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Swarm based Autonomous Landmine Detecting Robots

Rajesh Kannan Megalingam, Deepak Nagalla, Pasumarthi Ravi Kiran, Ravi Teja Geesala, Katta Nigam
Dept. of ECE, Amrita School of Engineering, Amrita Vishwa Vidyapeetham University, Amritapuri Campus, Kerala, India
rajeshkannan@ieee.org, nagalla.deepak@gmail.com, ravikiran.p3637@gmail.com, ramsrimanasi@gmail.com, 123nigam.k@gmail.com

***Abstract*— Recently it has been found out that, at least 60 countries in the world are contaminated by landmines. These landmines have become a growing concern, due to their threat to lives of human and cattle. There are more than 50-100 million landmines still not diffused in more than 50 countries like Egypt, Angola, Iran, Afghanistan, Cambodia, etc. Though several countries have started taking some important measures like funding the demining projects, training people with demining techniques, etc., landmines have become a major threat to the mortals. There are many detection techniques, but most of these involve humans, which in turn creates a great threat to their lives and limbs. The autonomous swarm based landmine detecting robots proposed in this paper involves a swarm of robots that could autonomously detect landmines and share the location to the control station. The algorithm and the theoretical concepts are shaped into a working model. This paper gives the reader a clear picture about how these robots help in demining.**

***Keywords*— autonomous, swarm robots, landmine detection, saving lives**

I. INTRODUCTION

The countries like Egypt, Angola, Iran, Afghanistan, Cambodia and etc. are mostly affected by landmines. Egypt is facing the major threat with an active landmine count of 23 million, followed by Iran with a landmine count of 16 million and similarly other countries. These mines are like an unpaid soldier, who is on duty every second waiting for the prey. Once the prey triggers the mine, it either kills or leaves the prey crippled. This does not affect the prey alone but also shatters the lives of those who are dependent on the prey. So, we have to be quick in demining the maximum landmines before it cripples other person. Our idea is to use multiple robots to communicate with each other in the fields for effective demining. One of the bot is called the master and others are the slave bots. All the instructions in the field will be provided by the master bot to the slave bots. If a landmine is detected in the field, its location coordinates are traced by using the Differential Global Positioning System (DGPS) technique and then the location coordinates are communicated with the master bot from the respective slave robot. Sequentially, after this the location coordinates are conveyed from the master bot to the host computer which controls the master bot. The location of the landmine detected by the slave bot is determined using a DGPS. DGPS gives a more accurate result so that the position of the landmines can be determined accurately. The research also aims at covering a large area in less time by using multiple slave bots controlled by a master bot. Each bot will cover a certain area and the remaining other bots will cover the area which is not traversed by this bot, all happening simultaneously. By this way the time taken to scan for mines is reduced a lot. The details of each part of the working model will be presented below. This work mainly focuses the use of swarm concept in landmine detection.

II. LANDMINES

Landmines have first been used in the American Civil War in the 1800s. Majority of the landmines were made and used during world wars, when the soldiers used these mines around the boarders to protect their base and their country from enemies. But after the war, no one cared to demine or diffuse them. Hence, there are millions of landmines threatening hundreds of lives every day.

Landmines are basically divided into anti-tank and anti-personnel mines. Anti-tank mines are designed to damage the war tanks. They are larger than anti-personnel mines. They are typically designed so that the personnel could not activate them. They require an applied pressure of around 158KG to 338KG in order to detonate. They have a minimum height of 125mm and a diameter of 337mm. They consist around 10KG of a mix of TNT and Cyclotrimethylene Trinitramine (RDX). They mainly focus on destroying as much of the structure of the tank as possible.

Anti-personnel landmines are designed to cause damage to the human life. They are of different shapes and compositions. They require a minimum pressure of 5KG to trigger them. But this threshold value varies from model to model. They are placed just about 5-10cm below the surface of the soil. Some of them are designed to target the sensitive parts like head or chest of the personnel, and hits those spots when triggered. This kills the personnel. Some of them contain fragments like sharp objects. When they are triggered, the fragments are thrown in all directions piercing the prey’s body and causing a lot of pain. This would also kill the personnel but in most cases, it leaves the personnel crippled.

III. MOTIVATION AND PROBLEM STATEMENT

The data states that over 1 million people have been maimed by anti-personnel mines, 26,000 people become victims every year, 70 or more every day and one person every 15 minutes. There are more than 100 million landmines still active. Everyone is vulnerable to these land mines including human and cattle. Women collecting water, children gathering firewood or playing, men working on the land or tending cattle and even the cattle lose their lives or get crippled. Anyone who goes about their normal day in a mined area is at risk. Most minefields are unmarked. So one may have no idea that you are in danger until it is too late. Land mines do not just kill and injure: they also create longer-term costs for communities like medical cost, employment and loss of land. Due to the blast the land is rendered useless for agriculture. We propose a swarm based robotic system in this paper to tackle the issues associated with landmines by detecting them in advance which would help the demining community a safe way for demining them.

IV. Related Works

There are many researches going on the improvement of demining of landmines through robots. In the research work presented in [1] metal detector and many sensors are used in order to detect landmine. The camera and the GPS transfer an exact coordinates and video footage to control station. This might take long time to scan a vast area single handed. The design of Ares robot is presented in [2]. It is designed such that it can go in all type of terrains. But again, as a single bot it might take long time as in [1]. In [3] the authors came with a brilliant suspension technique which gives more stability to the robot in all type of terrains. The bogie mechanism helps the robot to go steady even on a bump. The authors concentrated more on the motion of the robot. This bot too is having the same issue as in previous two papers [1-2]. There are bots that as in [4] which uses swarm concept but for different applications. Dividing the area of the field into a parallelogram tract and making the robot to follow the tract to detect the landmine is proposed in [5]. Works in [8-9] are the major motivation for including swarm concept and wireless communication in this work. In [6] too the authors came up with a basic model to detect the landmine which is similar to that in [5] except that it has a spy camera. Detecting the landmines by a movable robotic hand and a camera is proposed in [7]. We

V. Design and Implementation

The robots to detect landmines proposed in this work involve a complex task of going into the marshes and very harsh environments. So the communication among the robots, their body and their movement must be stable and synchronized. These robots should be of very light weight so that they do not trigger the landmine. They should move with a velocity such that sufficient amount of time is allotted for calibrating the sensor. The robot design shown in Fig. 1 involve a standard chassis made up of acrylic.

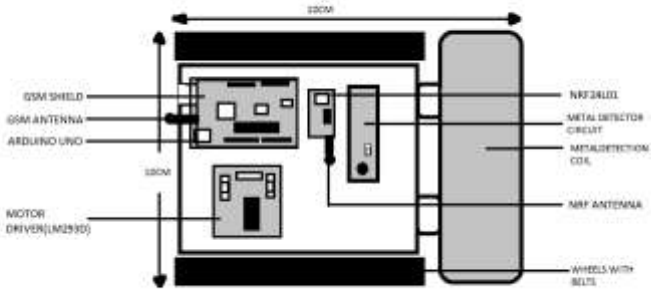

Fig. 1.Top view of the robot.

The chassis is 10cm×10cm×5cm so that it could go easily into the narrow places. The material of chassis is chosen in such a way that it is resistive to corrosion and adaptable in any environment. Acrylic is (Polymethyl methacrylate) and is highly cost-effective, resistive to temperature, non-conductor of electricity. For the movement to be smooth even in marshes, wheels are provided with conveyor belts made up of polyester.

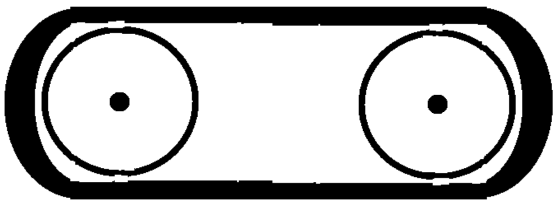

Fig. 2.Wheels and conveyor belt.

The wheels with the conveyor belt shown in Fig.2help the robots to move freely avoiding any obstacle in its way. Four such wheels two such belts are used in each robot. Hence the body and movement are so stable in almost all types of terrains and environments. And the motor driver L293D is used to run the motors. Its working is in the form of an H-bridge. It requires a supply voltage of 12V and it in turn provides an output voltage of 5V which helps us to power the Arduino during the run. This application is very helpful in adjusting the movement of the robots as desired by the operator.

A. Architectural Diagram

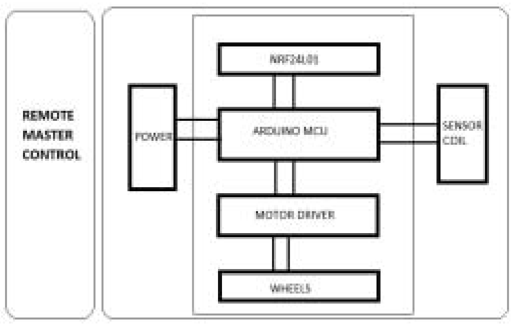

Fig. 3. Architectural Diagram

The architecture of the proposed bot design is shown in Fig.3. When the operator from remote control station sends a trigger signal, the wireless module in master senses the signal and gets activated. Then it establishes communication with all the other slave robots through wireless communication using NRF module. Once all the robots are activated, the operator receives the signal from master stating that the robots are ready to scan the field. Then the operator sets the location of each robot by using GPS module and sends the location to the robots. The Arduino MCU in each robot processes the information from the operator and then goes to the specified location by using the information from GPS module and Google maps. The MCU can read information from sensors, process the information and execute the required operations. For the movement of the robot, the Arduino sends commands to the motor driver based on the information it received for navigation.. As the operator sends commands to the master, the master shares the information with the slaves and all the robots move as per the commands from the control station. The metal detector sensor scans the field for the landmines. If any metal enters in the inductor loop, eddy currents are induced in the metal and hence the metal is detected. Whenever the metal is detected the location is sent to the control station via DGPS.

Fig. 4. Illustration of communication between master and slaves

Each master module can control 6 different slave modules and each slave can act as a master for another 6 robots and so on. Hence a single robot can control multiple robots indirectly. Master recognises the slave by the unique address assigned to each module. These modules can communicate over a range of 80-100 meters in open air and up to 50 meters when there are so many obstacles in its way. They work at 2.4 GHz and this frequency range is advantageous than 2.5 GHz in establishing wireless communication over very large areas i.e., 2.5 GHz supports communication only over smaller areas compared to that of 2.4 GHz. With the help of these modules, the operator can control the robots even when they are in the field. Hence the robots work as semi-autonomous.

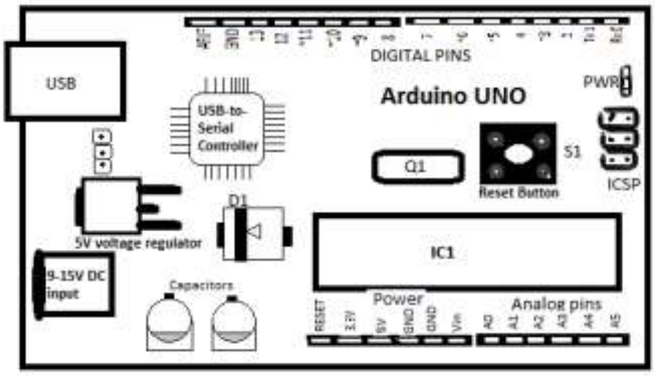

Fig. 5. Arduino UNO

The architecture of Arduino UNO board is shown in Fig.5. It is a micro controller board based on ATmega328P. It has Analog pins from A0-A5 and digital pins from 1-13 among which 3, 5,6,9,10,11 are PWM pins. The Arduino can be powered in three ways. One is through the USB, by AC or DC adaptors and other is by using the battery. Arduino can be programmed using Arduino IDE software specially designed for programming microcontrollers. Arduino has various applications. It can be used to calibrate almost all the sensors available and supports serial communication. In this project Arduino is used to control the movement of the robot, serial communication between master and slave robots, controlling the sensor and sending all the above processed information to the main station.

B. *Working of Metal detector*

In our design we use 10mH inductor which acts as the metal detector. When the inductor moves over any metal, eddy currents are induced in the inductor which in turn activates the buzzer. This detector can be used to detect metal of any type and of any size starting from the size of the pin. This directly leaves us with so many false alarms. But from a simple algorithm given below,

```
flag =0;
for(distance=0;distance<=250;distance++)    // distance measured in mm{
 if (metal==1)
  {flag=1;}
  else
  {flag=0; break;}
}
if (flag==1)
{Serial.println (“Mine Detected”);}
```

Above algorithm is based on fact that no landmine is smaller than in 25 cm in diameter. Hence any metal object less than the of 25 cm is neglected. Hence the false alarm rate is very less. The metal detector detects any metal which is at a depth of 7 cm from the surface of the ground. Table 1 shows the depth requirements as per the experiments conducted by us for various metals.

Table I. Minimum Depth Requirements

S.No	Metal	Depth (cm)
1	Iron	8
2	Aluminium	7.5
3	Steel	7.5
4	Brass	6

If a mine was detected, then GSM GPRS Shield for Arduino is used to share the location of the mine to the control station. DGPS (Differential Global Positioning System) method is used for sharing the location since it can share location with a degradation of just 0.22 m per 100 km. Hence the accuracy is very high. This also helps us to avoid the chance of an area being checked more than once and hence it saves a lot of our time. **NewSoftSerial10c** library is used to program the GPS shield using Arduino and a SIM with a sufficient data plan should be installed in the module.

AT+CMGF=1-*sets the GPS module to send text message to the control station*

AT+CMGS="+919999999999"-*accepts the text messages from the mobile number specified*

gps.location.lat( )-*gives the latitude of the mine location*

gps.location.lng( )-*gives the longitude of the mine location*

All the above components are installed in each robot. When the field location is set to the robots, the robots goes into the field and waits for the master robot to give commands. Then it scans the entire field without tracing a part that is already traced. Whenever a landmine is detected, the slaves send the location to the master robot, which in turn shares the information with the control station. The involvement of the swarm technology in landmine detection reduces the time required to scan the entire area and also increases the efficiency of detecting the landmines. Since NRF and GPS modules are used, robots can be operated as both autonomous and also can be controlled by the operator. Once the robots finish their work, a mine diffusion team enters the fields and diffuses the landmines based on the location shared by the robots. Since the work that should be done by a single robot is being done by several such robots, the time required to perform the work is greatly reduced.

C. Conceptual Diagram

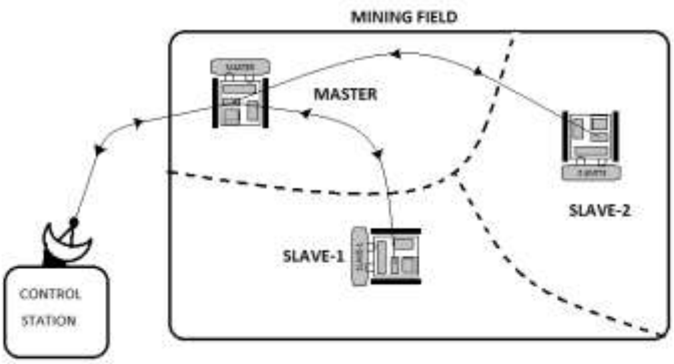

Fig. 6. Conceptual Diagram

We can see clearly from the conceptual diagram shown in Fig. 6 that the slave robots are searching for the landmines in the field. The main concept is that the slave robots get the commands through the control station accordingly they work. When the slave robots detect land mine they send location coordinates to the master robot and it send it to control station through DGPS. The purpose why we used this slave-master concept is that the robots divide the area of field among them and start demining.

D. Step-by-Step working procedure

Fig. 7 shows the flowchart of the control algorithm as implemented by us. The flow chart is explained through the following steps below.

Step1: The communication between the master and slave robots gets initiated and the master starts exchanging information with the control station.

Step2: If signal from master robot is available

Step2.1: The robots start scanning the field for landmines as per the commands of the master which in turn is controlled from the control station.

Step2.2: If landmine is detected

Step2.2.1: The bot shares the location to the master and the master sends the location to the control station and control goes to Step2 again.

Step3: If signal from master is not available

Step3.1: Entire program stops.

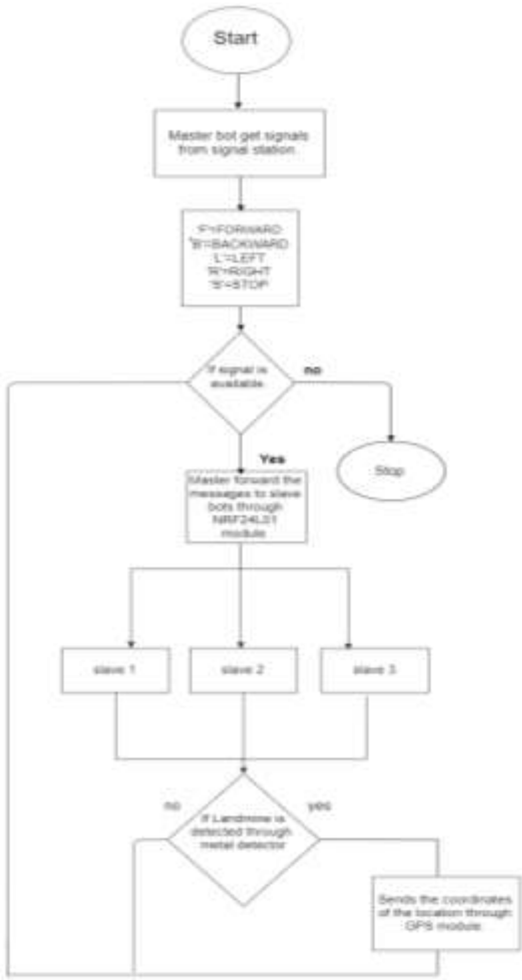

Fig. 7. Flow chart of working of the robots

VI. FUTURE IMPLEMENTATION

The model can be used in other project where they need a cost effective and stable communication module. As of now the modules are not internally connected so to reduce the weight of the bot we can integrate it internal the bot. We can even use a legged robot in future to get a precise accuracy of the location. Since this prototype wireless communication is limited to 80-100 meters distance. But the wireless range can be extended by adding highly developed wireless controllers in the robot. Camera can be installed in the robot to survey the minefield and gives report to the user or human controller. Wheels size should be increased to upload the landmine from the actual mine fields. We can install shock absorbers and adjusters to the wheel unit, so that it can run on any landmine field.

VII. CONCLUSION

The present investigation of the current prototype of automatic landmine detection and sweeper robot has been presented and it can be built using some hundreds of US dollars. So huge investments on landmine detection can be reduced in the countries that are threatened by landmines. This prototype provides less complex structure and reduced cost to build a landmine detection robot. Also, as per the current advancements in landmine detection technology, it takes around a thousand years to demine all the active mines. But since in our prototype, the work to be done by a single robot is being done by several such robots, this expectancy period can be reduced a lot and since the prototype is cost effective and easy to operate any individual who can operate a smart phone and who knows how to demine can use this prototype. As it was designed with a weight that was far less than the weight required to trigger a mine, there is very less chance of it being destroyed due to blast.

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