A Land Testbed for Experimental Research on Autonomous Ship Navigation

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Abstract

In the development of automated ship technology, experimental system is essential. The main navigation system is supposed to consist of GPS, AIS (Automatic Identification System), RADAR and cameras. In this paper, we introduce the setup of our land based test robot which simulates several essential functions needed for experiments of our research. In our land test robot, 2 ultrasound distance sensors are used as a model of GPS, which determine the coordinate of the test robot measuring the distances from 2 walls. A swinging ultrasound ranging sensor with a servo motor is used to simulate the RADAR. A xbee wireless communication module simulates the AIS. The camera is used for image processing to determine the control algorithm to avoid the collision from other moving obstacles. In this paper, we describe our test robot's system assembly and several experiments to confirm functions of our concepts for our future experimental research on autonomous ship navigation.

Keywords: autonomous ship navigation, land based test robot, unmanned vehicle control

1. Introduction

The unmanned vehicle technology has been investigated intensively for these years from a car to an aircraft and the development of unmanned ship is also being investigated by major shipping companies from the view point of being able to use them on commercial base. Although there are many aspects to be investigated for the development of unmanned ship technology, autonomous navigation technology is one of the most important key aspects. The research on automated ship navigation and control is not so new[1,2], which were investigated intensively during 1980s in accordance with the advancement of modern control theories as well as the navigation tools like GPS etc.

Unmanned and autonomous navigation have to be elevating to a new level of research these days. At present, there published many papers related to the autonomous navigation[3,4], most of them are based on the computer simulations or commercial simulators. In these simulations, taking into account all uncertainties which occur during the maneuvering of the ship is almost impossible.

The importance of experimental research on this field becomes more important than before because the uncertain incidents like malfunction of sensor or dynamics modeling errors are possible to cause major fatal accidents such as ship collision. So we need an experimental system which can simulate various real situations on the sea. In the near future, we will develop a tank test system using plural ship models.

As the cost of tank tests is not negligible, we developed a land robot whose systems are the same components with the tank test system as the first step of our research. In this paper, we introduce the concept of our test system and the modules we developed. We also explain the collision avoidance experiment which is introduced to check the assembled modules.

2. Components of the land robot system

The essential navigation systems are GPS, AIS, RADAR, and cameras. Every ship has GPSs to measure their global position. AIS is used to send the ship status to other ships. The ship status includes the position of the ship, velocity vector, ship name, ship size, ship's country etc. On the sea, we can check the AIS information on the monitor of RADAR. RADAR is used to detect obstacles or ships around us to avoid collision. We use not only RADAR but also AIS information to avoid collision. If a ship is entering our possible collision zone, we communicate each other and one of us must change the speed and course. The velocity vector of AIS is very important information to calculate the relative position between ships in the near sea area.

To emulate these systems, we set up the modules as shown in Table 1 and Fig.1. We will explain each module.

2.1. *Ultrasound coordinate detection module*

In our land or tank experiments, we cannot use GPS because the experiments are in the room. So we decided to use ultrasound raging sensors to detect the distance from 2 walls to calculate the coordinate in the test field.

Table 1. Correspondence of ship and land test robot modules

Real ship	Test robot
RADAR	Ultrasound ranging sensor With a servo motor
XBee	Wireless communication for AIS emuration
GPS	2 ultrasound ranging sensors
Camera	USB Camera

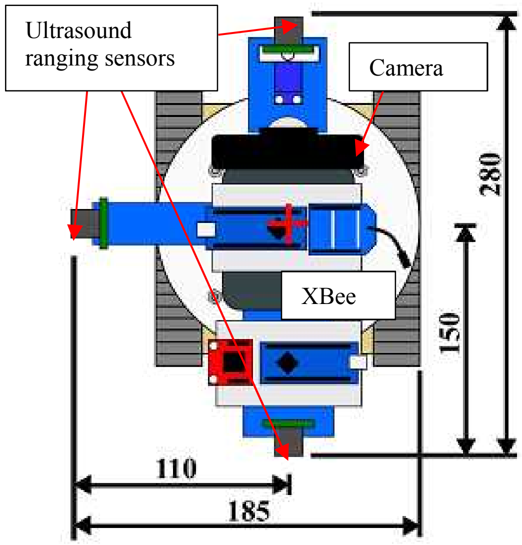

Fig. 1. Schematic view of the land test robot

2.2. *Ultrasound collision avoidance module*

This module emulates the RADAR of a ship. An ultrasound ranging sensor is attached to the front of the robot with a servo motor. By swinging it with a servo, we emulated a kind of front RADAR. Fig.2 shows a calibration result to verify this function. In Fig.2, upper image shows 2 obstacles, which are recognized successfully as shown in the lower graph.

2.3. *Xbee module*

AIS (Automatic Identification System) is very important for autonomous navigation algorithm. We implemented Xbee Series1 wireless serial communication module to emulate the AIS. A robot can broadcast its position and velocity to other robots as well as it can receive these information from others.

2.4. *Camera image processing module*

In the manned ship, the watch is very important. As for the unmanned ship, the image processing module will be used as the watch. We implemented a USB camera and are developing the collision avoidance program using OpenCV.

3. Experiments of the total system

The total system architecture is shown in Fig.3. The hardware modules are controlled by Arduinos. The main computer of the robot is a Raspberry Pi and the robot can be controlled or monitored through Wi-Fi from outside PC which emulates the computer of the control room where all the ships are monitored in land.

3.1. *The mission of experiment*

To develop the program which integrates each module, we made the mission of experiment as shown in Fig.4.

At first, the robot moves forward using its compass and ultrasound ranging RADAR. If the robot finds an obstacle by this RADAR and the distance from the obstacle becomes less than 10cm, the control mode changes to camera sensing mode. In the camera sensing mode, the camera image is processed to find a red object whose area is greater than a specific threshold value. If a red obstacle is confirmed, then the robot moves backward and turns 90 degrees left to avoid the collision to the obstacle. Then it keeps moving forward until it finds a wall and stops if the distance to the wall becomes 10cm.

3.2. *The actuators*

We will change the platform from this land based robot to a ship model in the near future. In this research, we hired crawlers as the actuator of the robot, considering its slow response in changing its heading angle. Usually, a ship's yaw motion response is not quick. That's why we didn't hire normal wheels.

3.3. *The experimental result*

The experimental field is as shown in Fig.5. The field is covered by 4 walls whose side length is around 1m, and the coordinate of the robot is measured by using 2 ultra-sound ranging sonars which are attached to the left direction and the backward direction.

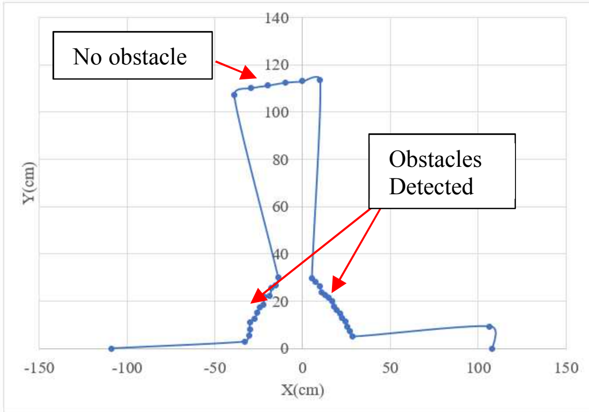

Fig. 2. RADAR emulated by a front ultrasound ranging sensor

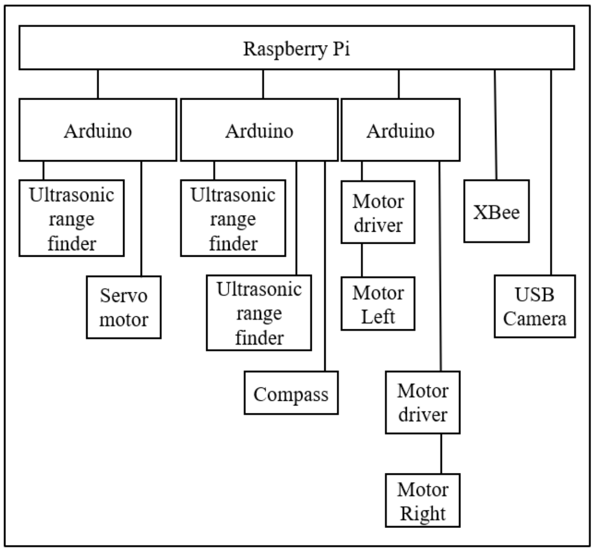

Fig. 3. The architecture of the robot

All the data were successfully transmitted from the robot to the monitoring PC by a Xbee module which emulates the AIS. We can also monitor the inner state of the robot and communicate through Wi-Fi connection.

Fig.6 shows the coordinate of the robot. The start point was around (87, 17). Then it moves parallel to the

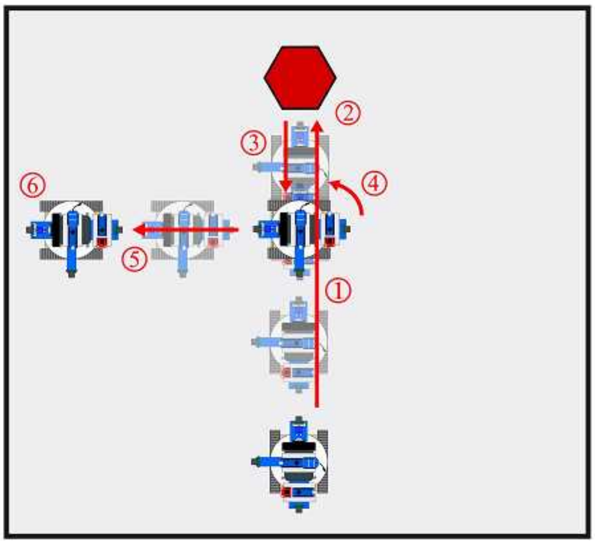

Fig. 4. Mission in experiment

Y-axis and found the red obstacle at around (80, 60). So it stopped and turned left then moved along parallel to the X-axis until it stopped around (12, 45), where the front sensor detected the wall to stop from 10cm distance.

4. Summary and future work

In this study, we developed a land robot which is supposed to emulate a ship model for our experimental research on autonomous ship navigation technology.

The essential navigation modules are GPS, AIS, RADAR and cameras. We emulated these modules by applying ultrasound ranging sensors, Xbee module, and USB cameras.

To confirm whether our system can work as we intended, we experimented the obstacle detection and avoidance test. The robot moves forward with measuring its coordinate and finding obstacles by the RADAR. When the robot finds an obstacle in front of it, then the image processing module is activated and if it finds a red obstacle, it turns 90 degrees left to avoid collision. Xbee module data communication as AIS emulation also succeeded. Although we still have several subjects to be improved, from the experimental result, all the modules we implemented functioned well as we intended.

We will fabricate more robots to develop the software for autonomous navigation algorithm. After brushing up the algorithm, we will transplant the system on several ship models to experiment in the tank.

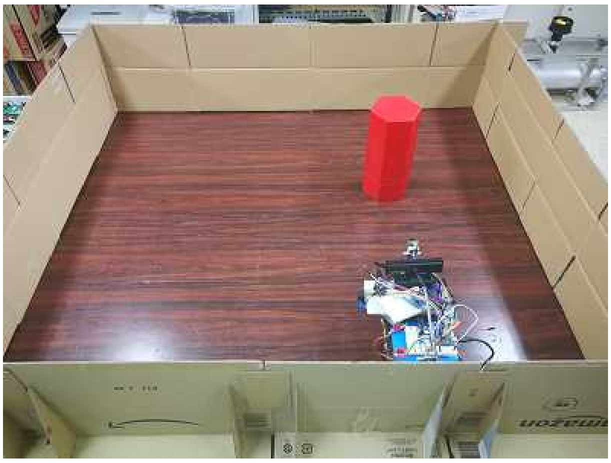

Fig. 5. The experimental field and the robot

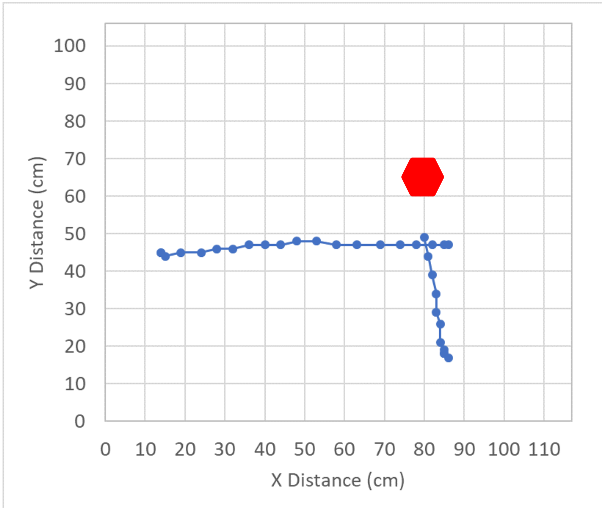

Fig. 6. The coordinate result of the experiment

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