THE DEVELOPMENT OF AN AUTONOMOUS PERSONAL MOBILE ROBOT SYSTEM FOR LAND MINES DETECTION ON UNEVEN TERRAIN: AN EXPERIENCE

Adzly Anuar, Salman Yussof, Ismail Said, Jeffrey Tan Too Chuan
College of Engineering
Universiti Tenaga Nasional
43009 Kajang, Selangor

Abstract

More than 68 counties around the world contain millions of land mines hidden beneath its ground waiting to be triggered. The process of clearing up these mines has been painfully slow due to lack of manpower and the manual methods used. Although researchers around the world have designed specially-designed vehicles and robots to help performing the task, this solution is normally very expensive. Inexpensive solutions, although they exist, often provide a less satisfactory result. This paper describes the design and development of a small, low-cost autonomous mine detection robot that is targeted to be used by the locals of mine-infested countries to check for the safety of their surroundings. It is targeted at solving the navigation problems that exist on other low-cost mine detection robots. A test was conducted to evaluate the performance of the developed robot. Several problems had been identified and possible solutions were proposed.

Introduction

One of the after-effects of previous wars that are still plaguing the people of today's world is the existence of land mines. According to UNICEF, over 110 million land-mines of various types plus millions more of unexploded bombs, shells and grenades remain hidden around the world waiting to be triggered by the innocent and unsuspecting [1]. These land mines exist on more than 68 countries around the world; most of them are developing countries. To make it worse, most of the victims are innocent children [1].

While the authorities of the affected countries and concerned international organizations are currently in the process of deactivating the mines, the process is painstakingly slow. This is because, the most commonly used method for deactivating or destroying the mines is by using human de-miners [2]. In order to clear up land mines, there are basically two major steps that need to be done. The first step is to detect the location of the mines and the second step is to deactivate or destroy the mines. Searching for the location is the process that takes the most amount of time. This is because, every single inch of the land needs to be manually and carefully probed with a mine detector. Therefore, the task becomes painstakingly slow and tedious. In addition to being very slow, this method is also very dangerous and costly. A skilled expert may take an entire day to just clear, by hand, a 20 to 50 square meters of mine-contaminated land [1]. A lot of manpower is needed. But, most authorities are lack of manpower to do the job. Due to the problems mentioned above, de-miner activists are now looking for new alternatives to do their job.

There are several alternatives that have been proposed in the past few years. One of the alternatives is to use specially designed vehicles that can be used to detect and destroy land mines. One such vehicle is described in [3]. While this alternative has an advantage of being able to destroy the mines on the spot due to the vehicle's mechanical structure that can withstand mine explosion, the search for the mines still needs to be done manually (a human needs to drive the vehicle). Another alternative is to use autonomous mobile robots to search for the location of the mines. While most robots cannot withstand mine explosion due to its delicate structure and circuitry, it can make the tasks of searching for the location of the mines much easier and less tedious. Once the locations have been discovered, the task of deactivating or destroying the mines would become straight forward.

There have been a number of robots developed by researchers all around the world. A number of those robots and the concept behind the use of robots for robotic mine search are described in [4], [5] and [6]. One of the problems with the current mine-detection robots is that they have quite a big structure and is very expensive. Because of that, they cannot be bought and used by local people. However, it is the locals who mostly encounter the mines.

In this paper, we are discussing the development of a personal, low-cost mine-detection robot targeted to be used by local individuals to test the safety of their surroundings. Even though there have also been a number of inexpensive mine-detection robots being developed, most of them use simple algorithms such that they can only operate in simple environments with no obstacles [7]. This paper tries to solve that problem by constructing robust structure and implementing object avoidance system so that the robot is more usable in real environments. Towards the end, we will also discuss the problems that have been faced and the possible solutions.

Mechanical Buildings

The mechanical buildings of the robot can be divided into 3 major parts which are the structure or platform, the track system, and the driving mechanisms and motor. The basic structure of the robot is simply two pieces of Teflon plate supported by several shafts. The controller, RF communication module, motors are mounted on top of this plate or base. Metal sensor is mounted at the bottom of the base. Each side of the robot, except rear side, is mounted with two infrared sensors. The track system is placed on the right and left side of the robot.

(a) Isometric view *(b) Side view*

Figure 1: *The sketch of the robot base*

The track system is similar to the track on military tanks. This system is used mainly because of its reliability in moving on the uneven terrain. The track consisted of two-inch wide double-sided timing belt being tensioned around four pulleys. The configuration is shown in Figure 2.

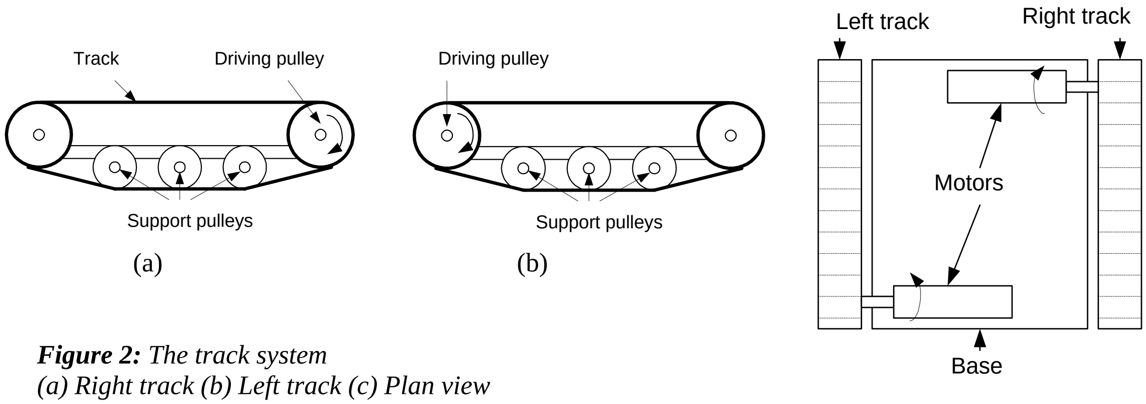

Figure 2: *The track system*
(a) Right track (b) Left track (c) Plan view

Two small pulleys at the bottom are used as the support. At rear, a bigger pulley is used as tensioner. The driving pulley is placed at the front of the robot. This arrangement is used for the right side of the robot (Figure 2a). It is the opposite for the left side of the robot. The driving pulley is placed at the rear of the robot (Figure 2b).

The main reason for this arrangement is to reduce the width of the robot, as the motors used are relatively long. Figure 3 shows placement of the motors.

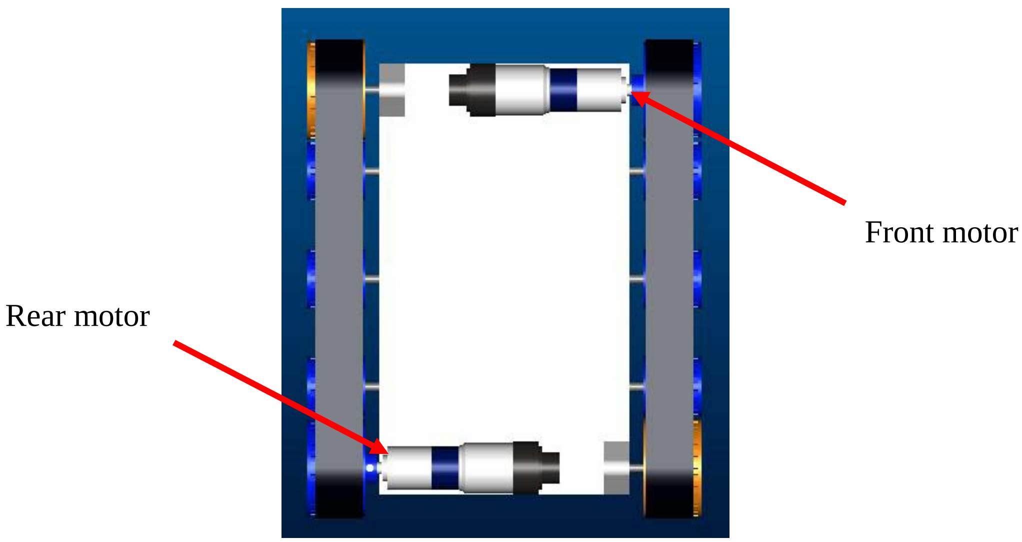

Figure 3: *Arrangement of motor*

Two DC motors with encoders and gear heads are used. The DC motor, rated 24V, 21 W, is attached with optical encoder and gear head. The optical encoders are used for the calculation of distance travel. These motors are supported by mounting brackets and their output shafts are connected direct to the driving shaft.

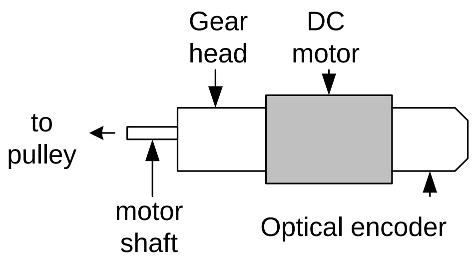

Figure 4: *Motor*

Sensors

The sensors used on the robot can be grouped into two, which are, navigational sensors and metal detection sensors. Three types of sensors are used for navigation, which are the infrared sensors, motor encoder and digital compass. These sensors will send signals to the controller to be processed, and appropriate output signals will be sent to the motors. For mines detection, a powerful metal sensor is used.

The infrared sensors are basically used to detect the presence of any large object. These sensors are mounted on the body of the robot at a certain height. This height is obtained by considering the height capability of the robot to climb. The sensor would detect any objects that are not climbable by the robot.

The arrangement of the sensors is as shown in Figure 5. Two sensors are placed on the front, right and left side of the robot.

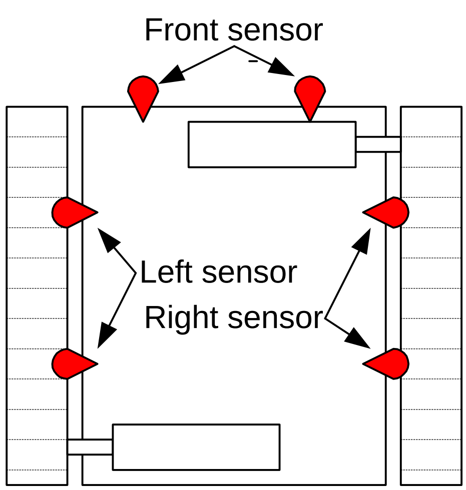

Figure 5: *Arrangement of infra red sensors*

The digital compass is a magnetic sensor module that is used for finding the relative direction of the robot [8]. It is used to align the robot so that it is able to able to navigate through its searching area. This sensor is very important for obstacle avoidance navigation. It is used to figure out the amount of degrees that the robot has to turn or rotate.

Optical motor encoder is attached to the DC motor. It is used to indicate and control the shaft velocity and direction of rotation, as well as for position control [9]. The value obtained from the encoder is used to calculate the distance traveled.

Navigation and Object Avoidance System

The navigation and object avoidance system of this robot are two essential components that enable this robot to operate in real environments. The navigation system is the component that ensures that the robot moves inside a pre-defined area. This area is defined as a square of defined length and width. Once the area has been defined, the robot is programmed to zigzag its way through the square area. The digital compass together with the motor encoder is used to ensure that the robot is moving in the right direction. The path pattern is shown in Figure 6 below.

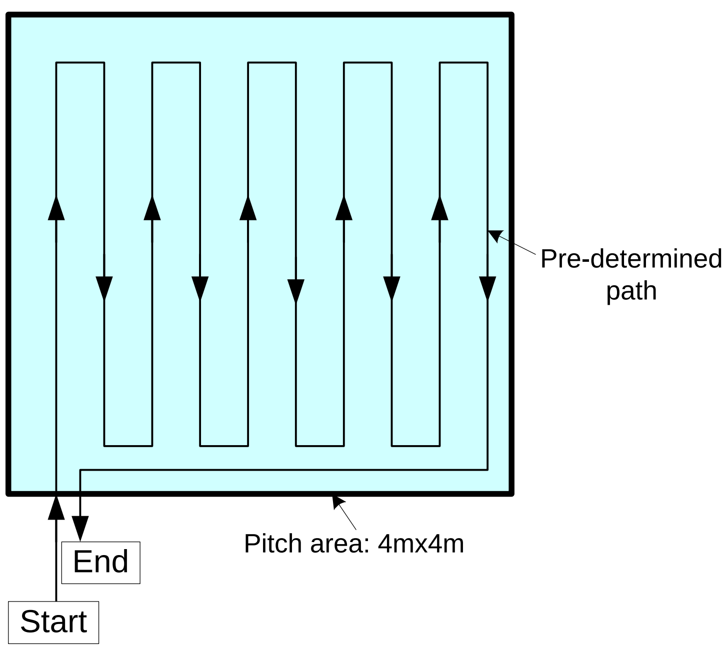

Figure 6: *The Path Taken Through the Predefined Area*

Since the area defined can contain obstacles such as rocks and boulders, the object avoidance system is needed to avoid those objects while at the same time continue to navigate in the predefined area. For the object avoidance system, the infrared sensors mounted on the front and on the left and right side of the robot play the crucial role of detecting objects. Once an object is detected, an object avoidance algorithm is executed to avoid the object and then put the robot back on the right track.

The object avoidance algorithm is designed in such a way that when the robot comes across an obstacle, it will try to go around the obstacle and then get back to its original path. The algorithm can be summarized in the following pseudocode.

```
While (true) {
        // No obstacle in front, continue to move forward
        If (no obstacle detected by the front sensor)
                Move forward
        // Go around the obstacle and get back to the correct path
        Else {
                Turn right 90 degrees
                While (The object is detected by the left sensor) {
                        Move forward
                        Distance++
                }
                Turn left 90 degrees
                While (The object is detected by the left sensor)
                        Move forward
                Turn left 90 degrees
                While (Distance > 0) {
                        Move forward
                        Distance--
                }
                Turn right 90 degrees
        }
}
```

This algorithm above is designed to cater for avoiding a single, big object that can be detected by the infrared sensors used on the robot. However, the algorithm can be expanded to cater for the condition where there are many obstacles located close to each other. Such a complicated condition, however, may decrease the ability of the robot to get back to its original path.

Hardware and Software of the Controller System

Two main controller systems are used to control the robot. Basic Stamp controller from Parallex Inc. [10] and EVB (68HC11) micro-controller are used. These controllers are general-purpose controllers. The Basic Stamp is a common micro-controller used in robotics project. They are used because of their availability, relatively low in cost and simple to learn.

The EVB is used to control the speed of the two motors with PWM using encoder and a feedback creating a closed loop system. The EVB directly controls the movement or the motor. The digital compass is used to provide information to the micro-controller on the direction that the robot is heading. Every time the robot turns 90^0, Basic Stamp controller receives a signal from the EVB through the brake pins. Basic Stamp will ‘tell’ EVB to stop turning. Basic Stamp ‘tell’ the EVB when to turn (left or right) when an object is blocking the robot’s path.

There are two software algorithms running in parallel. One of it is for navigation while the second is for metal sensing. The navigation algorithm is split into two; the main navigation routine and the obstacle avoidance routine. The metal sensing component has a separate circuitry and algorithm.

Discussion

The mine detection robot was tested on a pitch of 4 meter by 4 meter. The pitch was covered by sand and fake mines were put inside the sand for the robot to detect. Based on the performance of the robot on the pitch, three main aspects of the robot were evaluated. The first aspect is the ability of the robot to cover the whole square area, the second aspect is the accuracy of the mine detection and the last aspect is the ability to avoid obstacles.

The first aspect was evaluated by releasing the robot on the pitch and observing whether it was able to navigate its way through the square area or not. The test was a success. The robot did follow the zigzagged path defined in its program. By manipulating certain parameters in the program, the robot can navigate through any size of square area. However, there is one problem with the navigation that was discovered in the test. The accuracy of the navigation relies heavily on the digital compass. It was observed that if the robot were to navigate in an area that has high electromagnetic interference (such as around power cables), the robot would go haywire. This is because the digital compass relies on the Earth magnetic field and any electromagnetic waves would interfere with its operation. A possible solution to this problem would be to shield the digital compass so that it is not affected by the electromagnetic interference. One way to do this is to put the digital compass inside a container covered by ferrite. Ferrite has the property of being able to block electromagnetic interference [11]. This solution will be explored in the future to test for its effectiveness.

The second aspect was evaluated by counting the number of mines that was correctly detected. According to the result of the test, the accuracy of the mine detection can reach up to 80 to 90 percent. Even though this percentage seems quite high, it might still not be good enough for practical purpose. Therefore, better mine-detecting sensors need to be used.

The third aspect was evaluated by putting a number of obstacles of various size and shape on the pitch and let the robot to navigate through the pitch. The robot was supposed to be able to climb over small obstacles but try to avoid bigger obstacles while at the same time maintaining the navigation path. This test was only partly successful. The robot did manage to climb over small obstacles and avoid bigger ones. However, due to the various shape and size of the obstacles, the navigation accuracy was much less. After avoiding an obstacle, the robot might not be able to exactly go back to its original path. However, covering the whole square area is still possible. This performance of the object avoidance system can be improved by using more sensors and better algorithms. During this test, a glitch on the track design that limits the robot's movement on certain terrain has also been discovered. The use of better design and materials for the track should solve this problem.

Conclusion

An autonomous mobile robot that can be used for land mines detection was successfully developed. The development of this robot had achieved its objective to produce a small, low-cost mines detection robot that is affordable and easy to be used by the local individuals in countries with land mines problem. However, several problems have been found that cause the robot to perform less effectively in certain environments. Further research needs to be done to solve these problems. It is hoped that the development of this robot can later help to provide a safer environment for the people in countries that are plagued with land mines.

References

1. Land Mines: A Deadly Inheritence. Internet. http://www.unicef.org/graca/mines.htm
2. Kenzo Nonami, "Development of Autonomous Mine Detection Six-Legged Walking Robot for Humanitarian Demining", Chiba University, Japan (2002).
3. S.H. Salter, "Dervish: a Purpose-Designed Vehicle for Post War Detonation of Anti-Personnel Mines", internal report, Demining Technology Center (DeTeC), (1995).
4. J.D. Nicoud, Ph. Machler, "Robots for Anti-Personnel Mine Search", Control Engineering Practice, 1996, 4(4), pp 493-498.
5. J.Treveylan, Landmines Working Paper 1: Robotic Landmine Clearance", Internal report, Demining Technology Center (DeTeC).
6. Fractals Robots for Clearing up Land Mines. Internet. http://easyweb.easynet.co.uk/~robodyne/stellar/new/mine.htm
7. Robotic Institute: Robotic Demining. Internet. http://www.ri.cmu.edu/projects/project_220.html
8. Vector 2X digital compass. Internet. http://www.robotstorehk.com
9. Faulhaber Minimotor. Internet. http://www.minimotor.ch
10. Parallex Inc. Internet. http://www.parallexinc.com
11. Z. Hari, "Magnetic material: Ferrite as a EMI suppressor and sensor", (Ph.D. Thesis, Universiti Putra Malaysia, 2000).