Landmine Detection and Reporting using Light Weight Zumo Bot

Rajesh Kannan Megalingam, Vamsi Gontu, Ruthvik Chanda, Prasant Kumar Yadav, Allada Phanindra Kumar
Dept. of ECE, Amrita School of Engineering, Amrita University, Amritapuri Campus, Kerala, India
rajeshkannan@ieee.org, vamsi.gontu2308@gmail.com, ruthvikchanda1999@gmail.com, yprasant0@gmail.com, alladaphanindrakumar@gmail.com

***Abstract*— The purpose of this research work is to propose a simple bot to detect landmines and mark their locations using autonomous navigation using a simple Zumo32U4 robot. Landmine detection is an important and yet challenging aspect in many of the countries which are still plagued my landmine issues for several decades now. It is not only the problem of the military, but it is also a humanitarian concern. So, in order to address this issue we came up with simple, light weight, autonomous wireless controlled robot which is capable of detecting the landmine at the depth of 5cm to 9cm under group. The paper describes about the design and development of the landmine detection mechanism. The results are very promising that this bot can be well used in fields for identifying and locating the landmines.**

Keywords—ZUMO32U4, Metal detector, IC NE555, Coil, landmine detection, sensors, autonomous robot.

I. INTRODUCTION

Landmines are broadly classified into two types: anti-personnel and anti-vehicle mines. Both have caused a great suffering in the past decades. In order to tackle one of the long standing problems causing great distress and loss to the people of several countries affected by landmines, around 150 countries have formed a treaty to decrease the number of casualties and increase in the number of mine free countries. There are approximately about 110 million landmines in 70 countries. Out of them only 40 million are destroyed so far. Mine fields which are left after the wars or planted by terrorists claim more than 80,000 deaths every year. 80% of the victims are of anti-personnel mines, in which most of them are children. The top 5 countries which have most number of landmines are: Iraq: 9 million, Afghanistan: 11 million, Angola: 13 million, Iran: 16 million, Egypt: 23 million.

Anti-personnel landmines are usually buried 1-4 cm beneath the soil and require about 9kg minimum pressure to detonate them. So it is very important that the robot designed for this purpose is light weight and at the same time should be able to traverse in rough and uneven terrain to fulfill the purpose. Our proposed bot is simple and light weight and can move freely in the landmine area. The anti-tank mines are usually placed under the earth and close to the surface of the earth. This robot is able to detect landmines up-to an accuracy of about 90% and it detects the landmines based upon their dimensions which helps to find the exact place of the landmine. It can detect the landmine which is at a depth of 5-9cm depending upon the soil and the difference in the metals. It can also move easily on hilly and terrain areas which enables it to detect landmines even in rough and tough terrains.

II. MOTIVATION

The main objective is creating new sensor algorithms in the simpler way and implementing it on the robot for multiple purposes like scanning or detecting and movement of the robot i.e., path finding should be designed in such a way that it should be computationally in expensive and shouldn't be difficult to implement on the other software or hardware. Another great task would be implementing all these algorithms in the single robot. The objective of introducing these type of robots would be to reduce the human activities in the harmful environment since mine detection is always a risky process. Even though we are living in a world of technical innovations, we haven't spent enough time to wipe the tears of the family members who have lost their dear ones or to console those who are crippled because of this evil called landmines. This is the first step on our part to find solution to this issue using technology. The proposed work would be helpful for clearing the landmines by identifying and locating them in those countries which are affected by this evil. It would also help the soldiers in the war-fields as it sends the location of the landmine. They can follow the track of our bot which can lead them in the landmine free path ensuring safety of the soldiers.

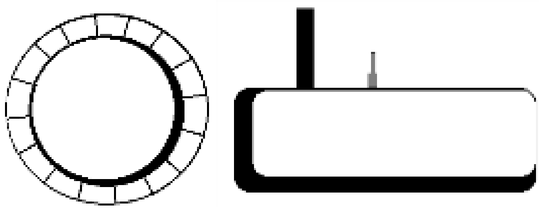
III. RELATED WORDS

The different sensor technology systems and also the special detectors for deeply buried mines like GPR (Ground Penetrating Radar) are discussed in the research paper [1]. In the research work presented in [2] the author has described about the different mine detecting technologies other than metal detecting coil like use of MDD's i.e. mine detecting dogs and other sensor technologies like QR (Quadrupole Resonance) and TNA (Thermal Neutron Activation). Different types of sensors used in landmine detection are discussed by the authors in [3]. They propose to use optical shaft encoders which are used to count the rotation of the wheels and a digital compass (CMPS03) which can measure the rotation angle of the robot using Earth's magnetic field for the detection of landmines. The authors demonstrate the problem and effects of landmines in defence fields in their research work in [4]. They are proposing a robot that has the aptitude to detect the buried mines and lets user to control it wirelessly to avoid human causalities. Mine detection using a surveillance drone is a modern conceptual prototype, which has been designed to detect landmines is discussed in detail in [5].

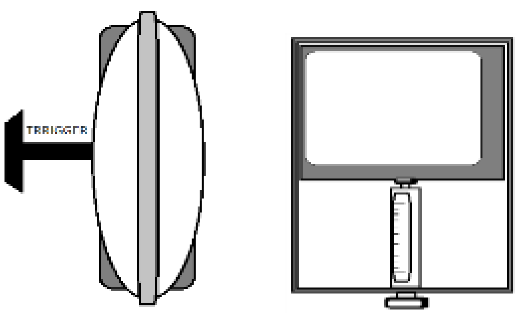
The authors describe about critical design constraints of mine detection for Korean minefields [6]. The design includes a track like platform with a simple moving arm and a mine detection sensor, which consists of a metal detector and a GPR. They claim it be a cost effective method. In [7] the authors describe about using of a buggy which helps in detection of landmines on unstructured terrain. Normally robots that rely on chemical batteries suffer severe limitations in operation times and mobility. So in this research they propose to use combustion engine to tackle this problem. The research work in [8] describes about detection of landmines underwater in a very short amount of time and form a map which helps in navigating easily underwater. A Mine Probe is used to map the minefields by the usage of sensors and fusion modules to detect landmines and unexploded ordnances (UXOs) [9]. The authors address the problem of detecting anti-personnel landmines, in an environment that could contain clutter, using features extracted via the fractional Fourier transform [10]. As we see there are several methods and approaches proposed in literature for detection, identification and safe removal of the landmines. The research work in [11] describes about using of wireless sensors for over speed detection. The research work in [12] describes about using of wireless sensors for detection of landslides using complex sensors.

IV. LANDMINES

The landmines can be triggered by number of ways including pressure, movement, sound, magnetism and vibration. Anti-personnel mines commonly use the pressure of a person's foot or any other object as a trigger. Many mines combine the main trigger with a touch or tilt trigger to prevent enemy engineers from defusing it. Landmine designs tend to use as little metal as possible to make searching with a metal detector more difficult. Some modern mines are designed to self-destruct, or chemically render themselves inert after a period of weeks or months to reduce the livelihood of civilians casualties at the conflict's end.



(a) (b)



(b) (c)

Fig .1 Different types of landmines

A typical land mine includes the following components: firing mechanism or other device (including anti-handling devices); detonator or igniter (sets off the booster charge); booster charge (may be attached to the fuse, or the igniter, or be part of the main charge); main charge (in a container, usually forms the body of the mine); casing (contains all of the above parts)

In Fig.1 shows landmines of different shapes and structures. Fig. 1 (a) shows surface area of the trigger used is larger than the normal mines and the material used is hard metal. As the surface area of the mine is larger it can only be removed by knowing the dimensions of the mine but not directly taken from the land. Fig.1 (b) consists of triggers in which one trigger works when it experience pressure and the other trigger (self-destruction) works when the mine tilts. The landmine shown in Fig.1 (c) is completely metal cased with cylindrical shape and it is a trigger sensitive landmine. A wooden cased landmine is shown in Fig.1 (d) and this is also not much filled with the chemical and also the metal powder is deep inside the landmine, which makes it difficult during detection. Apart from the shapes, in most of the landmines nitro group compounds (2, 4-DNT, TNT) are the chemicals used. Table 1 shows different types of landmines and their shapes.

Table.1: Types of landmines and their detailed study

S.No	Name	Shape	Material	Dimension(cm)
1	No6/8 mine	circular	Metal	30/25.9
2	Nr25	circular	Steel	30.5
3	Pingnone	circular	Plastic	33.5
4	M1936	Rectangular	Metal	24*14
5	M19	Square	Metal	33.2

V. DESIGN AND IMPLEMENTATION

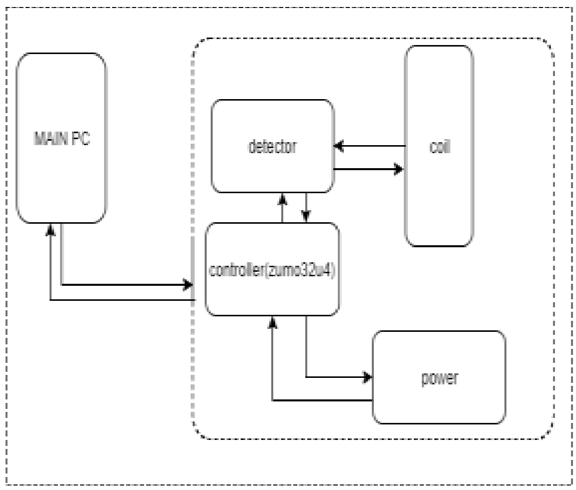


Fig. 2. Architecutral diagram of the land mine detecting robot

A. Zumo32u4

The highly integrated Zumo 32U4 is the latest Zumo robot. It includes a built-in Arduino-compatible ATmega32U4 microcontroller, an LCD, encoders for closed-loop motor control, and proximity sensors for obstacle detection. The robot is compact enough to qualify as a mini sumo robot, but its high-performance motors and integrated sensors make it versatile enough to serve as a general-purpose small robot. This can comfortably move in uneven terrain as we created an uneven test setup and verified the same.

B. Metal detector

The metal detector we used is functioned by a simple 555 timer IC. When the coil attached to the Zumo bot as shown in Fig.4, is energized, the flux associated with it changes and any metal in the vicinity can cut the flux. This creates a flux change in the coil which can be detected to identify the metal. A buzzer sounds when a metal is detected. We used a coil of 80 turns so that detecting the flux change through the field is deeper.

C. Working of coil

The coil is applied with a pulsing current and then the coil induces magnetic field and when there is a metal under the induced magnetic field, the field induces electric currents in the metal(called eddy currents).the eddy currents induces their own magnetic field and this causes the reverse current in the coil. Fig.4 shows the coil, magnetic field and eddy currents. For land mines of diameter 30-34 cm we required a speed of 4.7 cm/s to cross the mine in 8secs.

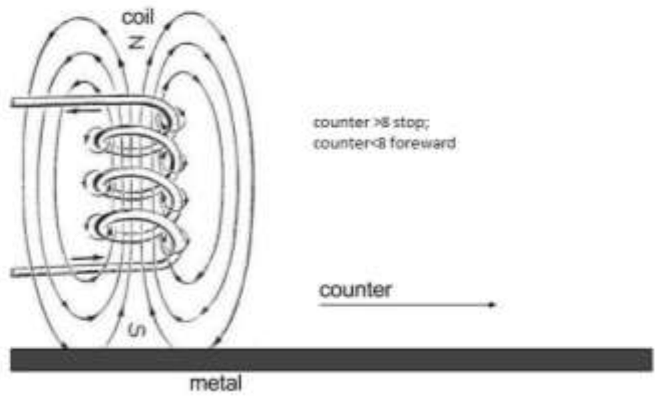


Fig. 3. Working of coil

D. Implementation and specifications

The Zumo bot is structured in such a way that it can move in any type of field. The wheels with the belt provide enough grip to move on the ground. The motors attached to the wheels can run at a maximum speed of 400 rpm. The weight of the robot is less than 1 Kg and hence can move over the landmine fields without fear of triggering the landmines thereby avoiding damage to the bot. The coil is wound in elliptical shape of length of 15.4 cm which can cover a rectangle area of 15.4 cm x 3 cm. An immovable arm like structure holds the coil in front of the bot and the bot is insulated so that the coil doesn't detect the bot as the metal and raise a false alarm. The coil is place at a height of approximately 5cm above the ground. Fig.4 shows the aerial and side views of the Zumo bot.

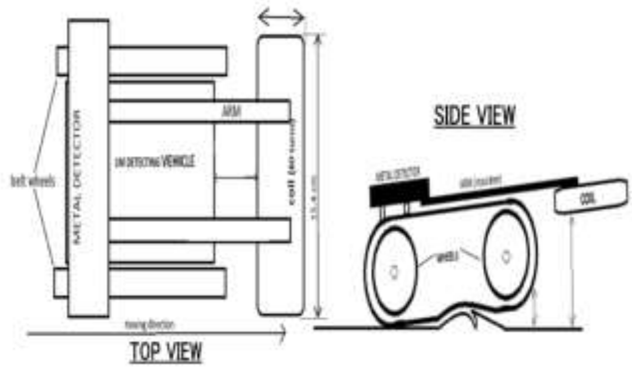


Fig. 4. Aerial and side view of the robot

VI. Experiment and Results

The tests are performed with the test setup in our lab with two fold purpose: one the bot should be able to detect the metal; the second is to detect the size of the metal in order to avoid spurious detection of metal and raise false alarm. The algorithm implemented in our bot takes care of both these purposes. The test setup consisted of mud of area 60 cm x 20 cm. The depth is about 12 cm. The metal of different sizes are placed at different depths and the bot is made to navigate over it several times. The success rate is measured to be 100% when the metal is placed as deep as 8 cm from the surface of the mud. Beyond 8 cm the success rate varied drastically. We can see from the Table 1 that the size and shape of the landmine varies. The shape can be either circular or rectangular. The maximum size can be 30cm in diameter for a circular landmine and 24cm in length for a rectangular landmine. There is another type of landmine which is called bar landmine of 100 cm in length.

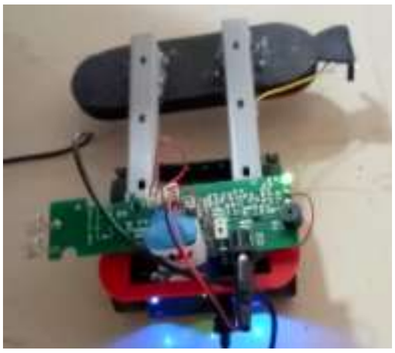
When the metal is first detected the speed of the bot is reduced to a known speed and simultaneously a timer is triggered in the bot. With the help of the timer, if the detected metal piece is of minimum length 24 cm then the bot detected the landmine successfully. If the size of the landmine is greater than 24 cm, it will be detected without any hitch. The following Table 2 lists the speed and rpm of the bot as measured by us. Fig 5 shows our implementation and testing of the same.

Table.2: The speed and rpm of the bot

s.no	Rpm	Length(cm)	Time(sec)	Speed(cm/s)
1	40	15.4	6.86	2.2
2	45	15.4	5.12	3.0
3	50	15.4	4.21	3.65
4	55	15.4	3.52	4.1
5	60	15.4	2.68	5.7
6	65	15.4	1.85	8.3

A. Algorithm

The bot starts and moves as per the control signal given to it: f=forward; r=right; l=left; b=backward; s=stop. When the coil detects the metal of the predetermined size the output signal value =1. The speed of vehicle at 55 rpm is 4.1cm/sec. As we discussed earlier if the length of the land mines is taken to be30.5cm. So to cover 30.5cm it takes 8 sec when the bot could move at 55 rpm.



(a)

(b)

(c)

(d)

Fig. 5. (a): The Landmine Zumo Bot; (b), (c), (d): During Tests

So the robot gets slow down to 55 rpm from its original speed when a metal is detected for the first time and a timer is triggered in Zumo bot for 8 seconds. If all through the 8 seconds a metal presence is detected then the bot informs the presence of landmine. Otherwise it is taken as spurious identification and ignored and the bot ventures to find real landmine. The flow chart of the algorithm is shown in Fig. 6.

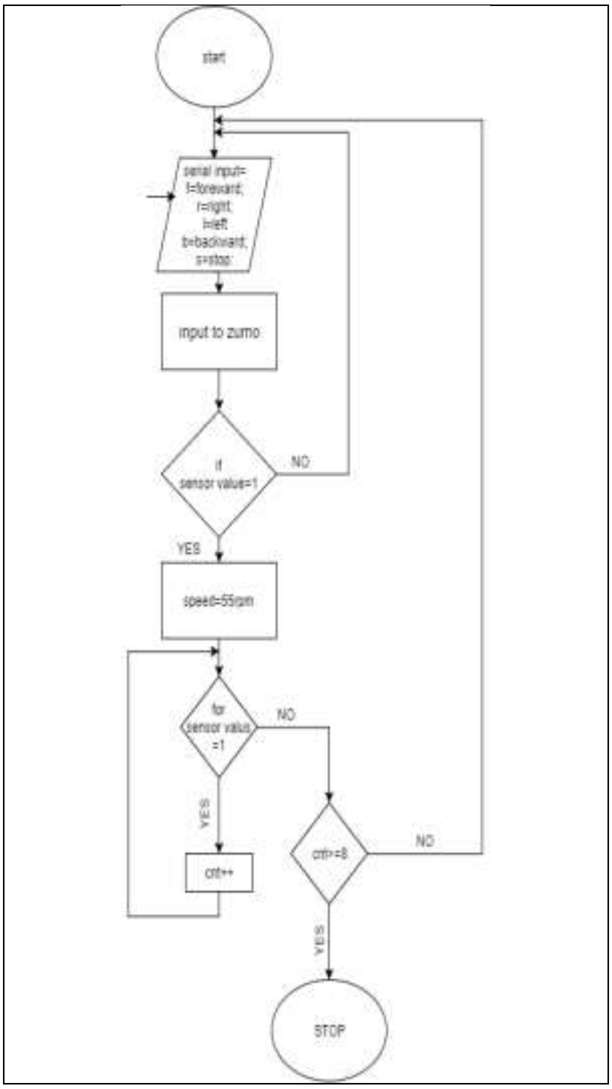


Fig. 6. Flow chat

VII. FUTURE WORKS

Even though this robot model detects the landmine successfully as we presented in the experimental section there is still scope of improvement. The circumference of the metal detector can be increased to cover more area while identifying the metal. Camera can be included to have a real time vision of the landmine area particularly when it is remotely controlled. In our proposed bot the detection coil is in fixed position. However this can be fixed in a movable way to cover larger area for scanning for metal. Currently the robot is controlled in a wired way which has to be wireless when operating in landmine fields.

VIII. CONCLUSION

It has been proved that this proposed theory and concepts for a landmine works perfectly. The greatest advantage that this light weight robot offers is the safety of the people affected by the landmine problem, safety of the workers and volunteers who are involved in defusing and destroying the landmines and the soldiers on war field. The proposed design for landmine detection is a cost effective which is an added advantage. In this research work we have proposed the design and implementation of a light weight robot design based on Zumo bot for identification and reporting of landmines. We have presented the experimental setup and the results which point to a successful model of our proposed work.

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