Autonomous Underwater Vehicle from Harbin Engineering University

Autonomous Vehicle Development Team
2012

Abstract: We are the under water robot team of HEU(Harbin Engineering University). We have attended many robot competitions and gained a lot of experience. This year we made a big change of the structure, and integrated navigation was used on our vehicle. We want to learn more from this competition, and make more friends in the robot.

http://auv.hrbeu.edu.cn

I. INTRODUCTION

The structure of robot is just like a submarine, the RAIDER is propelled by 5 thrusters, it can move freely in 5 DOF. The thrusters are fixed up in the classical way. Among which, there are 2 fixed equipments beside the vehicle to control the offset and heading of the vehicle, 2 fixed equipments vertically to control up and down. There is also 1 horizontal thruster to control the robot to move forward and backward. This kind of arrangement can ensure our vehicle move freely and then accomplish missions easier. All these thrusters and drivers are made by ourselves. There is an embedded PC -GM45 with P7350 CPU in our vehicle for image processing and navigation calculation. There is a STM32 controller board in our vehicle to control the motors. All the data of sensors are processed by STC12C5A60S2. A DSP board is used to process sonar information.

For improving the function, we use the FOG (Fiber optic gyro) and Doppler Radar to navigate, by using integrated navigation, the vehicle can move and make missions accurately.

Our team is compostioning by many students of different majors; we donated our own specialty to do robot competitions. We also learned so much and obtained a lot of experience from this competition.

II. MECHANICAL SYSTEM

The body of the vehicle is modularly designed and just like a submarine. The robot has 4 parts: main structure, capsule, thruster and mission execution unit.

A. Main Structure

The original concept for designing this robot is high reliability and changeable module so that the robot owns the ability to adapt different mission demands. There are many interfaces for modules swap. The 3D scheme of the robot shown in Fig 1 is designed by Solid works 2008. We can simulate the design process by this 3D scheme. By using this, we design process become more simple and effective .

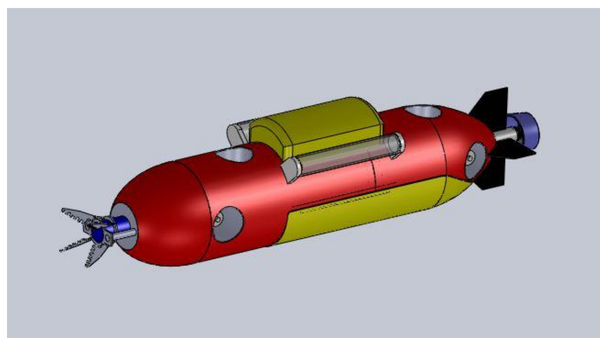

Fig. 1 3D Scheme

B. Capsule

The main frame is made of glass fiber and epoxy resin. For simplifying the machining work, all the parts of the main frame is divided into many parts. The capsule is designed as a removable box. So it is easy for us to carry and repair. All the electronic system is in the capsule. On the capsule, there are three hall sensor switches. There are 14 waterproof plugs on the aluminum plate; the capsule is showed in Fig.2.

Fig. 2 Capsule

The end caps are equipped with compression O-rings and rubber tape to create a water-tight seal effects.

All through-hull connections are made on the end cap of the hull and use water-proof connectors as shown in Fig. 3. These connectors have a technical grade and it can handle up to 1000 PSI (Pounds Per Square Inch) pressure. The technique of these connectors is a major promotion from last year; it is the key point of sealing. The leakage caused by some inferior quality connectors has bored us so much last year. Thrusters, hydrophone, power supply and debug wire etc. are all connected by these connectors. They are appended to modularity of the design, and enable rapid assembly and disassembly. When any of the modules is broken we can replace it easily.

Fig. 3 caps & Connectors

C. *Thrusters*

We developed a very cheap and effective solution for the low power motors. All the thrusters are made by ourselves. The shell is aluminum and o-ring sealed. We use the brushless DC motor. All the 5 thrusters and 1 servo are driven by STM32 motor control board.

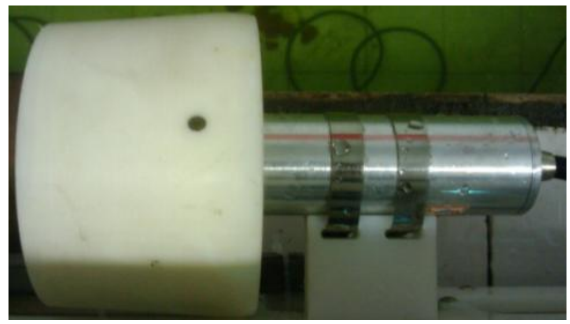

Fig. 4 Thruster

D. *Mission Execution Unit*

1) *Shoot and Throw Unit*

As we can see in Fig. 5, this part is designed as the head of the robot. We use electromagnet to trigger the gun to shoot and throw. The two weapons are mounted on the head of the vehicle.

Fig. 5 Throw Unit

2) *Claw*

The claw is made of 4 fingers and towed connecting rods, which are arranged in front of the head of the vehicle as shown in Fig. 6. When the vehicle is approaching the target, the capture will close to grab the target machines. The robot will float upward to the surface after it holds the crown judging by the front camera.

The marker can be hold in the pipe. It can be slide down when open the electro-magnet.

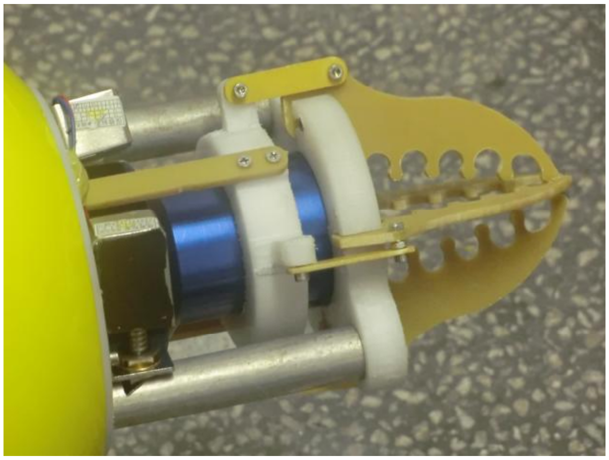

Fig. 6 Claw

III. ELECTRICAL SYSTEM

The industrial computer is placed upon the FOG (Fiber optic gyro). The industrial cameras are connected on the GM45 board. The Doppler equipment is connected to the PC by UART port.

There are parts of the electrical subsystem. They are STM32 MPU, DSP board, power management and sensors board and FOG (Fiber optic gyro). All the modules are connecting with each other serial port. This structure is a parallel model, this model makes it easer to install and uninstall the new attachment equipments. The architecture diagram is shown in Fig.7.

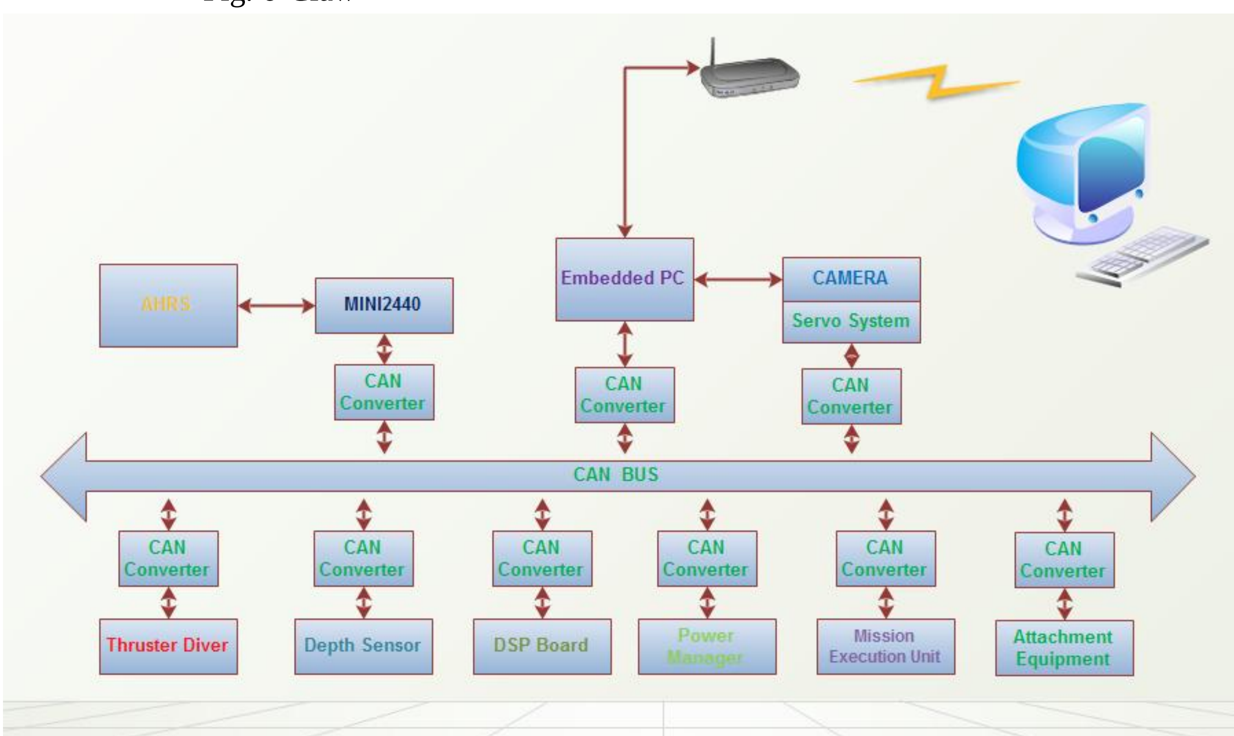

Fig. 7 Electrical system diagram

A. Embedded PC

The embedded PC model is GM45 with P7350 CPU. That's a industrial PC running under windows xp OS. GM45 is the 3.5 inch mini board, Intel 945GM(E) and ICH7-M chipset, integrated GM45 graphics, DDR3 memory, Realtek AC97 Audio, Serial ATA and one Intel 82573L Gigabit LAN. The power input is 12V DC. It is equipped with a P7350 processor running at 2.0GHz and 2 GB of RAM and for vision, mission, and control processing. The PC communicates with the sensors, motor driver, servo driver, STM32 board and FOG(Fiber optic gyro) and Doppler equipment. though UART and USB-UART converter. A Intel 32GB SSD is used for onboard data storage. It is fully equipped with 4 USB2.0, 4 UART ports. There are 2 cameras connected with the computer by USB. Ethernet LAN is connected to the aluminum board, there is a special debug connector and cable for robot debugging so that we can login the computer remotely. The most convenient thing is that we can use this PC to debug STM32 and DSP board because all the debug cable is connected to this PC. and we don't have to open the hull to debug them.

Fig. 8 GM45

B. STM32 board

As shown in Fig. 9, this board's CPU is a kind of ARM7 chip, STM32F103VBT6, it can run at 72MHZ. It can boost up within 10s. it is Performance line, ARM-based 32-bit MCU with Flash, USB, CAN, seven 16-bit timers, two ADCs and nine communication interfaces. This board has 3 UART, it is used to control the motors.

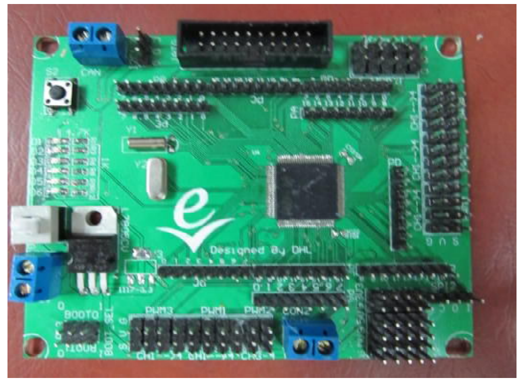

Fig. 9 STM32 Board.

C. DSP board

The DSP board is shown in Fig.10. There's a TMS320F2810 on this board, it's in charge of the acoustic signal processing and depth date collection.

Fig. 10 Passive sonar processor board

D. Camera

There are two industrial cameras on our submarine, they communicate over a standard USB2.0 bus via a USB hub. And images are captured through Emgu CV. The Emgu CV is a multi-platform, ".NET" wrapper to the Intel Open CV image processing library. The head camera is used to detect targets via color filter and image processing algorithms. The down-camera is used to follow the path and choose bins.

Fig. 11 Camera

E. Power Supply

There are 2 channels of power input from two independent batteries. Input voltage is between 12.8V and 14.2V. The maximum current can reach 10A. The battery pack is stored on the button floor of the main frame. These batteries are Ni-MH batteries with 4950mAh; it allows the vehicle to continue with its mission for at least 40 minutes at full power, longer than that during normal mission conditions. One group of cells is for control system and another group is for thrusters and mission execution unit. The battery pack is stored on the button floor of the main frame.

This unit has a power converter, it is designed for power control, it can convert the power to 3 standard voltage .They are 5V, 8V and 12V, and directly output to embedded PC. 5V is for the miniARM2440 and DSP board, and the controller on the motor driver board. The current and volt sensor will supervise the power situation.

F. Depth Sensor

The depth sensor is able to measure 0 to 2 bars and shown in Fig.12. An output of the depth sensor is analog current between 0~40mA potential to real depth and transmitted to the DSP board.

Fig. 12 Depth Sensor

G. FOG

The FOG (Fiber optic gyro) as shown in Fig.13 and Doppler equipment as shown in Fig.14 make up the integrated navigation system.

. Its internal low-power signal processor provides drift-free 3D orientation as well as calibrated 3D acceleration, 3D rate of turn and 3D earth -magnetic field data. The FOG is an excellent measurement unit (IMU) for stabilization and control of cameras, robots, vehicles and other (UN) manned equipment. This sensor is used to sense the angle of pitch, roll and yaw.

Fig. 13 FOG

Fig. 14 Doppler

The Doppler provide the accurate velocity to the FOG.

H. Passive sonar

The array of passive sonar consists of 4 unidirectional hydrophones mou nted in a precise diamond array in an acrylic mold shown in Fig. 14. The hydrophones attach to the waterproof Brad Harrison connectors, using shielded wires to reduce noise. The signals are implied by a pair of National Semiconductor LMH6646 dual operational amplifiers. The signals are received by DSP320F2812, which are TI optimized for digital signal processing. The DSP can filter out the erroneous frequencies, and further amplify the signal. It calculates the phase's difference between a pair of signals, and calculates the phase information and uses hyperbolic position on to determine a directional vector towards the pinger. The UART is used to sending the pinger's direction to the main control system. The UART also used as a main communication bus between different modules.

Fig. 15 Passive sonar

IV. Software and Control

A. Control System

In order to enable the main computer to focus fully on high-level mission and image processing functions, and to promote the reliability and real-time communicate, the underlying control functions are also programmed in the PC. It's convenient for the control pro -gram using the sensor data for several PID processes to control the heading, depth, and pitch of the submarine.

B. Mission Analysis

This year's missions have some difference with formers. First our vehicle needs to pass a gate; this gate is a starting of the competition. The size of the gate is so large that if the vehicle can't pass this gate it won't finish other missions either. Then the robot uses a camera to follow the yellow line to find the following mission. The Second mission is flowers; the camera is used to guide the robot to knock the target ball by adjusting its attitude. The third mission is going thought the hedge, it's similar as the former, the robot adjusts its attitude at first then holding its heading to go through it. The attitude is also needed to be adjusted for the following missions as letters and Cupid, the PID for keeping yaw and depth it very important and necessary in these missions. Next mission is to locate the right position of gladiator ring; by using camera, the robot need to throw the markers into the right box. And then next mission it need to grab the so called grape, it is a bit hard. Then comes the mission that shoots, for this mission, we make a gun for shooting. At last the robot needs to locate the right passion to grab the crown. It is hard for it to do. So we choose the simplest algorithm to do this job. We don't know its effect in the final because of lacking of the environment information. This claw is driven by servos. The grabbing process can be guided by camera.

In one word, there are 4 key techniques. They are acoustic locating algorithm, attitude maintain algorithm, depth keeping algorithm and the path planning algorithm. We pay much attention to them and use the methods as simple as we can.

C. Software System

C# is used to build our software system and Emgu CV is used to processing the images in vision. We write & read the variables in an XML file to save parameters and default values. There are numbers of test versions to reach complete version. The software system includes photo & video recording software, thrusters & PID test software. Single task executes software. Manual control multitask executing software and etc.

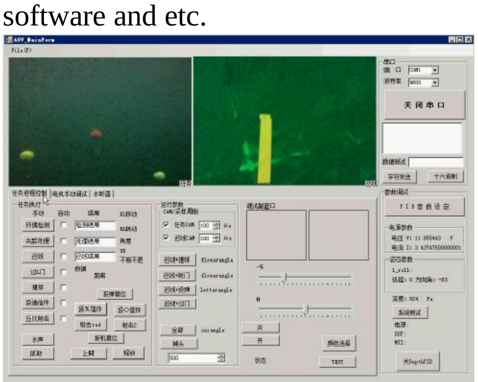

Fig. 16 Software

D. Mission Control

Our AUV system contains task detecting subsystem, mission state subsystem and executing subsystem. The task detecting subsystem detects the features using mission state, and decided how to executing tasks. Then, the executing subsystem executes the task through updating mission state. The priority of every task has an order tree, it can be updated in the whole process. The mission starts with the start gate detecting. In order to get the target quickly, we will set the depth according to the rule. Then the AUV will follow the path using orange color detector, canny edge detector, Hough Transform line detector with the heading angle updated in the mission state subsystem. The task detecting subsystem will find the characteristics of flowers and the executing subsystem will get the flowers in order and change the mission state. When the task detecting system detects a hedge, the executing subsystem will execute as a priority. Then select a way to execute Cupid or letters. In the Cupid task, the task detecting subsystem looks for isolating black areas and extracts the contours in the area with size and shape to detect the weapon. The executing subsystem uses the ROI to compare with source images with SURF algorithm. In the windows task, the task detecting subsystem finds four colors and the center of correct contour and adjusts the angle with the orange path. After the windows and weapons, the AUV will follow the sound to the counselor. In the task detecting and executing procedure, the mission states are used. And after every task has been detected or executed, the mission state will be updated.

V. Simulation Platform

This simulation platform can simulate the motion of the underwater robot; it's developed by the OpenGL Library and C++. The track of the robot to moving up and down, heading the target, dropping the markers and firing the torpedo can be simulated that we can study the strategy of this competition based on this platform.

A. Scene

The bottom of the pool is reproduced by the textures with Texture rolling technology to produce the effects of flow and sky.

B. Model

The 3ds format file is created by The SOLIDWORKS is converted by the 3DMAX to implement to the scene though the OpenGL.

C. The Object in the Scene

The object in the scene: The OpenGL is used to draw the gate, ball, target, box and pipe.

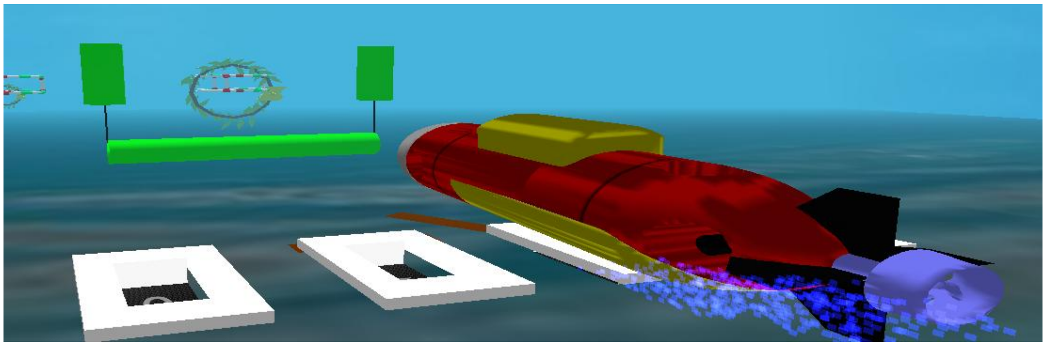

Fig.17 Simulation Platform

VI. Conclusions

Our AUV has fully functioned for all the missions. It has been passed the experiment run in the testing pool but the reliability and performance should be improved in the future work.

Acknowledgment

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