Robotic Sailing guide Documentation

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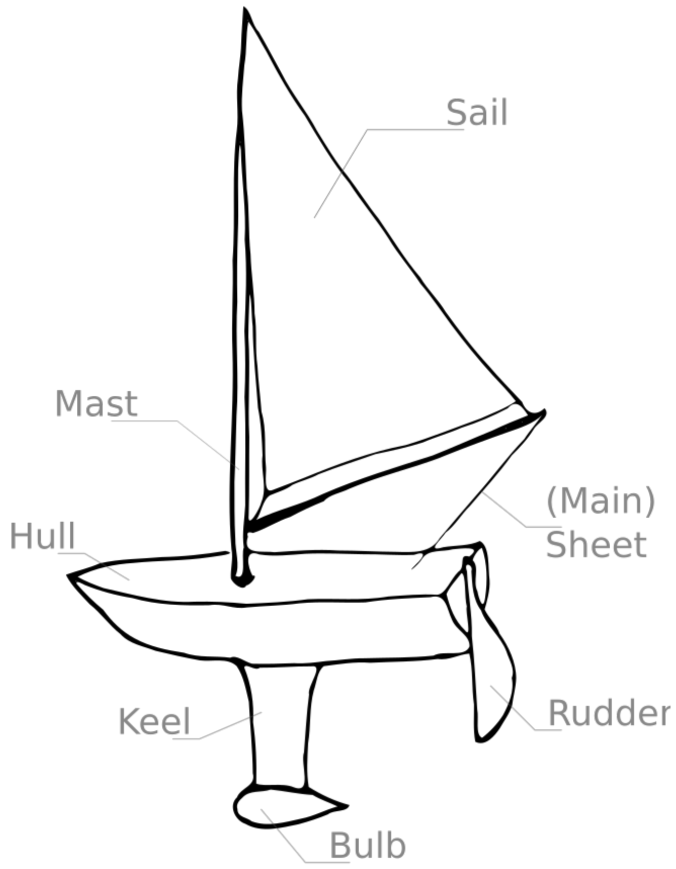
This is an overview of the steps you need to think about to build a small autonomous sailing boat, such as you might need to compete in WRSC. We've tried to provide pointers both for how to get something basic to work, and other approaches you might consider. Depending on the time, knowledge and resources you have available, you can pick which areas to innovate in, and where to get something basic working.

There are three main domains you'll need to think about: the boat, the electronics, and the control software.

CHAPTER 1

The boat



A standard sailing boat has four main parts:

- **Hull**: Base platform, floats in the water. Probably also holds most of your electronics.
- **Sails**: Transfers energy from the wind to the boat. Sails are most effective when acting as an airfoil, not just a bag catching the wind.
- **Keel**: Heavy weight underwater, stops the boat falling over.
- **Rudder**: Sticks into the water, turns to steer the boat.

If you don't want to build your own boat, a good shortcut is to look for remote controlled model sailing boats. Complete boats with servos for the sails and the rudder are available for a few hundred euros/dollars/pounds. The *RC laser* is one popular model, while the *International One Metre* class is a specification that many different models are made to.

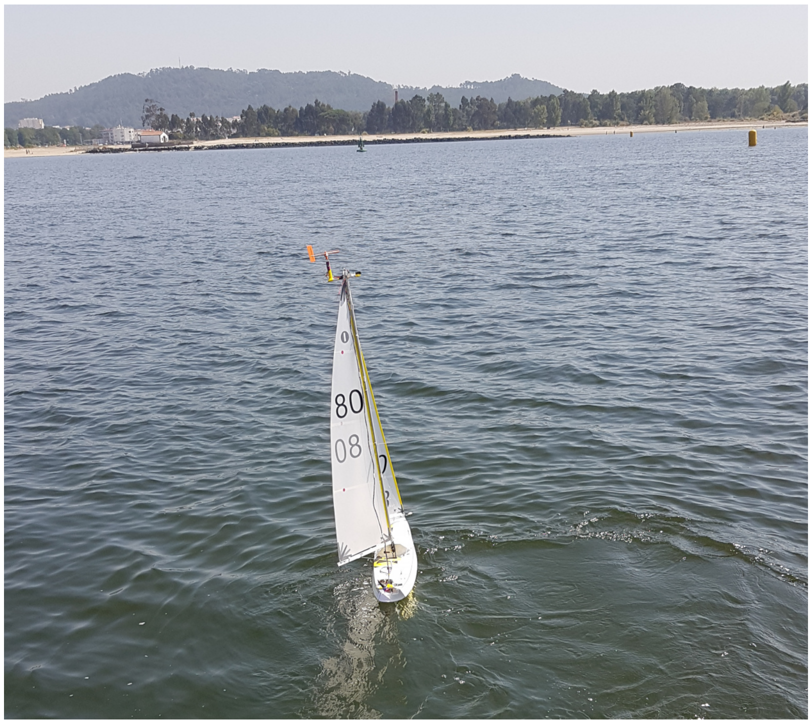


Fig. 1: The *Black Python*, based on an International One Metre class design, at WRSC 2016 (larger image).

If you are interested in building a hull, the MaxiMOOP design is freely available (files on GitHub). This is designed for robotic sailing, and among other features, it has much more space for electronics than most remote controlled boats.

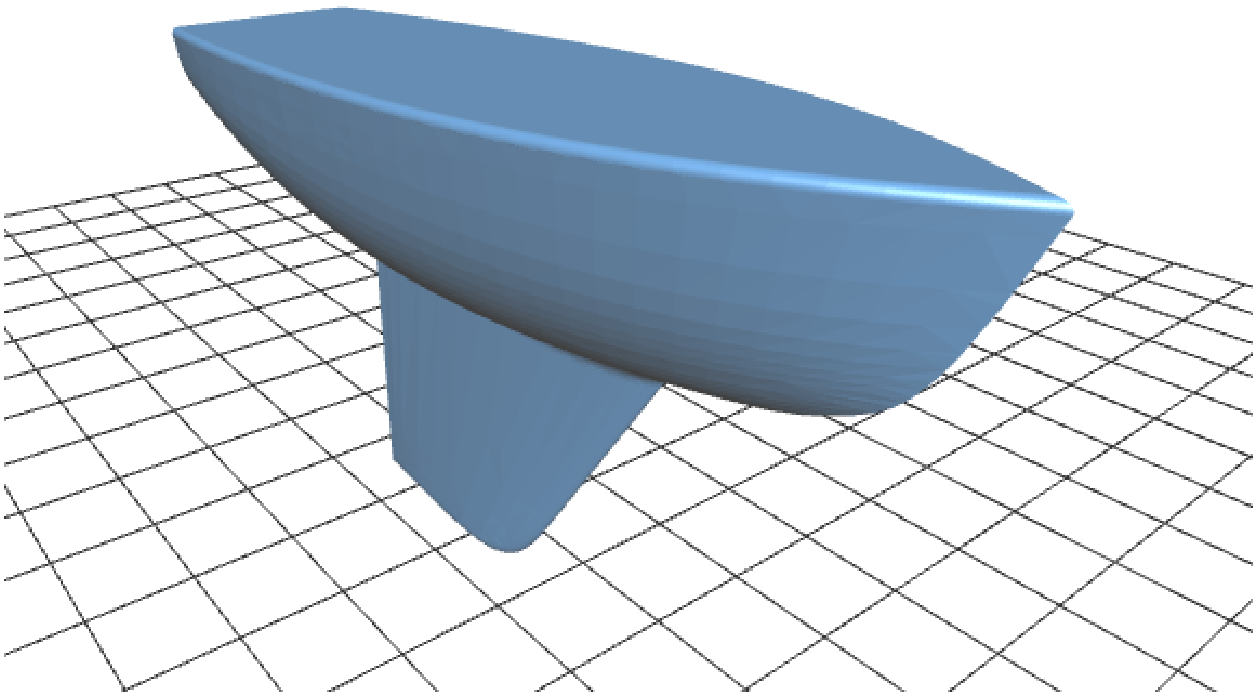
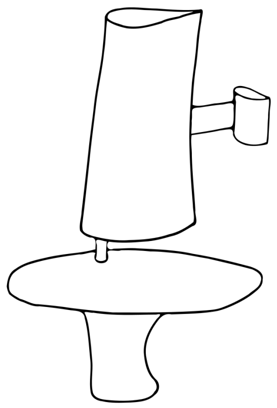


Fig. 2: The MaxiMOOP hull design

1.1 Other things to try



- *Wing sails* are rigid airfoils rather than a flexible sheet. They can be balanced so that changing and holding their position needs little force. Åland sailing robots have used a wing sail controlled by a smaller tail wing, avoiding the need to actively turn the main wing (2016 paper).
- An *air rudder* steers by deflecting air instead of water.
- *Multi-hull* designs, like catamarans and trimarans, have two or more hulls side-by-side, with a gap between them. This can help make the boat more stable.

CHAPTER 2

Electronics

You'll need a computer, at least two motors, and a handful of sensors.

2.1 Computer

Several teams have successfully used a Raspberry Pi as the brains of their boats. Microcontrollers such as Arduinos are another option: these make it easier to work with low-level hardware interfaces like PWM control for servos, but are less flexible for writing high-level control code. What sensors you choose may also affect the kind of computer you need.

2.2 Motors

You'll need to move the sails and the rudder to control the boat. For the micro-sailboat class, a typical hobby-grade servomotor can move the rudder, but more force is needed for the sails: sail winch servos are available for remote-controlled sailing.

If you have multiple sails or multiple rudders, you may want extra motors to control them independently.

2.3 Positioning

GPS - and its cousins generically known as GNSS - are amazing. With an inexpensive receiver you can tap into a network of satellites and get an accurate position.

Making sense of the data can take a bit of effort. You'll probably get a latitude and longitude in a coordinate system called WGS-84 - at this level of accuracy, getting the right reference system matters. For the small distances involved in WRSC, it's convenient to convert positions to coordinates in metres and assume a flat plane. This is what the UTM coordinate system does; you'll need to find which of the 60 UTM zones you're sailing in to get the calculations right.

2.4 Wind sensors

You need to measure the wind direction, and you may also want to know the speed. The simple approach is a physical wind vane and some way of measuring its position, such as a rotary encoder or a magnetic field sensor. Ultrasonic wind sensors measure the direction and speed of the wind with no moving parts, by comparing how sound waves move in different directions.

Wind sensors are typically placed at the top of the mast or near the front of the boat, to minimise interference from the sails.

2.5 Orientation sensors

Sensing which way the boat is pointing is surprisingly tricky. The obvious approach is to measure the earth's magnetic field, like a handheld compass. But the earth's field is weak, and your electronics can interfere with it. If your boat can heel over in the wind, you also need to account for the third dimension.

Combining gyroscopes and magnetic field readings can give more accurate estimates of direction. Inexpensive 'IMUs' combining gyroscopes, magnetic field sensors and accelerometers are readily available. But combining multiple sources of data can also make it harder to understand when things go wrong.

Other ideas, some more practical than others:

- Use only a gyroscope, along with knowledge of which way the boat was pointing when it was started. Relies on having a gyroscope with low enough drift.
- Infer the boat's orientation based on its movements tracked by GPS.
- Have two GPS antennae, one at each end of the boat, and find the difference between their positions.
- Use the position of the sun, along with the local time. It may be possible to use polarised light to estimate the sun's position through clouds; there are suggestions that 'sunstones' were used to navigate this way in mediaeval times.
- Use computer vision to recognise landmarks, in combination with position from GPS.

CHAPTER 3

Control system

Your control system is the code that will monitor your sensors, keep track of what the boat needs to do, and move the motors.

It's useful to have some separation between the parts of code that talk to hardware, and the sailing and navigation logic, so you can test the logic without all the hardware connected.

There are some frameworks that might help you structure your code. Using a framework is more work when you're getting started, but can make it easier for multiple people to understand and work on the same code.

- boatd is specifically designed for robotic sailing boats. It uses a Python-based 'driver' to talk to the hardware, while a separate process controls the behaviour using an HTTP API.
- ROS is a more general robotics framework. Your code is divided into nodes, which each perform one function, such as reading a particular sensor. Nodes can be written in different languages, and communicate by sending messages using a ROS-specific protocol.

3.1 Open source examples

Several teams have published their control systems as open source software, so you can examine them and even reuse them (making sure to follow the appropriate licenses).

Abersailbot Python code built around their boatd framework.

Åland Sailing Robots C++ code (TODO: brief summary of code structure)

Southampton Sailing Robot Team Python code using the ROS 1.x framework.

If your team has an open source codebase, please add it to the list by opening a pull request, or send us the details and we can add it.

CHAPTER 4

More resources

Microtransat Wiki A collection of information from the Microtransat challenge, in which unmanned sailing boats try to cross the Atlantic.

Help us improve this guide

With a free account on GitHub, you can suggest changes to any page by opening an issue or even sending a pull request. The URL is:

https://github.com/WRSC/getting-started

CHAPTER 5

Indices and tables

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