Vortex NTNU - Robosub 2020

Manta-2020
Norwegian University of Science and Technology

Abstract **- Vortex-NTNU is a student-organization that is located at NTNU at Gløshaugen in Trondheim. The organization has ranged from 18-24 students from different engineering disciplines at NTNU, hiring new students each year. The main purpose of the organization is to build underwater vehicles that is capable to compete in underwater competitions, such as Robosub and MATE international ROV competitions. The 2020 team consist of 25 members consisting of five groups. The software-control, software-perception, hardware-mechanical, hardware-electronic and marked. The control team is mostly responsible for the guidance and control system of Manta, while the perception team is responsible for most of the navigation system and sensor-interfacing. The hardware teams are responsible for the hardware-design, electronic communication with the sensors, embedded micro-controller and thrusters, waterproofing and computer aided graphics design. The marked team is responsible for the website, merch and marketing.**

COMPETITION STRATEGY

This year we have further developed the AUV aspects of Manta-2019. We have mainly focused on testing the software by performing experimental pool tests. With new sensor like the sonar, the focus were shifted to integrate this with the navigation algorithms, giving a more reliable localization. Our strategy was to reach the Robosub finals, gathering as many points as possible in the gate, bouy and torpedo tasks.

VEHICLE DESIGN

Manta-2020 is an inspection-class hovering AUV designed and developed by students of the student-organization Vortex-NTNU. Manta both serves as an experimental underwater platform for students writing their master thesis and as an AUV that competes in the Robosub competition. The main idea is to give students practical experience with underwater robotics and foster ties to organizations and companies developing AUV technologies.

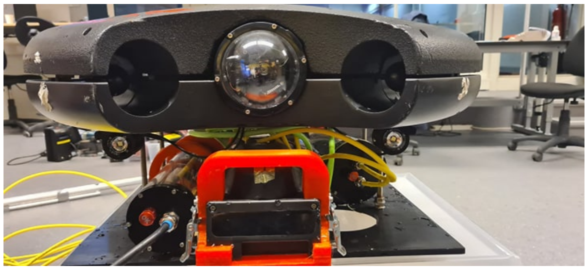

Fig. 1: Manta-2020 front view

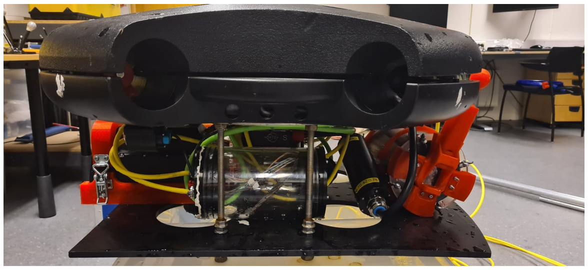

Fig. 2: Manta-2020 side view

A. Sensor and thruster stack

In order for the AUV to perform accurate maneuvers from the guidance and control system, it is critical that the navigation system is robust. An important part of this robustness comes from having accurate and precise sensors. The choice of sensors therefore plays an important part for the autonomy. What type of sensors also plays an critical role. By choosing sensors that provides measurements of the navigational states, will increase the observability of the GNC system. By having too few observable states will limit the control and guidance system, meaning less robust maneuvering in the AUV's mission plan. For example in trajectory and path following. Manta-2020 is here equipped with an IMU from Sensornor, STIM300, Blue Robotics Low-light HD Camera used for object detection, FLIR Blackfly S camera to use for object detection and slam, Gemini 720i-imaging sonar and a Nortek DVL1000.

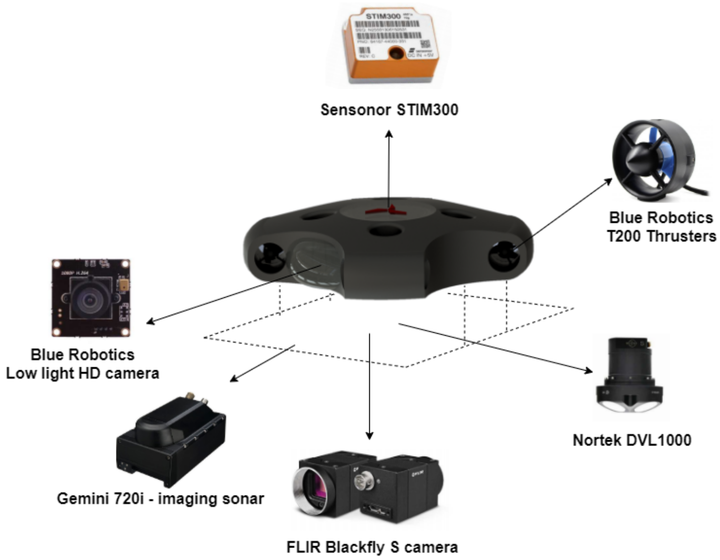

Fig. 3: Manta-2020 sensor stack

The design and choice of actuators also plays a critical role. There respective location and number determines the controllability of the system, which in the end determines how many degrees of freedom the controller can control. Here Manta-2020 is equipped with 8 T200 Blue Robotics thrusters, which is an three-phase out-runner motor, which run with a nominal voltage between 12-16 volt, with a maximum of 20 volt.

B. Electronics system

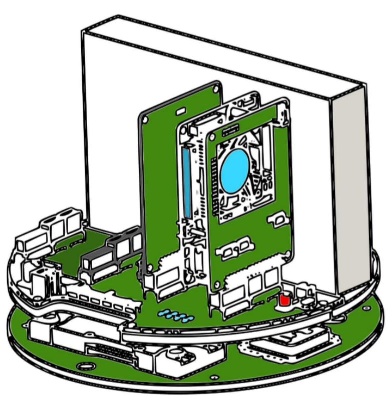

Fig. 4: Manta-2020 motherboard

Figure 4 shows the electronic motherboard on Manta-2020. On the lower right side, is an Odroid XU4 microcontroller. This computer acts as Mantas On-Board main computer (OBC), which is responsible to run the GNC system. The odroid has an Exynos 5422 application processer. This processer has a ARM quad-core Cortex A15 (2.0 Ghz) plus a ARM quad-core Cortex A7 (1.3 Ghz) CPUs. It is also packed with 2 GB LPDDR3 RAM at 933 Mhz. The OBC is installed with Ubuntu minimal 16.04 to make less use for graphical user interface and other background programs that are not needed. These programs may higher the computational burden on the microcontroller and may potentially lower the computing power needed for the GNC system. The Odroid is also interfaced with a number of peripheral modules which are connected with a dedicated NanoPi Neo plus 2 SBC for standalone communication with the OBC. The use of a dedicated SBC makes Manta-2020 modular and makes it possible to do changes without opening the main electronic enclosure. On the upper right corner is the location of the switch. This switch has 6 Ethernet input ports which are connected to the sonar,DVL, front camera and carrier board of the Nvidia Jetson TX2.

Manta is also equipped with a NVIDIA Jetson TX2 4GB module. Since this module is packed with a 256-core NVIDIA pascal GPU, it is responsible for pre- and post processing of the camera feedback coming from the FLIR Blackfly S and Blue Robotics HD camera.

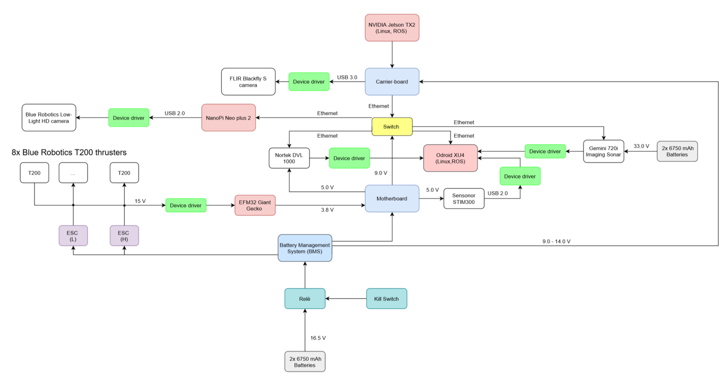

Fig. 5: Manta-2020 electronic overview

Looking at figure 5 the NVIDIA Jetson TX2 is connected to its TX2 carrier board j120. This unit is packed with 1 USB 2.0, 1 USB 3.0 port and ethernet jack. The USB 3.0 is used for communcation with the FLIR Blackfly S and the ethernet jack is connected to the switch. Also seen in figure 5 the STIM300 is connected with a USB 2.0 directly to the Odroid XU4 USB 2.0 hubs. This standard was used because of the easy interface with the device driver, that was written in-house in C++11. The DVL is connected with a Ethernet connection to the switch. Its device driver is also written in-house in Python 2.7. Manta-2020 is also equipped with a kill switch, which turns off the battery voltage with the use of an magnetic sensor packed on the relè.

C. Software system overview

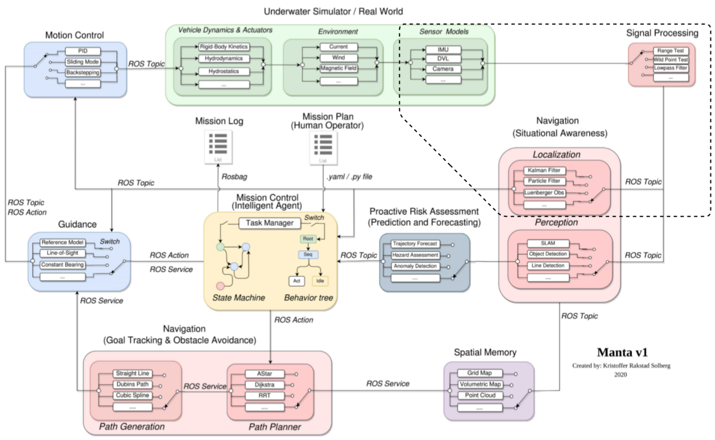

Fig. 6: Manta-2020 software system overview

Manta-2020 software architecture is based on a distributed network topology and a client/server network communication between the components. This communication is provided by ROS kinetic devel.

The complete general schematic overview of the software of Manta-2020 is seen in figure 6. The flow starts at the mission plan and travels clockwise as shown by the arrows. Here a human operator or a communicator sets apriori information. This is may be of the form of targeted way-points or a global or local map of the environment the AUV will operate in. This information is needed in order to get the reference information, such that the GNC can calculate its errors with the reference. These waypoints or maps are then added into a *.yaml* or *.py* file. These will then be interpreted by a task manager such as a finite state machine or a behavior tree. Once the mission controller is finished compiling, it will arm the thrusters and launch the exteriorceptive and interoceptive sensors modules by roslaunch commands. The raw_data coming from each sensor is being published through a ROS topic coming from their implemented device drivers as shown in the figure 6. The measurements are then going through a signal processing block, such as a range test, wild point test or a lowpass filter. The filtered measurements are then also published by a ros-topic to a localization node, such as a Kalman filter, nonlinear observer, particle filter or a Luenberger observer. Exteriorceptive sensory information such as camera feedback is going trough either SLAM, object detection or line detection. All of this "situational awareness" information is then going trough a Proactive Risk Assessment and spatial memory which then go further to the path planner and path generator. In this report the main focus will be the blocks inside the dotted lines shown in the higher right corner in figure 6. Specifically the sensor models for the interoceptive senors like the IMU, pressure gauge sensor and DVL, signal processing such as a wild point filter for the accelerometer and angular rate sensor for the IMU, a nonlinear state observer, Joan Solàs version of the Error-state Kalman-filter and a extended Kalman-filter from Charles River Analytics, Inc.

EXPERIMENTAL RESULTS

The testing has been both done in the Gazebo simulator and in a test pool at the MC-lab in Tyholt, Trondheim. Also the mechanical hardware team made a physical version of the gate and bouy tasks of the Robosub 2020 used to test the software algorithms.

ACKNOWLEDGEMENTS

Vortex NTNU would like to thank the following contributors for their support and guidance in the development and production of Manta, and making our journey to the 2019 RoboSub competition possible:

- Robonation: For hosting Robosub
- Equinor: Our main collaborator. Funding most of our components, and technical guidance
- NTNU Department of cybernetics and Department of Marine Technology: Providing offices, labs and workshop areas. Funding of lab equipment, components and pool facilities.
- FFU: Financial support and the opportunity to write for Norways largest news magazine for subsea technology and underwater robotics, DYP.
- Nortek AS: Providing one of their high quality DVL1000 - Doppler Velocity Log.
- Innova: Providing us with the Gemini 720i imaging sonar.
- Falk: Providing Vortex merch.

APPENDIX A

Component	**Vendor**	**Model/Type**	**Specs**	**Cost (if new)**
Bouyancy control	Mechman AS			
Frame	3A Prototype			
Waterproof Housing	Machined inhouse + bluerobotics			
Waterproof Connectors				
Thrusters	Bluerobotics	T200		8*170$
Motor Control				
High Level Control				
Actuators				
Propellers				
Battery				
Converter				
Regulator				
CPU	ODROIDXU4 + NVIDIA TX2			
Internal Comm Network	Ethernet			
External Comm Interface	Ethernet			
Programming Language 1	C++			
Programming Language 2	Python			
Compass				
Inertial Measurement Unit	Sensonor	STIM300		
Doppler Velocity Log (DVL)	Nortek	DVL1000		
Hydrophones	Water Linked AS	A1		
Manipulator				
Sonar	Tritech	Gemini 720i - imaging sonar		
Algorithms: vision	Yolo v3 tiny			
Algorithms: acoustics				
Algorithms: Localization and mapping	Orb - slam			
Algorithms: autonomy	Smach			
Open source software	ROS			
Team size (number of people)	25 members			
HW/SW expertise ratio	1/3			
Testing time: simulation	200 hours			
Testing time: in-water	100 hours			