UW Human Powered Submarine Autonomous Roll Control Validation

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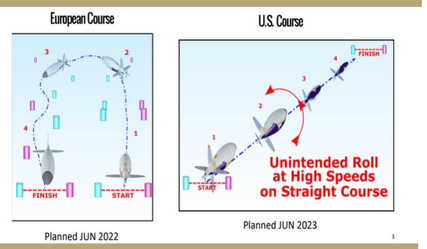
Overview

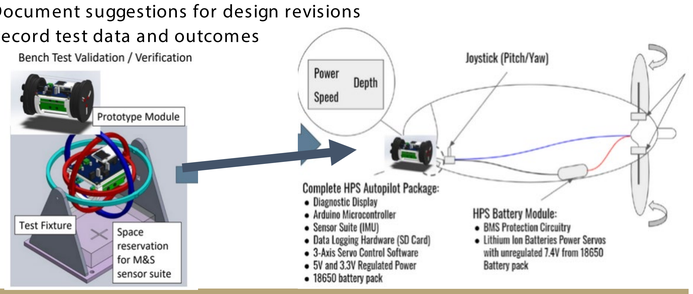
The HPS Autopilot Capstone is an ongoing project to develop a roll control module that will:

- Keep the submarine stable at high and low speeds
- Improve the handling experience of the submarine



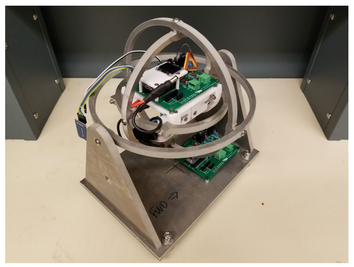
Phase Three Requirements

- Test design for implementation readiness
  - Investigate the hardware's functionality, performance, and reliability
  - Evaluate the control design's calculations and performance
- Document suggestions for design revisions
- Record test data and outcomes



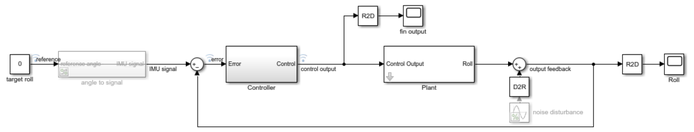
Hardware Test Plan

- Prototype Autopilot Module completed by previous year's team
- Two-board system to measure fixture rotation relative to a point
- Three phase test plan:
  - Functionality: Does the device function at a baseline level
  - Performance: Does the device function according to specifications
  - Reliability: Does the device maintain accurate results under real-world conditions
- Also required: methodology to translate rotation of gimbal to rotation of a reference point
  - Calculated using homogeneous transforms



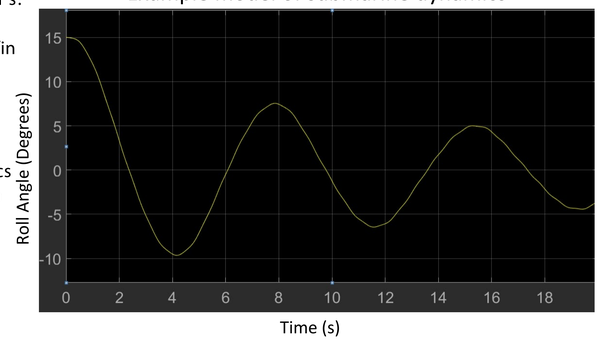
- Attitude and Heading Reference System:
  - Utilizes sensor fusion to estimate roll, pitch, and yaw
  - Three sensors need to each be tested in the IMU (Internal Measurement Unit):
    - Gyroscope
    - Accelerometer
    - Magnetometer

Controls Testing



- Controls modeling was performed in MATLAB Simulink
- Model simulated
  - Phase Two's Controller's:
    - PID settings
    - Fin actuation with fin limiters
  - Hydrodynamics
    - Hull lift and drag
    - Fin lift and drag
    - Rigid body dynamics
    - Added mass inertia
  - Hydrostatics
    - Weight
    - Buoyancy
  - Disturbances
    - Pilot pedaling
    - Sensor noise

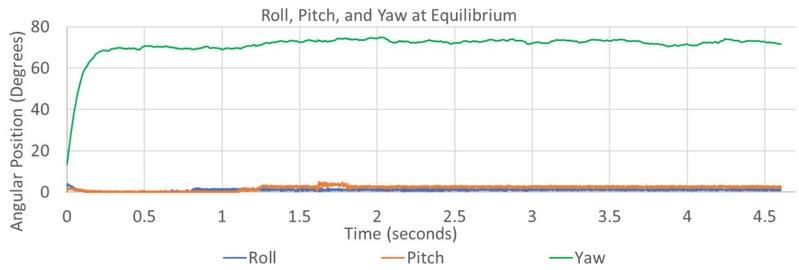
Example model of submarine dynamics



Hardware Test Results

1.1 (Module Power Delivery)	**PASS**
1.2 (User Interface Output)	**PASS** (Serial ver. only)
1.3 (Roll pitch and yaw Velocity Measurements)	**PASS**
1.4 (Acceleration Measurements)	**FAIL**
1.5 (Magnetometer Measurements)	**FAIL**
1.6 (Roll pitch and yaw Measurements)	**PASS**
1.7 (Measurement Storage)	**FAIL**
2.1 (Roll pitch and yaw Velocity Measurement Accuracy)	**PASS**
2.3 (Roll pitch and yaw Measurement Accuracy)	**FAIL**
2.2 (Acceleration Measurement Accuracy)	**FAIL** (Could not complete)
3.1 (Roll pitch and yaw Measurement Stability over Time)	**FAIL** (Could not complete)
3.2 (Roll pitch and yaw Measurement Stability During Test Fixture Rotation)	**FAIL** (Could not complete)

- Testing revealed significant error in yaw measurement
- Magnetometer calibration was determined the most likely cause



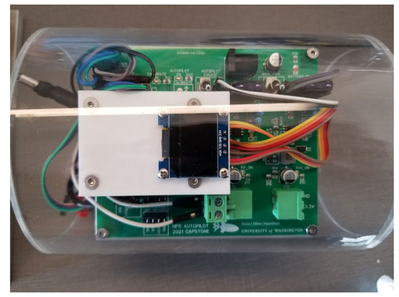
Discussion and Future Work

HARDWARE / SOFTWARE

Module is not ready for implementation in a submarine setting. Module cannot accurately measure yaw angles. Physical device is prone to pins breaking off in headers and the battery pack is cumbersome to remove.

Future teams will need to perform:

- Partial redesign of PCB
- Redesign of battery casing



Multiple options for AHRS redesign:

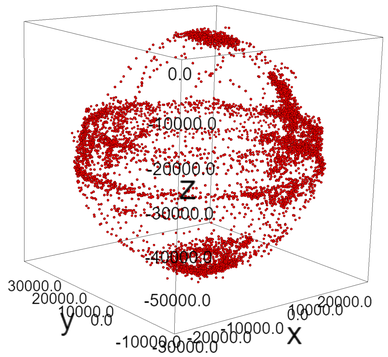
- Correct magnetometer error
  - Fix magnetometer calibration procedure to obtain better raw data
  - Utilize specialized calibration software and integrate code libraries for the IMU (Internal Measurement Unit)
- Use alternate methods to obtain yaw values
  - Position second module's roll/pitch axis to line up with main module's yaw axis and feed in data

CONTROLS

Controller does decrease roll error but struggles to reach steady state in under 20 seconds with normal use case body velocities (under about 2.5m/s). There is room for improvement in controller design.

Future teams may want to look into:

- Simulink's PID tuner
- Linear quadratic regulator controls (LQR)
- Further refining hydrodynamic equations
- Automating force and moment calculations using Computational Fluid Dynamics (CFD)



Raw magnetometer data (units in nanoTesla)

References and Acknowledgements

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