SNAME'S 00 Autonomous Robotic Boat 2011 Competition

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Abstract

The National Cheng Kung University has designed SNAME'S 00; an ASV (autonomous surface vehicle) to participate in the 4th annual competition organized for the Association of Autonomous Unmanned Vehicle Systems International. We focused on the following engineering concepts of; naval, system, mechatronics and electrical engineering. A catamaran made of high-density foam equipped with GPS, compass, onboard computer and USB cameras was developed to function autonomously to pursue its directed tasks. These tasks are focused on image recognition as well as navigation.

1. Introduction

SNAME'S 00 Robotic boat is the 2011 design of the National Cheng University of Taiwan. The boat was designed in order to participate in the 4th Annual International ASUV Competition (Autonomous Surface Unmanned Vehicle). With the dimension of 4ft x 1ft x 1ft and made of high-density foam, this design has a major purpose geared to achieve the missions of the competition. A key aspect of SNAME'S 00 design is the ease of transportability from Taiwan to the United States and for the ability to assemble as well as disassemble easily.

With limited funds and the need of high-tech devices it was decided to create a control board to manage the output signal generated from an onboard PC which analyzes and processes all the data. Last year's design made use of Compact RIO as the main controller, which is an integrated device with high costs. This year's controller system includes; 1) ASUS AT3IONT-I onboard 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. A Minn Kota Endura 30 thrust was included to generate the desire propulsion for greater speed.

2. Mechanical Design

The basic structure of the boat relies on a catamaran to avoid the usual problems of stability and reduce the amount of power needed to propel the boat. The boat contains two hulls connected together with two 3inch x 4inch wood stiffeners. Each hull has a U shape for shallow draft and its smooth motion through the water. One of the major advantages of a catamaran design is the big platform that is provided within the hulls; such platform was made of 0.6 mm fiberglass, in which we placed a small conventional water pump for the water cannon, wireless hub and the AUSV judge's camera/wireless box, it can also support a payload of about 30lbs.

On the middle part of each hull, a hole was made to put the entire electric and power system, so it was completely protected from any water contact. The protective cover was made by a combination of plywood and plastic. On the very front of the platform a 10 inch wide piece of plywood was placed to protect the other subsystems on the platform and also to accomplish one of the missions on the competition, which is to push a red button to stop a water fall. After a series of test we found out that the addition of a stiffener connected in between the front piece of the plywood and the hulls front stiffener was needed to provide a better altitude to the cameras and water cannon for better recognition of images and hitting targets.

Based on the V shape catamaran used last year, with little draft there was too much exposition to the lake water letting the electric part be exposed to danger. To counter this problem from last year, we made a double size boat with triple draft. At the stern a 0.2 aluminum alloy plate was installed for connecting the rudder steering gear and the carabiners required for the organizers. The most challenging part of the design was to make a puzzle boat that is as lightweight as possible, due to the international shipping conditions. Each part of the entire boat, screws/bolts joining method was decided for facilitating assembling/dissembling process and transporting, without sacrificing the structure strength.

Fig.1 Rhinoceros 3D model

Fig.2 Actual Model

2.1. Fabrication

Each hull was made of 6 layers of 138cm x 36cm x 5cm high-density foam plates, glued together with AV glue. After glued together the 3D Rhinoceros model was inputted into the CATIA to create the machining code and let a 3-axis CNC machine accurately cut the actual shape of the boat. Then a layer of gel-coat was applied onto the hulls to cover the foam and give it strength, the last touch was a thin layer of waterproof paint.

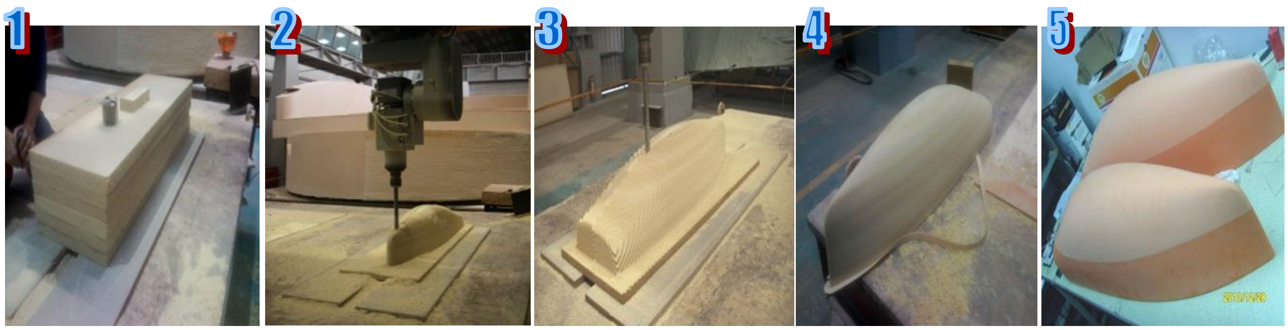

Fig.3 Hulls fabrication process

2.2 Propulsion

The propulsion system consists of an outboard motor. This Minn Kota Endura 30 motor is a unit which contains engine, gear box and propeller. It's mounted in the rear stiffener of the boat using its self bracket, which is the most appropriated for easy assembly and disassembly. The SSR (Solid State Relay) receives a signal from the NRF905 wireless module to control the pulse width modulation (PWM) which regulates the speed of the motor.

It provides 30lbs (13.6 kg) of thrust when a 360Watts is supplied. Because of the dimension of SNAME'S 00, such power is not needed, so we only made use of 120Watts. A 12V Lead-Acid battery provides enough power to the motor and water pump for about 1 hour.

This outboard motor was selected based on the experience from the last year's design, which was their own self designed motor. By self designing a motor, it had problems thrusting when running at full speed.

A 20cm long, 0.6 mm thick acrylic rudder was added to control the direction of the boat. One single servo motor has enough turning ratio strength for turning the rudder when the boat is at full speed. At first we added one rudder on each hull, but we found out that the turning ratio was too big, so it was too difficult for quick turns. We adjusted to a single rudder in between the 2 hulls and in front of the motor.

3. Electrical and Electronic Subsystems

Based on the problems encountered on the last year's design, we made a simpler and clearer electric setup. As the main purpose of this system was the simplicity of it, so we can have a stable power and signal transmission distribution on the boat.

The onboard computer consists on an ASUS AT3IONT-I small and weights almost nothing. The computer contains 1 GB of RAM, 6 ports USB 2.0 and 1.60 GHz Intel Atom processor. It works as the main control base which process all the input signals received from the electronic compass, GPS and cameras. These devices are our sensors to get the right coordinates and location of targets.

For this year's design, we included a new sub-system control board which allows us to have a faster processing response. It is cheaper than the use of an incorporated system such as NI CompacRio as the last year's model used. The following diagram shows the control board/computer communication system:

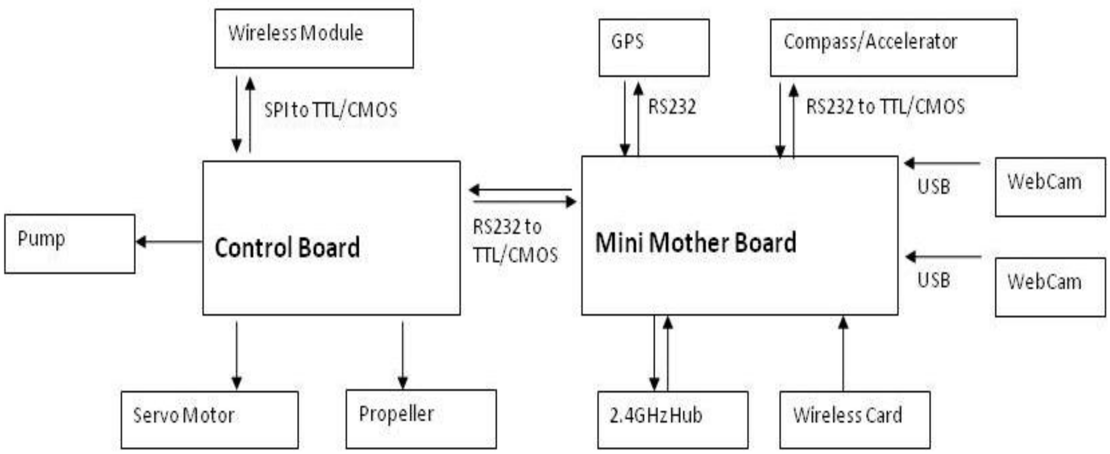

Fig.4 Control Board Diagram

The control board features the following main electric elements; 1) Relays for choosing an input signal in between the main computer or wireless module receiver, modulate the speed of the motor, turn on/off water pump and a SSR (Solid State Relay), 2) One IC-Atmel 89S52 to take the wireless SPI (serial peripheral interface) and transfer it to the UART (universal asynchronous receiver/transmitter), 3) Two IC-Atmel 89C2051 to control the propeller motor and the servo motors on the boat. These series of IC were programmed using C++ software.

The electrical system also is essential in controlling servo motors which allow one of our two vision cameras to move in X-Y direction. Two servo motors were added to the water gun to increase the strength on moving it upwards and downwards for better focus on the target. By using LabView software, the input data is analyzed, processed and outputted.

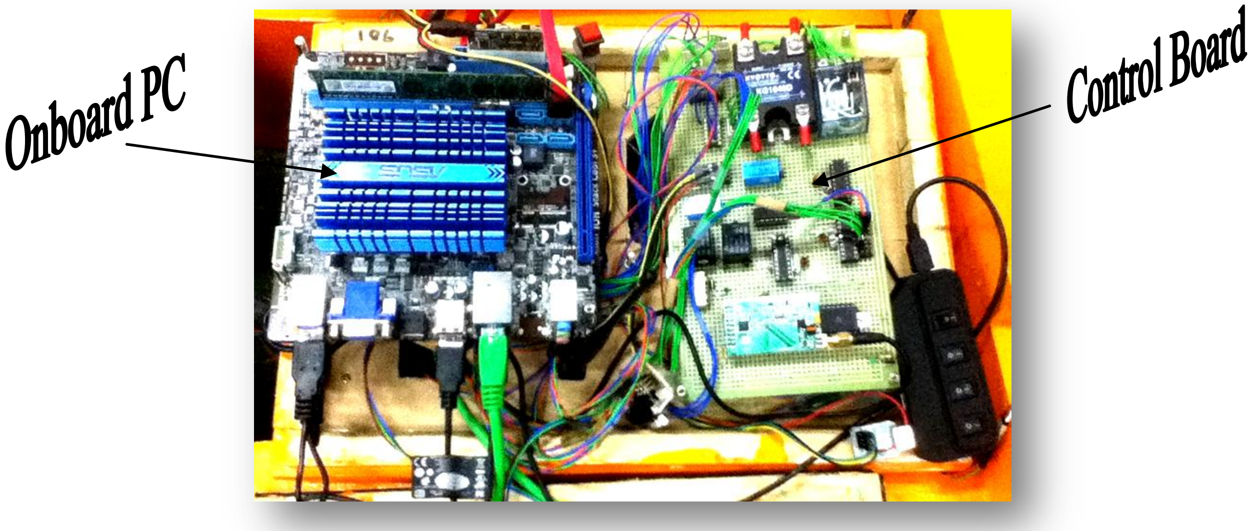

Fig. 5 Electric System Setup

In order to prevent water from getting into the onboard computer and control board, a plywood plate was placed on top of the hole of the right hull which works as a lid. That lid has two extra holes which are then covered with a hard plastic material for in/out ventilation of the computer fan. All the electrical components are totally covered and kept away from contact with water.

3.1 Communication Protocol

SNAME'S 00 uses a signal combined with 22 bits characters. The IC receiver mentioned above, receives the input signal from the onboard computer which tells it to work in either manual or automatic mode. For manual mode we made use of a wireless remote control.

The following table describes SNAME'S 00 communication protocol:

Character	S	F/B	H/L	PWM value	O/C	A/M	R/N	Y	PWM value	PWM value	PWM value	PWM value
ASCII code	83	70/66	72/76	48~57	79/67	65/77	82/78	89	48~57	48~57	48~57	48~57

Each abbreviation means:

- S: recognized character
- F/B: control the motor to forward (F) or backward (B)
- H/L: change the motor speed is high (H) or Low (L)
- PWM value: control the motor speed from 0 to 100 percent of whole thrust
- O/C: open or close the pump
- A/M: Auto (A) or Manual (M)
- R/N: Receive(R) the signal from boat or Not receive (N)
- Y: recognized character
- PWM value: control servo to change the angle of rudder
- PWM value: control servo to change the pitch angle of camera
- PWM value: control servo to change the roll angle of camera and pump canon
- PWM value: control servo to change the pitch angle of pump canon

4. Power Distribution System

Elaborating a power control board 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 board facilitates the distribution and stability of such power supply system.

In comparison with last year's design, this subsystem is a big improvement of design because of the power distribution being totally independent one another. This is an improvement because in case a failure occurs within one area of the system, the rest of the system will not be affected.

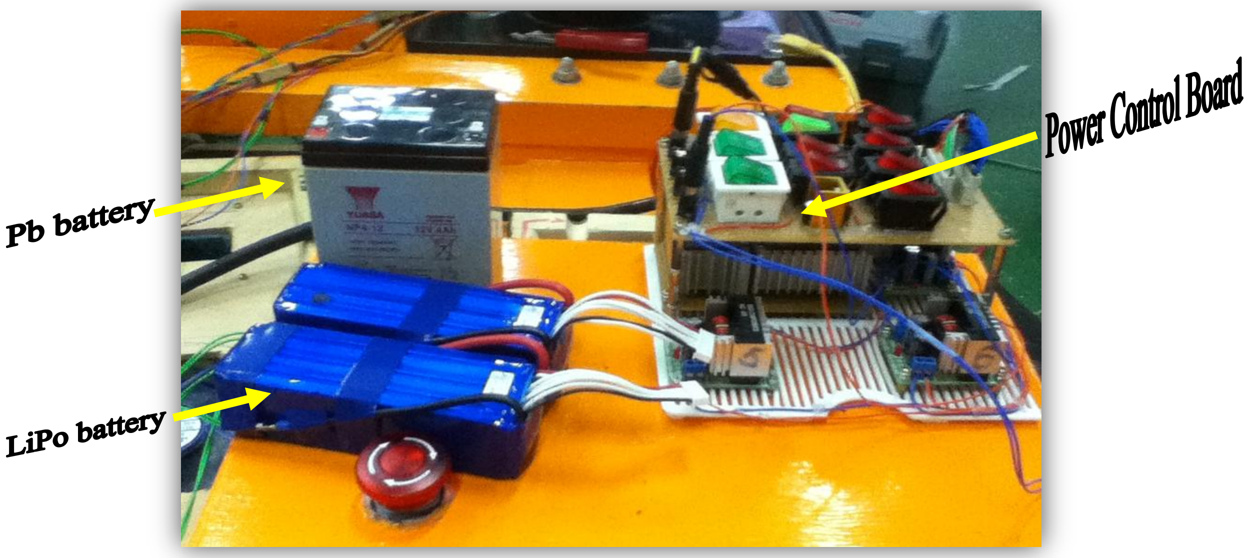

Fig. 6 Power Control Board

This subsystem contains one Li-Po 22.2V battery with 3AH and a 12V Lead-Acid battery with 7.2 AH. As Fig.7 shows, the Lead-Acid battery is designated to supply power to the propeller and water pump. The Li-Po battery is connected to a transformer which distribute the voltage around the control board and to the main onboard computer. The Li-Po battery is made of 6 cells of 3.7V each which equals the total of 22.2V 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 hub, servo motors, GPS, compass and others. The way these voltages are distributed is using a 16A max transformer connected direct to the Li-Po battery. To this transformer the onboard computer it is connected and three 3A max transformers. These transformers have the function to convert the input of 12V to 9V, 6V, 5V. The 9V is for the wireless hub, 6V for control board and 5V for AMS 1085 CT transformer which sends 3.3V to control board.

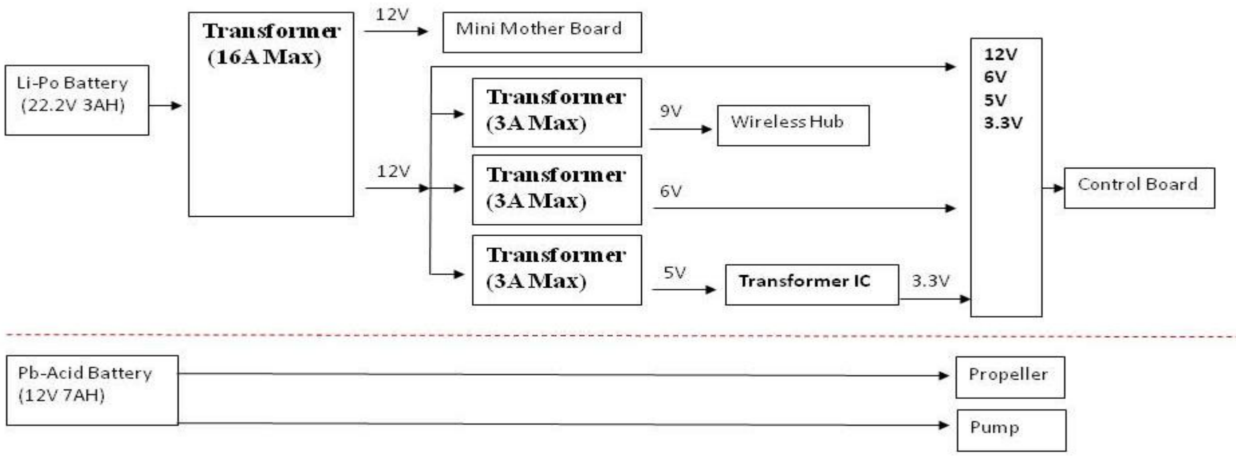

Fig.7 Power Diagram

Our first power system was carrying three Lead-Acid batteries which were adding an extra 2.5 kg 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 was not carried through because of these setbacks. Therefore, the uses of a Li-Po battery reduced gross weight and lets us eliminate the power box and made use of currently made hole on one of the boat's hull, without forgetting the advantages of convenience for traveling to the USA.

The whole power system is placed inside of the starboard's hole with the same waterproof setup as the electrical system, having one single hole for the output power to the entire boat.

5. Sensory Subsystems

5.1. GPS Module

A GARMIN GPS18-5Hz unit is used to determine latitude and longitude coordinates of a specific location. It is needed for navigating through the waters of Virginia Beach. This GPS features a 12-channel receiver tracks and uses up to 12 satellites for fast, accurate positioning and lower power consumption. It has a waterproof design, highly accurate measurement pulse output for precise timing measurements, differential DGPS capability using real-time WAAS corrections yielding position errors of less than 3 meters.

The technical specifications are:

- Size 61 mm in diameter and 19.5 mm in height
- Weight 161.6 g or 5.7 oz
- Input voltage 4.0–5.5 V
- Input current 65 mA @ 5.0 V
- CMOS Serial Output Levels 0 V to Vin, between 4 and 5.5 V
- Receiver sensitivity -165 dBW minimum

Fig. 8 GPS Module

We chose our GPS module based on a device having as minimum position error as possible in real time response. GARMIN GPS has all the requirements needed for great navigation, so we made use of GPS18-5Hz. Last year module was Fastrax UP500 GPS which is less accurate than GARMIN PGS.

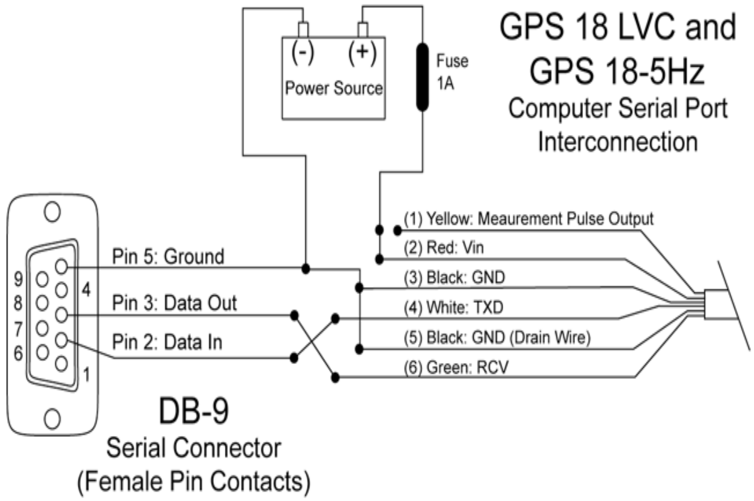

Fig.9 GPS/Computer Interconnection Diagram

On the preview Fig.9, we can see the interconnection diagram which describes the way how the GPS sends the recorded data to the computer port. The received data on the computer is analyzed and processed with LabView software which will read an initial input data as:
$GPRMC,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>,<11>,<12>*hh<CR><LF>

From the above data the latitude and longitude values are found as it shows on the following table:

<1>	UTC time of position fix, hhmmss format for GPS 18 PC/LVC; hhmmss.s format for GPS 18-5Hz
<2>	Status, A = Valid position, V = NAV receiver warning
<3>	Latitude, ddmm.mmm format for GPS 18 PC/LVC; ddmm.mmmmm format for GPS 18-5Hz (leading zeros must be transmitted)
<4>	Latitude hemisphere, N or S
<5>	Longitude, ddmm.mmm format for GPS 18 PC/LVC; ddmm.mmmmm format for GPS 18-5Hz (leading zeros must be transmitted)
<6>	Longitude hemisphere, E or W
<7>	Speed over ground, GPS 18 PC and LVC: 000.0 to 999.9 knots, GPS 18-5Hz: 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

5.2. Electronic Compass

The Ocean Server OS4000 digital compass was added to the sensory system as a flux gate detector for the reading of the earth's magnetic field so we could determine the direction of travel. It is affected by the magnetism of the boat which produces deviation when navigating; this phenomenon is corrected electronically and automatically with the combination of the GPS's coordinates. It uses 3.3 ~ 5VDC.

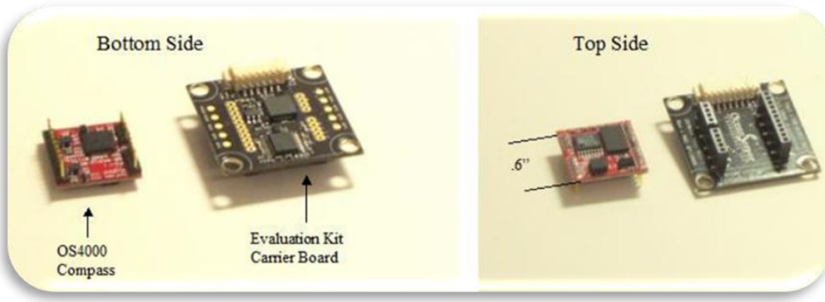

Fig.10 View of electric compass

The way the compass communicates with the onboard pc is similar to the GPS, using a simple wire connected to a computer port. Using LabView we acquire its recorded data, analyze and process it to let the navigation system be as stable and accurate as possible that are the main goals.

5.3. Vision Cameras

Last year's visual sensing system was achieved by an National Instruments IP Camera that was connected to CompactRio for processing. This vision system led to the problem of slow processing for real time response, creating a noticeable time delay on the output signal, hence creating an unstable navigation system. We utilized two USB cameras connected to the main onboard computer which can process much more information at a time.

These cameras are used to detect the location of the boys and targets through image recognition. Using USB cameras allow our boat to have lighter gross weight and are easier to be mounted on servo motors for motion when looking for targets when navigating. One camera is placed on the very front of the boat for the navigation through boy's task and the second camera is placed on the very top of the boat to have for better panoramic view of the environment. The second camera has autofocus for better recognition of the targets. USB cameras need little power supply which is very convenient on a system that is dependent on batteries.

6. Supplementary Features

6.1. Water Cannon

As requirement for the one of the missions, we included a water cannon mounted on a series of R/C servo motors connected to a small water pump. The servo motors are all controlled from the onboard computer. Using input from the connected computer, it can aim and fire a stream of water to the selected target from the USB camera.

6.2. Wireless Transmission Module

The wireless transmission system is one of the most important areas on an autonomous unmanned vehicle. With the Nordic Semiconductor single chip Transceiver nRF905, SNAME'S 00 was tested and programmed to transmit the desire signals within the communication system for the 433 MHz ISM band. This wireless module has major advantages, for example, the capability of adjusting output power up to 10 dbm, automatically retransmit data packages, the need of low current supply (11mA @ -10dBm output power for TX and 12.5mA @ -10 dBm output power for RX).

The configuration is easily programmable by use of the SPI interface and it performs well in remote control through simple Tx Rx transmission.

7. Conclusion

For a less than a year preparation, SNAME'S 00 is able to accomplish the tasks proposed for the ASUV 2011 competition. A well engineered design allows it to have a great autonomous control, stable power distribution, naval architecture performance and assemble/disassembly design.

Our group is appreciative to the AUVSI for allowing our team to participate in this competition. The tasks asked from our group were challenging and seen opportunity that most university students are not presented with. It helped us to improve our robotic and naval knowledge. The skills attained through this process are invaluable and will be taken with us into our workplaces.