SAILBOT 2011

Design Summaries

13 May 2011

Participating Teams:

Memorial University of Newfoundland (MUN Sailbot)

Queen's University

Royal Military College of Canada

United States Naval Academy

University of British Columbia

School/Firm/Team Name:
Memorial University of Newfoundland (MUN Sailbot)

Boat Name(s):
The Missus

Team Members:
Andrew Swan, Ben, Brian Claus, Jordan Smith, Justin Royce, Kyle Howlett, Liam Johnston, Mike Manuel, Nathan Smith, Raj Mandke, Robert Moulton, Ryan Sampson, Ryan Williamson, Scott Stevenson, Simon Rees, Tom Allston, William Ferguson, Wojtek Pagacz

Faculty Advisors: Ralf Bachmayer

Length: ~2.0 m
Beam: ~0.34 m
Draft: ~1.5m
Displacement: ~50.0 kg
Sail Area: ~3.0 m2
Team History:
The team began with ocean and naval architecture students at Memorial University hearing about the sailboat competition. Coming from a sailing background and having an interest in autonomous vehicles this competition was a perfect fit. A Small RC boat was purchased as preliminary testing and development model. Once the team proved to themselves that they could build a boat the team proceeded to build 2 m fractional rigged sloop.

Boat Design Summary:
The 2 m hull is a scale model 70' sloop and was designed as part of a senior term project with the Marine Institutes Naval Architecture program. The hull is constructed of foam-cored fiberglass laid up in a female mold. The hull was stiffened using transverse and longitudinal bulkheads. Areas such as near the keel and mast step where additional loading is a concern have been reinforced with extra matte glass and chopped strand glass fibers. The initial goal was to ensure all bulkheads where water proof, however due to the requirement for deck penetrations in the current design extra care has been taken to ensure that compartment containing electronics, batteries and motors are watertight. Electronics will be housed aft the keel box on the centerline. The winches for the running rigging are driven by DC brushed motors on either side of the keel box immediately below the deck. The batteries will be distributed between holds beneath the electronics and the motors; additionally they will also be stored forward the mast for completion of the endurance race. The mast is step is adjustable and forward of the midsection, mounted on the flat deck. The vessel is rigged as a fraction sloop, with a square top main. The carbon fiber foiled mast or aluminum mast is racked aft using one set of upper and lower shrouds in place of a backstay. The combination of the two masts along with two dramatically different sail sizes will allow for sailing in all conditions. The keel consists of a hydrodynamic foil composed of a glassed aluminum and foam core. The bulb is made of molded lead shot. The twin rudder system generates a greater steering moment to drag ratio than a single centerline rudder. A single motor controls two push-pull cables that drive both rudders.

Controls Summary:
The sailboat's main controller is Atmel Atmega 1280 Arduino board. This board makes all of the high level decisions using the input from the sensors and actuator feedback. The boat is outfitted with a GPS receiver, a 2.4 GHz XBee wireless communications board, an attitude and heading reference sensor, a wind speed and direction sensor and a number leak detection sensors.
The rudder and sails are actuated using three brushed DC gear-motors. The motors have encoders on their output shafts to provide feedback and directly drive the drums for the main sail, jib sail and rudder. Control for the motors is provided through an Atmel Atmega 328 Arduino board. Commands are sent from the main control board to the motor control board. The motor control board interfaces to the main control board through a serial connection.
The software for the boat is written in C++ using the eclipse development environment. The main controller runs a real time operating system which is used to schedule events. The real time operating system allows for easier integration of system components by separating each components code into individual tasks as well as guaranteeing operating frequency. The control for the boat is done through nested state machines operating as a task in the real time operating system.

School/Firm: Mostly Autonomous Sailboat Team, Queen's University

Boat Name: TDB

Team Members: TDB

Faculty Advisors: Dr. Michael Birk

Length: 2.00 m (78.74 in) Beam: 0.30 m (11.81in) Displacement: 20 kg (44.09lb)

Draft: 1 m (39.37in) Sail Area: 1.6 m^2 (17.22ft^2)

Team History:

Queen's Mostly Autonomous Sailboat Team (MAST) is a student design team which designs, constructs, and races robotic sail. It was founded in 2004 as a result of the absence of a naval architecture and mechatronics design team on campus. MAST soon became a competitive team once UBC approached Queen's about hosting a competition for autonomous sailing vessels. It now continues to develop as it designs and constructs an entirely new boat each year, competing in two international competitions: Sailbot and World Robotics Sailing Championship (WRSC).

MAST has also started work on a 4 meter hull designed specifically for the transatlantic race.

Boat Design Summary:

When reviewing the design of last year's boat, GaelForce, it was decided to increase the volume. Overall the team was happy with the shape. However, the team decided not to go with a foam core hull because it was difficult to construct. Instead the hull consists of Kevlar and uni-directional carbon.

On the boat there is a main sail and a jib sail, both with booms. The mast being used in for this years design is a wound carbon mast making it lighter than last year's two piece aluminium and carbon fibre mast. The team decided to use a luff sleeve around the carbon mast because it simplifies the mast profile.

Navigation System Summary:

The boat's navigation control system consists of two stages: data filtering and processing, and decision making. The control logic is programmed with an Arduino Mega2560 microcontroller, with a 16 MHz ATmega2560 chip.

Major waypoints (such as marks to round) are pre-programmed before the boat enters autonomous mode. Once in autonomous mode, navigation data is first polled from the sensors. These include the PB100 Weather Station, which has an onboard GPS and wind sensor, and True North Revolution GS compass. Data errors are detected through the NMEA0183 protocol, and if no error has occurred the data string is parsed to retrieve the sensor information. GPS and wind speed and direction data are used to set a route of closely spaced intermediate waypoints, taking account of allowable points of sail and the desired direction of travel. The compass is then polled at least once per second to keep the boat on course, rechecking the GPS and wind every few seconds.

The boat is able to detect when it is in irons through the wind direction sensor, and can pull in the sails and turn the rudder to return to a valid heading and recapture it's speed, after which it resumes it's navigation protocol. When sailing to windward, intermediate waypoints are set to keep the boat within a downwind corridor of it's mark, such that it does not sail too far on one tack, but avoid points of sail which point the boat too much to windward.

The output from the microcontroller is a serial signal sent to a Pololu Micro Servo Controller. The servo controller sends PWM signals to the rudder servo and the main sail servo in order to steer the boat. These PWM signals go through a multiplexer which is controlled by the microcontroller and allows control to be transferred to manual Futaba remote control.

Sail Control System Summary:

The boat's sail control system consists of sensors and motors, with an Arduino Mega2560 microcontroller. The set of the sails is determined by the direction of the wind and the tilt of the boat. The sails are set proportional to the wind direction, with the area in front of the boat and 20 degrees to each side designated “irons”, where the sails are completely close-hauled. The wind direction is sensed at least every 5 seconds, and the heel of the boat at least every second. In the case that the boat is heeling more than 45 degrees, the sails are let out until the boat returns to less than 45 degrees of heel.

On the boat there is a main sail and a jib sail, both with booms. The main sail is controlled by a SmartWinch 380EH servo. The jib sail is controlled by a HS-785HB winch servo. Each servo receives a PWM signal from a multiplexing circuit, which allows the control signal source to be switched from manual Futaba RC receiver control to autonomous microcontroller control.

School/Firm/Team Name: Royal Military College of Canada

Boat Name(s): LaLiberté

Team Members: Robbie Edwards

Sebastien Royal

Aaron Bradley

Jacob Hardes

Faculty Advisors: Lt(N) Stephane Lachance

Length: 2m Beam: 2m Displacement: ~55lbs

Draft: 0.65m Sail Area: 1.8 m^2

Team History:

Started in January 2010, the RMC autonomous Sailboat design team competed in Sailbot 2010 with a 2m long 3.5m tall wing sailed trimaran. The tall, solid element sail boat proved to be unstable in the larger waves during the competition. The team has since carried out many mechanical refinements on the boat and is now testing the autonomous software.

Boat Design Summary:

Many updates have been made to the platform used in the 2010 competition:

The wing sail has been shortened from 3m to 2.25m which has increased the oscillation frequency away from that of the larger waves. All the electronics have been thoroughly waterproofed in anticipation of salt water trials in the 2011 competition.

A team of fourth year mechanical engineering students carried out a variety of mechanical upgrades to the boat as a design project. The wing sail may now be set by the tail system from last year or by a DC motor driven worm gear system with the tail removed for stability. The camber actuation system has been improved for increased robustness and a second wind sensor mounting system has been constructed.

Navigation System Summary:

An Arduino based microcontroller system is used for navigation, sensor input and communication with the shore. A second arduino microcontroller actuates the servos and DC motors. A tilt compensated digital compass along with an ultrasonic wind instrument and GPS provide information with which a simple path planning algorithm makes sailing decisions.

Sail Control System Summary:

This year the sail can be set using one of two different methods: the aerodynamically set tail system which was used on the boat last year. This system effectively decouples the hydrofoils in the water from the airfoils used to power the boat and allows for proper setting of the wing sail by a simple one-time adjustment to the angle of attack of the wing in place of constant adjustment by a winch system.

The undergraduate design team has constructed a worm gear system which drives the sail orientation and removes the long tail system which was responsible for capsizing the boat during last year's competition.

School/Firm: U.S. Naval Academy

Boat Name: "Gill the Boat"

Team Members: Thomas Deeter, Sean Rohrs, Chris Blevins, Matthew Harmon, Matthew Debbink, Mark Nichelson, Tres Penny, Peter Gibbons-Neff, Nicholas Taschner, and Cody Keef

Faculty Advisors: Brad Bishop, Paul Miller

Length: 1.994 m (78.50 in) Beam: 0.304 m (11.97 in) Displacement: 28.58 kg (63 lb)

Draft: 1.476 m (58.11 in) Sail Area: 3.1 m^2 (32.8 ft^2)

Team History:

The United States Naval Academy Sailbot team was formed in 2007 with the construction of "First Time" which was entered in the 2008 SailBot competition. In 2009 the Sailbot team designed and built "Luce Cannon" and entered it and "First Time" in the Sailbot competition and World Robotic Sailing Championships taking 1st and 4th place respectively. In 2010, the Navy Sailbot team delivered another boat named "Gill the Boat" and continued to work on "Luce Cannon." The Navy team ended up winning 1st and 2nd in Sailbot and came in 4th in the World Robotic Sailing Championship. The 2011 Sailbot team has made a few improvements on "Gill the Boat" for this year's Sailbot competition including more freeboard and newer systems components. The team has also built a new boat that will be entered in this year's Sailbot competition.

Boat Design Summary:

"Gill the Boat" was designed using a VPP study to show performance trends. It competed in last year's Sailbot competition and had a few issues which have since been corrected. There was a problem last year with bow submergence so freeboard has been added to counteract this issue. "Gill the Boat" also had some weight taken out of it on the deck. This lowered the center of gravity and increased performance. The boat has also had a systems component upgrade.

Navigation System Summary:

"Gill the Boat" is equipped with a Rabbit 3000 microprocessor. Information including heading, wind direction, GPS location, speed and heel are fed into the microprocessor from the Airmar PB200 WeatherStation, along with wanted waypoints, using a C programming language. "Gill the Boat" has the capabilities to be wirelessly monitored and programmed. With this data "Gill the Boat" will calculate what point of sail it will be on, and if sailing upwind, it will determine proper up wind courses to sail, when to tack, and will react to wind shifts.

Sail Control System Summary:

The Rabbit 3000 microprocessor has the ability to output PWM signals which control both the rudder servo and sail winch. A separate PIC microprocessor controls relays which switch between autonomous and manual sail control. Manual sail control is achieved using a standard Futuba radio PWM transmitter and receiver.

School/Firm: U.S. Naval Academy

Boat Name: “Spirit of Annapolis”

Team Members: Thomas Deeter, Sean Rohrs, Chris Blevins, Matthew Harmon, Matthew Debbink, Mark Nichelson, Tres Penny, Peter Gibbons-Neff, Nicholas Taschner, and Cody Keef

Faculty Advisors: Brad Bishop, Paul Miller

Length: 1.99 m (78.35 in) Beam: 0.48 m (18.89 in) Displacement: 52.62 kg (116.0 lb)

Draft: 1.495 m (58.86 in) Sail Area: 2.22 m^2 (23.9 ft^2)

Team History:

The United States Naval Academy Sailbot team was formed in 2007 with the construction of “First Time” which was entered in the 2008 SailBot competition. In 2009 the Sailbot team designed and built “Luce Cannon” and entered it and “First Time” in the Sailbot competition and World Robotic Sailing Championships taking 1st and 4th place respectively. In 2010, the Navy Sailbot team delivered another boat named “Gill the Boat” and continued to work on “Luce Cannon.” The Navy team ended up winning 1st and 2nd in Sailbot and came in 4th in the World Robotic Sailing Championship. The 2011 Sailbot team has made a few improvements on “Gill the Boat” for this year’s Sailbot competition including more freeboard and newer systems components. The main goal of the 2011 team however has been to make an autonomous voyage across the Atlantic. The team’s newest boat, “Sprit of Annapolis,” is much different than past hull forms and hopes to perform well in this year’s Sailbot competition.

Boat Design Summary:

“Spirit of Annapolis” is unlike any previous boat the Navy team has built. The goal of this vessel is to make an autonomous voyage across the Atlantic. The vessel design was driven by a large, high rake keel that will be used to shed weeds. A VPP was also used to track performance trends. The results of this analysis showed that in order to improve performance there must be a large righting moment and greater canoe body draft. Additionally, there was a need to have much more battery power than in previous year so, in order to keep our center of gravity low, the vessel was designed around keeping one of the largest weights, the batteries, as low as possible. The deck of “Spirit of Annapolis” is also very wide in order to make more room for solar panels which will provide added power sustainability.

Navigation System Summary:

“Spirit of Annapolis” is equipped with a Rabbit 3000 microprocessor. Information including heading, wind direction, GPS location, speed and heel are fed into the microprocessor from the Airmar PB200 WeatherStation, along with wanted waypoints, using a C programming language. “Spirit of Annapolis” has the capabilities to be wirelessly monitored and programmed. With this data “Spirit of Annapolis” will calculate what point of sail it will be on, and if sailing upwind, it will determine proper up wind courses to sail, when to tack, and will react to wind shifts.

Sail Control System Summary:

The Rabbit 3000 microprocessor has the ability to output PWM signals which control both the rudder servo and sail winch. A separate PIC microprocessor controls relays which switch between autonomous and manual sail control. Manual sail control is achieved using a standard Futuba radio PWM transmitter and receiver.

School/Firm/Team Name: University of British Columbia

Boat Name(s): Thunderbird 1

Team Members: Gaelen Krause, Alan Donohoe, Karl Jensen, Ian Saari, Byron Roelfe, Maxime Chin, Phil Barron, Henry Poon, Don Martin, Grahame Shannon

Faculty Advisor: Jon Mikkelsen

Length: 2 m Beam: 0.28 m Displacement: 20.5 kg

Draft: 1.25m Sail Area: 1.75 m^2 (#1 rig)

Team History: UBC has had a team since 2003, although the team has been inactive since 2008. This year, ten students from Mechanical and Integrated Engineering restarted the team and built an entirely new boat and control system. Construction began in February 2011 and Thunderbird 1 will be launched in early April.

Boat Design Summary: Our design is based on a light and well-balanced yacht that will sail ably in any conditions. It has a narrow canoe-shaped carbon-fiber hull with a sharp bilge, making it directionally stable with little wetted surface. The 75% ballast ratio ensures high stability, with a lead bulb affixed to a 1 meter tapered keel foil. There are three interchangeable rigs to be exchanged depending on conditions, all with equal area jibs and mainsails.

Navigation System Summary: The navigation system centers around an ATmega 1280 micro-controller board that interfaces with a Trimble Copernicus GPS receiver, Dual-axis ADXL203 inclinometer and Bournes EN optical encoder-based apparent wind sensor. Using data gathered from these sensors the navigation system performs navigation calculations and controls a rudder servo and sail winch to achieve desired boat performance. Sensor data is also transmitted wirelessly to a ground station via Xbee 900 Hz. Telemetry for data logging purposes.

Sail Control System Summary: The sail control system is based on an inclinometer and a wind vane. Both the main and the jib are controlled by a single 45 mm. tapered-drum sailwinch (RMG 380 EH). The sails are high-aspect ratio to minimize sheet loads. All three rigs have the same distance between the pivots and sheets, and are thus very quickly interchangeable. Our power source is a pair of 7.4 volt 5400 mAh LIPO batteries.