Human Powered Submarine Autopilot Roll Control Module

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NAVSEA NAVAL SEA SYSTEMS COMMAND KEYPORT

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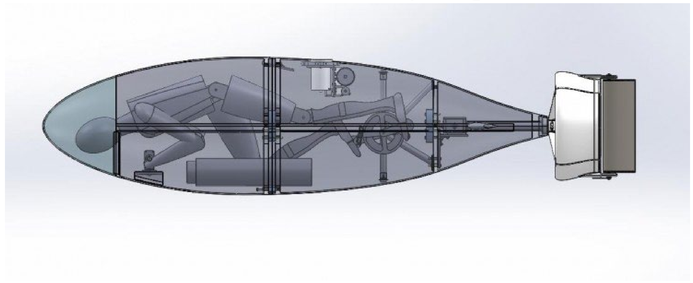
Human-Powered Submarine

- University of Washington Human-Powered Submarine (HPS) team competes at international submarine races
- Pilots control the submarine by pedaling with their legs and has only one free hand to control the direction of the craft
- Pilots experience difficulties maintaining consistent orientation and speed during timed races

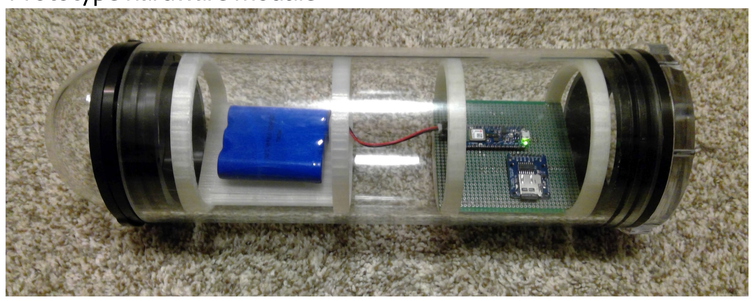
Human Powered Submarine concept diagram [1]



Autopilot Module

- Our team is developing a system to ease the pilots control burden.
- Independent roll-control module with self-contained microcontroller and power system built for integration into HPS designs

Prototype hardware module



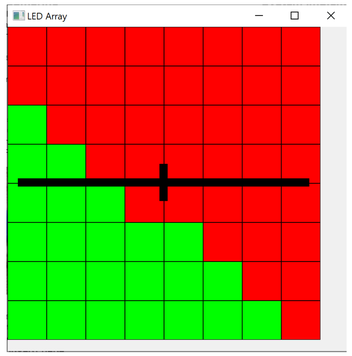
- Additional software and hardware features to benefit both the pilot and operating team
  - Pilot display designed to show vehicle orientation for pilot's reference and for use in low-visibility conditions
  - Route tracking system records the orientations and movements of the device in three dimensions
- Module designed for minimal impact on the pilot ability to control the submarine craft

System Specifications

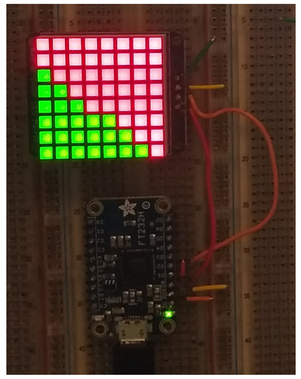
- Arduino Nano 33 BLE Sense microcontroller [2]
  - Bluetooth Low Energy communications for short range testing and data gathering
  - Onboard sensors for control navigation and environmental data
    - Inertial measurement unit (IMU), temperature, light, humidity, pressure,
  - Support for additional sensors and system modules
  - Coded in C using Arduino IDE
- Onboard microSD card storage system for data gathering and testing with support for two or more gigabytes of storage
- System powered by 6600 mAh 3.7 lithium ion battery for at least five hours of operating time
- Pilot display logic code for both software simulated display and hardware display written in C++
- Hardware LED matrix for proof-of-concept pilot display
- Data Visualization using Python for data processing

Pilot Display

Software simulation



Hardware Proof-of-concept



Pilot heads-up display coded and simulated in software using C++. Simulates an attitude indicator to give pilots a quick reference for submarine orientation. The attitude indicator gives the orientation of the vehicle as the relative position between a fixed plane (black bar in left image above) and a theoretical horizon represented by the border between the green and red halves.

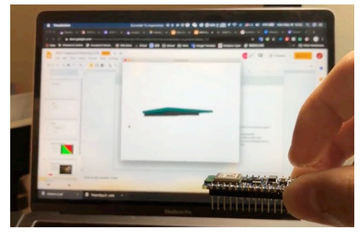
A proof of concept hardware display demonstrates the physical submarine hardware. Display system operated by local PC receiving Bluetooth gyroscope data from module.

Data Controller

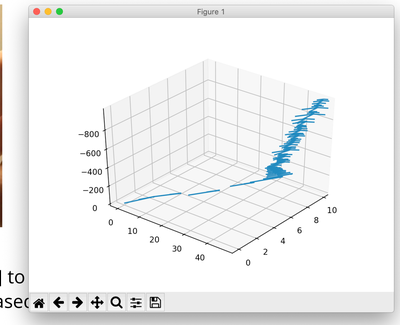
- Roll control calculated by proportional-integral-derivative (PID) controller
- PID controller implemented in Simulink environment for MATLAB [3]
- Models the operation of the HPS fins
- Designed to be highly variable for implementation in different sub designs

Route Tracking System

Device Orientation on Processing



Data Visualization on Python



This system applies a Madgwick Filter [4] to calculate the orientation of the device based on IMU sensor data. After removing the gravity component from the sensors, the system calculates the displacement of the device and stores the values in the SD card. These values can be interpreted and plotted into a vector graph using a python script.

Goals Reached

- Constructed autopilot hardware
  - Established Wireless Communication via BLE
  - Added on-board microSD storage
- Pilot display
  - Coded attitude indicator logic
  - Built both software simulated display and hardware display
- Data controller
  - Designed foundational PID controller in Simulink
- Route tracking system
  - Implemented the conceptual model of the Routed Tracking System
  - Visualized and recorded continuous movements of the device using Python

Future Work

- Expand autopilot data control to support pitch and yaw
- Translate Simulink module to Arduino compatible code
- Implement pilot display logic into microcontroller
- Construct waterproofed module and pilot display for HPS installation
- Integrate autopilot module with HPS control servos
- Remove the Gravity from IMU sensors
- Implement accurate data processing algorithm for route tracking system

Acknowledgements/References

- Thanks to Nikolas Johnson and Jack Ryan from the UW HPS team
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- [1] K. Vyas, "Engineering Students Build Human-Powered Submarine That Moves By Pedaling," *interestingengineering.com*, June 8, 2018. [Online]. Available: https://interestingengineering.com/engineering-students-build-human-powered-submarine-that-moves-by-pedaling. [Accessed: May 2020].
- [2] "ARDUINO NANO 33 BLE SENSE" *store.arduino.cc*, [Online]. Available: https://store.arduino.cc/usa/nano-33-ble-sense. [Accessed: May 2020].
- [3] "Simulink," *mathworks.com*, [Online]. Available: https://www.mathworks.com/products/simulink.html. [Accessed: May 2020].
- [4] P. Stroffregen, "MadgickAHRS," *github.com/arduino-libraries*, [Online]. Available: https://github.com/arduino-libraries/MadgwickAHRS. [Accessed: May 2020].

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