Implementation of Wireless Sensor Network and Fuzzy logic in Smart Coal Mine Monitoring System

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Abstract : This paper presents implementation of Wireless Sensor Network technology and fuzzy logic in the field of coal mine monitoring. Here the client-server communication is established between an unmanned vehicle Rover and control console (HMI) where the Rover acts like a client and the control console acts as server system. The coal mine monitoring system acts on TCP/IP protocol where the server request a data by sending a pull up command to the client .As soon as the pull up command received by the client, it immediately send the information required by the server. Here the system also use an android platform to communicate directly to the operator using a HMI(Human Machine Interface) in the form of tablet or android phones. A software like LabVIEW is developed which work on GUI platform which makes the project more versatile and user friendly. The system provides real time monitoring of the coal mine environmental condition and also determines the critical levels by developing fuzzy rules. This helps the operator to take necessary action accordingly to avoid any type of hazard

Keywords- WSN ,LabVIEW , TCP/IP protocol ,Coal mine monitoring,fuzzy logic.

I. INTRODUCTION

Coal plays a significant role as a major source of energy as well as large industry around the world. But the underground coal mine environment is very complex. Many accidents can occur in coal mines which lead to loss of human life and property. Presence of toxic gases like methane and carbon monoxide; high temperature , chance of fire are the main reasons for these disasters. Therefore to reduce accidents and to increase productivity a continuous monitoring of coal mine parameters with accurate and effective sensing system is necessary [4].

For a good monitoring system, the transmission of collected data to the control room outside through some effective ways is also necessary [6]. Data can be transmitted wirelessly or by using cable. Wired network using cables or fiber optics inside coal mine is not efficient and reliable. The entire communication system of the wired network may crumble due to the unexpected roof fall at any moment [1]. Moreover it is inappropriate to lay cables in coal mine because they consume time and also of high-cost.

In recent decades , several methods are adopted for monitoring. Article [1] describes a Robot using wireless technology and IOT to detect coal mine. The robot can be send to the explosion area of coal mine and data assembled by it sent through SMS to the rescuers using GSM module. Bluetooth is used for data communication. Robots are effective but sometimes their complexity and costly components make them a little unreliable. An IOT based smart helmet is implemented in article [3]. It provides real time monitoring of environmental parameters of coal mine and also provides emergency alert to the control room. The system uses Wi-Fi technology for data transmission to the control room. A monitoring system based on MEMS (Micro Electro Mechanical System) sensor and ARM7 is developed in article [10]. The data is collected by the MEMS based sensors and transmitted to the ARM7 microcontroller. Wi-Fi, IEEE 802.11 wireless protocol is used for data communication and the workers are also alerted when critical situation are detected in data processing. The Wi-Fi technology is a good transmission media but it can be explosive t in coal mine environment.

A LabVIEW based monitoring system which uses Zigbee and GSM is described in article [2}.LabVIEW compares the sensor value with the predefined critical safety value and gives alarm through GSM module. A combination of traditional and modern method also found in article[7]. The system integrates optical fiber cable with wireless gas sensor network. The system has a underground substation, data transmission system and control centre. Optical fiber cable is used for communication between the wireless gas sensor and the control room.

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In this paper, a WSN network technology is implemented in an unmanned vehicle Rover using client-server communication system and TCP/IP protocol.WSN being low-power wireless communication technology have some characteristics of good flexibility, self-organization, dynamic topology [12].This makes the monitoring system more accurate, efficient, reliable and fast. It continuously monitor the coal mine parameters using LabVIEW based on HMI or by using an android platform and provides immediate and necessary information to the operator. It also determines critical levels of environmental conditions by developing fuzzy rules.

II. SYSTEM DESCRIPTION

The system consist of a sensor unit ,a microcontroller unit, power unit and motor driver unit. It has two gas sensors and a temperature-humidity sensor. MQ4, MQ7 sensors are used to detect the concentration of methane(CH_4) and carbon monoxide (CO) gas respectively in coal mines. DHT11 sensor is used for temperature and humidity measurement. Arduino Pro Mini is used as microcontroller which basically collects the environmental information from the sensor unit. It converts the analog sensor values to digital ones and sends them to the control room section through wireless sensor network using Bluetooth communication. Here a client-server communication is established between the rover and the control room. Rover acts as client and control room acts as server. The system communicates in Mesh networking using TCP/IP protocol [4].

A. Block diagram

As show in the figure 1 ,it is observed that the system consist of a sensor array which send the data to the controller. Then the microcontroller receives the sensor data and relays it to the control room through a WSN. Power supply unit is enabled to energize the sensors and transmission unit. The data transmission is done using Bluetooth module and arduino controller. Serial communication through Wireless Sensor Network is done in the project.

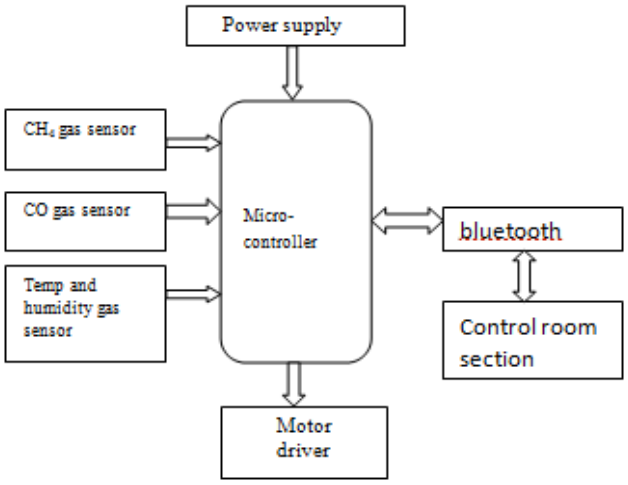

Fig1: Block Diagram of the system

III. WORKING PRINCIPLE

The sensors embedded in the system send the data to the controller unit and it is monitored in a continuous manner using a loop program. The controller receives the pull up request sent by the server ,it initiates the loop and sends the sensed value of the sensors to the server. Every sensor has unique pull up request for example ‘a’ for methane, ‘b’ for Carbon Monoxide etc. As soon as the controller receives a pull up request from a sensor ,it immediately sends an acknowledgment receipt so that the data send properly. If the server denies the acknowledgement receipt, immediately it send another pull up request and the process continues. This wireless networking system is called client-server communication where the Rover act as a client and the control room acts as a server..The sending and receiving of data between the client-server is done by using TCP/IP protocol .It also perform error checking on all data so that there will be no error in any data that are send and received.

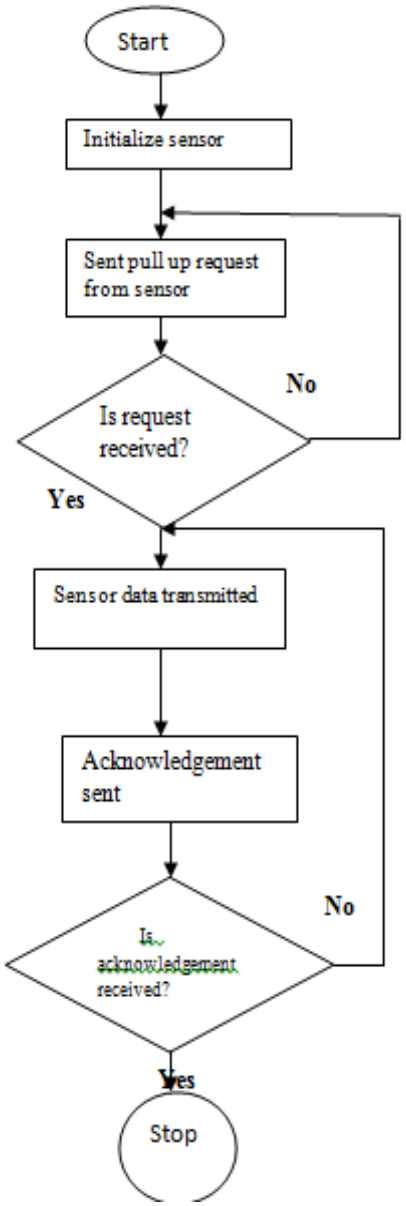

Fig.2 Design flow for data processing

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Table 1: Pull up requests and theire associated values

Pull up a request	Associate
a	CH4
b	CO
c	Temperature
d	Humidity

IV. EXPERIMENTAL DATABASE

Table 2: Experimental database

Pull up request	No of packet transmitted	No of packed received successfully	Accuracy (%)
a	25	25	100
b	25	23	92
C	25	24	96
d	25	25	100

It has been observed that the data has transmitted with an success rate of 92-100 percent

A. Monitoring of data using LabVIEW

LabVIEW is a graphical user interface and a system design platform from National Instruments [NI] . It creates HMI (Human Machine Interface) which displays the various sensor values on PC which are sent through wireless sensor network. LabVIEW can monitor as well as drive the system by putting the switch on respective modes as shown in the Fig 5. Whenever the operator wants to know the sensors value, it sends command from LabVIEW to the rover(client). As soon as the rover receives the command, it immediately responds to the command to the sender (server). The corresponding value associated with the command is displayed on LabVIEW on PC.

Fig.3 Data monitoring in LabVIEW software

B . Data Monitoring Using Android

An android platform can also be used for monitoring the data. A software is developed in an android platform where it displays the respective values of the sensors associated with the command given to it by the server.

Fig.4 Monitoring of data in mobile phone

V . IMPLEMENTATION OF FUZZY SYSTEM FOR DETERMINATION OF CRITICAL LEVEL

In a coal mine monitoring system the main two deadly gases CH4 and CO of coal mine are odorless and can't be detected by human organ., therefore determination of critical level is crucial. Here a fuzzy system is implemented for determination of the critical level of the environmental parameter. In coal mine, methane gas and temperature are interrelated..The system is based on the idea that when temperature increases, CH4 evolution rate increases and the concentration of methane becomes critical quickly. Here two parameters are chosen as input for the system- A)Surrounding temperature, B) CH4 Concentration. The output is obtained by determining the critical level of the parameters.

The range of temperature is selected from 30^0C to 50^0C. The entire range is divided into five membership function..Similarly CH4 concentration is also divided into five membership function ranging from 20-380ppm.

Table 3: Different membership function for temperature range

Membership function	Temperature range (deg Celsius)
Very low	30-37
low	34-42
normal	37-47
high	42-51
Very high	47-54

Table 4: Different membership function for CH4 Concentration

Membership function	Concentration of CH4(ppm)
Very low	20-130
low	65-200

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normal	130-270
high	200-330
Very high	220-400

A fuzzy system design is developed in LabVIEW. When the user enters the value of different parameters and their ranges in the fuzzy system, the different membership function for variables temperature and CH4 is appeared as show in the figure 5 and figure 6. The fuzzy system also determines the different membership function for the output critical level .

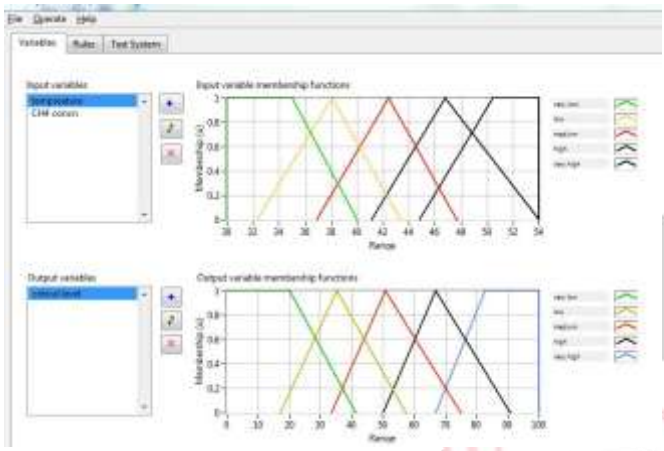

Fig. 5 Design of membership function for temperature in LabVIEW

Figure above shows the 5 different membership function – very low, low, normal, high and very high which are obtained for the parameter temperature in the fuzzy system. It also gives the 5 different membership function – very low, low, normal, high, very high for the output critical level .

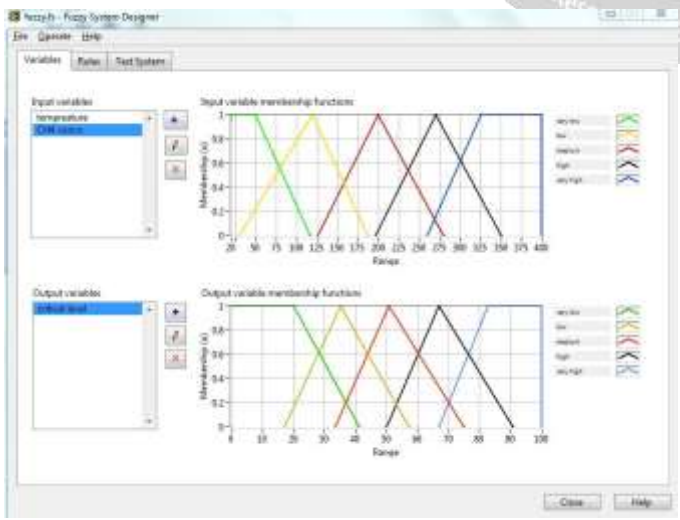

Fig.6 Design of membership function for CH4 concentration in LabVIEW

Similarly from the figure 6, it is observed that, the 5 different membership function- very low, low, normal, high, very high for the variable CH4 concentration along with its critical level output are also obtained in the fuzzy system.

Now from the above figures, the 5 different membership function for the output i.e. the critical level are obtained and are tabulated below.

Table 5: Different membership function for the output critical level

Membership function	Critical level in percentage
Very low	10-25
low	25-45
normal	45-65
high	65-85
Very high	85-100

In this fuzzy system, Fuzzy Mamdani rule is applied..Here the data sensed by the coal mine monitoring system is fetch to the control room through Bluetooth. In the monitoring station, data are monitored remotely and the operator fetch the data to the fuzzy system. The system analyses the signals and gives output according to fuzzy rules. For 5 different membership function, 25 rules are developed . De-fuzzyfication method is center of area. With Antecedents 'IF' and Consequent 'THEN' , fuzzy rules are developed.

Figure 7 shows the developed fuzzy rules in LabVIEW. For example if the temperature and CH4 values given to the fuzzy system are 35^0C and 230 ppm respectively, then in the output, it is obtained that critical level is medium i.e. the zone is at medium critical level. Similarly for different temperature and CH4 values, different critical level states are obtained.

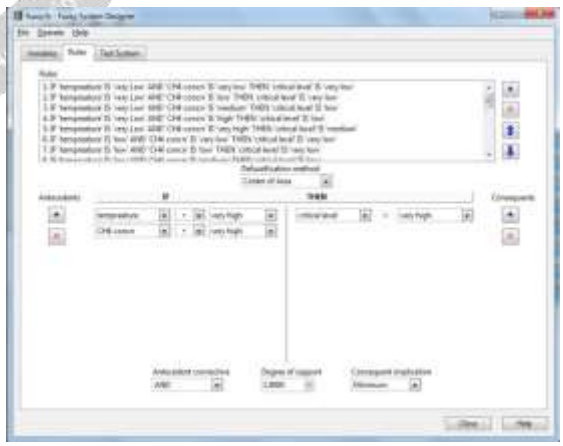

Fig.7 Development of fuzzy rules in LabVIEW

Now using the rules, a fuzzy system designer , a critical level determination output system is designed in LabVIEW as show in figure 8. Here the change in temperature and CH4 concentration is made manually and the critical condition (output) is viewed in the meter.

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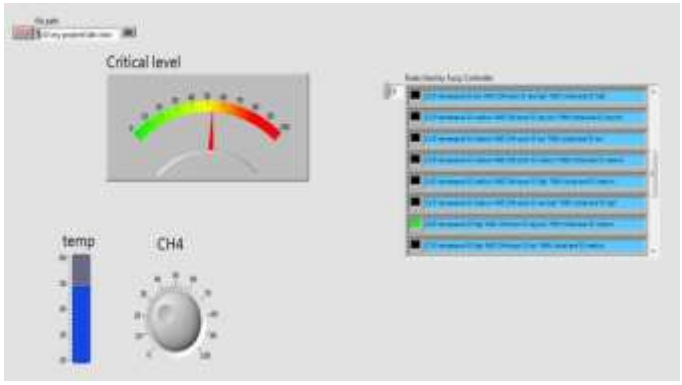

Fig.8 Critical level rules are designed in LabVIEW

VI. CONCLUSION

The smart coal mine monitoring system based on wireless sensor network can detect concentration of toxic gases methane and carbon monoxide and also provides data about temperature and humidity in underground coal mine. Use of wireless sensor network in the system makes it more reliable, effective and advantageous over the traditional wired methods. Data has been transmitted with an accuracy of 92-100% in the system. The system gives accurate monitoring in LabVIEW and in android platform also which makes it more practical and user friendly. It also determines the critical parameter conditions by developing some fuzzy rules in LabVIEW. The system can replace human work in some dangerous coal mine environment and helps the workers to get rid of any type of hazard.

VII. FUTURE WORK

In future work, the system can be designed as a versatile one by implementing different types of sophisticated sensors. It can be used as a path finder in rubble places and also as surveillance camera to get proper images of the inside environment. The system can be developed to travel a great extend by applying advance high speed data transmission technology and can be used in different environment .It can be sent to the hazardous places for rescue operation where rescuers can't go and it collect information effectively. Also for more advanced level performance, IOT can be implemented in the system.

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