This project can be very broadly divided into two segments, the simulation segment and the control system segment. The goal is that the simulation is to be as true to reality as possible. With a true-to-life simulation, a control system can be built to work in the simulation. Once the control system is created and tested satisfacotrily, it can hypothetically be "transplanted" to the physical test. Because of these two different segments, I will talk about them separately.

1 Details on the simulation setup

The exact details of the implementation are more specifically brought up in the specialization project [?]. Below is a brief elaborate of the simulation setup, further than what was mentioned in **??**.

The two vessels to be simulated are the surface vessel and the ROV. The ROV was simplified as a cuboid with the proper dimensions according to the manufacturer's specifications. The ROV to be used is a modified BlueROV2 Heavy made by Blue Robotics. The dimensions of which are 575 x 254 x 457 mm (WxHxD). The density of the ROV has not been tested, but is implemented in the simulation as 2000kg/m$^{\mathbf{3}}$. This is a rough estimation and the real density is likely lower.

The surface vessel was modelled roughly in CAD and then exported as a `.obj` 3D-file for AGX to work with. The dimensions and shape of the vessel are roughly corresponding with the real vessel, though not exactly as it was intended to be exchanged for a more detailed model produced by a different master project at a later date. The density of the surface vessel is implemented at 600kg/m$^{\mathbf{3}}$ which was arrived at by taking a rough average of the different densities of carbon fiber sandwich plate we had for building the hull and then adding some extra mass to account for batteries, sensorics and other added weights.

As a note on the densities of the vessels: while AGX is able to model non-uniform densities and varying density distributions, this was not implemented in this simulation simply for the constraint of time. It was assumed that the loss of accuracy from assuming uniform density is small enough not to matter. This will be further discussed in **??**

Since the ROV sinks it needs help staying afloat. This is achieved by a tether connected to the surface vessel. The tether is modelled as a non-buoyant rope/wire with a radius of 10mm and a Young's modulus of 10^9. These figures are all assumed values and should be corrected when the real values from the physical implementation are known.

The two vessels and the tether are placed in a 200x200x120m pool of water. It is possible in AGX to simulate different sea-states, this was a part of the development work done for this project.

1.1 Improvements made since specialization project

During the specialization project, it was not possible to implement the simulation as one decoupled from the controller. As such, the end result was that both the controller and the plant were running in the same simulation script. This has been improved upon now as the controller and its parts has been separated from the simulator and are now running as separate nodes commuicating via ROS2. The full ROS2 graph can be seen in **??**. Decoupling the simulator and the various controller nodes has allowed for work to progress slightly faster and more reliably.

In addition, the simulator now is capable of simulating the winching movement of the winch on the ROV. Previously it was implemented as a fixed length wire. This means that the crane now is able to operate. A basic controller for the crane has been created as well.

The simulation has been further developed to allow for more dynamic changing of the seastate. Originally the seastate was implmented as no sea. This is now changable by changing a single variable. The sea is simulated using the wave height equation, **??**

$$h = 0.5\sin(0.5x + 0.6t) + 0.25\cos(0.6y + 0.3x + 1.45t) \tag{1}$$

Where h is the height above $z = 0$, x and y are the position in the horizontal plane and t is the time since the simulation started.

2 Case description

The USV controller implemented is quite simple. It has no predictive capability and is completely reactive. This scenario is made to compare the controller's actions as well as the error of the system in calm seas as well as in more moving seas. The simulation framework does allow for current and wind simulations as well, but these are not implemented and thus will not be simulated. The goal for the surface vessel is to stay stationary, simulating an operation where dynamic positioning is necessary for the ROV to do its work.

Three cases will be compared here: No sea, low sea and high sea. The different kinds of seas are simulated with the same wavelength but different wave heights. The wave simulation is a simple regular wave in two dimensions with its wave height defined by the equation **??**. The equation was taken from Algoryx's examples for buoyancy simulation for simplicity and ease of use. The actual value of the equation is irrelevant in the larger scheme of things because the only thing it's doing is providing a local height offset. This offset will then be used to determine how far from the zero-height of the world the vessel is. This equation has been deemed to be "random enough" for the control system to get some challenges. Further discussion around using a regular seastate is done in **??**

The expected response assuming a well functioning system is that the error should be relatively minor, but there is the danger of the seas being too high.

If the seas are two high there are two potential faults, the surface vessel might capsize or the thrusters might exceed their authority. The first fault is obviously disastrous and should be avoided at all costs. The second is unfortunate and might lead to loss of control or scrubbing of the mission. Both of these faults can be used as limits to find the maximum acceptable operational criteria for a mission.