Marine Cybernetics Vessel CS Saucer:

Design, Construction and Control

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Introduction

CS Saucer is designed to be a highly maneuverable vessel driven by three azimuth thrusters. This master thesis aims to provide a fully functioning vessel with multiple operational modes and serve as a teaching tool and a stable platform for future projects in the MC Lab at NTNU.

Construction

The hull of the vessel is bowl shaped and a plexi glass lid is fitted on top. The hull is constructed with a milled ring of divinycell fitted to a mdf plate. A construction drawing of the divinycell ring taken from the 3D model of CS Saucer can be seen in Figure 1. The outer surface of the hull is coated with carbon fiber sheets and epoxy. The thrusters are powered by three Torpedo 800 motors which in turn are controlled by three Marine 30 electronic speed controllers. The rotation of the three thrusters is controlled using three Graupner DS8311 servo motors. Both the servo motors and the electronic speed controllers receive PWM signals from a National Instruments myRIO. The myRIO is a FPGA re programmable target with wifi, accelerometer and multiple digital and analog in and out connections.

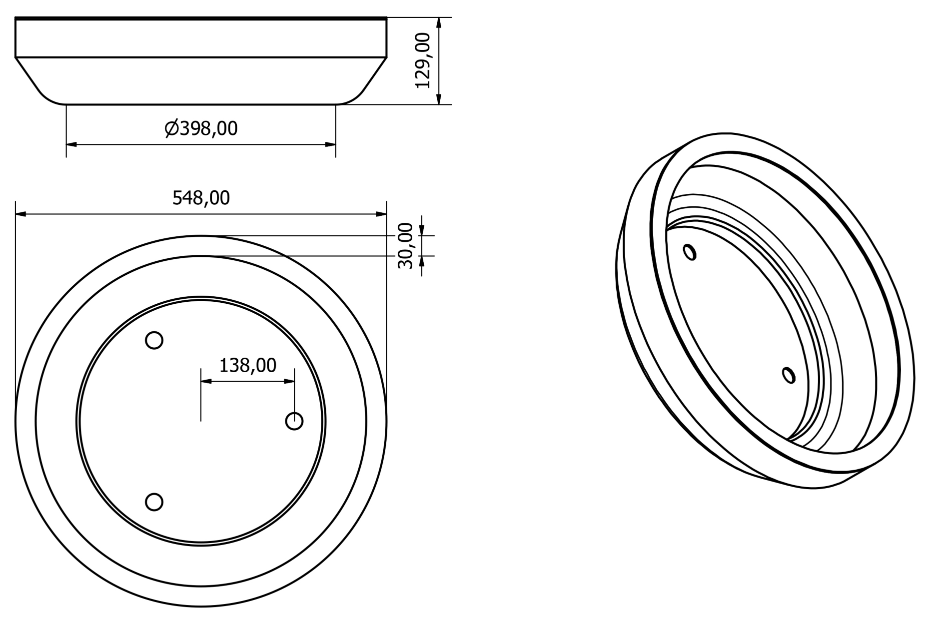

Figure 1: Divinycell foam ring modeled by Jostein Follestad.

Figure 2 shows CS Saucer as it looks today. The construction process is completed except for a few cosmetic issues.

Figure 2: The finished vessel CS Saucer.

Thrust Allocation

The thrust allocation for the CS Saucer has been simplified by using fixed angles on the azimuth thrusters. The orientation of the three thrusters is shown in Figure 3.

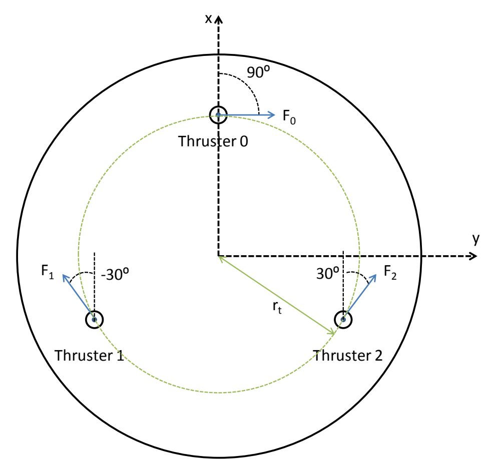

Figure 3: Thruster configuration for CS Saucer with fixed azimuth angles.

The equation for the forces and moments in three degrees of freedom can be expressed as

$$\tau = TKu_e$$

$$\begin{bmatrix} X \\ Y \\ N \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 1 \\ r_t & l_x & -l_y & -l_x & -l_y \end{bmatrix} \begin{bmatrix} K_0 & & & & \\ & K_{1_x} & & & \\ & & K_{1_y} & & \\ & & & K_{2_x} & \\ & & & & K_{2_y} \end{bmatrix} \begin{bmatrix} u_0 \\ u_{1_x} \\ u_{1_y} \\ u_{2_x} \\ u_{2_y} \end{bmatrix}$$

where the extended vector u_e is created using the fixed angles of the three thrusters and their mapping to the original vector u.

$$u_e = Lu$$

$$u_e = \begin{bmatrix} 1 & 0 & 0 \\ 0 & cos(\frac{\pi}{6}) & 0 \\ 0 & -sin(\frac{\pi}{6}) & 0 \\ 0 & 0 & cos(\frac{\pi}{6}) \\ 0 & 0 & sin(\frac{\pi}{6}) \end{bmatrix} \begin{bmatrix} u_0 \\ u_1 \\ u_2 \end{bmatrix}$$

The gain matrix K has been designed based on the experimental data where the force produced by each thruster has been measured while running the vessel in surge and sway with force rings attached. An approximation of the force generated by each thruster has been obtained using linear curvefitting in MatLab. The results for positive surge and sway command from this thrust allocation test is shown in Figure 4.

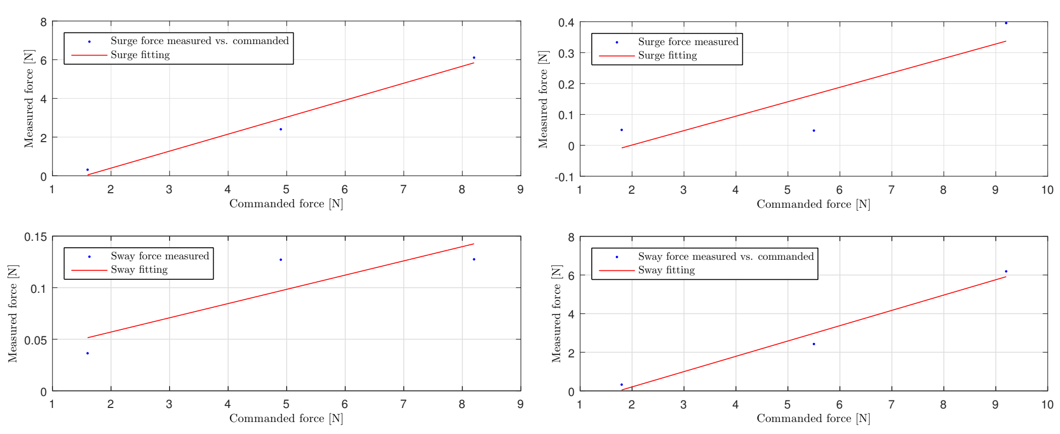

Figure 4: Thrust allocation test, positive surge (left). Thrust allocation test, positive sway (right).

Operational Modes

The software controlling the vessel is developed in LabView. The host interface running on the host laptop provides realtime monitoring and the availability to switch between operational modes. Alternatively, the vessel can be directly in one of the manual modes from the National Instruments Dashboard app available on Android and iOS devices.

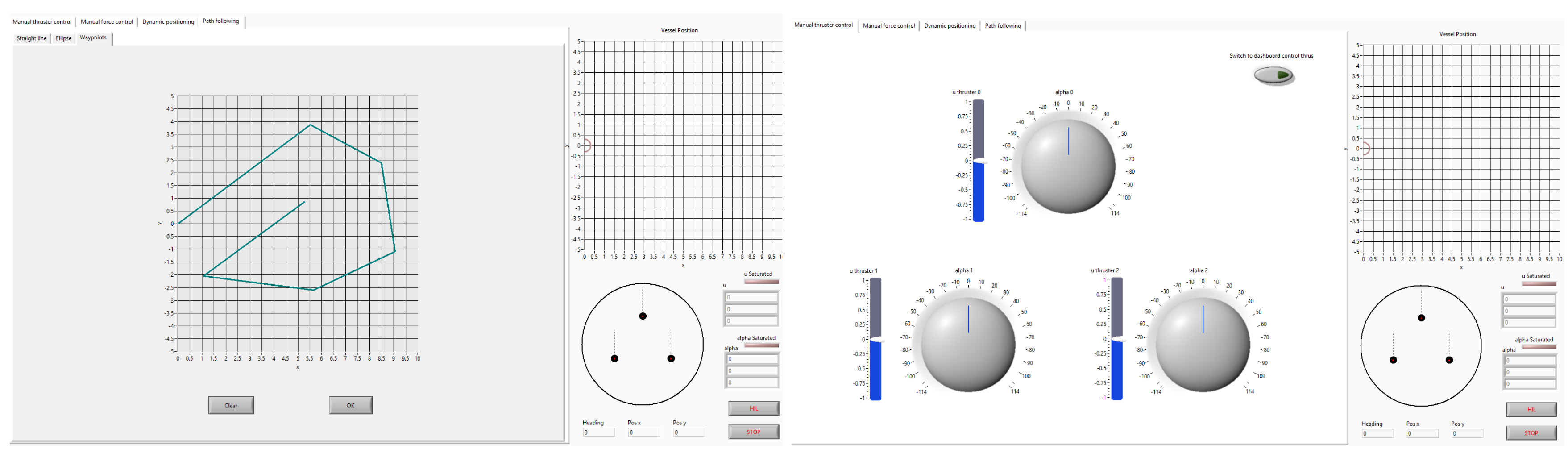

Figure 5: Path following user interface (left). Manual thruster control user interface (right).

Figure 5 shows two of the operational modes that can be run from the host user interface. Waypoints are set using a mouse event listener in LabView so that the user can generate waypoints by clicking on the graph. In addition to waypoints it is also possible to generate a straight path trajectory and an ellipse trajectory. Manual thruster control enables control of the three thrusters and their rotation. In the manual force control interface the user commands a desired combination of forces and moments in surge sway and yaw. Dynamic positioning is implemented with a PID controller in LabView. Both manual thruster control and manual force control can be commanded directly from the Dashboard app to the target myRIO. The user can set the reference and adjust the PID gains from the host user interface. Path following is implemented using heading and speed control and using heading on waypoint as a maneuvering strategy.