

Smart Mecanum Wheels UGV for Landmine Detection

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Abstract

Land mines and unexploded artillery are the major challenges faced in warfare. They are most difficult and dangerous because they are hard to detect. This has impelled us to propound a robot that can be controlled over long distance and has ability to detect the land mines and unexploded explosive material underneath the ground. In order to achieve high accuracy mecanum wheels are used in the robot which are controlled by H-Bridge module. Mecanum wheels allow the robot to move in eight different direction including diagonals and 360 degree rotational movement. In contrast with conventional wheels which don't allow the robot to move in above mentioned directions. The input from the sensory equipment is fed to microcontroller. Obstacle avoidance is done by sonar sensor which is mounted on the top front side. A spy RF camera is used to capture snapshots and real time video streaming of the location and send back it to pilot. The wireless communication between robot and operator is done by 2.4 GHz RF module.

Keywords: Landmine Detaction, Mecanum Wheel Mobility, Ardurino Controller, Obsticale Detaction, Wireless Communication, GSM, RF Modules, Autonomus Navigation.

1. Introduction

Now Robotics is becoming a very innovative subject these days and lots of analysts are generally accomplishing outstanding work in the field of robotics. We are right here dealing with Mines Detection Robot. Modern tactics are widely used within this particular autonomous robot [1]. It is very reasonable to build such an autonomous robot that could detect land mines without the guidance of human personnel. In case there is any blast regarding landmines, the robot will face the impact of explosion and the humans will remain safe throughout the operation due to distance from war zone. More over the robot can be created again. The paper explains step by step method of developing military mine detection robot. In Initial stage we discussed about how the structure of robot is being created. Each sensory gadget, including sonar and mine detector senses the analog input from the environment and direct this data to Arduino. Sensing instruments like mine detector and sonar sensor are used in the robot. Calibration of sonar sensor is also a tough task that is achieved at desired level. Basically the safe long distance is kept between the object and the robotic vehicle and then this measured distance is matched with the reference distance. Likewise metal detector finds the underneath mines and the detector has sensitivity about 5 feet deep in the ground [2]. Once the detector picks up the signal from ground then it triggers the constant beep sound. For the safety of the whole apparatus, smoke sensor is also mounted on the robot. While doing so, the Arduino also provides instructions to the motor assembly and direction controlling modules. Paper also consists of flow charts to go into detail regarding the instructions delivered to the robot.

The secondary section of paper describes the selection of hardware and its assembling of robot. To attain motion in every direction, including diagonals and even in spin motion of 360 degree rotation [3], unique sort of wheels are used known as Mecanum wheels [4]. Chassis is constructed of lightweight aluminum metal to improve strength of the robot and to make the structure lightweight, for achieving the effective battery consumption and for improved speed of robot. 7.2Ah LiNi battery provides sufficient amount of power to the electronic and electrical components of robot. Forward and backward motion of motors is attained by utilizing H-Bridge module. Four H-Bridge modules are utilized to fully control the robot [5]. For live broadcasting and taking snapshots of real time situations in open as well as bounded environments, an instant wireless camera module is mounted at the front top of the robot chassis, and it can effectively cover 180° area in front of it. The Camera module consists of built-in wireless transmitter and receiver. The receiver has AV output which is connected to the monitor for live streaming. A unique approach is utilized in order to use the camera in reduced lightning conditions. To further enhance the night vision capability of camera additional infrared LED's are used. The light of infrared LED's can only be seen by the camera because this light could not experience by human eye. By using this technique, the robot can be utilized as a spy in night operations.

Up next the third section of paper is about programming of Arduino. Arduino provides an open source software package. It can operate on MAC OS, windows and on Linux as well. The Language structure of Arduino is written in Java and C++. The basic reason of selecting Arduino is due to its easy and compact programming. It has a very user friendly GUI. Libraries and functions that are already built-in made the programming very brief and simple. We just have to accurately and effectively utilize those functions that are predefined. The programming on other platforms is very lengthy and complex as compared to Arduino, predefined functions and libraries are also very small in number on other controller platforms, so user had to make the functions himself, then calling them increases the size of program and this results in inefficient and problematic debugging. In Arduino error detection and debugging are not the challenging issues anymore.

The fourth and the last part of paper is related to conclusion and future work that will be accomplished on the robot later on. With the help of couple of features we can improve the efficiency of robot. These features include use of solar powered energy under specific extreme conditions . During our research we come to a point that, inefficient operation and drainage of electric battery can cause critical difficulties for robot to operate. Perhaps the robot is probably not capable to return back on the command station. Fire extinguishing setup could also be installed on this robot and could be utilized for firefighting.

Similarly another additional feature that we can add include is shielding from heat and fire, so in case of short circuit, fire and heat produced can damage the equipment installed on robot. Heat and fire shielding can save robot from excessive temperature and from fire itself. Other features include blasts & explosions proofing. In case robot goes into such intensive areas, then it can handle those difficulties mentioned earlier. Shock absorbers (dampers) can also be installed with the suspension to increase the stability of robot on rough tracks.

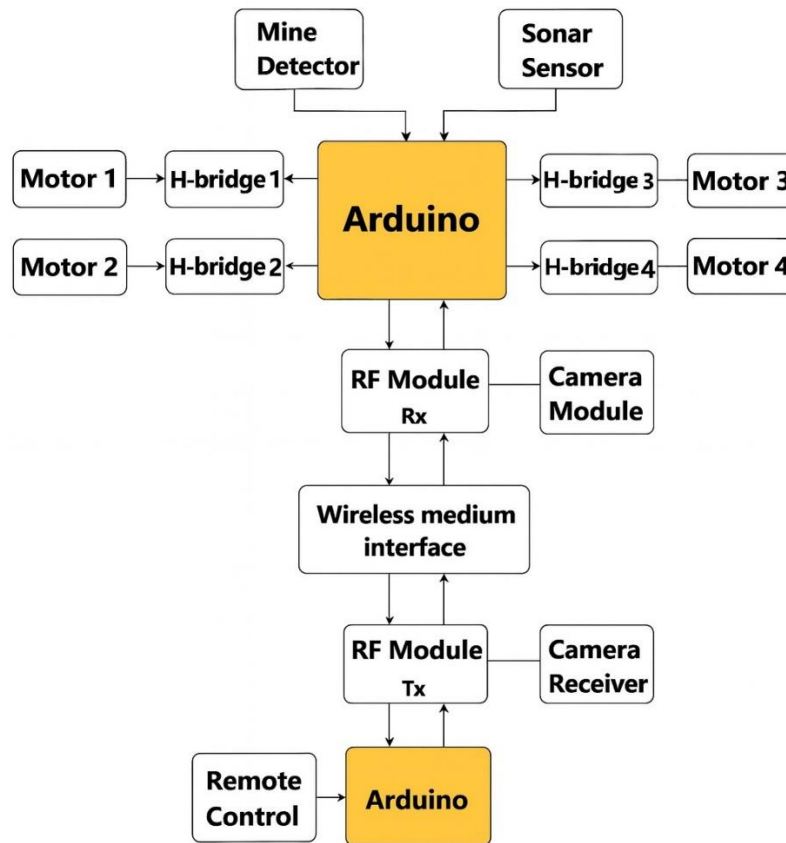


Fig. 1 Block Diagram of the UGV.

2. Architecture

The structure a UGV actually uses Commands that are generated in form of input by the sonar sensor, metal detector and pilot as well. Sonar sensor feedback is the distance detect from the obstacles [6]. The Coding for the sonar sensor module is done on Arduino along with “if Statement”. If the spacing between obstacle and the robot will be less than 20cm, the microcontroller will execute the instruction to stop the motors and the collision will not occur. Mine Detector in fact detects the metallic objects and sends the signal to Arduino and it further initiates the instructions as per programming logic.

Second Controller (Arduino) is Attached in remote unit which takes instructions from the UGV operator. The NRF receiver module in the UGV takes instructions from the NRF transmitter placed in transmitter side of the Controller. These instructions are then decoded and controlled output is generated by the Arduino controller present in the robot and the actuators perform accordingly. Motors perform as actuators in the robot which are controlled by H-Bridge modules. The camera module installed on chassis transmits the real time video streaming of the location using RF and is received by the RF receiver module present at the user end.

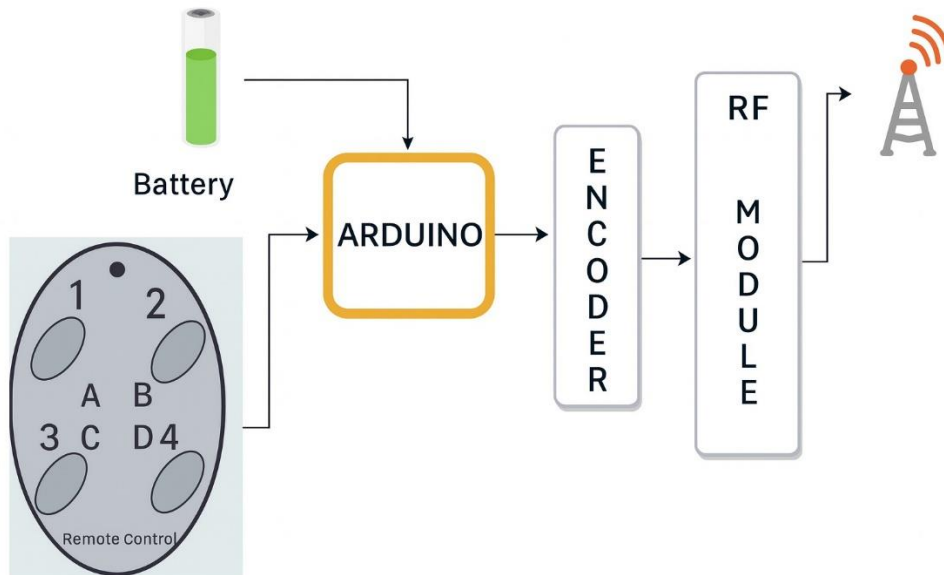


Fig.2 Transmission module

3. Working of UGV

Operator Switch on the Controller, the transmitter module on remote tries to connect with the receiver module present in the robot. As the operator pushes the button on remote, a signal will be generated and transmitted to the receiver and in response the robot moves in any specified direction i.e., forward, backward, right, left, diagonals or in spinning motion as per the buttons are programmed.

However there will be an “if statement” within the robot coding that “if” hurdle is detected, robot will instantly stop and then it will wait for the operator to generate next instruction. In case, a landmine is detected instead of hurdle the robot will rapidly stop at that moment and it will send data of the landmine location to the operator end. At the same instant remote control unit displays a message on screen “Warning.....Mine Detected!!!!”

4. Hard Ware

4.1. Control Unit (CU)

The most important part of any machine is the Control unit through which the whole process is controlled. The controlling architecture of obstacle and Mines Detection Robot is explained below.

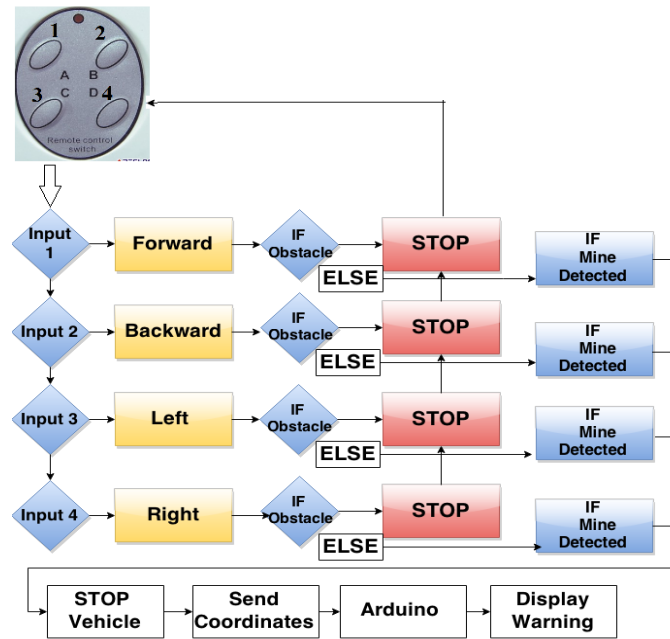


Fig.3 Robot Flow chart

4.2.DC Motors

Four Pitman DC motors are utilized to move the wheels of robot. The specific reason behind using of Pitman DC motors is that, they produce sufficient amount of torque due to the presence of inbuilt gear ratio system. These motors operate on 12 volts DC and the single motor is rated to bear maximum 11A current. The motor takes round about 0.6A to 0.9A current at no load condition. The current taken by motors is directly proportional to load applied on the UGV [7].



Fig 4 Permanent Megnat DC Motor

4.3.Sonar Sensor

Sonar sensor transduces Sound waves. These general purpose transducers are efficiently used in various sort of applications like, remote controlling applications, motion detectors, proximity sensors, level control and in counter gadgets etc. The Robot uses ultrasonic sensor as a proximity sensor for detection of objects and for hurdle avoidance. The particular ultrasonic sensor circuitry includes two vital parts, the controlling circuitry and transducer. The transducer is made of two parts a transmitter part and receiver part. This unit produces an ultrasonic sound wave of 40 kHz that travels in the air and reflects back after making contact with the object or hurdle in its way. That reflected ultrasonic wave is received on the receiver unit and in result an electronic signal is generated. This 40 KHz ultrasonic wave is generated in the control circuitry of ultrasonic sensor module [8].

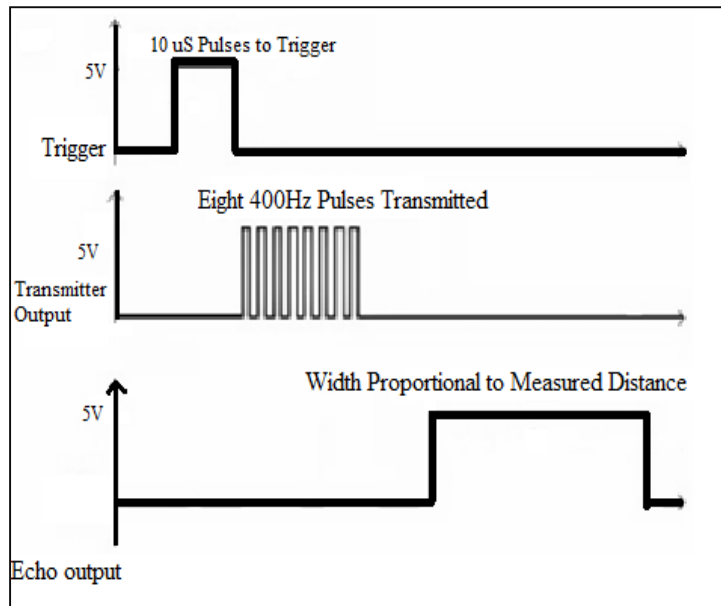


Fig.4 Measuring distance with sonar

It can be seen in the timing diagram that the 40 KHz train pulse is emitted right after sending 10μs trigger pulse to controller and after some time echo is received at the output. The next cycle can only be generated right after the previously cycle is completed. The cycle period must not be below 50ms for HC-SR04 Ultrasonic sensor [9]. The distance can be measured easily by using pulse width with the help of following equation.

$$\text{Length From Obstacle (Inches)} = \frac{\text{Echo Pulse Width (micro Seconds)}}{148} \quad [9].$$

The particular HC-SR04 sensor is used to detect obstacles. It offers fantastic stability as well as accuracy and reliability. It cannot be influenced by sunlight and dark black objects. However, it is difficult to detect cloths or soft materials. Due to surface tension of water, even sonar waves can't penetrate in water.

A small pulse of ultrasonic signal is transmitted at zero time interval ($t=0$), which reflects back by the entity. After that the Ultrasonic sensor acquires the broadcasted pulse and transforms it into electric signal. When the echo of previous signal fades away, then the next pulse will be broadcasted. Hence that interval of time is known as cycle. The end of cycle cannot be smaller than 50 ms. When a 10μs trigger pulse is applied to the trigger pin, the Sonar module will emit a 40 kHz ultrasonic burst and then listens for the returning echo [10]. The measured distance is directionally proportional to the width of received echo pulse. If no obstacle is detected, the output pin produces a high signal lasting approximately 38 ms [11].



Fig.5 Sonar Sensor Modules [11]

4.4. Full-Bridge Motor Driver Module

Full-Bridge Motor Driver Module is one of most important part of any UGV vehicle which is used to drive the motors. With its support the motor's can rotate clockwise or anti-clockwise. Its working is simple but circuit is complex. It can be created by BJT's or either by FET's/MOSFETs. BJTs are used for low current motors as these particular high torque DC motors take nearly 10A current thus MOSFETs are used in H-Bridge modules. 8 MOSFETs are connected in a specific configuration to acheave free and independent movement of all the wheels [12].

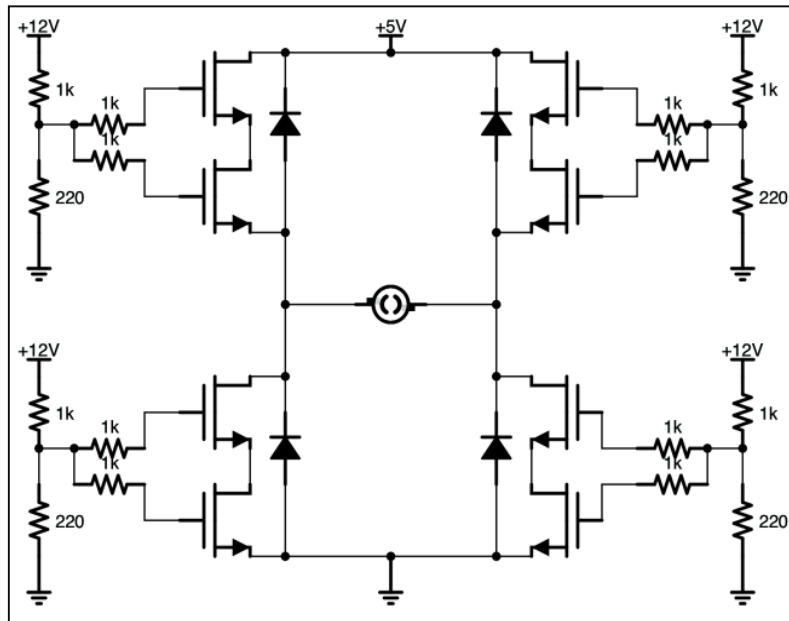


Fig.6 H-Bridge Circuit

The switching of MOSFETs is controlled by Arduino. The switching speed of MOSFETs is very fast. They can bear large amount of current. They also need a protection which is provided by freewheeling diode [13]. Each MOSFET divides current into 2.5A current, so the circuit is also heat efficient. The circuit operates on 12V dc which is provided by external source. On stopping the motor, it generates back EMF which could be hazardous for the controller module, as it could burn the whole Electronic control apparatus. To prevent this issue Optocouplers are used. The robot has four H-bridge modules which drives the wheels individually.

4.5. Optocoupler Protection

Optocoupler is a protection component used to isolate a high ampere circuit. It's a pakage of LED and photo transistor.

1. Microcontroller provides a high signal to LED.
2. Load is attached to photo transistor.

4N25 is an NPN phototransistor IC in which +5V signal is given to collector and the emitter remains grounded. The IC could be used in positive as well as in negative logic. The schematic given ahead is showing its connections. The H-bridge is a driver circuit to drive motors using microcontroller. There could be a condition where high current can flow back to controller. To avoid this issue we used Optocouplers. We isolated the controller from high ampere circuit. So if high current flows back nothing will happen to controller. It also controls the direction of motors using AND gates and NOT gates. Circuit has two pins. Pin one is logic and second pin is of PWM. PWM is used to control speed of motors and logic pin controls the direction of motor [13].

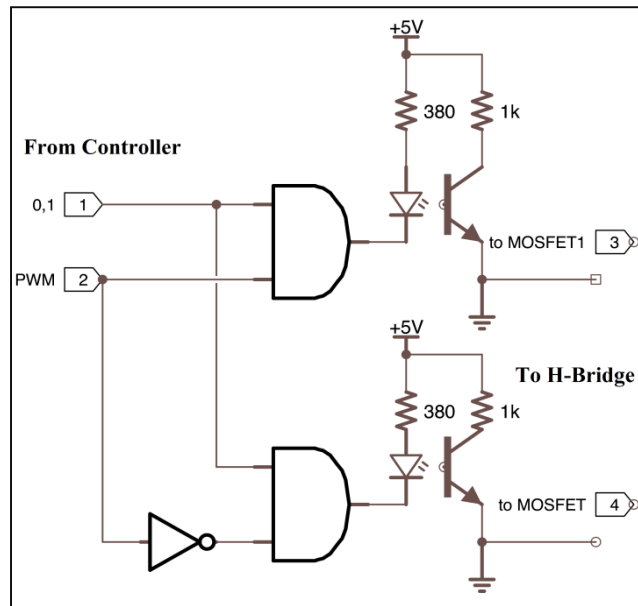


Fig.7 Optocoupler Protection Circuit [13].

4.6.Mecanum Wheels (Omni Directional)

Wheels are basically for the movement of the UGV but conventional Methods had limitations.

1. No instant turns
2. Large turning radius
3. No diagonal movements
4. No rotational movements

Mecanum wheels are unconventional. They produce very versatile and quick movement. Their turning radius is zero. Their movement is 360 degrees. They can rotate the vehicle to 360 degrees. They have 9 rollers which gives them freedom to move in any direction [3]. But on the other hand they also cost much more than conventional tires [16].



Fig 8 Typical Mecanum Wheels

Mecanum wheels are ideal for spy robots, which gives them freedom to move in vents and ducts. Each wheel must be driven by individual driver circuit. This allows them to move freely. Some movement can be performed by varying speed of wheels [17].

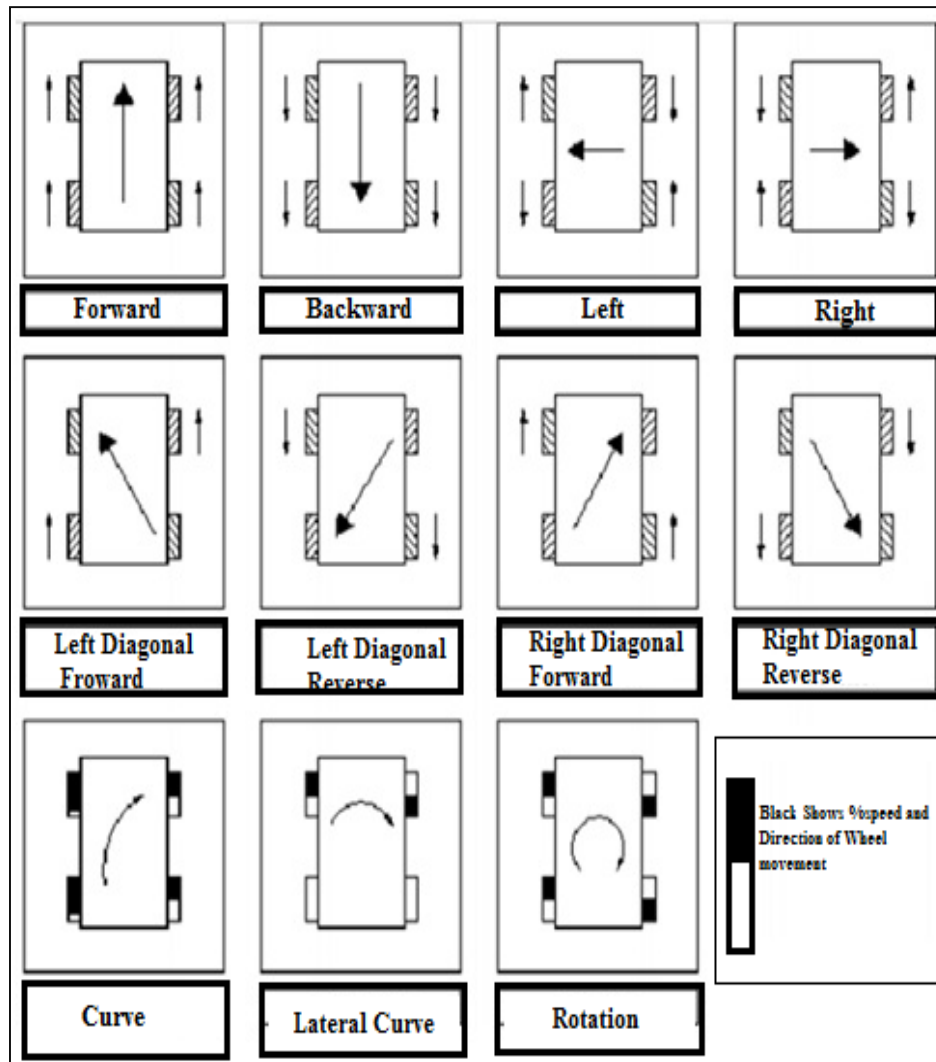


Fig.9 Degree of freedom with Mecanum Wheels [18]

For forward and backward movement all wheels must rotate in same direction. To move right or left, the wheels positioned diagonally should be in same direction. Applying break on two diagonal wheels enable diagonal movement. For rotation movement all the wheels should rotate in the same direction [18].

4.7.Camera Module

There could be some places where human approach is difficult, to explore those places wireless cameras are used for spying and security purposes. Choosing a camera is a difficult task. A good camera should have long range and easy installation. According to the requirement RF AV cyc-564 camera module is used [19].



Fig.10 Camera with Transmitter and AV Receiver [20].

4.8.NRF Transmitter module

Nordic NRF module controls the robot and electronic devices by means of wireless communication. For transcribing of RF signals air is used as a transmission medium.

To increase the efficiency of robot using art of wireless technology for communication. NRF24L01 is wireless device which use for communication purpose. NRF24L01 is transceiver so using low passes etiquette (Enhanced shock burst). This technology works on Ultra- low power wireless communication at frequency of 2.483GHz worldwide. Serial peripheral interface is used to operate the NRF24L01. From this interface all configuration data contain by register map [21].

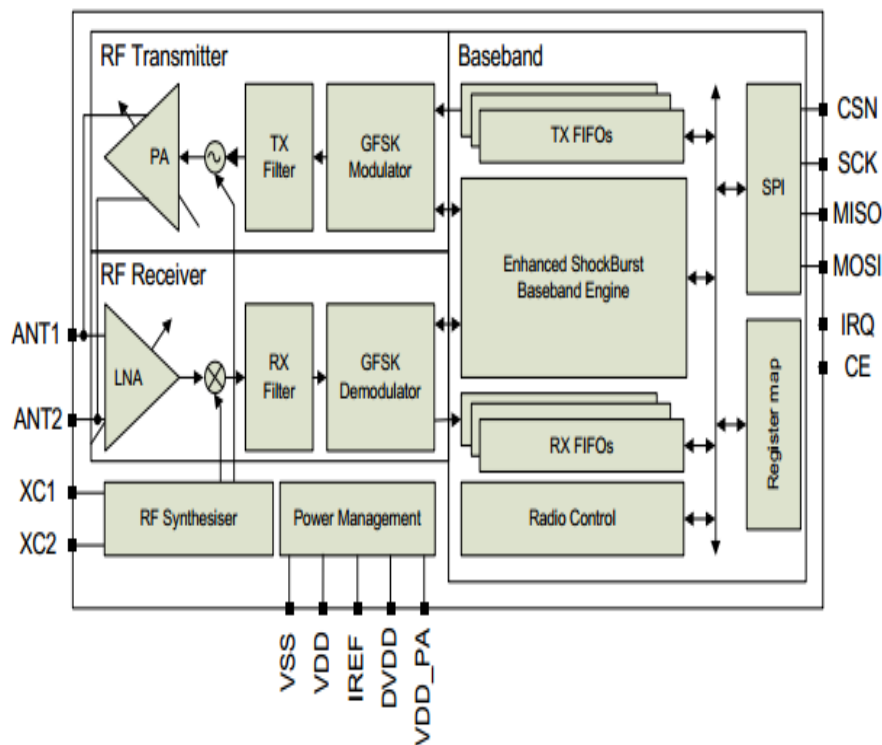


Fig.11 nRF24L01 block diagram [22].

Information in low pass filter is transmitted and received by packet communication using FIFO phenomena. Minimum cost of system and maximum speed link achieve by blow-rupture (shock-burst). Air data rate of NRF24101 is 2Mbps. For low power components this data rate is very good to save power and cost.

Manages the sequence of packet and timing using shock burst. In transmission shock burst sequence the packets and clocks at transmitter. Packet data is transmitted in bit form. At receiver shock burst searches the valid address for demodulating the use full information moreover it find the valid and strong signal by CRC. When signal is confirmed then the packet managed in sequence uses FIFO. Shock burst at receiver manage the bit rate and control increasing speed of timing. Features of shock burst includes handling and controlling, communication of data in two ways. Packet exchange between transmitter and receiver by an enhanced shock burst.

Circuitry of transmitter consists of LCD to show process, push buttons are used to move robot in various direction, nRF module for communication, Arduino board as controller. Binary signal is sent to Arduino by pressing push button. From input signal Arduino in pilot control starts processing and then signal is sent to receiver of the robot. LCD shows the command which is performed at receiver end [23].

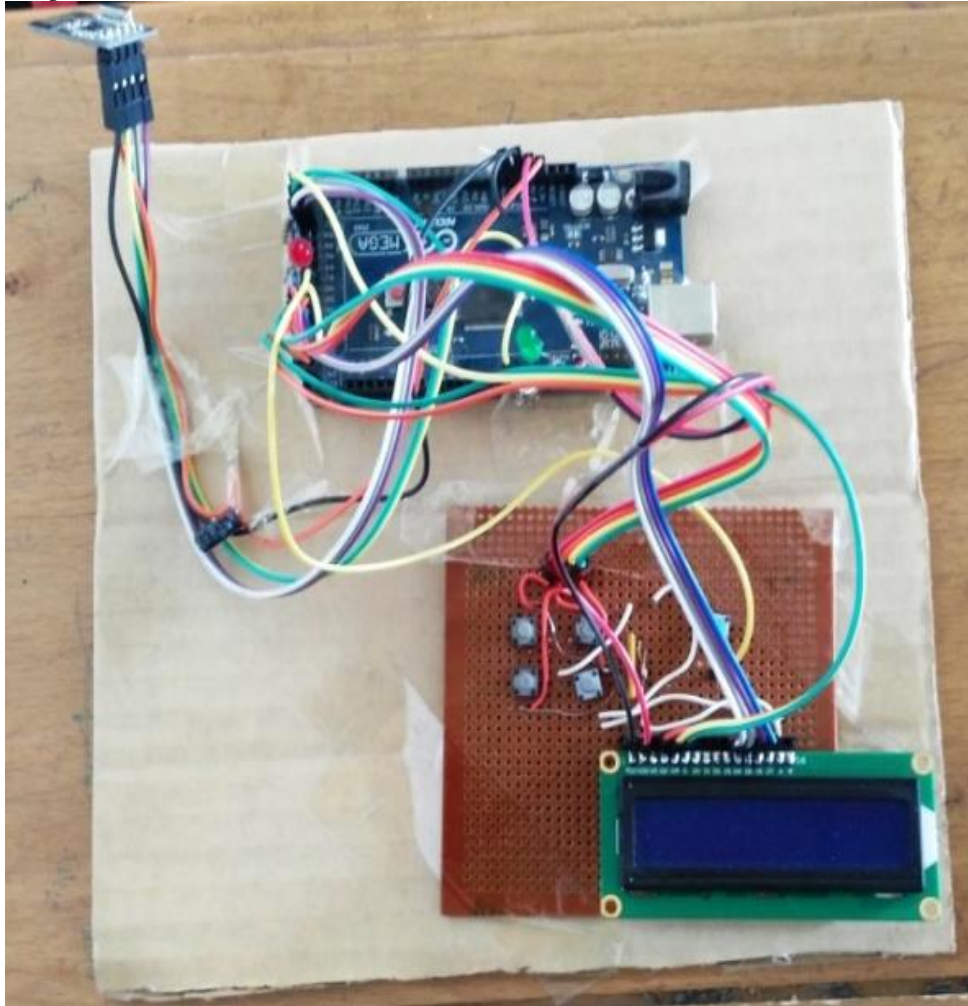


Fig.12 Robot's Transmitter Module

LCD also displays the message if any obstacle or metal is detected. If one or both of cases are detected then message displays on LCD "metal detect" or "obstacle detect". LCD also shows latest situation of robot.

4.9.NRF Receiver Module with Land Mine Detector

At receiver end metal detector, ultrasonic sensor, motors and nRF modules are attached with Arduino. Metal detector detect the metal and sends the input signal to Arduino similarly ultrasonic sensor also sends input signal to Arduino then Arduino generates the output instructions as per programming [24].

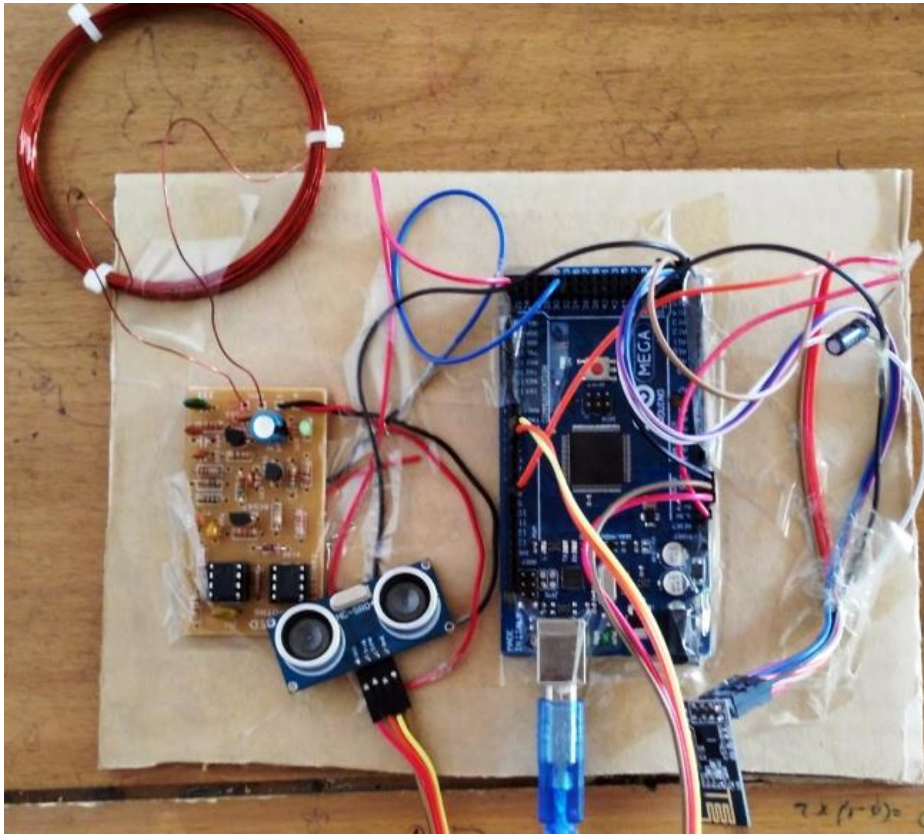


Fig. 13 Robot's Receiver Module

Arduino also sends the signal to drive the motor in any desired direction according to input which comes from transmitter end by pressing the push button. Arduino send signal to “H-bridge” to rotate the motors. Sonar sensor sends input signal in analog form and metal detector send signal in binary form. When metal is detected or obstacle come in the way then all motors stop and the message is also displayed on LCD [25].

4.10. Programing

Opt coupler a code is demonstrated below for moving robot in only forward direction. The Arduino pins that are assigned to move the tires are initially set as output ports. Those pins were set to high by the built-in function ‘digital Write’ so tires could move in forward direction. If it is desired is to rotate the tires in backward direction then the pins should be assigned ‘LOW’ [26]. To vary the speed of tires PWM is used. In the code below for demo PWM is set to 500. The range of PWM is from 0-1023. PWM is set to 0 if stopping the motor is required.

5. Methodology

The development of the Smart Mecanum Wheels UGV for landmine detection followed a structured hardware and software integration approach. The methodology centered on constructing a lightweight aluminum chassis equipped with four independent Pitman DC motors, each driven by a dedicated H-bridge module to enable precise control. The core of the system utilized an Arduino microcontroller, which processed inputs from two primary sensors: an HC-SR04 ultrasonic sensor for obstacle detection and a metal detector capable of identifying metallic objects up to 5 feet underground. For mobility, the UGV employed Mecanum wheels, allowing omnidirectional movement including forward, backward, lateral, diagonal, and 360-degree rotation based on differential speed control of each wheel. Wireless operation was achieved using a 2.4 GHz NRF24L01 transceiver module for command transmission and an RF AV camera module for real-time video streaming and night vision via infrared LEDs. The control logic was programmed in the Arduino IDE, incorporating conditional statements to halt the UGV upon detecting obstacles or landmines and to transmit alerts to the operator's LCD interface. Electrical protection was ensured through opt coupler circuits to isolate the controller from motor back EMF.

6. Results & Conclusions

The implemented UGV demonstrated successful functionality across key design parameters. The Mecanum wheel system provided the intended full omnidirectional mobility, allowing the robot to navigate complex paths with zero turning radius. The obstacle detection system reliably halted the UGV at distances less than 20 cm from objects, preventing collisions. The metal detector effectively identified subsurface metallic objects, triggering an audible alarm and sending a “Mine Detected” warning to the operator's LCD display. The wireless communication system maintained stable control

and real-time video transmission within the tested range, with the camera providing clear 180-degree coverage even in low-light conditions using infrared illumination. The integrated Arduino-based control system performed robustly, with efficient program execution and effective sensor fusion. Overall, the prototype validated the feasibility of a remotely operated, highly maneuverable robot for landmine detection, though future enhancements such as solar power, shock absorption, and extended sensor suites were identified to improve operational endurance and adaptability in rough terrain.

7. Future Scope

It has been observed during designing and research of the robot that it could be solar power driven. For protecting the robot from excessive heat & fire, heat shielding material can also be used on external structure [27]. To save the robot from mechanical disturbance on uncertain tracks shock absorber must be attached to tires. Object handling capability in robot can be added by mounting a robotic arm. In certain situations if a building catches fire, fire quenching mechanism may also be mounted for firefighting.

Acknowledgement

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