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Sensor Controlled Defense Purpose Robot for Land Mine Detection

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***Abstract*— This paper present an automated metal detecting rover-robot which can be operated by remote to help in the landmine detection. The objective of this metal detector robot is to identify the landmines in war-affected rehabilitation places. The detection of landmines through this proposed method is free of risk and less human effort. Integration of inductive sensor, video camera and ATUNO microcontroller are used here to discover landmines. The system functions using radio frequency (RF) module for device control and Bluetooth module for communication between operator and robot. While experimenting, this robot shows high metal detection ability which is competent enough to be used in the applications in landmine covered regions.**

Keywords—metal detector; robot; landmine; defense purpose; Arduino UNO microcontroller

I. INTRODUCTION

There are a lot of landmines still hidden under the ground all over the world. It causes life loss, permanent and temporary disability to humans and other living creatures. It affects the economy and peace of the nations. Due to the conflicts between countries, landmines have become a serious global issue and clearance of it needs a huge amount of money to be spent on it. Many developing countries which are affected by land mines, to make this mission successful, spent a lot of gross national income and human effort on clearance of it. Even though technology kept on developing, the manual landmine clearance is still highly preferred because of its consistency, predictability and reliability [1]. But the drawbacks in a traditional method are, the process is slow and it is hazardous to the workers. This research has established a landmine detection rover-robot to assist in the field, which is faster, secured and precise than the traditional method.

Mine detection is usually performed by metal detecting sensors. The distance between sensor head and the buried landmine is the important parameter which determine the performance of landmine detection capacity of metal detector. By adjusting the gap and altitude between landmine and sensor head, the performance of the metal detector can be improved. The function of robot-assisted land mine detection can be performed in a convenient way, if the sensor heads maintain uniform gap with ground level. More priority is given to the human safety in this project. The robot can be operated from a safer distance or from the region where the landmines have already been cleared. Since the landmine detection head is projected in front of the rover, the hazard of explosion is eliminated. By this approach, the rover as well as the person operating it by remote are safeguarded.

Bluetooth controller is used for communication between rover and operator since it is of low cost and high-level security benefits. Many defense activities can be accomplished by this rover robot. It can carry equipment and soldiers. Also, the basic rover robot model is shown in Fig. 1. can be converted into special task assigned robots like Metal detection robot, Army carrying robot or Battle robot.

This paper is elaborated as follows. Section one describes the introduction about the system, section two depicts the literature review, section three discuss methodology, section four depicts the results and discussion and section five concludes the paper portraying the future scope briefly.

Fig. 1. Hardware picture of the working model of the rover-robot

II. LITERATURE REVIEW

Several attempts by researchers have been made for research and development of rover robot in the above mentioned regards. The main concern of the researchers is to replace human land mining with an automated one. Usually, when the human involved in mining and scanning process of land mines, there are various issues like excess effort, extra time, huge cost and human life risks. Different types of sensors like metal detectors (MD) [1], ground penetrating radar (GPR) [2, 3], infrared cameras [4], and chemical sensors [5] were used in the past to identify the landmines.

The land mine detection robots are very rarely used in military because of poor knowledge of the operation, high cost of development and difficult to operate in improper surfaces. These factors are considered to design and develop the mine detection rover which is presented in this paper. The technology mentioned in this research work is very simple and flexible to the user. Anybody can operate it using their mobile phones from a safer distance. According to research done by Seiji Masunaga et al., 3D ground mapping technology is used to adjust the metal detection arm of the rover automatically [1]. But 3D mapping for this purpose is a very complicated process since in this research most of the parts are done by mathematical modeling and analysis. Ultrasonic obstacle detection technology is used in the current research work to overcome the above-mentioned problem. Also, the distance between the arm and the ground is measured and fixed. Once it is fixed, it is programmed to maintain the measured distance as a constant one. The research was done by Hakim Adil Kadhim et al. says that the internet-based system was used to register the positions of land mines [6]. This idea is suitable only to the areas which have proper network signal. The rural areas or jungles where network signal is so poor cannot be treated by this device and land mine register may not function. GPS is used to identify land mines in the current research work. It is more ideal than an internet based system because the later has problems in internet coverage. Suraj Namdeo Rathod et al. mentioned that underwater wireless communication can enable many scientific, environmental, commercial, safety, and military applications [7]. Zigbee communication technology is used by them to link with an underwater robot. With the help of Zigbee technology, data received and transmitted by a robot. Finally, data sent to the ARM controller, and the robot will work based on the command. Commands are used for a different type of movement of the robot. The main function of this robot is underwater metal detection and measuring the physical parameters like Temperature and PH level inside the water.

According to F.Y.C. Albert et al., the rover functioned based on solar power [8]. In this research work, a small solar panel is added to recharge the batteries. Even though there is an advantage of solar energy which can be used to power up the rover, the solar system requires large space is the disadvantage associated with it. With such a design plan, it is very difficult to move the rover inside jungles. This issue is also solved in the current research work by a design called the foldable mechanism of solar panel that makes the rover compact to move in different topographies. K.S. Ruchitha et al. used GPR (Ground Penetrating Rader) technology for determining the land mines. This technology can scan the ground for more than 5m depth [9]. This method will be of great use to the archaeology excavations sites, but for land mine detection that much deeper analysis is not required, because land mines are buried very closer to the ground surface. GPR is very expensive than magnetic metal detection method. Though GPR is a good technology for mine detection, it is complicated due to soil surface irregularities. The results were affected by soil conditions [10]. Some of the papers [6, 7, and 11] used wheelbase architecture to build the rover. This construction is not feasible to all terrains especially the muddy and sandy. The rover presented in the current research work can be driven through all terrains by using a belt driving system.

Mars navigation technology is used by Clark F. Olson et al [12] to identify the rover and get more images. They introduce 3D terrain maps using all images. These maps brought together the images to the system to merge the multi-resolution model and integrating 3D terrains. Prithviraj Dasgupta et al [13] focused on overcoming the difficulties of autonomous landmine detection with the help of a mobile robot. They used multi robots to identify the landmine with proper coordination. They explained about multi-robot system called COMRADES to use a various different function of the autonomous landmine detection problem. Ahmed Ismail et al. [14] focused mainly on sensors technology. With the help of sensor technology, they identified the land mines. This robot gathers data from the sensors and guides people when they pass landmines. Identifying the landmine, in any position of land is the main purpose of the research work conducted by Tanpure Ganesh. D et al [15]. It identifies the land mine and sends the signal to a relevant person with the help of an android app. At the same time, it identifies the location of the landmine with the help of GPS technology.

III. METHODOLOGY

Arduino microcontroller is the controlling unit in this research work. HC-6 Bluetooth module is used to link the robot and the Arduino interface. The Arduino electronic board receives the input signal from sensors, process it, and send the output signals to the wheel and arm of the rover. The navigation of the rover managed in a way, that automatically it analyses the surrounding environment and act accordingly. The motion sensor is connected in the robot so that the exact environmental status such as the motion of the rover and conditions around the rover can be monitored. The basic block diagram of the system is shown in Fig. 2. The hardware requirements for land mine detecting rover-robot is as follows:

a. Arduino UNO board
b. Metal detector
c. Ultrasonic sensor
d. HC -6 Bluetooth module
e. Motors
f. Tank mechanism
g. Monitoring system
h. Power Supply

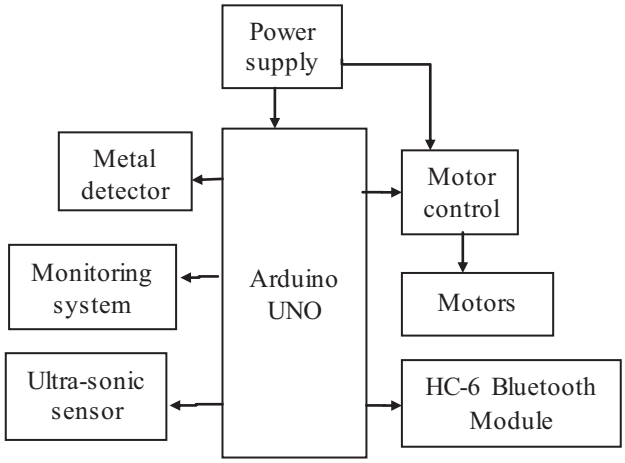

Fig. 2. Block diagram of the complete system

When the robot notices a land mine, it makes sound and sends a signal to the operator using GPS navigation along with the exact location of a detected land mine. The robot has an ultrasonic sensor which guides the rover-robot according to the given program.

A. Motion Control of the system

Bluetooth pairing device is used for communication between rover-robot and the operator. It can connect the robot with the operator from a safer distance from land mines. The rover consists of ultrasonic sensors placed at the front part of the rover to detect the obstacle on its way, which is the main condition for the safe movement of this robot. If an obstacle is detected on its way, the arm changes its positions up, down and sideways to analyze the height and size of the obstacle. This data sent to the microcontroller and the person monitoring it. The person in charge decides whether to move the robot in an alternate path or to move it forward ignoring the obstacle. In this regards, mobile phone or laptop can be used to provide command through the serial monitor to move the robot.

The control module consists of Arduino board, motor controlling module, motors and power source as shown in Fig. 3 and 4.

TABLE 1. MOTION CONTROL OF THE ROBOT

Motion of Rover	Left side Motor	Right side motor	Active Pins	Signal
Forward	Rotating Clockwise	Rotating Clockwise	7, 5	1010
Backward	Rotating Anticlockwise	Rotating Anticlockwise	6, 4	0101
Left turn	Stop	Rotating Clockwise	5	0010
Right turn	Rotating Clockwise	Stop	7	1000
Suddenly to left	Rotating Anticlockwise	Rotating Clockwise	6, 5	0110
Suddenly to right	Rotating Clockwise	Rotating Anticlockwise	4, 7	1001

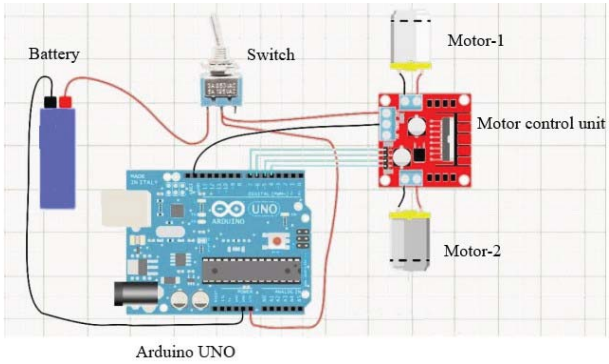

Fig. 3. Hardware diagram for motion control

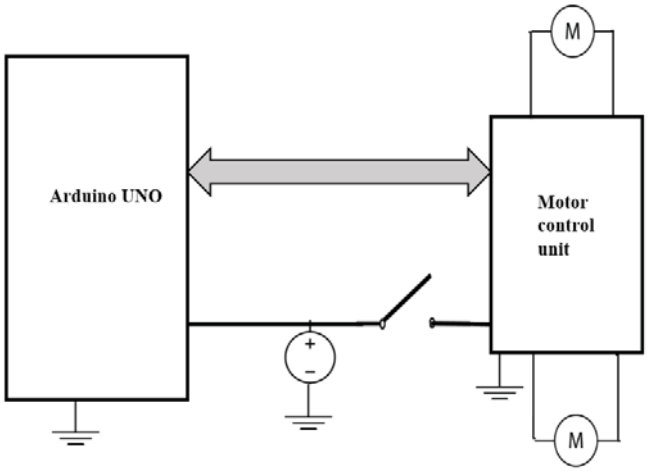

Fig. 4. Circuit diagram for motion control

The chain drive mechanism is used in this rover to move since it has to travel in rough terrains, as like chain blocks. According to the H bridge motor controller used in this circuit, only two motors are needed to control the motion. The motor controlling device circuit is connected to the Arduino pins 7,6,5,4. Here pins 7 and 6 connected to right side motor and pins 5 and 4 connected to left side motor.

Rover can be operated in 6 directions; Forward, Backward, Right, Left, rapid to right, and rapid to left. The rover-robot starts moving when the command “start” is given. To move the robot in the forward direction, the forward arrow key is to be pressed. The Arduino pins 5 and 7 send the signal 1010 to the motor control module so that both DC motors rotate in a clockwise direction. The left arrow key along with forward key is used to give a command to move the robot to the left side. When the signal 0010 is given from the pin 5 of the Arduino board to the motor controlled module, the left DC motor stops working whereas the right DC motor keeps on rotating in a clockwise direction. Until the command is changed, the robot keeps on moving in the left direction. A command should be given through the right arrow key along with forward key through the mobile device to move the robot to its right side. The signal 1000 is given from the pin 7 of the Arduino board to the motor control module so that the right

DC motor stops working whereas the left motor keeps on rotating in the clockwise
direction. Until the command is changed, the robot retains to move in the right direction. A command is given through bottom arrow key to make the robot to move to the backward direction. It is achieved by sending the signal 0101 from Arduino pins 6 and 4 in order to drive both the DC motors in the anticlockwise direction. A command is given by pressing the right arrow key on the mobile device to move the robot to the right direction rapidly. It is achieved by sending the signal 1001 from pins 4 and 7 of the Arduino board to the motor control module so that the right DC motor rotates in anticlockwise direction whereas the left DC motor rotates in the clockwise direction. A command is given by pressing the left arrow key of the mobile device in order to move the robot to the left direction rapidly. It is achieved by sending the signal 0110 from the pins 6 and 5 of the Arduino board to the motor control module so that the left DC motor rotates anticlockwise while the right DC motor rotates clockwise direction. This data is shown briefly in Table 1.

B. Bluetooth module and communication

The robot is controlled by HC-6 Bluetooth module. HC-6 Bluetooth module is used for the communication purpose as shown in Fig. 5 and 6. The RX pin of the module connected with the Arduino pin 2 and TX pin of the module connected with the Arduino pin 3. The Arduino is programmed to receive signals from the Bluetooth module. An android based application called Bluetooth RC controller is used here to control the robot by providing instructions. The decisions made by the operator and the directions of movements are transferred in the

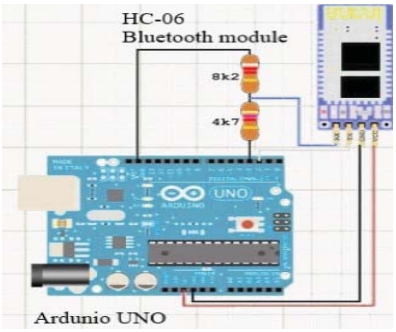

Fig. 5. Hardware diagram for bluetooth module

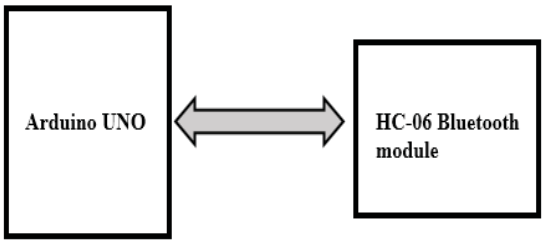

Fig. 6. Block diagram for bluetooth module

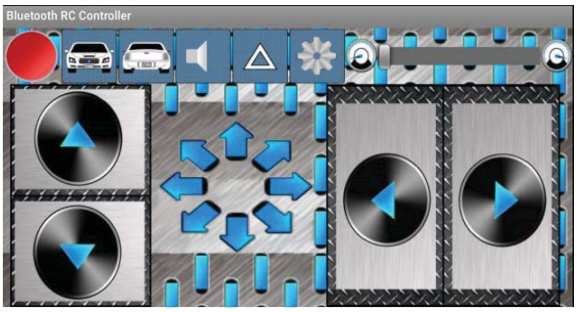

Fig.7. Google play store app to control the direction of the moving rover

form of commands to the robot through this Bluetooth module. The maximum working coverage distance from the remote monitor to rover-robot is around 40m. The diagram of the google play store app for controlling the direction of motion is shown in Fig. 7.

C. Metal detection system

Arduino Uno is the controller of this Metal Detector Part. A LED and Buzzer are used to indicate the output signals in the form of light and sound. A Coil and capacitor are used to identify the metals. A diode is used to control the voltage. The resistor is used to limit the current to the Arduino pin. The pulse signal generated by the Arduino Uno sent to the LC circuit. The basic principle of this operation is electromagnetic induction. As per this theory, when a signal is sent from Ardunio to LC circuit, and if any metal is found near the LC circuit, the signal would be changed due to the loss occurred. The same principle is applied here; if a land mine is detected, the signal would be changed. Under such incident, LED and a buzzer would be activated and makes light and sound indication respectively. On the other hand, if no metal is found close to the LC circuit, when the signal sent from Ardunio to LC circuit, the signal would not be changed; so LED or buzzer would not be activated. The circuit diagram for metal detection system is shown in Fig. 8.

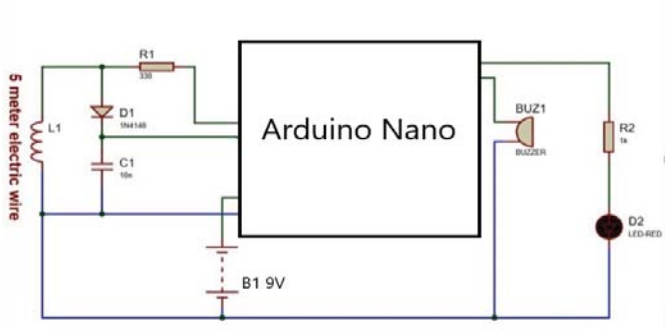

Fig. 8. Circuit diagram for metal detection system

D. Tank Mechanism

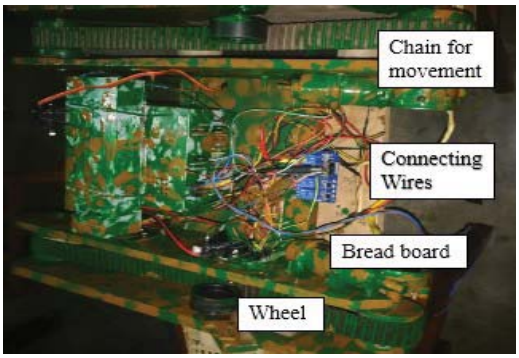

Fig. 9. Hardware picture of the tank of the rover-robot

The tank has two main components. Two sets of wheel housing consist of four wheels, chain drive and base plate are those two components. Wheel housing is strongly mounted with a base plate. Centre of gravity of the robot act in the middle portion of the robot to eliminate swaying effect and other imbalances. The base plate is given two inches ground clearance throughout the centre line starting from front to rear end. The robot has four wheels per side. A chain drive is used to move the robot easily on rough land, muddy region, sandy area, building ruins, jungle topologies and all other types of terrains. The motors are used to give the required power to each side wheels through the belt. The image of the hardware model is shown in Fig. 9.

E. Monitoring System

The monitoring system is the display where the operator observes the motion and location of the robot. The location of the detected land mine sent by the GPS navigator appears in this display along with the light and sound indication. From this GPS data, the operator can go to the exact location to clear the land mine. If any obstacle is detected on the path, those data will also be sent to this display so that the operator can come to a conclusion about the next action of the robot.

IV. RESULTS AND DISCUSSION

- The robot consists of a motion control system, communication system, tank mechanism; metal detector arm and monitoring system.
- The motion control system obtains the input from the ultrasonic motion sensor, process it with the Arduino board and give the output command through the motor control module to the motors attached with the wheels.
- Bluetooth module is used for communication between a robot and the operator by sending to and receiving a signal from the operator.
- Tank, wheels and entire hardware component is designed to enable the movement in a different type of terrains and the balancing of the robot is also considered.
- Metal detector arm is projected in front of the robot so that the land mine detection can be performed effectively without damaging the robot. If the land mine is detected, the robot sends the signal to the operator and operator can clear the mine.
- A monitoring system is a kind of display. The robot continuously sends the status of the surrounding environment. It alerts the operator if a land mine is detected showing the location of the land mine.

V. CONCLUSION AND FUTURE SCOPE

At present, the robot is replacing human in almost and every field including defense field. The application of robotic technology is expanding in various fields due to its continuous development. A land mine detecting robot is designed in this research, which can sense metals in its arm range and on its path. HC-06 Bluetooth module application is used to control this robot. The ultrasonic sensor is used to detect the obstacles in its way in various directions. Based on the dimensions of the obstacles present, the mine detecting robot decides whether to take an alternate path or to move in the same path removing the obstacles.

In future, the sensors can be modified to work based on the radio controller or IoT controller instead of Bluetooth controller. And also a camera with night vision can be added for better image visualization of hidden mines. The hardware may include Shock absorbers, self-balance system and adjusters that can be mounted to the wheels so that the robot can run fast on any complex terrains. It can also be used in the future to save lives in disaster locations like building fire, building collapse etc if an image processing system is included. It can also be modified in future to dig land mines by itself if proper arm set is provided with necessary safety precautions.

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