HAZARDOUS GAS DETECTING RESCUE ROBOT IN COAL MINES

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Abstract- Rescue operation in coal mine is extremely dangerous due to several factors. It is particularly very harmful for the rescuers to get into the coal mine tunnel in disaster without the prior knowledge of environment because the subsequent explosions may likely to occur at any time it is therefore essential to detect the explosive environment details such as toxic gases, high temperatures and also to perform a visual inspection of miners, trapped in collapsed tunnel through a wireless camera. These details will help the rescuers to make a preparatory plan and to equip themselves for carrying the rescue operation defensively. This paper designs a rescue robot for coal mines. It is composed of a mechanism to bear the rest of the subsystems and also to assist the locomotion, a control system to control and a communication system to transfer the environment data acquired through the camera and other sensors. Also it can carry some food and medicine to the miners trapped in the disaster. With the help of this mobile robot, we reduce the loss due to coal mine disaster and efficient rescue operation can be carried out.

Keywords- Mobile Robot, Coal mine, Rescue, Self Localization, Sensors.

I. INTRODUCTION

A coal mine is an underground tunnel system. There only a few pitheads on ground. If there are some accidents, people are easily trapped in tunnel and often cannot escape from it. It has dangerous accidents as collapse, gas explosion, CO, CO2 poison gas, low O2 content, high temperature, smoke, coal dust, fire, water, etc. All these accidents can kill people easily. CH4 gas is intergrowth with coal. When coal is mined, CH4 gas is released. Gas is pushed off by forced ventilating system. But if the ventilating system is faulty or gas is leaked from coal layer, gas diffuses throughout the tunnel. A flame current can cause a heavy gas explosion. Mine tunnel passageway is narrow, so the explosion wave can destroy any thing in the tunnel. All devices and people may be affected, and the gas of CH4, CO, CO2 and coal dust are filled in the tunnel, and the environment of the tunnel comprises of low O2 content and high temperature. Besides, the forced ventilate system has been damaged, the gases cannot be push out and gets accumulated in tunnel. A fire may cause a second explosion. People in tunnel could be poisoned by CO, stifled by CO2 and low O2 content, high temperature and coal dust. Rescuers on ground daren't go into explosion mine tunnel. Because situation is not known, any one may be killed by second explosion. So detect of mine tunnel situation is the first mission to the rescuers. Robot is an ideal tool in coal mine disaster. The robot used in coal mine tunnel must have many special characters which are different from other robots on ground. Coal mine tunnel is a special environment. The first problem is explosion gas is everywhere in tunnel. Any fire can cause an explosion. Robot must be designed as a flame-proof device to avoid malfunction of components. The second problem is the mine have narrow tunnel and rugged. The middle of the tunnel is railway. One side of the railway is belt transmission. The other side is a narrow road on coal. The mine passageway is filled with many obstacles and rugged coal road, so it is difficult to move on the mine tunnel. But various obstacles must be crossed. Communication is another difficult problem in mine tunnel because electromagnetic wave is absorbed and echoed in a coal tube. Because of many corners in the tunnel, Wave cannot cross these corners easily.

II. LITERATURE REVIEW

The collecting data from [1] reveals that large number of accidents occur in a coal mine during and after a disaster. The main reasons being, gas accidents, explosives, flood, caving, etc. It requires the development of a system that can help minimize the human and material loss that happens during rescue operations in coal mines. [2] Thus sensors for detect the gas are mandatory in the robot to be deployed.

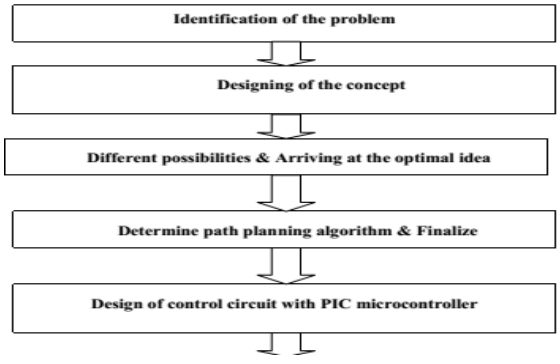
The idea of a Mobile Robot is able to aid the rescue team entering into a coal mine [3] got picked up with the tremendous uplift in the technology. The Robot is used to get in to the disaster zone and rescue research operations. The robot can go in to mine and detect O2 levels, temperature, gas contents, etc. The data can be sent to controller in safe field.

The mobile robots designed for that it can run in explosion environment, climbs over uneven surface areas, check gas, and provided where in it can carry

food and first aid kit to the workers trapped inside. A biped robot was initially tipped to be used in the coal mines [4] which can move inside the tunnel interfacing with RS 232 cable. The robot couldn't travel a long distance it tripped on moving across the path and also the cable RS 232 couldn't be used for a long distance. Thus different types of legged robot had to be used and after research, a belt type robot was developed. The conveyor belt as seen on the military tanks would move over debris and rough terrains. For communication Blue Tooth would work only to a specified area and the robot couldn't be controlled beyond the signal region. This lead to the usage of wide wireless communication technologies like RF transceiver and ZigBee[6]. The ZigBee had much better range when compared with Blue Tooth and it could transmit the data or commands and receive data from long distance from the mine. Once the communication and sensing of robot was finalized the focus is shifted on how to make it more reliable. The idea of camera on the robot helps in getting live feed of what is happening inside the tunnel and it will help the rescue team to follow the less dangerous path and the way for rescuers get in to the mine. Robot wireless sensor networks are an highly capable platform and show great potential in environments to disaster discovery. Mobile robot wireless sensor networks had multimedia surveillance and provide the great strategies based on multi sensor integration [7]. The IEEE paper of Zhao-long, Xu Jie, Yang Xiao-zhi Liu et al [8] robot system is fit for detecting mine disaster information. It introduces in details the structure of the robot system, the technology of obstacle avoidance by using various sensors, and collection of information, wired, wireless transmission modules, local area network , wireless cameras, including gas sensors and temperature sensors.

III. METHODOLOGY

The approach towards the making of proposed mobile robot has been split into different steps called the methodology. The steps start from designing, modeling, simulation, fabrication and controlling of the robot. Figure1 depicts the steps of the methodology.



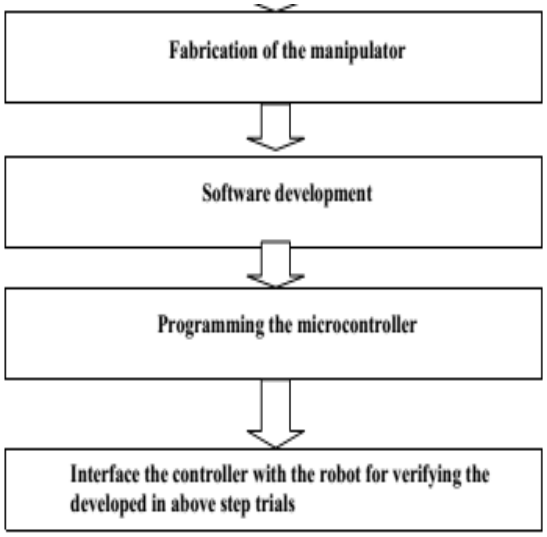


Fig 1: Methodology of the system

IV. ROBOT STRUCTURE

A. Basic Structure of Robot

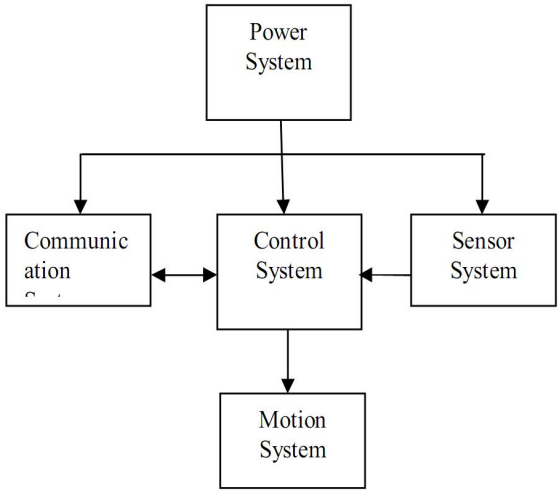


Fig 2: Basic Robot Structure

After taking account of the described issues on coal mine detect and rescue robots, we have developed a robot with belt type transmission in place of wheels, which has 8kg in weight, 1.8 km/h in speed (maximum speed), about 4 hours in working time (about 2 hours in moving continuously), 35 degrees in climbing slope and at least 1 Km in communication distance. Also it can carry 5 kg food or medicine. Robot is composed of mechanical vehicle,

Control system, driving system, communication system, sensor system and remote control system. Four DC geared motors are used to drive the vehicle, where the two motors are on front and another two are on rear. Motor Power is chosen 30W and reducer ratio is 60:1. Another four motors with 60 rpm 10 kg torque are used for flippers. The individual axis differential drive mechanism is using for run the robot.

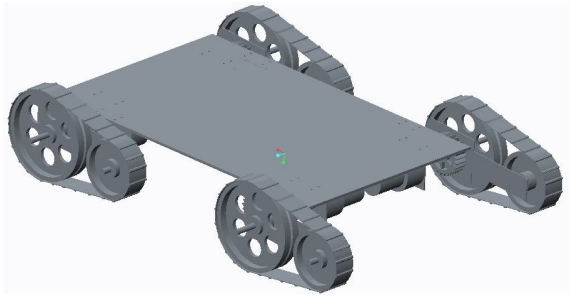


Fig 1: The schematic diagram of the robot.

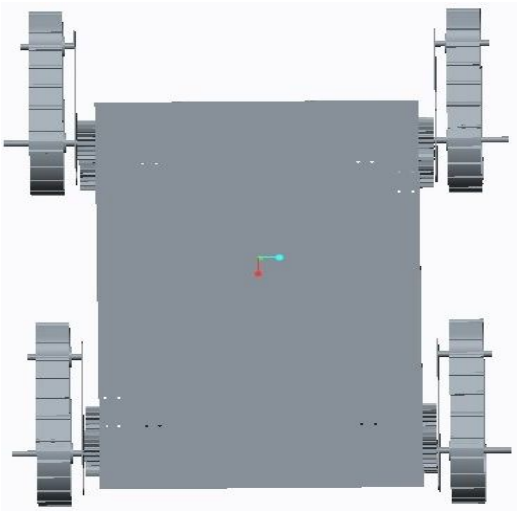


Fig 2: Top view of the robot.

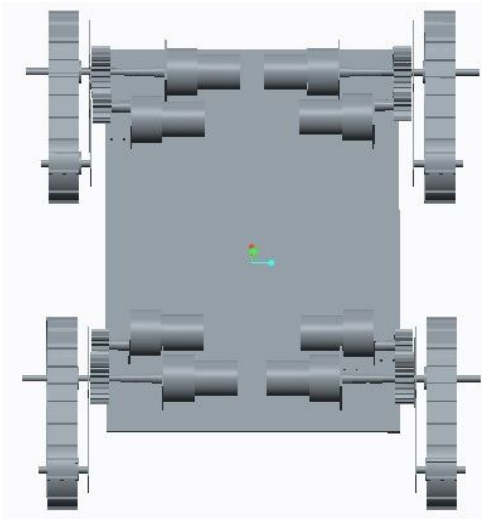


Fig 1: Bottom view of the robot..

B. Mechanical Design

The robot has dimension (500x320x130) mm which is the length, width, and height respectively, as shown in Figure(2).

Gears and its Dimension:

The robot requires eight small gears with diameter of 40 and 25mm, as shown in Figure (3) these are joined together for robot movement to enable the robot to travel through fairly large amounts of rubble,. The four large gears join with four small gears with a diameter of 25mm to be able to climb the stairs. The gears are used to lift and rotate the flippers in 360 degrees in Z axis. Also robot can move in top and bottom side.

Robot Movement Mechanism:

The robot mechanism drive works with the front and rear wheels being directly powered with individual axis. Flipper system being driven by the other four motor via gear mechanism. Gear ratio is 0.6. Speed reduction from the driving shaft to the driven shaft of the flipper is 40% (60 rpm to 35rpm). The movement of the robot is established by using two motors in each side. Two flippers are installed at front and two are at back side of the robot as shown in fig3.

Extra Mechanical Parts:

Galvanized Iron is used for the body of the robot because they are strong and can bear the motor weight and movement. The outside cover of the robot is fiber plastic because it is light. Plastic wheels, rubber tracks are used to move the robot. The robot is supported by a wireless camera at the top of its surface connected by a stepper motor to control its movement.

V. ELECTRICAL SYSTEM

Robot electrical system is composed of driving system, control system, communication and sensor system, storage batteries and remote control system etc... The remote controller has a PLC, a communicator, a battery, a power module, a keyboard. Operator can sends instructions through the remote control box. The Controller in the box sends the commands through wireless communicator zigbee to the robot and the robot can receive the command signals from its communicator. PLC controller in the robot can control the robot to execute the tasks.

A. Motor selection:

The robot has to need 4 motors for run (locomotion). This robot is 8kg weight, and the maximum speed can be reached at 1.8 km/h. Calculation for motor power is taken as the following.

Move on level ground:

$P = mg \times \mu \times v$

$= 8 \times 9.8 \times 0.2 \times 1.8/3.6$

$= 7.2W$

We supposed the slope angle is 45°, the power of motor is P, then

$P = mg \times (\sin 45° + \cos 45° \times \mu) \times v$

$= 8 \times 9.8 \times (\sin 45° + \cos 45° \times 0.2) \times 1.8/3.6$

$= 33.2 = 34W$

Where, μ-Friction coefficient between slope and track, V-Moving speed of the robot.

We have selected four 20W motors; maximum speed

is 100 rpm and continues torque is 0.05 Nm. These motors have some abundant power.

B. Sensor Unit:

A sensor (also called detector) is a converter it can measures a physical quantity and converts it into a Signal which can be read by an instrument or observer. Sensors used in this project are CH4, Temperature Sensor, and Ultrasonic sensors for which MQ-6, LM35, HC-SR04 sensors are used respectively. Sensor MQ-6 can detect the gas concentrations in many conditions from 200 to 10000ppm. The LM 35 has a range of 0-110 degree Celsius. The HC-SR04 sensor is used to detect the obstacles in front of the robot within range 3m from it. The sensors module is designed by using the electronic software Proteus ISIS and soldering of the sensors in to the printed circuit board is done. The values read by the sensors are transmitted to a PIC wherein it compares the measured value with that of the set points and if the measured value goes above the set points, Rescuer will be made aware of it by the window saying "CO2 level has exceeded". It helps in having good knowledge about the environment. By using wireless video camera we can track the information about inside the tunnel.

C. Microcontroller Unit

The microcontroller ATMEGA328-PU is used which is ATMEL microcontroller family. PICs are popular due to their large user base, low cost, wide availability, and extensive collection of application notes, free development tools, and serial programming capability. The microcontroller is used to collect the parameter value from the sensor unit and compare it with the set point and transfer the corresponding data to the CPU. The microcontroller is the core of the surveillance robot.

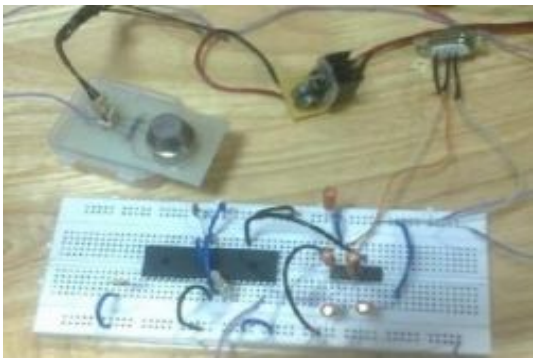


Fig 3: Methane Sensor Module connected to a voltage regulator

D. Robot Driver Unit:

The robot driver unit is primarily concerned about the movement of the robot in x-axis and y-axis. The robot is of conveyor belt type as it helps to maneuver over debris and rugged terrain. The wheels are run by four DC geared motors of 100rpm. When both the wheels are given with positive pulse, the robot moves in forward direction, when the supply is negative pulse, it goes in backward direction and similarly by varying the negative and positive, left and right turn can be achieved. To choose the supply given to each motor, L293D IC is used. The robot movement circuit drives the robot to move in forward, reverse and turn left and right.

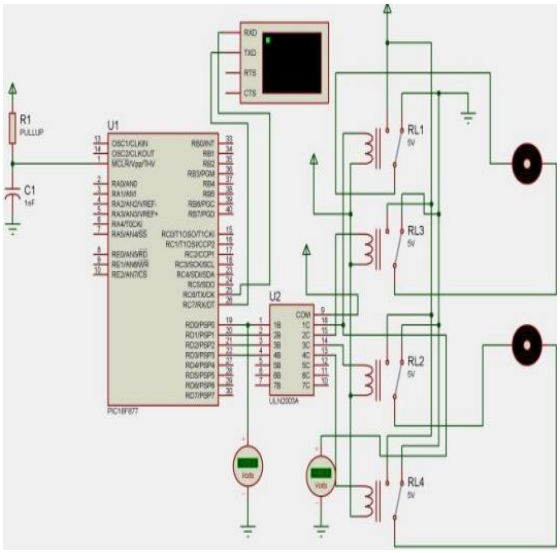


Fig 4: Robot Movement Unit

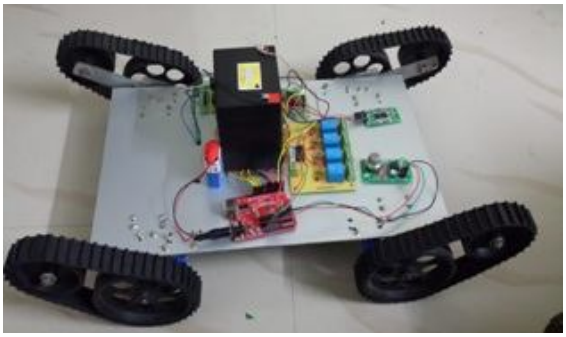
E. Data Transceiver Unit:

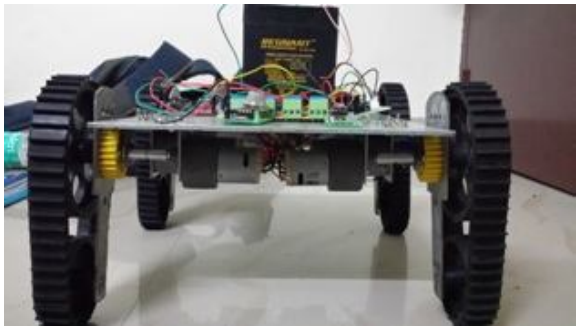
The transceiver unit is used both transmit and receive data. In this system we used zig bee technology for communication between mobile robot and rescuer. Zig bee transceiver is used 2.4GHZ RF band width, to improve the security, other frequencies can be used. One transceiver is mounted on the robot unit, which gets the data from the microcontroller and sensor is transmits to the control room where the other transceiver is placed. Likely, the transceiver placed in the control room will transmit commands to the transceiver mounted on the robot for the control. According to given programmed commends the mobile robot can move in the mine tunnel.

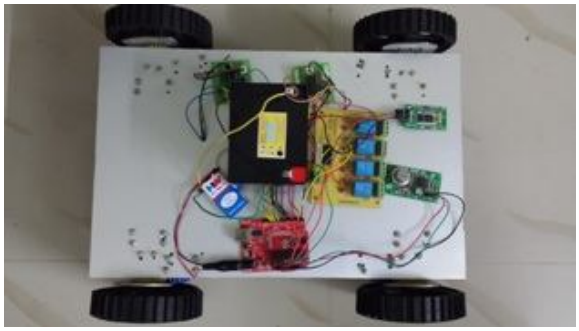
F. Camera Module:

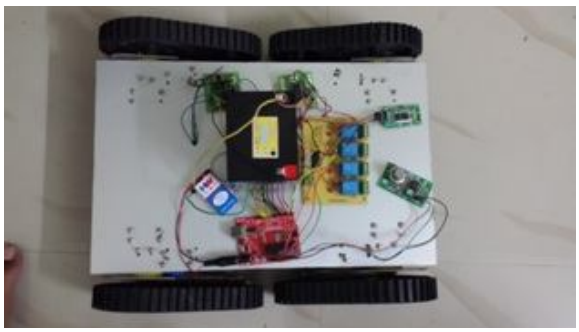
The camera module consists of a wireless camera and an AV tuner card and an AV receiver. Wireless camera is mounted on the robot and the video signal is transmitted to the AV receiver and it is tuned to get the original signal. Then the video is transmitted to Control room PC by interfacing an AV tuner card. The camera module will transmit the video coverage of mine environment, paths and thus helping in easier mapping of the path to be taken by the rescue team. For real time applications, wireless camera of high range is to be used to get good clarity and good coverage. The camera employed will also help the robot from getting stuck in a pit as the obstacles lying in path is foreseen and required action can be taken, thus improving the life of robot inside the tunnel.

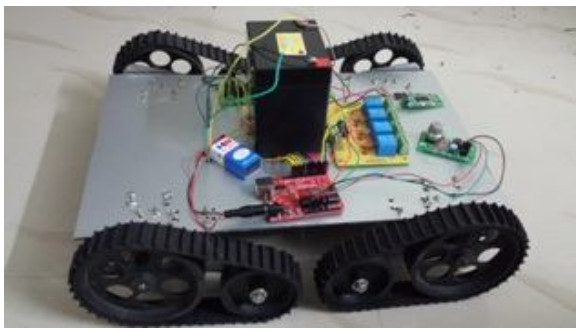
DIFFERENT SHAPES IN ROBOT MOVEMENT:











CONCLUSION

The mobile robot for mine rescue, disaster surveillance is designed and with its camera and other components attached to it. A 12V/4A rechargeable battery is used to run the robot. The robot was test run and it moved autonomously well on debris and over rough terrains and the video was transmitted with much clarity. The sensors are tested for their performance and to conduct the test, a wick or any other source of smoke is brought near to the MQ 7 sensor. This prototype robot has its safe values of CO2 set at 10 ppm and 70 ppm. The set point for temperature is 40 degree Celsius. Once the measured

value goes beyond these set points, a popup the monitor showing the parameters' level has exceeded. In future this can be developed by flame proof materials, use of higher transmission it can travel for a greater distance and can be used in different environments based on the transmission range. A much improved image of the environment inside. Implantation of an arm on the robot can help the robot pick up samples or remove small debris from path inside the mine.

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