NAVISUITE MOBULA (BLUE ROBOTICS)

FRAME SELECTION

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Contents

1 Frame selection

A frame stands for the thruster configuration on an ROV.
NaviSuite Mobula (Blue Robotics) for the **BlueROV2** supports three configurations:

- **Standard** (6 thruster BlueROV2 configuration)
- **Heavy** (8 thruster BlueROV2 configuration) - used as default frame configuration.
- **Custom** (custom-made thruster configuration)

This document describes the **Custom** configuration in detail.

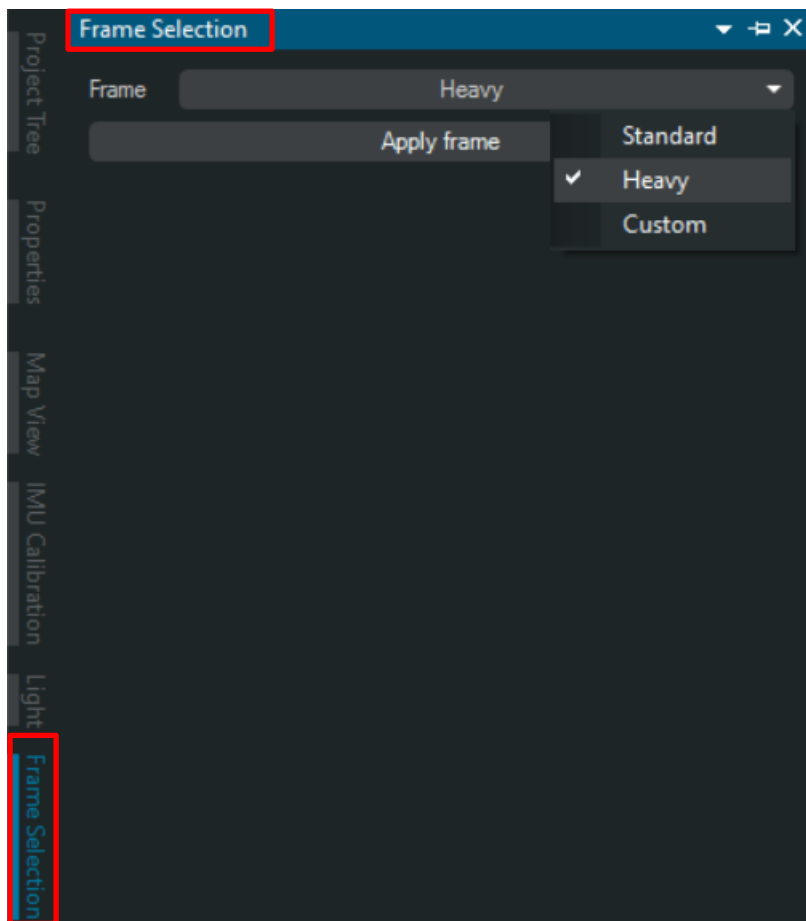The user can find the **Frame Selection** option in NaviSuite Mobula as shown here:

Figure 1 Frame Selection option

More information on frames can be found here: https://www.ardusub.com/quick-start/vehicle-frame.html.

2 Custom frame

2.1 Loading the custom_frame.xml file

The custom frame allows to operate any ROV that is built using the Blue Robotics architecture and/or platform that differs from the Heavy or Standard frame (in other words the number of thrusters and their location on the ROV differ).
The user defines a frame and writes it in into a file (*.xml). See also chapter 2.2 for the file description.
Ideally, the thrusters should be of the T200 type.

When the ROV is connected to the operator's computer and the **custom** frame option is selected in the **Frame Selection** window, a window opens where the user can use the **Browse** button to browse to the file location and load it.
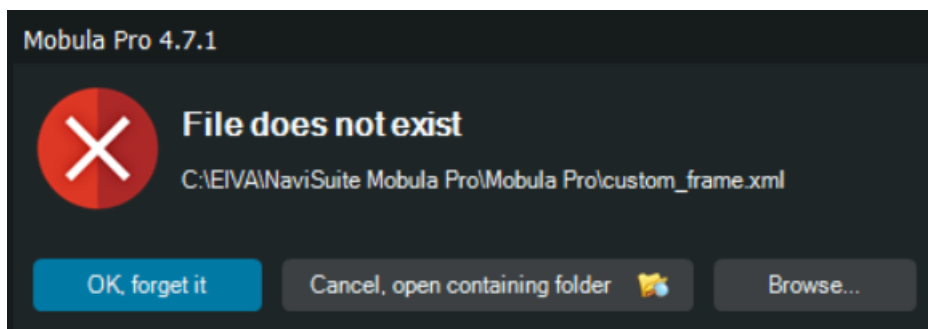

Figure 2 The pop-up window when the file custom_frame.XML is not present in the installation directory

When the file is named **custom_frame.XML** and saved in the installation directory (eg inside **C:\EIVA\NaviSuite Mobula Pro\Mobula Pro)**, the frame within Mobula is changed to **Custom** without prompting the window shown above.

NOTE: The custom frame is an internal, NaviSuite Mobula specific, configuration. It is unique to each project. This means that creating a new project will result in the default configuration, which is not a custom frame.

2.2 Creating a custom_frame.xml file

A custom frame refers to the ROV's thruster layout, or their location on the vehicle relative to the CoG (centre of geometry). Technically, the reference point can be any common point on the ROV, as long as the user is consistent throughout the later use of other software features.

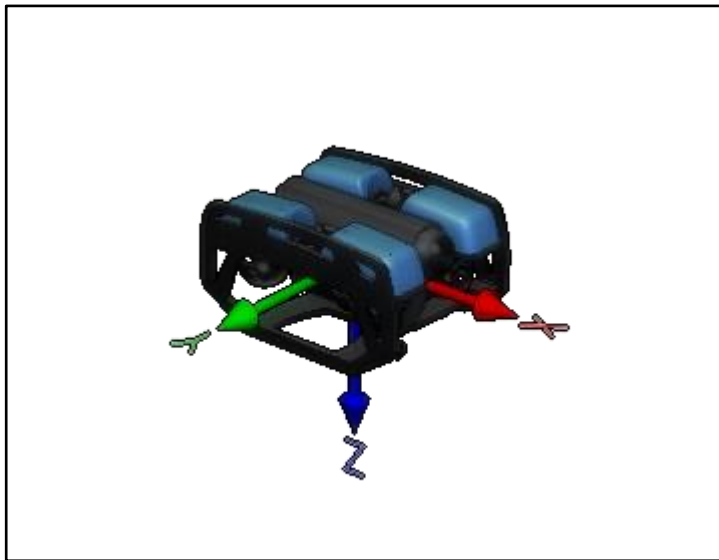A reference frame is the north-east-down body frame, shown in the figure below:

Figure 3 ROV reference frame with north-east-down body frame

To create the file **custom_frame.xml**, the following is needed:

- Position of the thruster frame in the reference frame
- Orientation of the thruster frame in the reference frame
- The blade-direction (eg clockwise or counterclockwise) of the thrusters

This information is specified using three notations:

- **Vector notation**, using the position from CoG to the thruster
  - Orientation is specified with a unit vector in the vehicle frame that aligns with the thruster frame's **X-**direction. The thruster frame **X-**direction is defined from the base of the thruster to the sharp point of the nose. **NOTE**: This representation does not account for thruster mount orientation and only specifies the thrust line produced.

- **Euler notation**, using the position from CoG to the thruster

- Orientation is defined with consecutive elementary rotations using the conventions of yaw-pitch-roll intrinsic rotation or roll-pitch-yaw extrinsic rotations in the ROV frame.
- **SE3 notation**, using the position from the CoG to the thruster and using the orientation from SE3 notation. The convention is the same as in the previous point.

Examples of the three types of notations are shown below.
The examples use the thrusters 1 and 6 from the BlueROV2 Heavy frame.

2.2.1 Vector notation

The Vector notation consists of a vector from the CoG to the thruster, p, and a unit vector in the thruster X direction, $\hat{v}$, in the ROV body frame.

$$\boldsymbol{p}_1 = \begin{bmatrix} 0.156 & 0.111 & 0.085 \end{bmatrix}^T$$
$$\boldsymbol{p}_2 = \begin{bmatrix} 0.12 & -0.21805 & 0 \end{bmatrix}^T$$
$$\hat{\boldsymbol{v}}_1 = \begin{bmatrix} -0.7071068 & 0.7071068 & 0 \end{bmatrix}^T$$
$$\hat{\boldsymbol{v}}_2 = \begin{bmatrix} 0 & 0 & 1 \end{bmatrix}^T$$

```xml
<?xml version="1.0" encoding="utf-8"?>
<frame>
  <frame_name>BlueROV Heavy</frame_name>
  <motor>
    <unique_id>1</unique_id> <!--Channel motor is connected to in Pixhawk. First channel is 1-->
    <direction>ccw</direction> <!--Spin direction of the motor. cw or ccw-->
    <position>
      <fore>0.156</fore>
      <starboard>0.111</starboard>
      <heave_NED>0.085</heave_NED>
    </position>
    <attitude_rotation_vector>
      <roll_deg>-0.7071068</roll_deg>
      <pitch_deg>0.7071068</pitch_deg>
      <yaw_deg>0</yaw_deg>
    </attitude_rotation_vector >
  </motor>
  <motor>
    <unique_id>6</unique_id> <!--Channel motor is connected to in Pixhawk. First channel is 1-->
    <direction>cw</direction> <!--Spin direction of the motor. cw or ccw-->
    <position>
      <fore>0.12</fore>
      <starboard>-0.21805</starboard>
      <heave_NED>0</heave_NED>
    </position>
    <attitude_rotation_vector >
      <roll_deg>0</roll_deg>
      <pitch_deg>0</pitch_deg>
      <yaw_deg>1</yaw_deg>
    </attitude_rotation_vector >
  </motor>
</frame>
```

Figure 4 Example of Vector notation

2.2.2 Euler notation

The Euler notation consists of a vector from the CoG to the thruster, $\boldsymbol{p}$, and the euler angles between the two frames (Thruster frame in ROV Body Frame). The convention is yaw-pitch-roll as intrinsic rotations or roll-pitch-yaw as extrinsic rotations in the ROV frame.

$$\boldsymbol{p}_1 = \begin{bmatrix} 0.156 & 0.111 & 0.085 \end{bmatrix}^T$$
$$\boldsymbol{p}_2 = \begin{bmatrix} 0.12 & -0.21805 & 0 \end{bmatrix}^T$$
$$\boldsymbol{\theta}_1 = \begin{bmatrix} 0 & 0 & 135 \end{bmatrix}^T$$
$$\boldsymbol{\theta}_2 = \begin{bmatrix} 0 & -90 & 0 \end{bmatrix}^T$$

```xml
<?xml version="1.0" encoding="utf-8"?>
<frame>
  <frame_name>BlueROV Heavy</frame_name>
  <motor>
    <unique_id>1</unique_id> <!--Channel motor is connected to in Pixhawk. First channel is 1-->
    <direction>ccw</direction> <!--Spin direction of the motor. cw or ccw-->
    <position>
      <fore>0.156</fore>
      <starboard>0.111</starboard>
      <heave_NED>0.085</heave_NED>
    </position>
    <attitude_euler_angles>
      <roll_deg>0</roll_deg>
      <pitch_deg>0</pitch_deg>
      <yaw_deg>135</yaw_deg>
    </attitude_euler_angles>
  </motor>
  <motor>
    <unique_id>6</unique_id> <!--Channel motor is connected to in Pixhawk. First channel is 1-->
    <direction>cw</direction> <!--Spin direction of the motor. cw or ccw-->
    <position>
      <fore>0.12</fore>
      <starboard>-0.21805</starboard>
      <heave_NED>0</heave_NED>
    </position>
    <attitude_euler_angles>
      <roll_deg>0</roll_deg>
      <pitch_deg>-90</pitch_deg>
      <yaw_deg>0</yaw_deg>
    </attitude_euler_angles>
  </motor>
</frame>
```

Figure 5 Example of Euler notation

2.2.3 SE3 notation

The SE3 notation uses the following notation:

$$\begin{bmatrix} \boldsymbol{R} & \boldsymbol{p} \\ \boldsymbol{0}_{1\times3} & 1 \end{bmatrix}$$

where **R** is the rotation matrix, and *p* is the position of the centre of the thruster from the CoM. An example of a custom_frame.XML file is shown below using the SE3 notation. The convention is yaw-pitch-roll as intrinsic rotations or roll-pitch-yaw as extrinsic rotations in the ROV frame.

$$\boldsymbol{p}_1 = \begin{bmatrix} 0.156 & 0.111 & 0.085 \end{bmatrix}^T$$
$$\boldsymbol{p}_2 = \begin{bmatrix} 0.12 & -0.21805 & 0 \end{bmatrix}^T$$
$$\boldsymbol{R}_1 = \begin{bmatrix} -0.7071 & -0.7071 & 0 \\ 0.7071 & 0.7071 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$
$$\boldsymbol{R}_2 = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ -1 & 0 & 0 \end{bmatrix}$$

```xml
<?xml version="1.0" encoding="utf-8"?>
<frame>
  <frame_name>BlueROV Heavy</frame_name>
  <motor>
    <unique_id>1</unique_id> <!--Channel motor is connected to in Pixhawk. First channel is 1-->
    <direction>ccw</direction> <!--Spin direction of the motor. cw or ccw-->
    <SE3>
      [-0.7071, -0.7071, 0, 0.156;
      0.7071, -0.7071, 0, 0.111;
      0, 0, 1, -0.085;
      0, 0, 0, 1]
    </SE3>
  </motor>
  <motor>
    <unique_id>6</unique_id> <!--Channel motor is connected to in Pixhawk. First channel is 1-->
    <direction>cw</direction> <!--Spin direction of the motor. cw or ccw-->
    <SE3>
      [0, 0, 1, 0.12;
      0, 1, 0, -0.21805;
      -1, 0, 0, 0;
      0, 0, 0, 1]
    </SE3>
  </motor>
</frame>
```

Figure 6 Example of SE3 notation

3 Changing a thruster's direction of rotation

It is possible that one or more of the thrusters needs to change direction of rotation. This can happen because it has been wired in a different way, or a different propeller type was used. There are two ways of changing the direction of the thruster's rotation, so that the ROV is propelled in the correct way.

1. Changing the **direction** tag inside the **custom_frame.XML** file for the respective thruster. The XML file needs to be saved and reloaded using the **Frame Selection** window.
2. For a temporary solution that does not require reloading the XML file or rebooting the vehicle, the **Thruster properties** window can be used, as shown in the following figure as well as presented in the user guide:
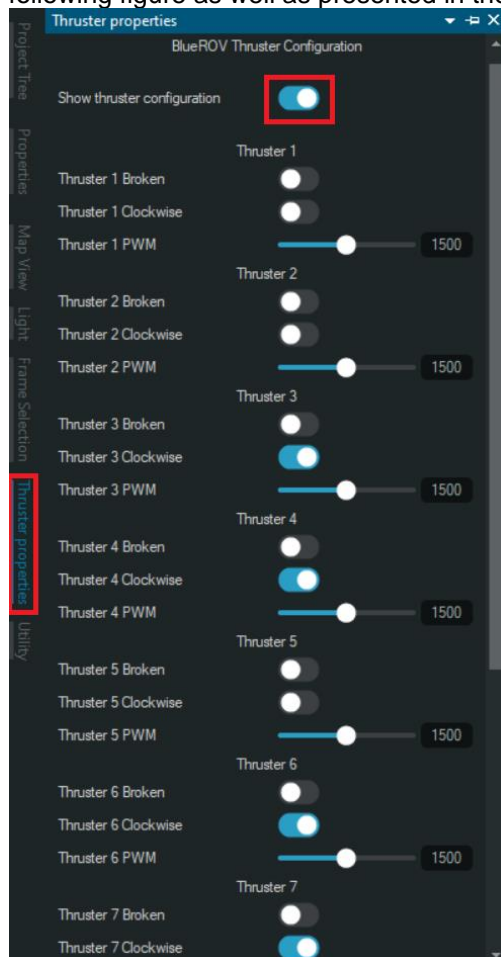

Figure 7 Thruster properties window

When the **Thruster properties** window is open and the **Show thruster configuration** toggle is activated, the direction of each thruster's rotation is available. For example, if the toggle **Thruster 1 Clockwise** is active, then for PWM values above *1500* thruster 1 will spin clockwise.

Thruster properties can be saved with the project. The same project needs to be loaded inside NaviSuite Mobula so that the saved configuration is also loaded.

4 Appendix

Abbreviation:

CoM Center of mass
CoG Center of geometry

5 Version descriptions

Version	Date	Author	Description
1	15/11/2021	IMA	First version of the document
2	09/11/2022	AHO	Extension to additional orientation specifications