ECE 445 Final Presentation

Group 24: Autonomous Sailboat

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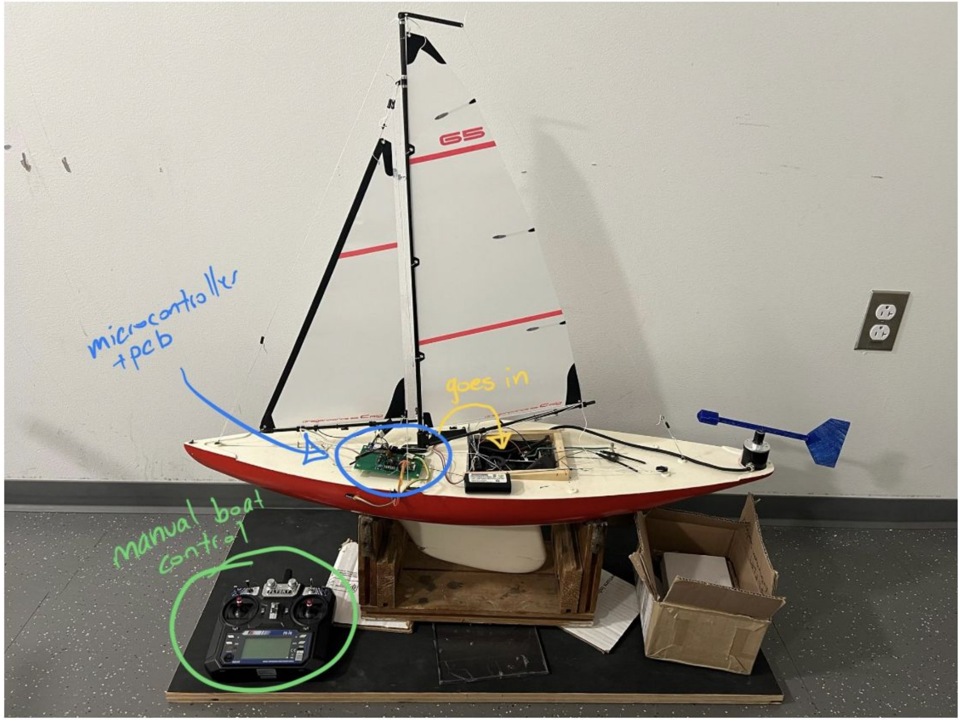
Introduction

- **Goal/Objective:** Create an autonomously sailing sailboat with manual remote-control
- **High-Level Objectives:**
    - The boat successfully maintains a course autonomously
    - The microcontroller effectively manipulates data from sensors and servos
    - The remote controller switches between manual, autonomous and Return-To-Base mode



What did we change from SP22?

Power, Charging, and Battery Indicator

- Upped battery voltage, included a charger, a battery indicator, added on/off switch, and updated power delivery

IMU and Accelerometer Data

- Gives us additional information about the boat's state like velocity

PCB

- Redesigned all footprints and started the board from the beginning, using the same dimensions as the previous board.

Algorithms

- Return to shore, enhanced directing

Functional Overview of Subsystems

Power

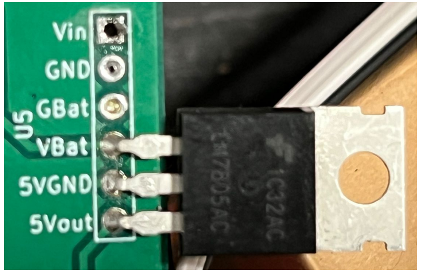
7.4V LiPo Battery:
- Power supply for all components

5V Regulator
- 1.5 A maximum output
- Powers Windvane, Telemetry, RCd

3.3V Regulator
- 800 mA maximum output
- Powers Microcontroller, IMU

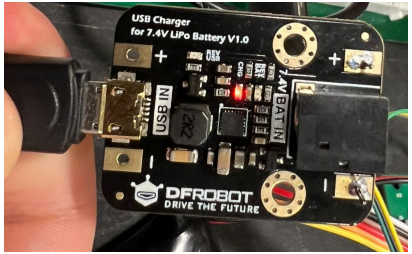
Micro USB Charger
- 5V 1A Power Delivery
- Charges .3V above battery voltage

7.4V Li-Ion Battery

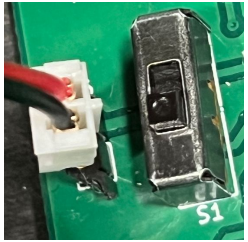


5V Regulator

3.3V Regulator



Micro-USB Charger



Switch

Communications & Ground Control

Remote Controller

Telemetry Radio transmitter and Receiver

FS-i6 Transmitter

Communication Subsystem

RC Receiver:

- 6-Channel Radio Receiver. PWM Input

Telemetry Transmitter:

- Relay sensor and location data to laptop

Ground Control Subsystem

RC Remote:

- 6-Channel Radio Remote Control
- Manual mode and switching

Telemetry Radio Receiver:

- Receive sensor data for laptop

Sensors

GPS:

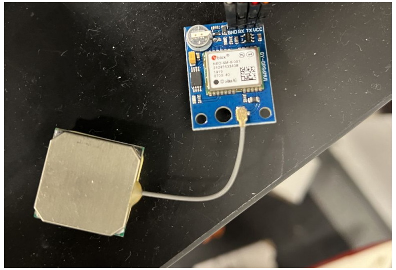
- Transmits data via UART protocol
- GPS Coordinates for navigation

Wind Vane:

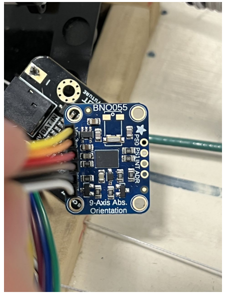
- Two Phase Rotary Encoder with 3D Printed attachment
- Reports Wind Angle through PWM

IMU:

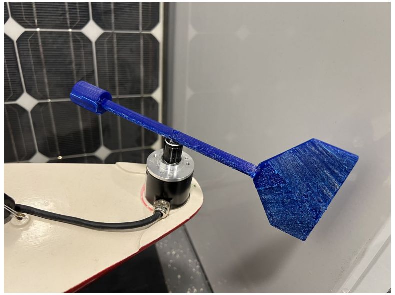
- 9-DOF Absolute Orientation (Euler Angles), Magnetometer, Accelerometer
- Used as Compass and Speedometer



GPS



IMU



Wind Vane Encoder

Control

Microcontroller

- STM32 microcontroller
- Process all sensor inputs and sends outputs to Servo and Telemetry

Winch Servo

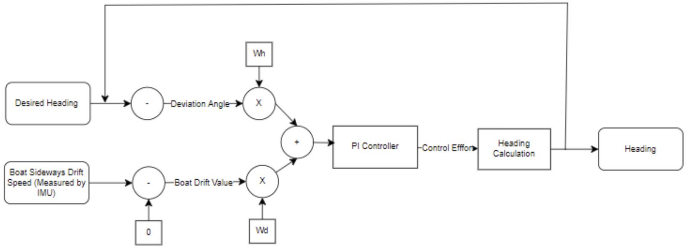
- Controls Sail Chord Angle

Rudder Servo

- Controls course and heading corrections

Control Algorithm

- Rudder: PI Control Algorithm based on heading deviation
- Winch: Optimal angle lookup table



Rudder Control Algorithm

Apparent Wind Angle	Point of Sail	Sail Angle
$0 \leq \theta \leq 45 \| 315 \leq \theta \leq 360$	No-Go Zone	0°
$45 \leq \theta \leq 75$	Close-Hauled	15°
$75 \leq \theta \leq 105$	Beam Reach	-45°
$105 \leq \theta \leq 135$	Broad Reach	-60°
$135 \leq \theta \leq 225$	Running	±90°
$225 \leq \theta \leq 255$	Broad-Reach	60°
$255 \leq \theta \leq 285$	Beam Reach	45°
$285 \leq \theta \leq 315$	Close-Hauled	15°

Rudder Control Algorithm

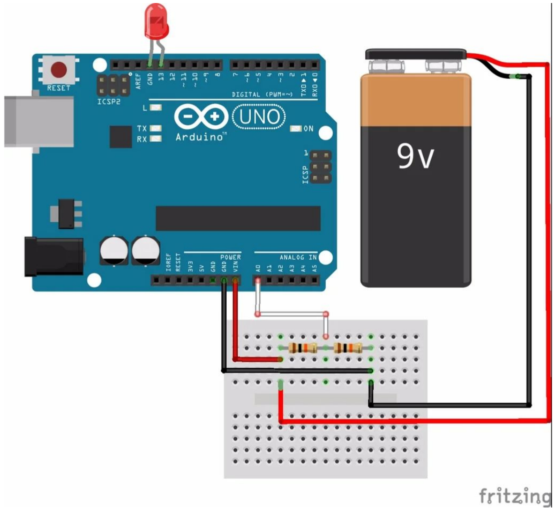
STM32

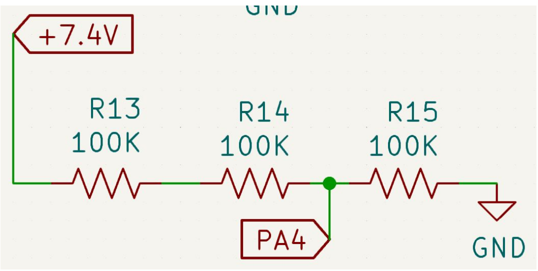
Design Considerations

Battery Indicator

Problem: LED may not be visible under bright conditions, and can't provide accurate information on battery percentage.

Solution: Use resistors to split voltage into the safe readable range of the microcontroller



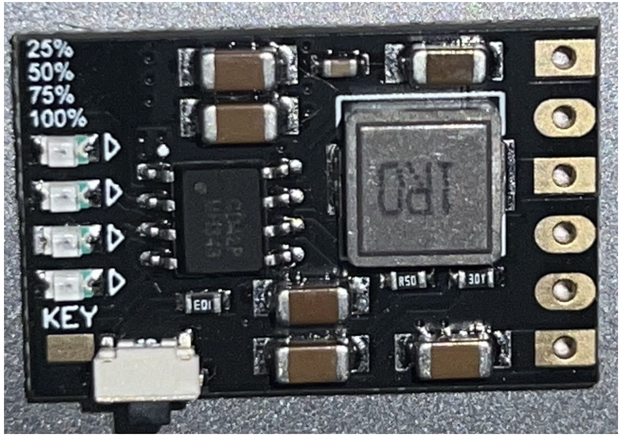


battery is: 7.58 volts
battery is at: 64.67 percent

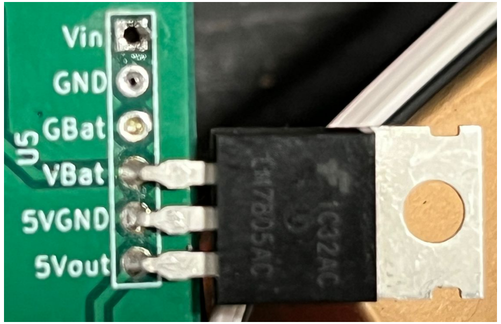
New Battery

Problem: Original design had to step up voltage to power 5V regulator, but new battery was found to be incompatible with the regulator.

Solution: New 5V regulator (with similar pinout in battery, ground, and 5V out) from supply shop.



Old 5V Regulator

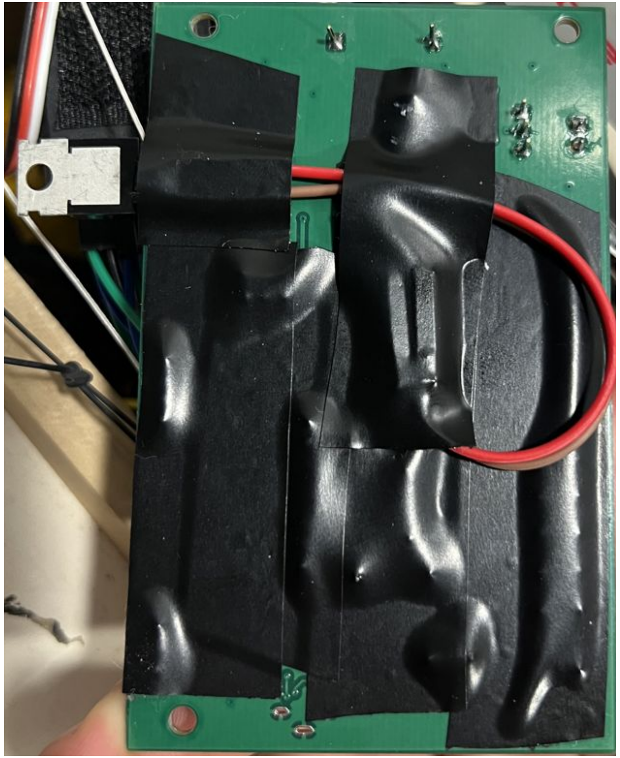


New 5V Regulator

Power Delivery and Insulation

Problem: Exposed header pins on PCB caused a shorted connection, frying our Telemetry Radio

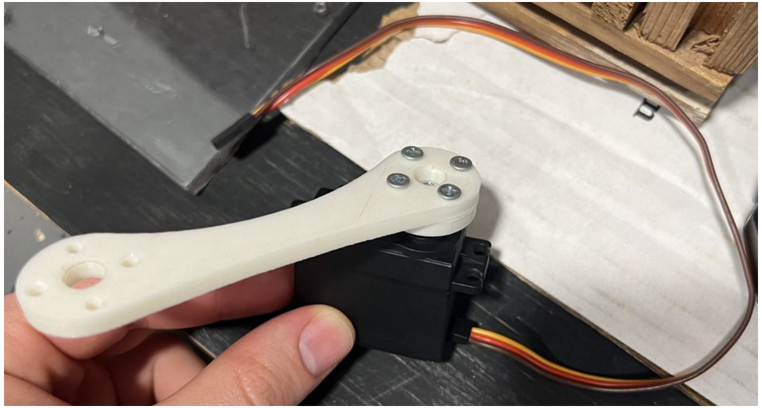
Solution: Cover bottom of PCB with electrical tape, insulating from environment



Shorted Servo

Problem: Servo shorted during operation, no known cause. Replacement unit we obtained did not have correct threads, and identical unit would take far too long to obtain.

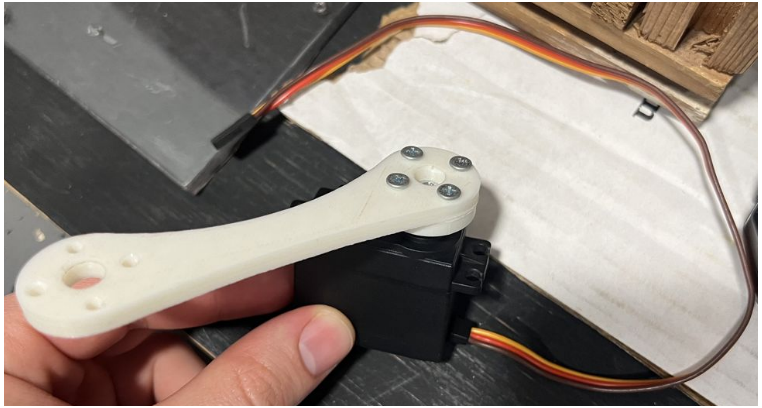
Solution: Use another replacement servo that has an attachment that can visually show rudder movement



Shorted Servo and 5V Regulator Current Draw

Problem: Original rudder servo shorted, and temporary test servo draws too much current

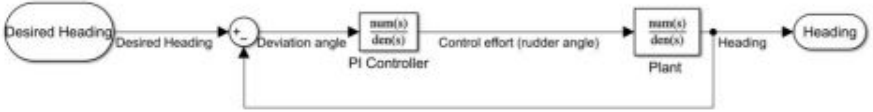
Solution: Ultimately no solution, but demoing without servo, or getting the correct replacement would resolve this problem



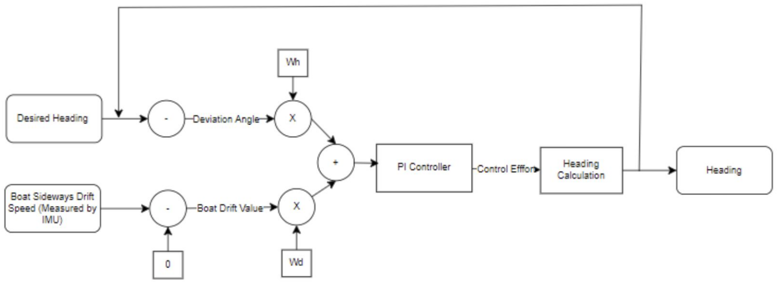
Control Algorithm

Problem: Original demo video showed boat going in a pronounced zigzag route

Solution: Incorporating boat sideways drift into the rudder PI control algorithm as a weighted sum



Old Control Algorithm



New Proposed Algorithm

New IMU Problems + Code Readability

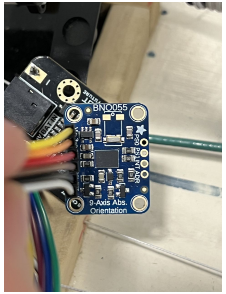
Problem: Old IMU does not give appropriate accuracy for direction and accelerometer readings to estimate speed drift.

Solution: Get new improved IMU

New Problem: New IMU does not have library for compass heading

Final Solution: Make heading function based on other IMU Library code

Additional: Changed to PlatformIO and made code more readable



New IMU

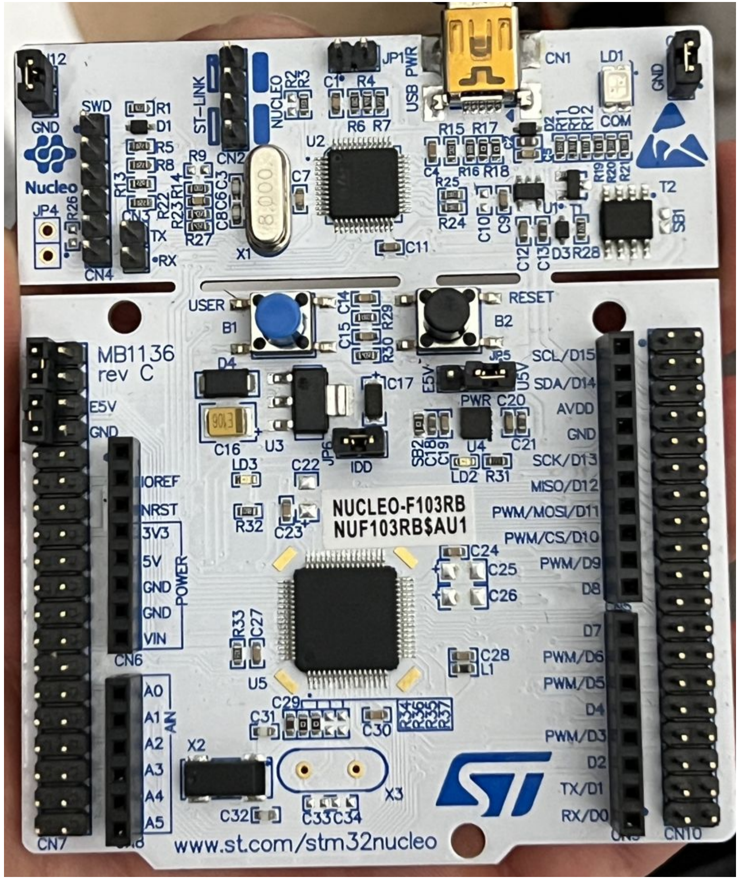
```
loat getHeadingRoll(Adafruit_BNO055 &bno){
  imu::Vector<3> from(1,0,0);
  imu::Vector<3> mag = bno.getVector(Adafruit_BNO055::VECTOR_MAGNETOMETER);
  imu::Vector<3> acc = bno.getVector(Adafruit_BNO055::VECTOR_ACCELEROMETER);

  imu::Vector<3> E = mag.cross(acc);
  E.normalize();

  imu::Vector<3> N = acc.cross(E);
  N.normalize();

  float heading = atan2(E.dot(from), N.dot(from)) * 180 / PI;
  if (heading < 0) heading += 360;
  float roll  = atan2(acc[1],acc[2]) * 57.2957;
  float ret = heading;
  //std::vector<float> ret = {heading, roll};
  return ret;
```

Compass Heading IMU Code

Programming the Board

Problem: Several incorrect programmers used (segger j-link, serial port, st-link w/ incorrect pins), and RST button not yet soldered due to incorrect understanding.

Solution: Using the STM32 dev board with proper pinout and RST set to high



Demonstration Video

Conclusions

Conclusions

- Very successful overall with what we set out to do
- PCB and component implementation worked as expected
- Ran into time constraints and allocation of work
- Found solutions to major setbacks

Future Additions

Future Additions

Design-Level:

- LED for battery level in addition to the percentage indicator
- Waterproofing PCB/Circuit

Testing:

- A test in Water
- Test the Return-To-Base model

Thank you!