Marine and Naval Technological Advancements for Robotic AutonomY (MANTA RAY)
KRILL

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MANTA RAY Mission

Team MANTA RAY is an interdisciplinary marine robotics project focused on seafloor mapping and underwater perception. As shown in Figure 1, the project emphasizes inter-vehicle communication, autonomous behavior, and all system and subsystem improvements to increase precision and performance.

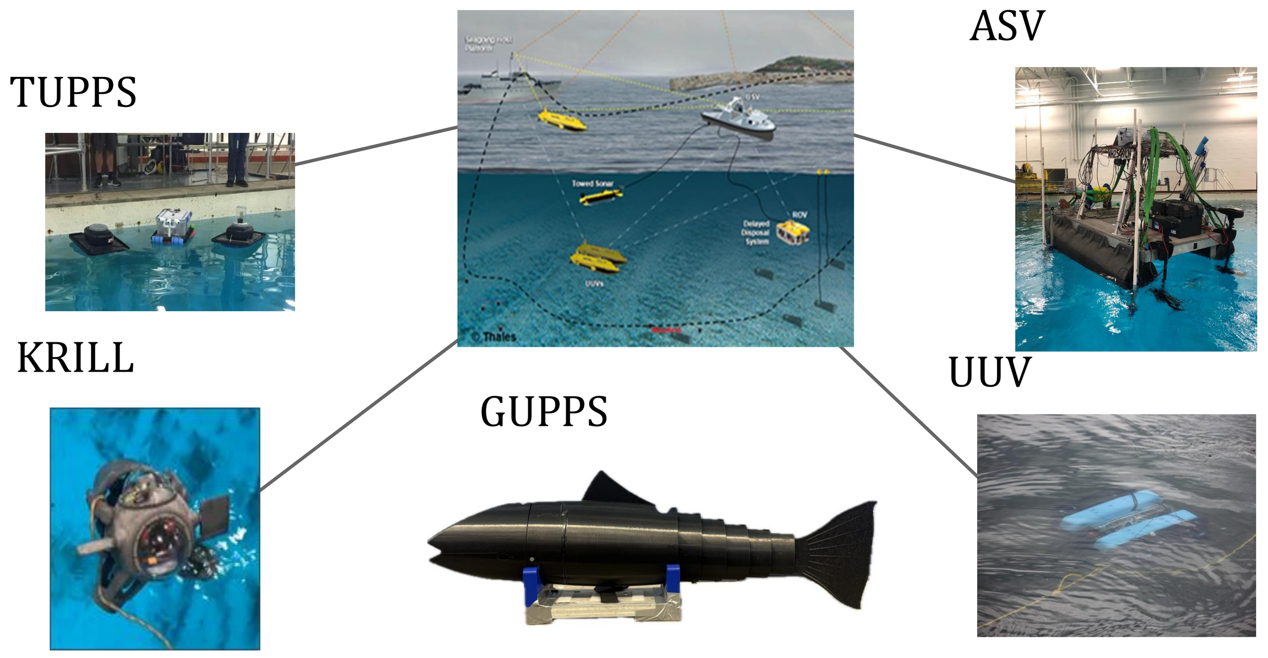

Figure 1: MANTARAY Mission

KRILL Mission and Goals

KRILL is an Uncrewed Underwater Vehicle (UUV) developed initially by the Naval Undersea Warfare Center (NUWC), Keyport WA. The purpose of KRILL is to be a modular observation class UUV which can be outfitted easily to new technologies. KRILL is also designed to be rapidly assembled and deployed allowing for a swarm to be created and work together mimicking a much larger vehicle.

Goals:
- Redevelop electronics for ease of production
- Integrate sensor feedback and build further autonomy
- Replicate KRILL to create swarm

Key Features:
- Fully enclosed hull
- Magnetic connections between motors and propellers
- Built from 3D printed parts, increasing modularity and customization.

Fig 2: Mission ready KRILL

Software Enhancements

- Remapped joystick axes for intuitive control; servos hold position when idle to prevent drift
- Independent side motor control enabling differential drive, point turns, and wall-following
- Acceleration smoothing ramps thrust gradually to reduce jerk and improve underwater stability
- Auto-depth hold via closed-loop Bar30 pressure feedback, engageable by button with manual override
- Rewrote codebase for Arduino-based motor control with custom Tkinter GUI displaying live depth, temperature, and pressure data

KRILL Electronic System

- Limited space and overheating Raspberry Pi required redesign
- Integrated Arduino Nano as secondary controller
  - Offloads motor control to free computation on PI
  - Compact size saves space compared to previous versions
- Decreased overhead allows sensor connection to PI
  - Reads data such as pressure, acceleration, and angle
- Test bed created to aid development and testing.

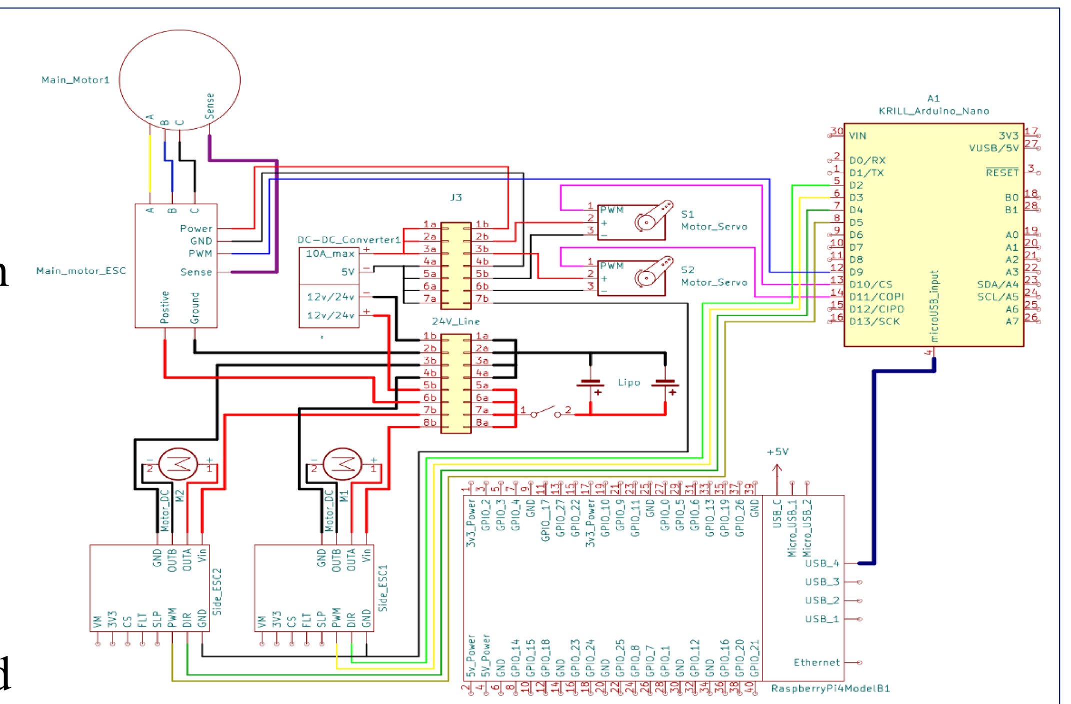

Fig 3: KRILL internal wiring diagram

"Slot" design for housing uses modular slots
- Each slot holds key components
- Improves accessibility for maintenance and upgrades
- Electronics are assembled externally then slotted in
- Organizes control system into power, computation, and control sections.

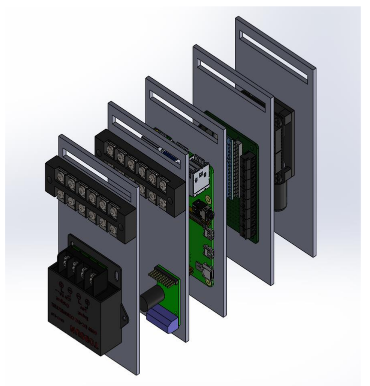

Fig 4: Electronics unit assembly

Testing

- Weight distribution of the components and hull create an unevenly ballasted UUV
- The placement of motors on the hull do not make for comprehensive or intuitive control of the vehicle.
- Side propellers cause unwanted pitch due to location on hull
- Rear propeller causes roll preventing further precise control of KRILL
- Pectoral fins are too small preventing adequate control of pitch and stabilization.
- Difficult to reliably deploy into and retrieve out of water

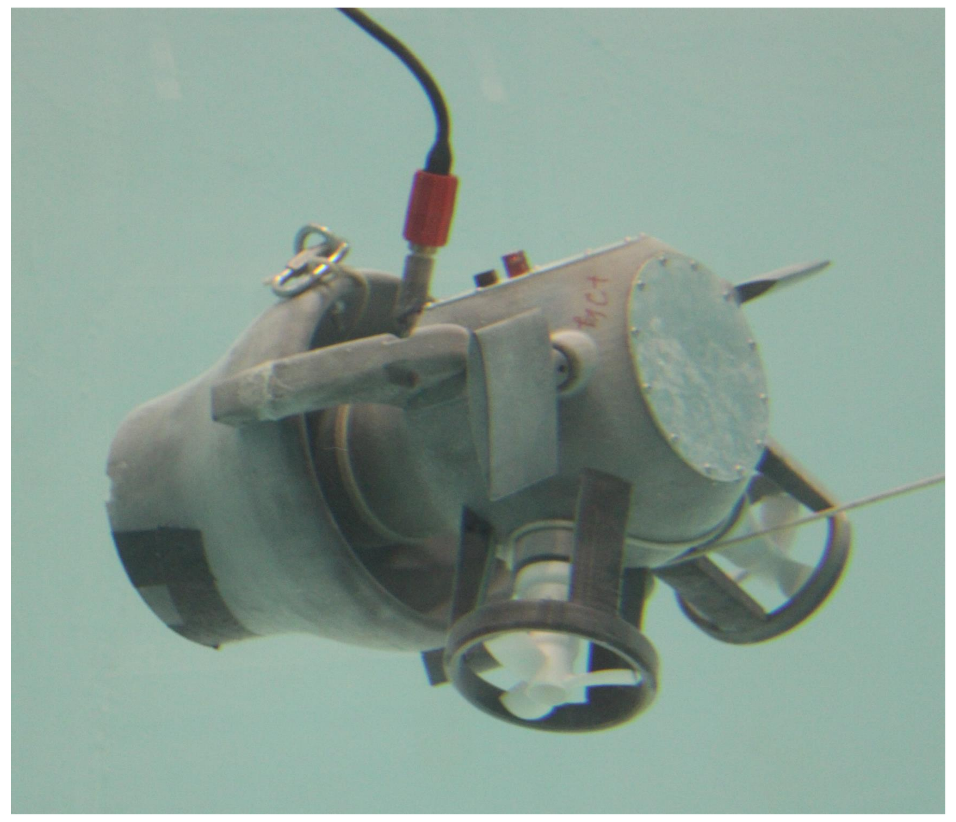

Fig 5: Negatively buoyant and rear heavy KRILL

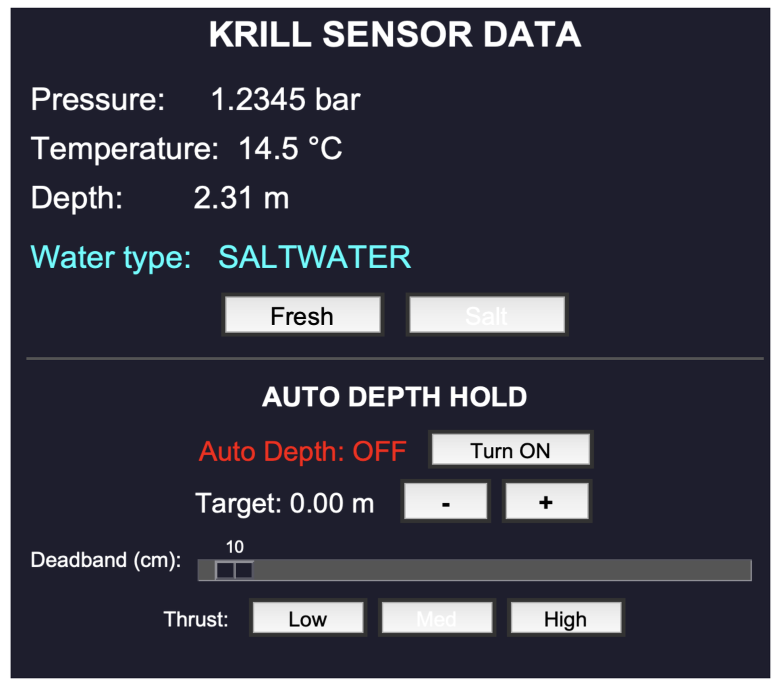

Fig 6: Krill Control GUI

- Buoyancy testing revealed that when front ballast is added KRILL becomes negatively buoyant before reaching zero pitch.
- External ballast must be added to correct buoyancy.
- Sensor integration allows for automatic depth setting and holding.
- Repeated testing of KRILL proves reliability of design for waterproofing.

Mechanical Improvements

- Changed all external components to be 100% infill 3D printed PETG or resin to limit component waterlogging
- New tether assembled for better cable management when operating
- Combined rear propeller assembly into single object
  - Reduced weight at the rear of KRILL
  - Simpler design
  - No risk of losing rear propeller
  - Safer propeller installation
- Plastic BBs replaced with Delrin balls as rolling element in external propeller bearings
  - Plastic BBs would friction weld together under prolonged operation
  - Damage to the bearing with plastic BBs not seen with Delrin
- New internal rear motor assembly improves reliability
- Modified electrical system reduce thermal impact

Fig 7: Damaged bearing after continued operation

Fig 8: New tether

Conclusions and Future Work

The challenges with hull design of KRILL have been addresses as best as possible given the current hull design. Control and buoyancy issues render KRILL practically inoperable and require a complete redesign to effectively address.

- KRILL's hull redesign to better optimize the electronics as well as its underwater control
- Tether less control will be designed and developed using acoustic nodes from a buoy
- Begin using ROS2 Jazzy and Gazebo for controls, dynamics, and simulations
- Work towards basic scripted autonomous control
- Build fleet of KRILLs to operate simultaneously and collectively
- Incorporate IMU sensors for PID
- Camera integration for increased maneuverability

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