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Motion Planning of a Landmine Detection Robot

Kuo-Lan Su[1], Hsu-Shan Su[2], Sheng-Wen Shiao[2], Jr-Hung Guo[2]
1. Department of Electrical Engineering, National Yunlin University of Science & Technology, Taiwan
2. graduate school Engineering Science and technology, National Yunlin University of Science & Technology
E-mail: sukl@yuntech.edu.tw, g9610808@yuntech.edu.tw, g9710801@yuntech.edu.tw

Abstract: The article develops a landmine detection system that contains a landmine-detection mobile robot and a following mobile robot. In this system, the landmine-detection mobile robot goes ahead, and uses landmine detector and GPS module to find out landmines, and record the coordinate location, and transmits the landmine's coordinate to the following mobile robot via wireless RF interface. The following mobile robot can record the location and orientation of the landmine detection robot and the landmines on the region. The following robot moves closed to the landmine, and programs the motion path to avoid obstacles automatically. The driver system of the landmine detection mobile robot uses a microprocessor dsPIC 30F4011 as the core, and controls two DC servomotors to program the motion path. The user interface of the landmine detection mobile robot and the following mobile robot uses Borland C++ Builder language to receive the location data. In the experimental results, the landmine mobile robot records the location of the landmines using GPS module, and transmits the location to the following robot via wireless RF interface. The following mobile robot avoids landmines quickly, and enhances the safety to carry peoples or materials cross over the landmine area.

Keywords: mobile robot system**,** landmine-detection mobile robot, following mobile robot, GPS module, wireless RF interface, dsPIC 30F4011, Borland C++ Builder

I. INTRODUCTION

Landmines are one of the great scourges on the human life. Thousands of people are injured each year by accidental landmine explosions on the known or unknown environment. There are approximately 100 million landmines buried throughout the world in approximately 70 different countries. Current methods can neutralize only about 100000 per year. The procedure for landmine removal varies greatly depending on such factors as: location, terrain, landmine distribution, soil density, age of minefield, covering vegetation and locally available resources [1]. How to develop a safety processing method to detect landmines is a challenge problem.

The currently floating to detect and dispose landmines and explosive ordnance is to commit an unmanned vehicle that equips a detection and disposal system to the suspected terrain. In landmine detection, a huge amount of research has been directed at sensor technology such as: odor sensors, acoustic sensors, electromagnetic induction sensors, electrical impedance sensors, infra-red and microwave, radiometry and radar [2,3].

There are many studies about landmine detection in the literature. Sweeping, detecting and clearing landmines is possible thanks to electromagnetic induction spectroscopy [4]. There are some studies related to a landmine detector assembled on a remote controlled mobile platform or vehicle [5]. There are also landmine detectors with inductive and capacitive [6] RF microcontrollers, as well as GPS-based [7] and GPR-designed ones [8]. A six-legged walking robot was equipped with a metal detector and communicated with a supervisory computer to mark suspected landmine locations using a differential GPS system [9]. Furthermore, rolling machines are also faster and more stable than legged device on landmine detection. [10,11].

The paper is organized as follows: section II describes the system structure of the landmine detection system. The system contains a landmine detection robot and a following robot, and explains functions of the two mobile robots. The section III presents how to program the motion trajectories of the two mobile robots avoiding landmines in the landmine region. Section V presents the experimental results of the landmine detection and avoidance using the proposed method. The brief concluding comments are described in Section VI.

II. SYSTEM ARCHITECTURE

The architecture of the landmine detection system is shown in Fig. 1. There are two mobile robots in the system. One is the landmine detection robot, and the other is the following robot. The controller of the landmine detection robot is personal computer, and drives two DC servomotors through dsPIC 30F4011 chip. The mobile robot can find out locations of the mines in the dangerous region using landmine detector and GPS module, and transmits the locations of the landmines to the following mobile robot using wireless RF module. The following robot programs the trajectory to avoid the landmines, and enhance the safety moving in the landmine region. The driver system of the following robot is similar to the landmine detection robot.

The platform of the landmine detection robot is shown in Fig 2. The mobile robot has the shape of rectangle, and its length, width and weight is 80cm, 50cm and 10kg. The rubber belt was used as a track on the mobile robot, and rolled tightly on the ground using fixed wheel. The mobile robot drives the rubber belt using DC servomotor. The landmine detector is arranged on the front of the mobile robot, and is driven by stepping motor with reduce gear. The rotation angle range is about 50 degree, and rotates back and forth on a fixed joint. The GPS module is on the side of the landmine detector to record the location of the landmine.

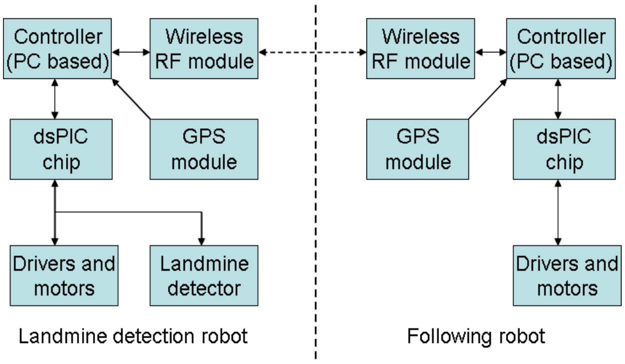


Fig. 1 The system architecture of the landmine detection system

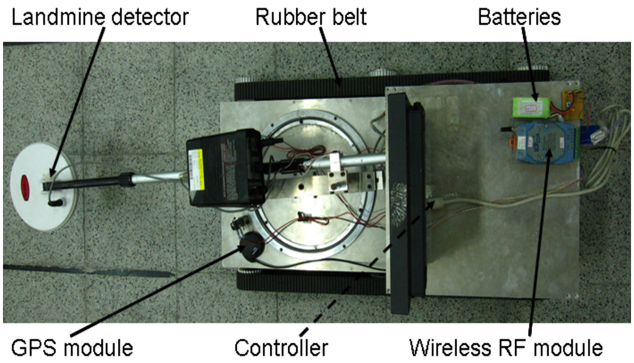


Fig. 2 The platform of the landmine detection robot

The platform of the following robot is shown in Fig 3. The mobile robot has the shape of rectangle, too. Its length, width and weight is 90cm, 71cm and 12kg respectively. The mobile robot is driven by four DC servomotors. Each rubber belt is driven by two DC servomotors to increase loading capability. The controller of the mobile robot is arranged on the front of the mobile robot. The GPS module is on the front of the mobile robot to record the coordinate of the following mobile robot.

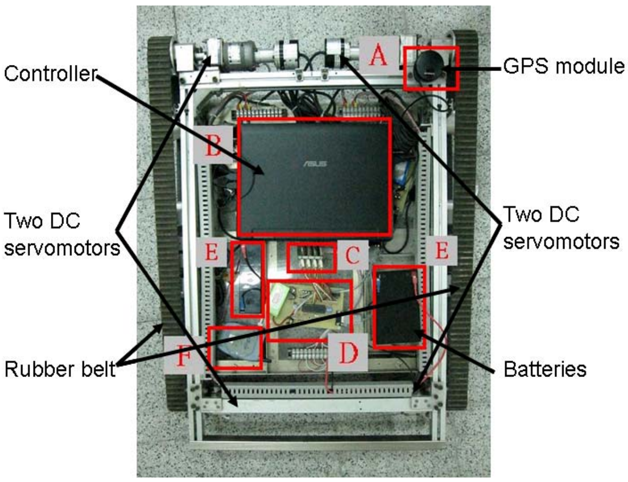


Fig. 3 The platform of the following robot

III. MOTION PLANNING

The GPS is the only fully functional Global Navigation Satellite System (GNSS) [12]. The GPS uses a constellation of between 24 and 32 Medium Earth Orbit (MEO) Satellites that transmit precise microwave signals to determine current location, time and velocity. These signals travel at the speed of light and the receiver uses the arrival time to measure the distance and position. We use the GPS that is produced by GARMIN Company to determine the coordinate of the robot. GPS takes longitude and latitude values from satellite [13]. We calculate the angle σ and distance d using the great-circle distance formula.

$$\sigma = \arccos\left(\sin\phi_s \sin\phi_f + \cos\phi_s \cos\phi_f \cos\Delta\lambda\right) \quad (1)$$

$$d = r\sigma \quad (2)$$

ϕ_s is the start value on latitude. ϕ_f is the final value on latitude. $\Delta\lambda$ is the difference on longitude. d is distance from the start location to the target location. r is radius of the earth.

The landmine detection mobile robot to detect mines using the mine detector moving on the free-space, and transmits locations of the landmines and the landmine detection robot to the following mobile robot. The following robot tracks the landmine detection robot according the coordinate of the landmine robot. The experimental area of the system is 20mX10m. The mobile robot moves forward from the start location to the target location. The mobile robot detects landmines to stop, and transmits the coordinate of the landmine to the following robot via wireless RF interface. The simulation result is shown in Fig. 4. The mobile robot turns right to avoid the landmine, and crosses over the dangerous area to be shown in Fig. 4. Finally, the landmine detection robot moves to the target location, and transmits coordinate of the fixed position from the motion path to the following robot.

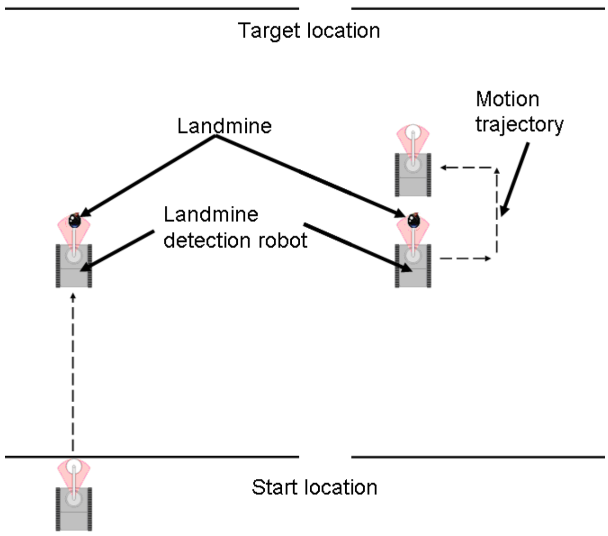


Fig 4. The motion path of the landmine detection robot

The following mobile robot moves forward according to the trajectory that is built using the fixed coordinate from the landmine detection robot, and receives the landmine location from the landmine detection robot via wireless RF interface. The mobile robot moves ahead the landmine to be 3m, and turns right moving forward 3m to cross over the landmine area. The simulation result is shown in Fig. 5. Then the mobile robot turns left moving forward about 6m. The mobile robot turns left moving 3m to avoid the landmine. Finally, the mobile robot turns right and moves to the target location. The simulation result is shown in Fig. 5.

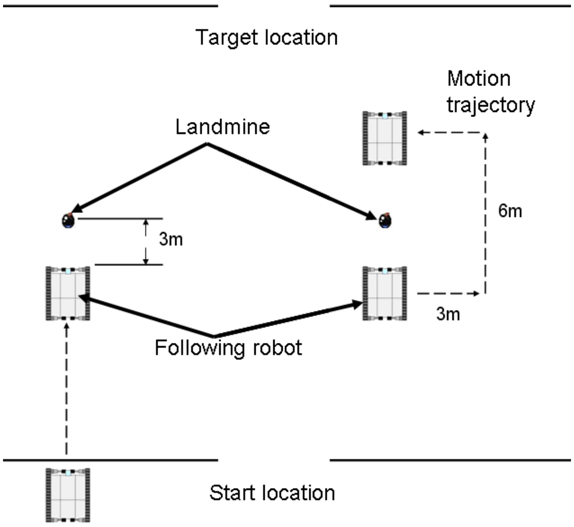
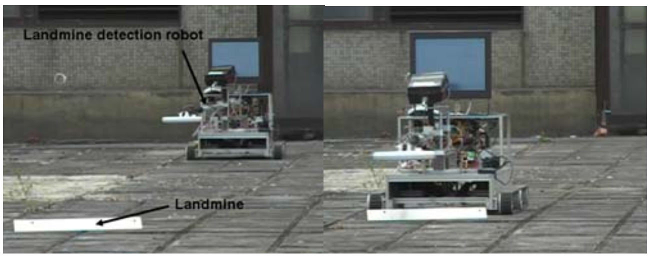


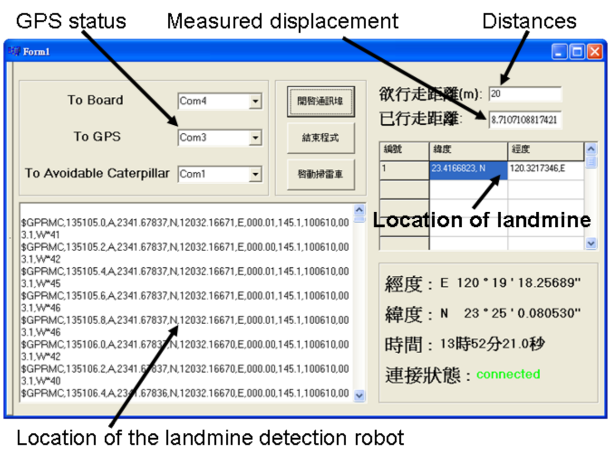
Fig 5. The motion path of the following robot

IV. EXPERIMENTAL RESULTS

We implement the experimental scenarios on the four floor of the department of electrical engineering in my school. In the landmine detection, we use a metal bar as the landmine. The landmine detection mobile robot moves forward from the start location. The scenario is shown in Fig. 6 (a). The mobile robot uses the mine detector to detect the coordinate of landmines around the region, and transmits the coordinate of the landmine to the following mobile robot.



(a) (b)

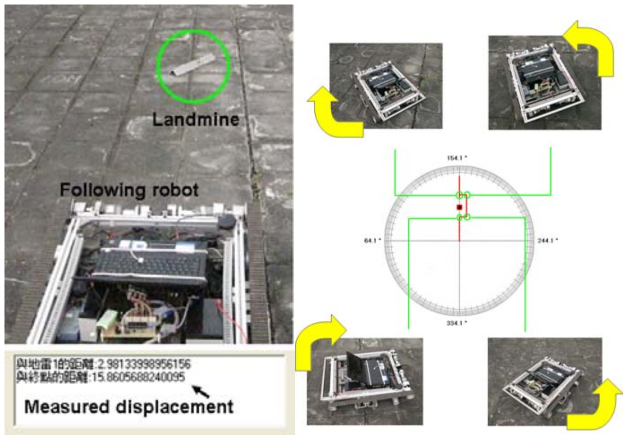


(c)

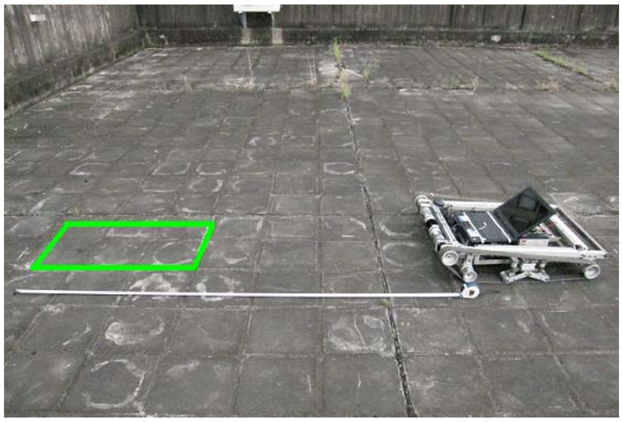
(d) (e)

Fig. 6 The experimental result of the landmine detection robot

The mobile robot detects the mine on the motion path, and displays the coordinate of the landmine and the displacement of the landmine detection robot on the user interface. The experimental results are shown in Fig. 6 (b) and (c). Then the mobile robot transmits the coordinate of the landmine to the following robot, and moves to the target location step by step. Finally, the mobile robot stops at the target location. The experimental result is shown in Fig. 6 (d). The measured displacement is calculated from the encoder of two DC servomotors is 20.07m to be shown in Fig. 6 (e). The error displacement is only 7cm on the test.



(a) (b)



(c)

Fig. 7. The experimental result of the following robot

The following robot receives the coordinate of the motion path from the landmine detection robot, and moves forward to target location. The scenario is shown in Fig. 7 (a). The user interface of the following mobile robot can displays the motion displacement and the distance far from the target location. The following robot moves forward closed to the location of the landmine that is recorded on the memory, and avoids the landmine according to the proposed motion path. The motion processing of the mobile robot is shown in Fig. 7 (b), and displays the orientation to implement the programmed trajectory. Finally, the mobile robot moves to the target position to be shown in Fig. 7 (c). The error displacement is smaller than 1 meter from the start location to the target location.

V. CONCLUSION

We have presented a landmine detection system that contains a landmine-detection mobile robot and a following mobile robot. In this system, the landmine-detection mobile robot goes ahead, and uses landmine detector and GPS module to find out landmines, and record the coordinate location, and transmits the landmine's coordinate to the following mobile robot via wireless RF interface. The following mobile robot can record the location and orientation of the landmine detection robot and the coordinate of the landmines on the region. The following robot moves closed to the landmine, and program the motion path to avoid obstacles automatically. In the future, we want to develop the curve path to avoid landmines on the landmine detection robot and following robot, and program the uniform user interface of the landmine detection system.

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