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MULTI SENSOR DATA FUSION AND VIDEO STREAMING BASED MINE SAFETY MONITORING SYSTEM THROUGH IP

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Abstract

The research is an internet-connected mine safety monitoring system that streams live camera images and other vital information about the underground environment and makes it available on the web. This helps the ground control person to monitor and understand the actual mine condition remotely from anywhere on the globe, check the local environment conditions, make clear decisions based on the live video feed, and to provide other emergency services. The system uses an Ethernet wired connection and acts as a web server over the internet, which means, everything used in the system is digital including the camera sensor. An IP-based solution such as this offers reliability and does not suffer from signal degradation problems when transmitted over longer distances, unlike the existing analogue solutions. Ground control persons need to have a connected device such as a Smartphone or tablet or a PC with an internet browser to monitor the video and other data. There is no need to install and maintain a separate mobile app. The system could be integrated with a network video recorder system to handle multiple devices such as this. The application firmware runs on top of an RTOS to handle the multitasking requirements of the system.

Keywords: Ethernet, Mine, Process innovation, Product innovation, RTOS, Web server.

1. Introduction

In the mine safety monitoring system, the underground monitoring people could fully grab the actual situation of mine through the real-time live video monitoring and audio environmental parameters. The monitoring can detect potential accidents, reinforce early warning, and improve the overall efficiency of rescuing. However, in related work discussed by Disputed articles, the existing mine monitoring equipment has the following imperfections. First, the video monitoring equipment is mostly analogue cameras whose poor signal quality and not long transmission distances [1]. Second Solar driven air conditioning system integrated with latent heat thermal energy storage described the information channel is not shared and the equipment cannot combine image, voice, and data together, which is difficult to improve information availability, and causes a large waste of human and material resources [2].

Third, most of the existing underground monitoring equipment has high power consumption and large volume. Information and communication technologies, including robotics, big data, 3D printing, artificial intelligence, and the Internet of Things (IoT), have become key players in many industries during the fourth industrial revolution. Smart mining technologies, which combine the previously stated technologies, have been created to enhance safety and productivity in the mining industry. Drills, trucks, shovels, and conveyors are examples of mining equipment that can be automated, and from them, useful data can be gathered. Nevertheless, small mining companies find them costly and challenging to operate.

Mining started off as an artisanal activity and has since grown and changed, becoming extremely complex [3]. Mining is unquestionably an essential activity for the advancement of humanity in the modern era, given the need for commodities from the digital electronics and device components industries as well as the growth of the renewable energy sector. A number of chemical elements have been needed by humanity to create the tools, machines, artifacts, and utensils that are necessary for daily living and well-being. Mining projects have historically presented difficulties due to factors such complex geographic locations, harsh terrain, severe temperatures, and the presence of nearby communities and ecosystems [4].

Due to the several areas that comprise a mining project's systemic structure, another problem is that it is complicated and diverse, necessitating the involvement of experts from numerous disciplines. However, due to a limited culture of taking on a certain amount of risk and utilizing novel, cutting-edge technological solutions that have not yet undergone extensive testing, the mining industry is highly conventional and somewhat hesitant to adopt new technological systems .For certain mining firms, implementing a completely automated system can be a realistic problem because of infrastructure constraints related to data storage, management, and transmission. Many mining businesses currently have a tendency to push new technologies that diverge from conventional approaches in order to rely on creative techniques that hasten the transition to a digital mine.

In this context, Industry 4.0 denotes a paradigm shift toward a new industrial revolution that combines intelligent digital technologies with sophisticated production and operations techniques to create a digital mine that is not only autonomous and connected, but also capable of communicating, analysing and using data to inform more intelligent actions in the real world.

2. Literature survey

At present, underground mine operations go far deeper into the ground facing difficult terrain and poor environment and are vulnerable to accidents. Underground mining surveillance plays a critical role in the safety and security of the mine workers and other valuable equipment. A recent trend in the mining business is to use CCTV analogue cameras as a remote video monitoring solution and uses ground control personnel to monitor and record the underground work site safety [5]. These solutions are purely analogue-based and hence suffer from poor signal quality and short transmitting distance disadvantages [6]. To transfer this video content over the internet; they need an expensive DVR (digital video recorder) device [7].

Other solutions to bring the information above the ground based on wireless technologies also suffer from a similar set of problems considering the depth of the site below the ground Impact of parameter variations on the steady state behaviour of grid-connected renewable energy conversion systems. By defining the parameters and sending out instant notifications in the event of a potential or escalating threat, the proposed WSN expedites the evacuation process. Password-protected dashboard that displays the live status and real-time values. Because the NodeMCU being used has a built-in Wi-Fi module, the system is effective, inexpensive, and power-efficient without requiring an additional transceiver for connection [8].

Usmanova et al. [9] addressed the function of IP video surveillance systems in integrated security systems as well as the significance of a developed telecommunications infrastructure for the state's economic development. The topic of discussion is how to integrate video surveillance with different technical solutions to help solve issues unrelated to security while also guaranteeing the well-known safety of agricultural produce. The average delay and packet transit time were ascertained by the authors by looking closely at the features of the IP camera communication, analysing the flow parameters, and gathering statistics. The authors created a simulation model of an IP video surveillance system using the data they had collected, which may be used to identify the ideal switching equipment characteristics for the system.

Certain visual requirements must be met for the surveillance system to operate in autonomous mode. One of the most important criteria for ongoing environmental monitoring is live streaming. Motion detection and people detection are required for the surveillance system to function and operate smoothly. The primary goal of this proposed work is to use machine vision to construct modules such as live streaming, motion detection, and people detection in order to supply the surveillance system with the necessary characteristics. Sivarai et al. [10] proposed a user-specific Telegram Bot to facilitate communication between the user and the surveillance system while the user is in a faraway location.

By investigating the use of an electronic card system as a substitute for gathering local data from the vehicle and broadcasting it remotely to a graphical supervisory interface, the primary goal of this effort is to know and follow the driving in real-time [11]. To track the vehicle's present activities, we employ a data logging device that can be placed in any car that complies with OBD-II and CAN Bus standards. The monitoring system that will be installed in the vehicle collects the important variables for our study, including the vehicle's location coordinates, coolant temperature, speed, and engine speed. It is made up of a GPS module, an MCP2551 transceiver, a PIC microcontroller, and a WIFI transceiver.

Assuring the safety and security of a home can be greatly aided by smart home security systems [12]. This makes it easier to keep an eye on any suspicious activity occurring in or around the house, from anywhere at any time. The need for sophisticated home security systems is growing as a result of recent technical advancements and a rise in fire and burglary incidents. Consequently, in order to satisfy the need, this study work has created and developed a novel model.

The problem of resource constraints would be resolved by integrating IoT with edge. However, because of IP-based solutions provided by IoT, effectively retrieving health data from a big pool of data would still be problematic. Based on name-based content searching, Named Data Networking presents a viable approach for effective data delivery. This study developed a secure remote healthcare monitoring platform based on NDN communication, which integrates edge computing with IoT [13]. It provides security to each individual piece of content using encryption and hashing techniques. The suggested framework's performance is compared to that of its Icarus simulator companion. The outcomes demonstrated the effectiveness of our methodology in terms of content retrieval latency and associated costs for obtaining the necessary data.

In order to conduct the review, Kim et al. [14] research was categorized into three categories: wearable, autonomous, and field monitoring systems for Arduino. The majority of mine investigations were categorized as atmospheric or geotechnical monitoring in terms of field monitoring systems. The miner's health status was taken into account in wearable systems, together with the mine's ambient parameters. When developing an early prototype for autonomous mining systems, Arduino can be a helpful tool. Arduino has the advantage of being affordable and able to be integrated with a wide range of electronic items. As a result, even though a lot of research has been done in the lab rather than in real-world settings, Arduino applications in the mining industry may still grow in the future.

3. Overall Mine Monitoring System

The mine safety monitoring system overall block diagram is shown in Fig. 1. The monitoring system is depicted as a hierarchy structure where the sensor nodes are placed at level 1 to which the sensors like temperature, pressure and vibration are interfaced. These sensor nodes are placed at predefined locations such that each and every sensor node0 falls within the transmission range of at least one sensor node. Only with this placement it will be possible for the data to reach the intermediate node. The intermediate node will have a raspberry pi board with a camera interfaced to it. The intermediate node will be at level 2 and gateway node as level 3. From the gateway node the data will reach the monitoring site through cloud platform Thingspeak. Based on the data received the monitoring person can take appropriate action.

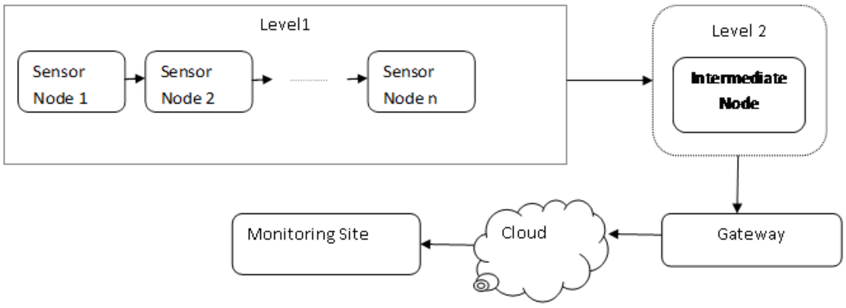

Fig. 1. Mine safety monitoring system.

Modules of mine monitoring system (MMS):

1. Level 1: sensor node (SN)

The sensor nodes will be placed as the regular nodes for monitoring the environmental parameters inside the mine. The sensors that are interfaced with sensor nodes are temperature, pressure and vibration. The mining area's temperature is determined by the temperature sensor. Additionally, pressure sensors assess the mines' pressure. Notifications and alarms are generated in response to temperature threshold readings, which might activate exhaust fans or raise fan speed.

Within the mine, proximity sensors are useful for finding miners and large machinery. By using this knowledge, miners can shield one another from potentially fatal incidents. The vibrations are also a major factor in detecting changes in mining levels as these sensors are crucial because they assess the intensity of vibrations and promptly notify the miners. The smallest variations in the mining patterns can be detected by vibration sensors. The level 1 is depicted in Fig. 2.

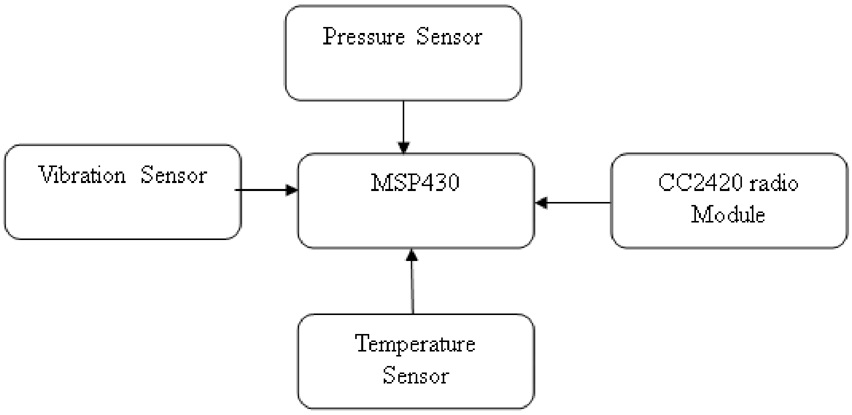

Fig. 2. Level 1: Sensor node.

The processor used for processing the sensor data is MSP430 and CC2420 radio module is used for transmitting the information to the nearby nodes till it reached the intermediate node. These sensor nodes using zigbee communication protocol for transmitting the data. These sensors will be triggered at regular intervals to sense the environment.

2. Level 2: Intermediate node (IN)

The IN is a raspberry pi with a camera and loudspeaker attached to it. The IN collects the data from the sensor nodes in its vicinity and aggregate the data and further forwards it to the gateway or nearby intermediate node. The camera is triggered to capture the video at regular intervals of time and the video of 2 seconds is captured. The loudspeaker is used whenever the person from the outside wants to communicate with the workers inside the mines. Further the aggregated data will be forwarded to the level 3 gateway node. Figure 3 depicts the structure of the IN.

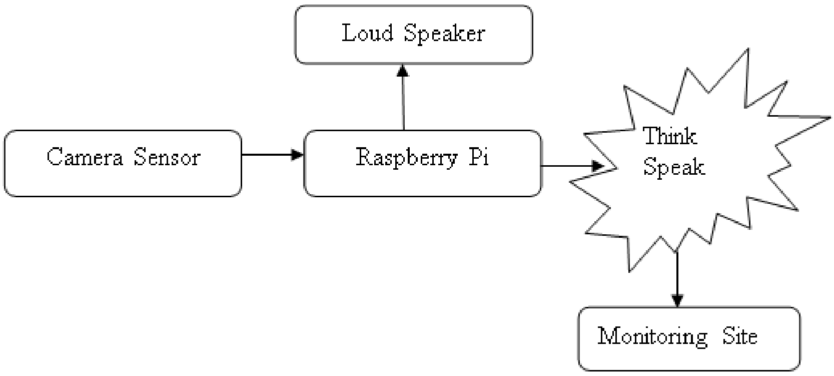

Fig. 3. Level 2: Intermediate node.

3. Level 3: Gateway node (GN)

The gateway node also has a raspberry pi which collects the data from all INs and further aggregates it and transmits the data to the Thing Speak IoT cloud platform where the parameters are monitored, and appropriate action is taken using the actions available at the platform which can be used for actuations.

4.Thing Speak IoT platform (TIP)

The TIP is used for monitoring the environmental parameters of the mine periodically and remotely. Whenever there is a change in the data the actuations will be triggered accordingly.

5. Performance Evaluation

The software of mine safety monitoring system uses atollic True STUDIO software with j link debugger. System software is composed of embedded c language and application programs. The application program is mainly divided into the following modules: the video acquisition and coding module, the audio module, the environmental parameters access module, and the network transmission module.

The performance of the system can be evaluated by deploying the sensor nodes in real time in a random deployment scenario and from the SNs the data is collected by the INs and further by the gateway. From the gateway the readings are uploaded to the cloud. The environmental parameters uploaded to the cloud are depicted in Fig. 4.

It is observed from Fig. 4, that whenever there is an increase in the environmental data, the actuations can be triggered. Whenever environmental data exceed even the camera can be triggered to capture the video and transmit it which can be viewed using any of the open source IoT video platform. The data depicted in the figure was taken over a day and observed. These data can be remotely monitored from anywhere with the channel id available. Since the channel has a unique channel id, write and read API keys unauthorized access to the system can also be avoided. It is also imported to place the SNs, INs and gateway at correct locations and within the transmission range in order to avoid the loss of data and also to ensure timely delivery of data as it is a time sensitive application.

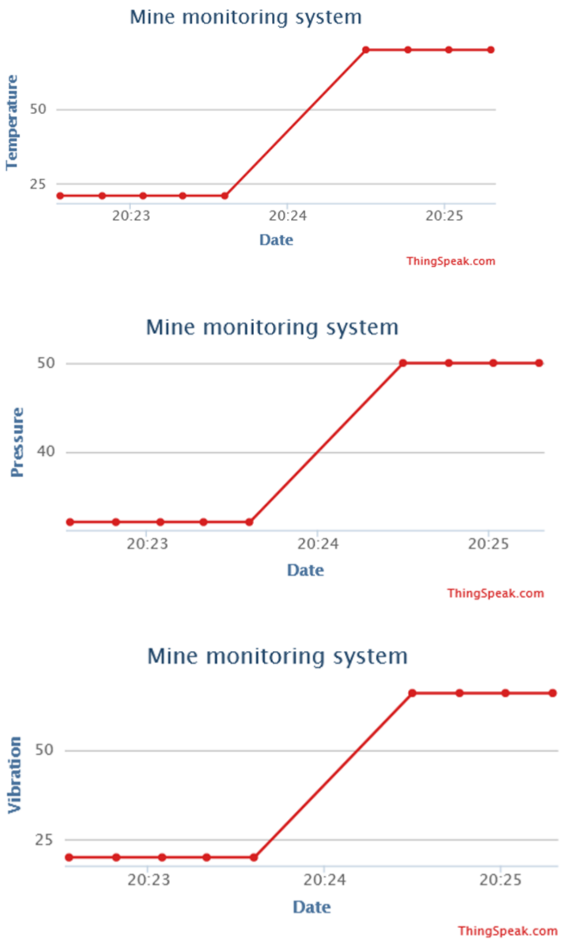

Fig. 4. Data monitored through TIP.

6. Conclusion

The mine safety monitoring system uses to monitor underground mines with the help of live video streaming, audio monitoring, and environmental conditions measuring and network remote transmission. It has the following advantages like achieve high image quality with hardware video codec and low power consumption. Most importantly the system is applicable to the monitoring of mine safety and security production. All the design determines that the system would have a more valuable application and broad prospect. In future the mine monitoring system will be implemented in real time by deploying it in mesh or hybrid topology. Once deployed in real time the system can be evaluated using metrics such as packet loss and time delay.

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