SNAME101 Autonomous Robotic Boat 2012 Competition

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Abstract

The National Cheng Kung University has designed the SNAME 101- an autonomous surface vehicle(ASV) to participate in the 5th annual competition organized by the International Association of Autonomous Unmanned Vehicle Systems. Using the knowledge and experience in the previous years, we have reengineered the vehicle to be more nimble, stronger and exquisite by refining ship lines and reducing dimensions and gross weight of it. We focused on engineering concepts and teamwork. For this project, a catamaran made of high-density foam combined with GPS, compass, onboard computer and also four USB cameras which can complete the entire prescribed tasks. These tasks are focused on image recognition as well as navigation.

1. Introduction

SNAME 101 Robotic boat has been developed for the 5th Annual International ASUV Competition (Autonomous Surface Unmanned Vehicle). SNAME101 is a combination of system advantages and improvements. After analyzing SNAME'S 00's benefits and weakness last year, we designed a new hull which is lighter than last year's vehicle with $LiFePO_4$ battery instead of Pb battery which can supply our system 12V 20AH DC power. With the dimension of 3ft x 1.7ft x 0.87ft, made of high-density foam, this design has a major purpose to achieve the scope of the competition.

To reduce the costs and need to fast processing devices, it was decided to redesign a control board to manage the output signal generated from our PC which analyzes and processes all the data. This year's controller system includes; 1) ASUS P8H61-I motherboard and Intel G840 CPU PC for LabView 2009 software as the main coding source, 2) USB cameras, compass and GPS as the sensory systems, 3) Wireless hub for communications and programming. Additionally, self-designed water cannon with a small conventional water pump and series of servo motors were added to find targets in different orientations. Two 18 lb thrust propellers were included to generate the desire propulsion for greater speed. The ship is functioning well in every test.

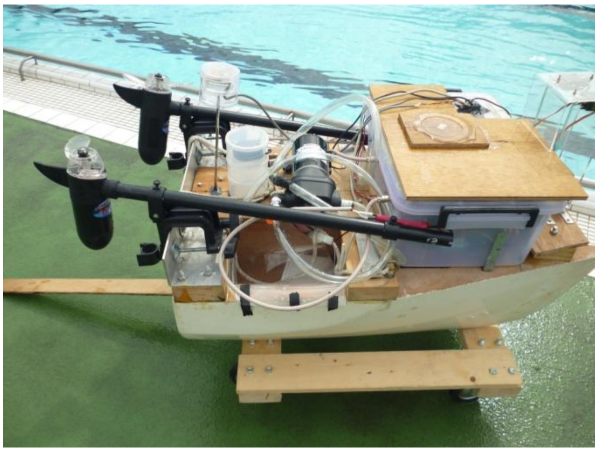


Fig.1：ASV-SNAME 101

2. *Mechanical design*

2.1 Ship design

Based on last year's experiences of designing twin hull ship, a catamaran design concept is still in used these years due to easy transportation and lots of merits. Our ship is composed of two single hulls and two aluminum alloy stiffeners.

The followings are the advantages of catamaran:

- Larger transverse stability.
- Larger platform for multipurpose equipment to install.
- Two thrusters propulsion provide good maneuverability.
- During transportation, the ship structure can be split into two single hulls to be transported and then can be easily installed at the destination.

Additionally, there are some differences between our new ship and the last year's one shown as follow:

- ship's dimensions:
  In order to satisfy the weight and dimensions of luggage limitation according to Transportation Security Administration(TSA) of the USA and the airlines, one single hull is within 62 inches(158 cm) and weights bellow 50 pounds.
- ship's drafts:
  Our ship's drafts is lower than the last year's one to decrease the influence of wind force.
- ship's propulsion:
  A pair of outboard motors is used instead of rudder.

The following is our ship principal dimensions:

Table 1-1：principal dimensions.

Principal dimensions		
item	size	unit
Length of over all	88	cm
Extreme Breadth	52	cm
Depth of ship	26	cm
Designed draft	16	cm
Freeboard	10	cm
L/B	1.73	

Waterline length	83.5317	cm
Wetted area	6253.5	cm^2
Beam max extents on waterline	51.8169	cm^2
Displacement	27760.7	cm^3

2.2Fabrication of ship body

After using Rhinoceros 4.0 platform to built our ship's 3D model(Fig.1), our sponsor ,a yacht company's mold center help us with our ship's fabrication. Each hull was made of 6 layers of 100cm x 50cm x 5cm high-density foam plates, glued together with AB composite glue.

With their sophisticated craftsmanship and advanced 5-axis CNC machine, the shape of ship hull is perfectly cut. After the ship shape is completed, the ship is coated with a layer of white waterproof paint.

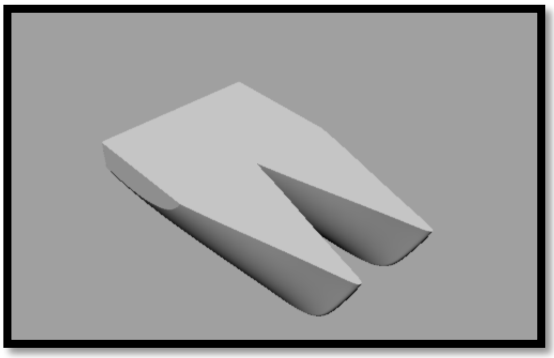


Fig.2：3D ship model

Fig.3：ship hull fabricating process.

(1)cut and glue together(2)stick and construct (3)perfectly cut by CNC machine

2.3Propulsion

A pair of outboard motors are installed in our ship's stern which can provide nearly 36 pounds thrust in maximum and also better maneuverability. This makes us controlling the ship motion more directly than using rudder like last year's ship.

One outboard thrusters provides nearly 18 lbs(8.16 kg) when a 180W power is supplied. However, we only use half of its full power to propel our ship to increase the ship's cruising distance and also the endurance of the propellers.

Fig.4：outboard motor.

2.4Water cannon

We designed a simple two axis tracking mechanism with water cannon and camera installed to achieve the challenge task “The Cheater’s Hand”. The structure of the tracking machine is made of 5 mm thick acrylic plate and servo motors for rotation. We use easy fuzzy control with vision processing technique to aim the water cannon at the target and shoot it.

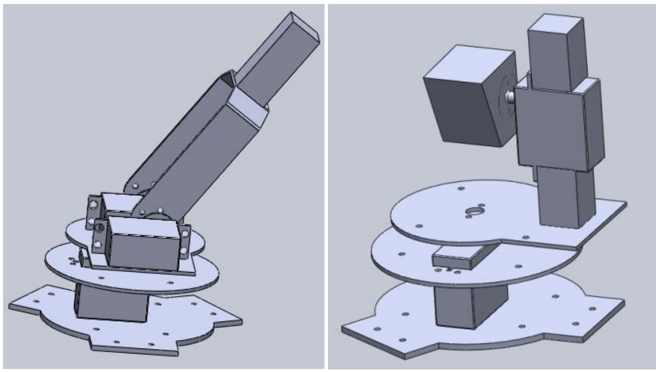


Fig.5：tracking mechanism

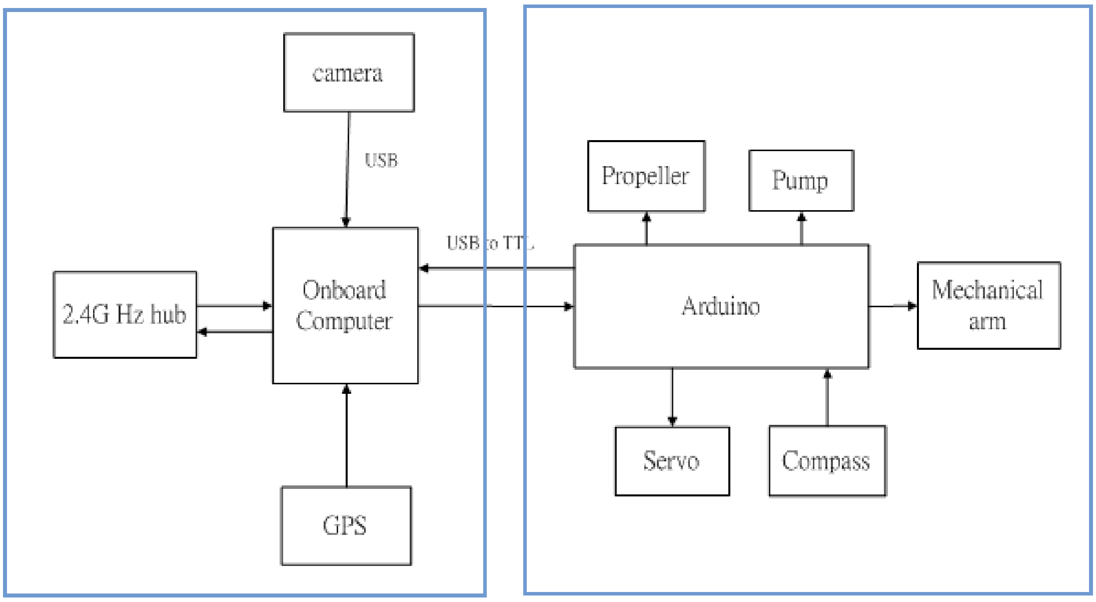
2.5 Robot Arm

On purpose of accomplishing the challenging task “The Jackpot”, we designed a simple robot arm also made of acrylic plates, actuated by a pair of servo motors.Since the position of emergency button is taller than last year’s one, we designed a long arm(more than 2ft) and placed it in the middle of ship’s bow.

Fig.6：robot arm drawing.

3. *Electrical Design*

We use Arduino mega 2560 microcontroller board instead of last year's control board which features 8051 chip. As the major purpose of our system is having a more stable and enduring power, so we use $LiFePO_4$ battery instead of Pb battery.



(a) (b)

Fig.7：(a) controllabe Core and sensor (b) controller

- Controllabel Core

Our system's computer consists of an ASUS P-I motherboard which is so small that it can fit our system box. The computer contains 4GB RAM, 6 USB ports and Intel G840 CPU. System's computer works as main signal processing unit. It receives all the input signals from USB cameras and GPS module.

- Controller

Arduino board receives signals from the electronic compass module and sends heading degrees computed by FTDI module. These devices are the main sensors to get right coordinates and location and to determine SNAME 101's situation.

This year we use Arduino board to replace last year's control board which allows us to have a faster synchronous processing response and also Arduino program is easy to debug. Another advantage is that it is cheaper than the use of an incorporated system such as NI CompactRio as the previous years' model used. The following diagram shows the sensors and computer communication system:

The control system haves two main electric elements:1.SSR (Solid State Relay) turn on/off water pump. 2. Arduino mega 2560 to processing signals from electric compass module and make commend from computer to control the propeller motors and the servo motors on the boat.

The electrical system also is essential in controlling servo motors which allow one of our four vision cameras to move in X-Y direction. By using LabView software, the input data is analyzed and processed to make the output data.

In order to increase waterproof functionality and prevent water from getting into the computer, this year a smaller and lighter box was used. The smaller and lighter box allows for easier assembly and transportation. The electronic box contains the computer, batteries, and all electrical components. All the electrical components are totally covered and kept away from contact with water.

4. Power System

This year's power system is completely redesigned. This year we connected four 3.3 V 20AH $LiFePO_4$ batteries is series, the voltage of the battery is 13.2 V. Voltage regulators drop the 13.2 V to 9 V for 2.4GHz Wireless Pocket Router and the water pump. Elaborating a power control system was an essential part of this project due to the need for excellent and stable distribution of voltages around the subsystems. Having electric elements with different voltage requirements and onboard computer with the need of 12V, this power control system facilitates the distribution and stability of such power supply system.

In comparison with previous year's design, we design only one power source to supply computer, propeller motors, and the other electric materials and the power distribution is totally independent of each other. This is an improvement because in case of a failure occurance within one area of the system, the rest of the system will not be affected, and allows the computer to keep on it's work.

This power system contains one $LiFePO_4$ 13.2V battery with 20AH and two voltage regulators drop the voltage to 9V for Wireless Pocket Router and the water pump. As Fig.7 shows, the $LiFePO_4$ battery is designated to supply power to the propeller motors, water pump, servo motors, GPS and computer. The $LiFePO_4$ battery is made of 4 cells of 3.3V each which equals the total of 13.2V that are essential for maintaining the stable 12V that the onboard computer needs and also supply power to the rest of the electric and electronic elements on the system such as wireless pocket router, servo motors, GPS, compass and others. We use ITPS power supply which can provide 150 watts output stable supply to the computer and it can effectively prevent the computer from reverse current. The H bridge board can send control signal to the propeller motors and it allows us to control the propellers more easily.

Our first power system was carrying two Lead-Acid batteries which were adding an extra 2kg to the gross weight of the boat and we had to make a special power box to put on the front acrylic platform of the boat. This method did not carried out because of these setbacks. Therefore, the uses of $LiFePO_4$ batteries reduce gross weight and let us eliminate the power box, without forgetting the advantages of convenience for traveling to the USA.

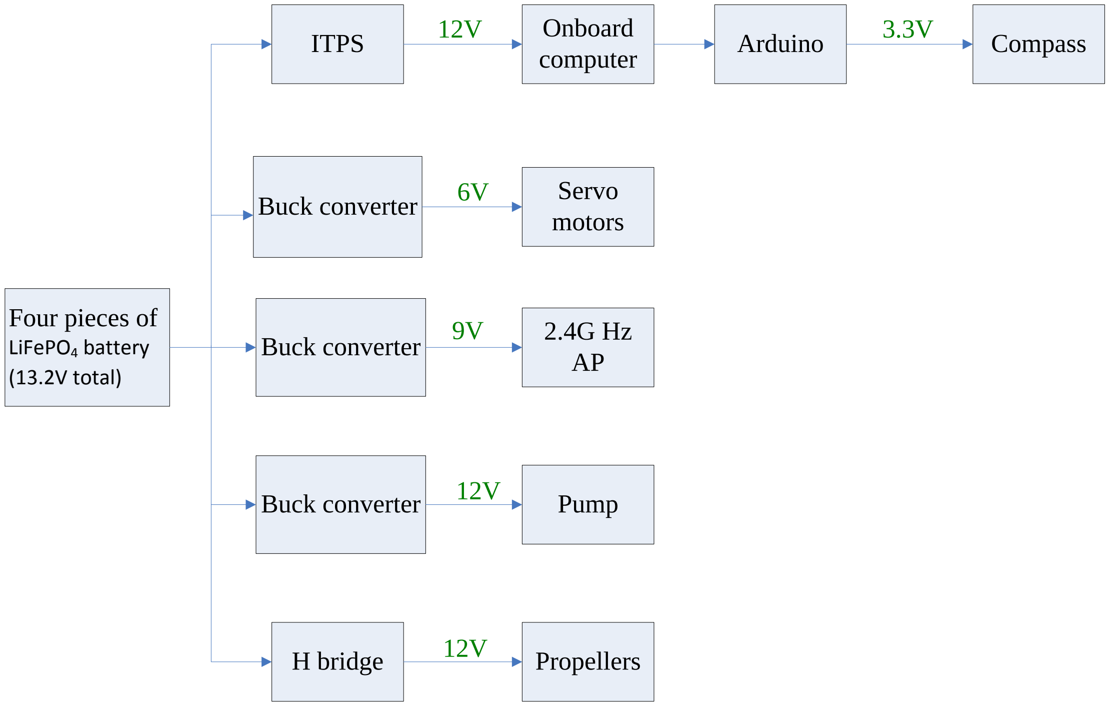


Fig.8：parse tree diagram of power system

The whole power system was placed inside of the electric box with the same waterproof setup as the electrical system, having one single hole for the output power to the entire boat.

5. *GPS Module*

A GARMIN GPS18x-5Hz unit is used to determine latitude and longitude coordinates of a specific location. It is needed for navigating through each mission.

This GPS designed to withstand rugged operating conditions and are waterproof. In addition, the GPS receivers require minimal additional components. It features a 12-channel receiver tracks and uses up to 12 satellites for fast, accurate positioning and lower power consumption. It also has highly accurate measurement pulse output for precise timing measurement and differential DGPS capability using real-time WAAS corrections yielding position errors of less than 3 meters.

Fig.9： GPS Module

Technical Specifications, Performance and Interfaces：
Size：61 mm(2.4 inches) in diameter and 19.5 mm(0.77 inches) in height
Weight：165 g(5.8 oz)
Input Voltage：4.0-5.5 Vdc
Input Current：100mA @ 5.0 Vdc
CMOS Serial Output Levels：0 Vdc to Vin, between 4 and 5.5 Vdc (RS-232)
Reveiver Sensitivity：-185 dBW minimum
Update Rate：5 records per second
Accuracy WAAS Position：< 3 meters, 95% typical
Velocity：0.1 knot RMS steady state
Electrical Characteristics：TIA-232-F(RS-232) compatible asynchronous reveiver
Default seing is 19200 baud.

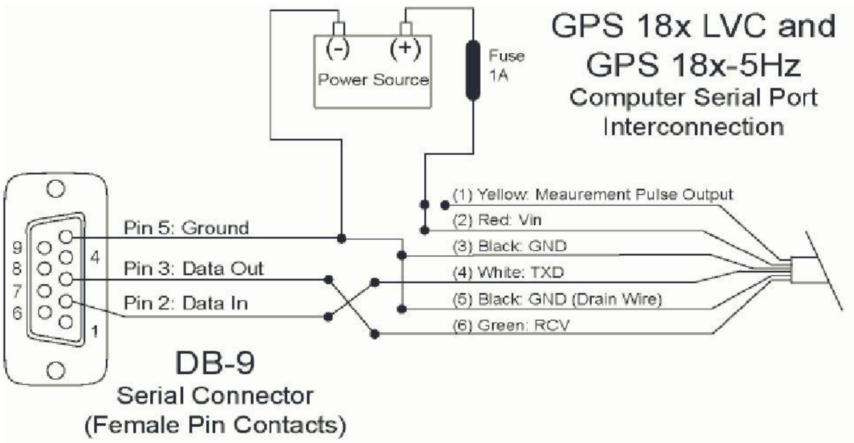


Fig.10：Computer Serial Port Interconnection

On the Fig.10, we can see how the GPS connects and send data to the computer. We used LabVIEW software to analyze and process the received data code as:
$GPRMC,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>,<11>,<12>*<CR><LF>
From the above data latitude, longitude and other values are found as the table：

Table. 5.1

<1>	UTC time of position fix, hhmmss format for GPS 18x PC/LVC; hhmmss.s format for GPS 18x-5Hz
<2>	Status, A = Valid position, V = NAV receiver warning
<3>	Latitude, ddmm.mmmm format for GPS 18x PC/LVC; ddmm.mmmmm format for GPS 18x-5Hz (leading zeros must be transmitted)
<4>	Latitude hemisphere, N or S
<5>	Longitude, dddmm.mmmm format for GPS 18x PC/LVC; dddmm.mmmmm format for GPS 18x-5Hz (leading zeros must be transmitted)
<6>	Longitude hemisphere, E or W
<7>	Speed over ground, GPS 18x PC and LVC: 000.0 to 999.9 knots, GPS 18x-5Hz: 000.00 to 999.99 knots (leading zeros will be transmitted)
<8>	Course over ground, 000.0 to 359.9 degrees, true (leading zeros will be transmitted)
<9>	UTC date of position fix, ddmmyy format
<10>	Magnetic variation, 000.0 to 180.0 degrees (leading zeros will be transmitted)
<11>	Magnetic variation direction, E or W (westerly variation adds to true course)
<12>	Mode indicator (only output if NMEA 0183 version 2.30 active), A = Autonomous, D = Differential, E = Estimated, N = Data not valid

6. *Electrical compass*

A 9-degrees of freedom sensor sticks is used in our ship. This sensor module contains ADXL345 accelerometer, HMC5883 compass and ITG-3200 3-axis gyro and uses simple I2C interface and low voltage supply 2V~3.6V. We combine the accelerometer and compass to a tilt-compensated compass to detect the direction of travel.

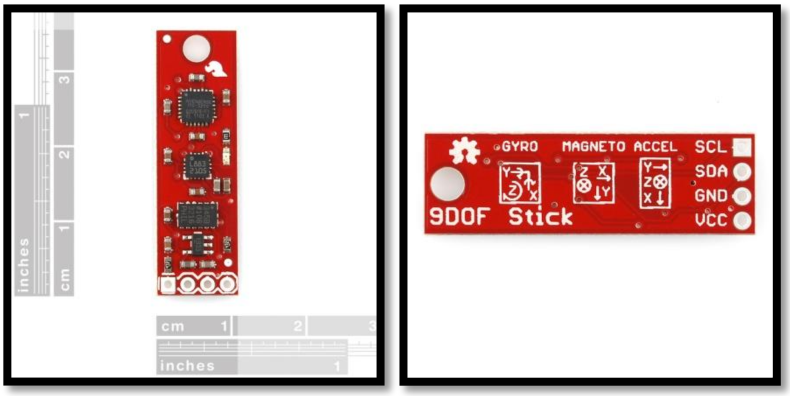


Fig.11：9-degrees of freedom compass

7. *VISION*

7.1 Camera

USB cameras need little power supply, it is very convenient on a system that is dependent on batteries. Using USB cameras allow our boat to have lighter gross weight and are easier to be mounted on the boat anywhere. However ,most webcam used CMOS sensors which equipped with “rolling shutters”,that can exhibit skew, wobble, and partial exposure. By try and test different USB cameras on the market,we choose a proper one,which have clear image,pantoscopic lens,auto focus,etc.

Fig.12：Microsoft life cam cinema

7.2 Image processing

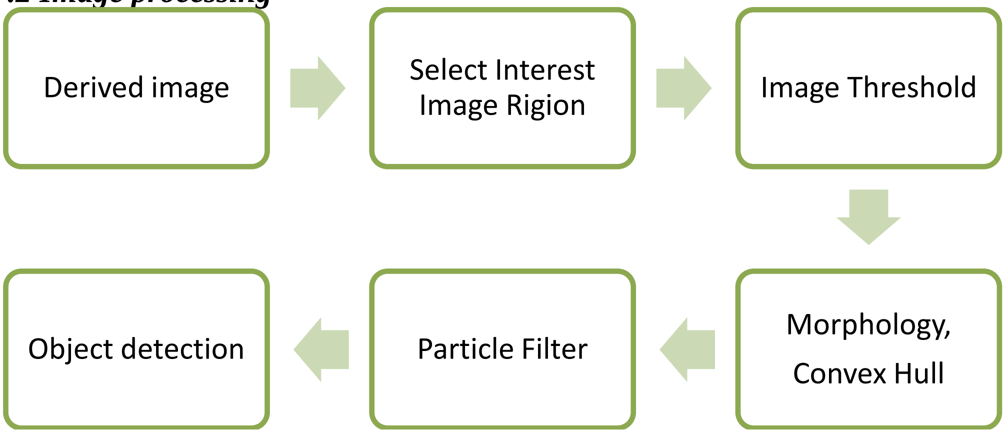


Fig.13： Flow chart of image processing

At first,we can do image processing through LabView Vision Assistant,which would display the result in every calculated step ,which let us properly segment the target from background.

Selecting interest rigion is to reduce calculating image size and exclude unwanted region, so calculation process will be faster. Thresholding is the simplest method of image segmentation. Through morphology mathematics,noise or unwanted particle will be eliminated and left some probable particle to further detection,such as geometric detection . As centriod of object calculated,computer will send commend to propeller system according to the programming.

8. Conclusion

In general,equipments of the new vehicle is better than the previous one; moreover,well engineered design allows it to have a great autonomous control, stable power distribution, naval architecture performance and assembly/disassembly design. So, we designed our vehicle for mandatory tasks and some challenging stations and believe the SNAME101 will complete these task successfully.

Our group also appreciate the AUVSI for our participating allowance in this competition. It helped us to improve our programming and robotic knowledge. The most important point is that we learned the spirit of teamwork from this experience. The skills attained through this process are valuable and will be taken with us into our workplaces.