follow to approach to this paper.

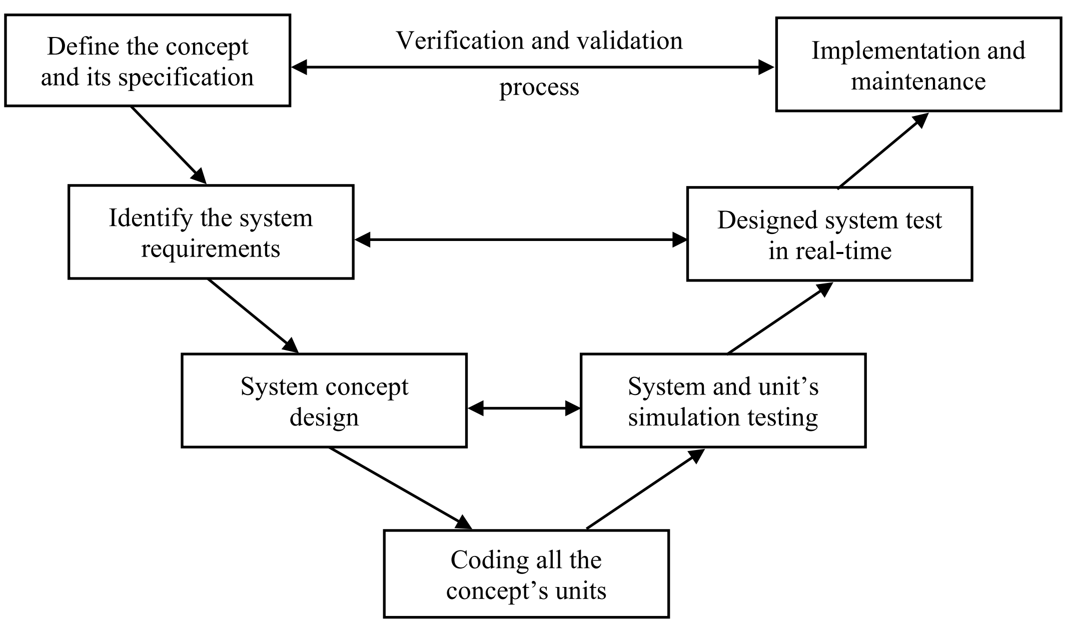

Figure 1. The used V methodology in this paper

PROPOSED WORK:

The project concept consists of four main stages. All stages collaborate with each other to make this project functions well, where each stage represents a purpose in the project concept. The first two stages represent the different nodes which are distributed in the mine. On other hand, the last two stages represent the communication to the IoT platform which provides the observation and control for the mine ventilation and siren systems. Starting with the first stage is the sensing stage, which contains from different sensors such as oxygen concentration sensor, methane sensor, temperature sensor, humidity sensor, carbon monoxide, switching relays for the ventilation system, and the siren alarm. Different sensors are connected to development boards where both components (development board and sensors) form a single node. All sensor in the first stage reports to the next stage which is the processing stage. The second stage is the processing stage, where it consists of a development board and LCD display. The development board receives the sensed data from the previous stage and processes it to send it to the next stage or the WIFI module. Also, the sensed data can be observed through the LCD display and to work as in mine monitor. The third stage is the communication stage, which is consists of a WIFI module, where it provides the communication between the sensed parameters in the development board and the IoT platform. The WIFI module sends the sensed data to the IoT platform and receives data for controlling both the ventilation and siren alarm. The last stage is the control and monitoring stage, which represents the IoT platform, where the observing of the sensed parameters and controlling ventilation fans and the siren alarm systems of the mine.

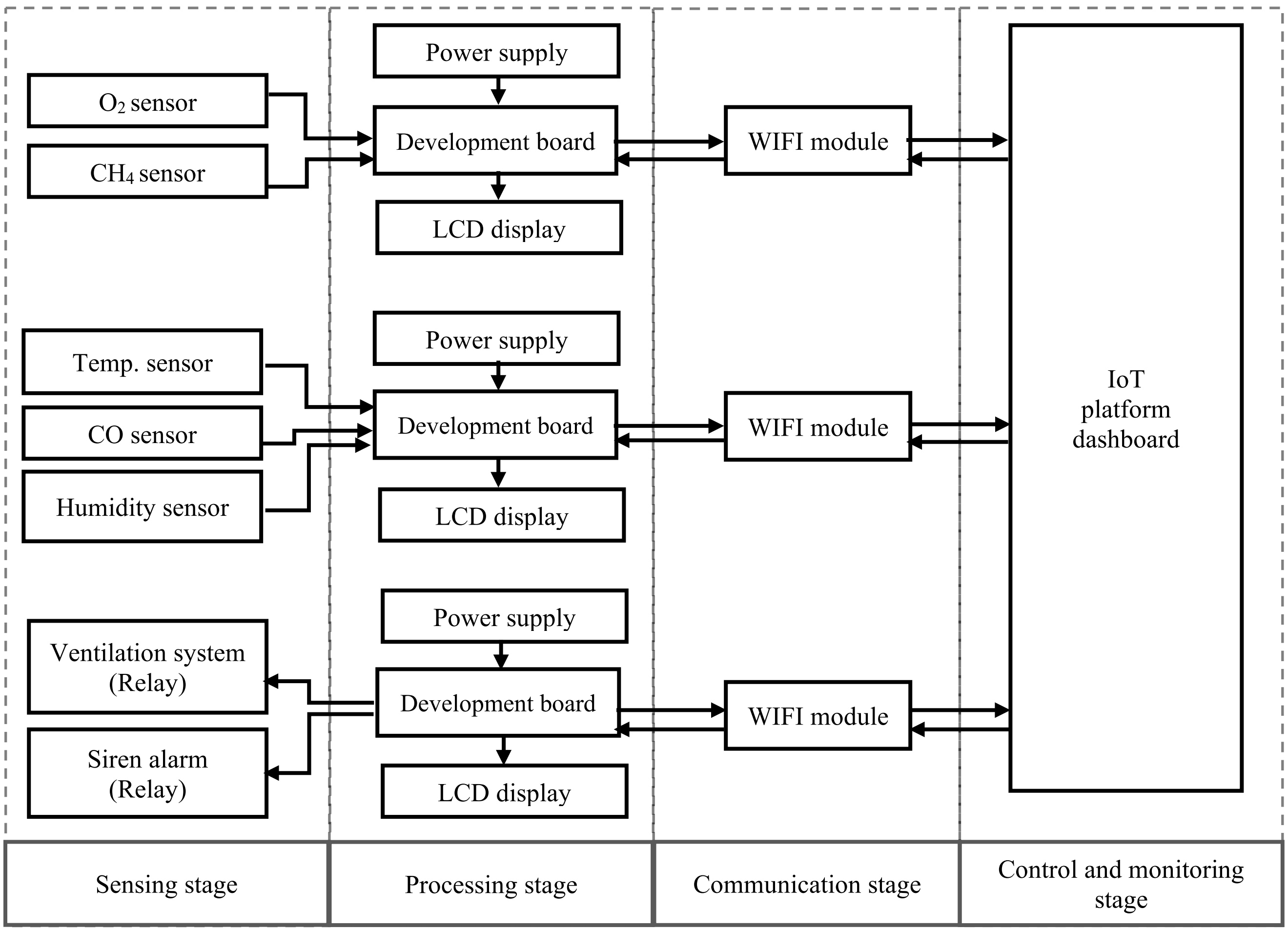

Figure 2. The designed system and its block diagram

The system process starts from the sensing, where sensors report to the development board with sensed parameters. The development board process the received data and prepares it to be sent through the WIFI module. Meanwhile, the sensed parameters are observed in the LCD display which connected to the development board. The WIFI module connects to the internet as an IoT platform which is used for received and transmit data from and to the IoT platform. On the other hand, the received data are processed and shown in different graphs widgets. Also, process the received data and make an index for air quality. Also, make sure the received data parameters are in the safe range and there is no toxic or flammable gas detection. And, in case if the received parameters are abnormal, the IoT platform sends to the development board to turn on the ventilation and siren alarm system.

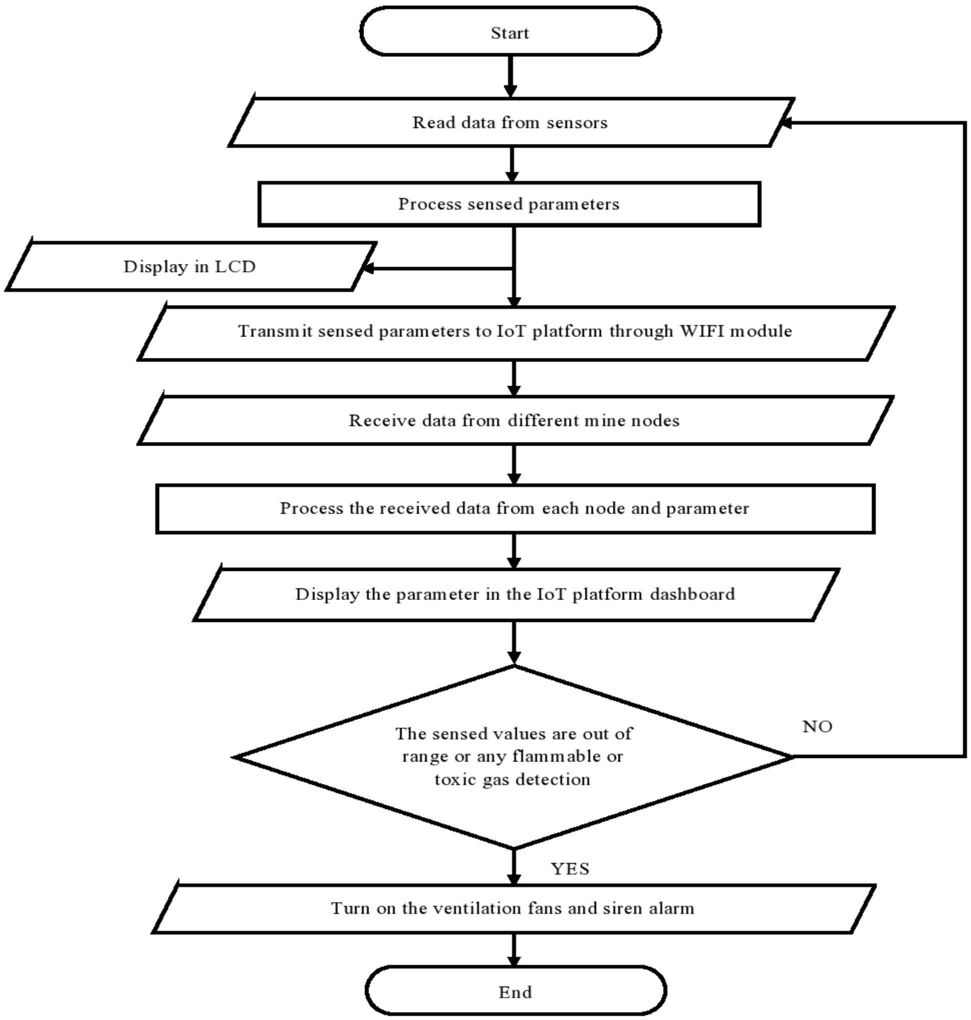

Figure 3. The flow chart of the proposed system

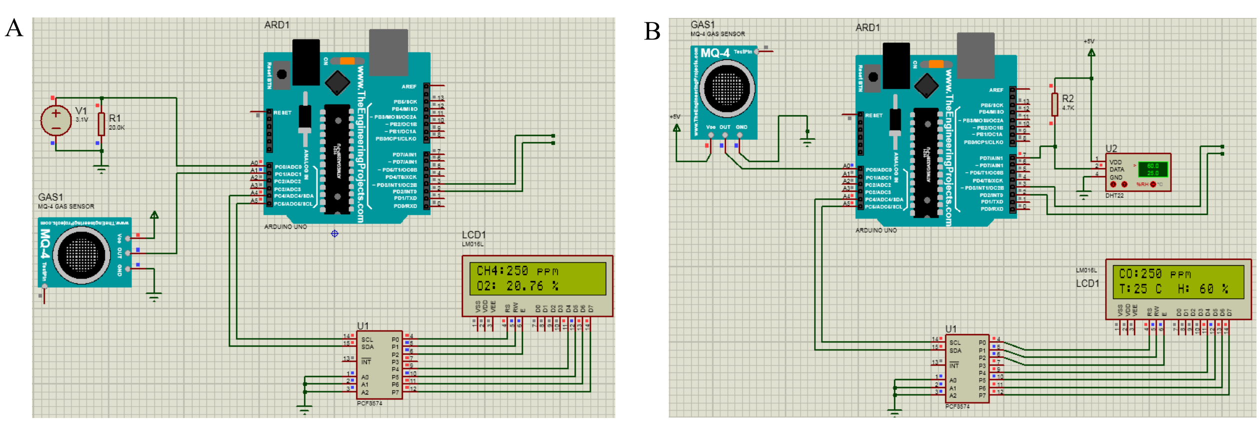

Figure 4. Testing stage: A- First node simulation, B- Second node simulation in Proteus software

RESULTS

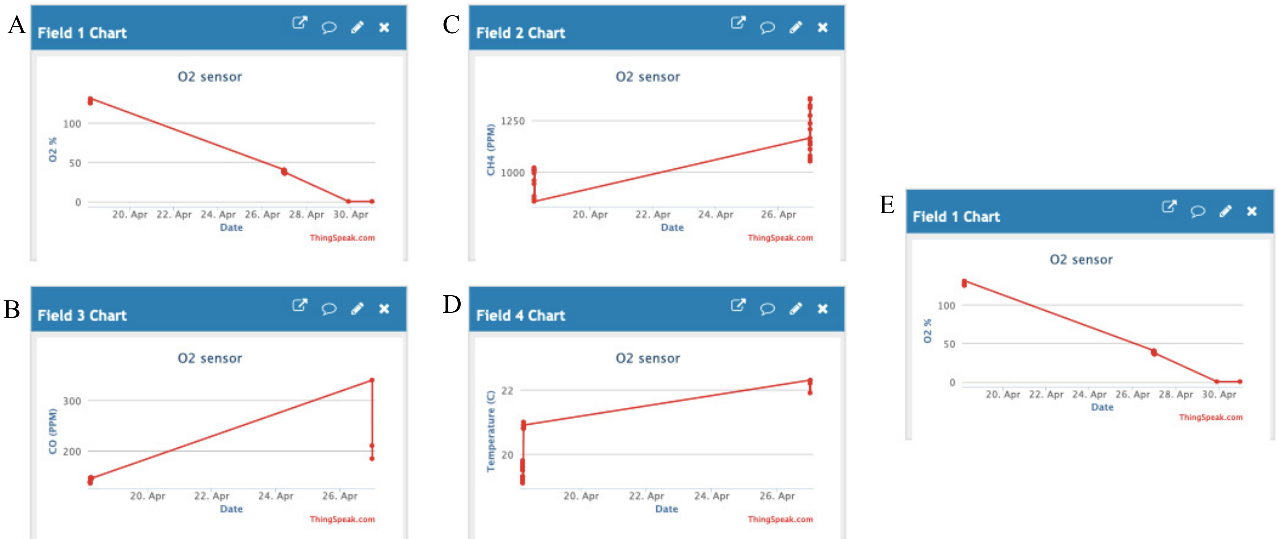

Figure 5. A- Oxygen measurement in percentage, B- Carbon Monoxide measurement (ppm), C- Methane measurement (ppm), D- Temperature in Celsius, E- Humidity (%)

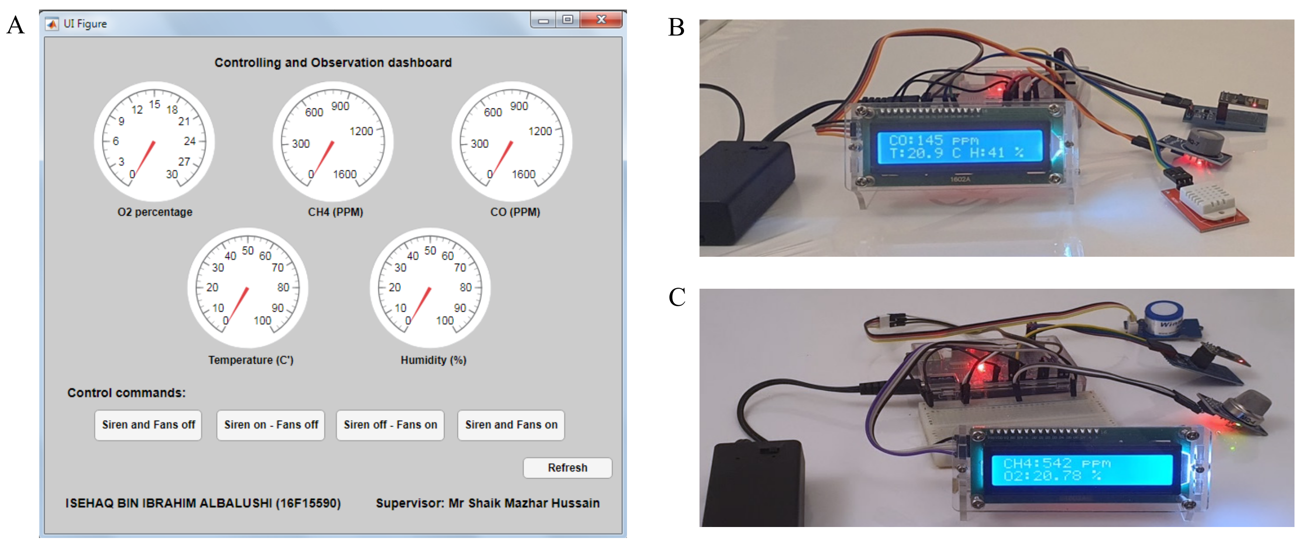

Figure 6. A- Controlling and Observation dashboard interface made with MATLAB GUI, B- Implementation of the second node, C- Implementation of the first node

CONCLUSION

The proposed prototype in this paper is designed to demonstrate the monitoring of air quality parameters and controlling the air environment of underground mines. The prototype is connected in different places in the underground mine to observe and monitor the much air coverage, where also to control the ventilation system and siren alarm based on the observed parameters from sensors. The collected parameters are observed in the ThingSpeak IoT platform and the made dashboard. Actually, the dashboard is made with MATLAB GUI tool to observe the data from the IoT platform and control the system which is also connected to the IoT platform. The proposed system gave the controller the reading of the sensor and the controller decide threshold levels of air quality parameters and indicates the harmful situations. Future work can be done as upgrades, such as sending SMS messages or emails to the authorized people of the mines and they make decisions.

LIMITATIONS

There are few limitations in the proposed system such as the response time (delay) of sensors used in the project affects the actual response. The maximum volume in which the oxygen deficiency sensor can be measured is 25%. Any internet connection loss while monitoring gases such as oxygen and controlling the ventilation system could affect the response of the system. Any error or false reading from any sensors used may cause monitoring error as reliability and bad response. Need to provide a Wi-Fi connection signal to connect all project's nodes in the underground to the internet and the IoT platform. Some of the used sensors require ideal oxygen concentration which is 21% to perform well and accurately.

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