Team B17: Autonomous Control Systems for VV-ECMO

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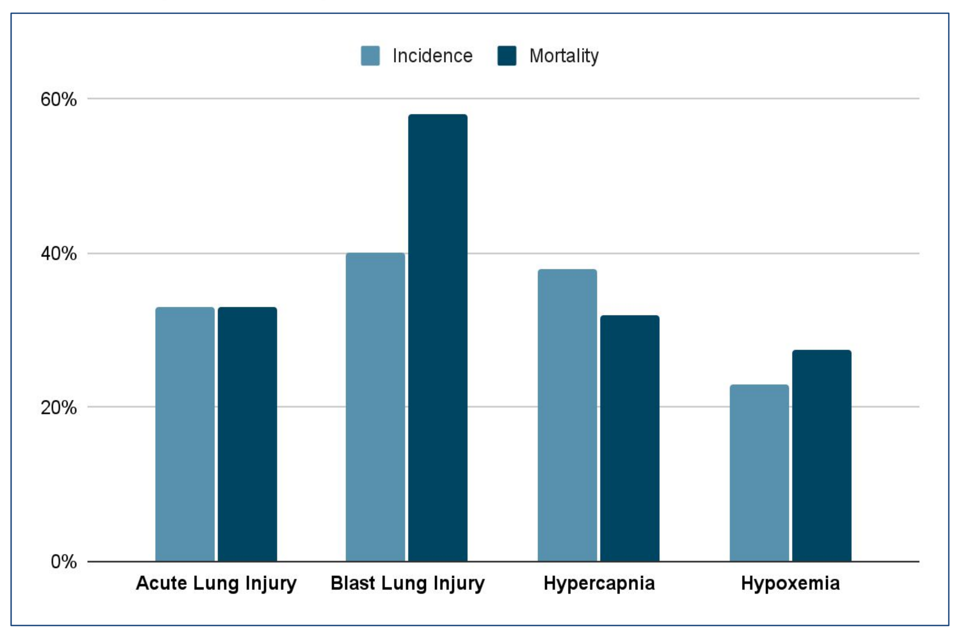
MOTIVATION/OBJECTIVE

Clinical Need:
VV-ECMO assists patients with any form of lung injury by acting as a lung bypass that removes blood from the patient, performs the function of the lungs, and returns the blood.

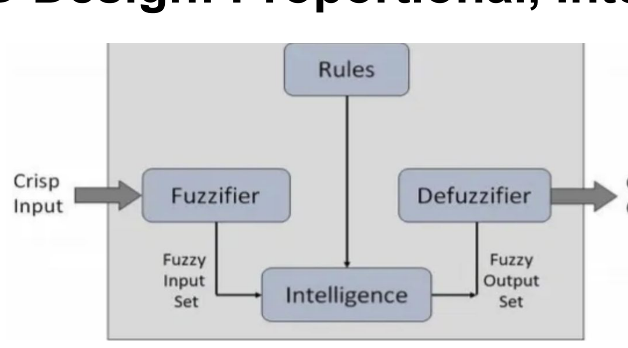


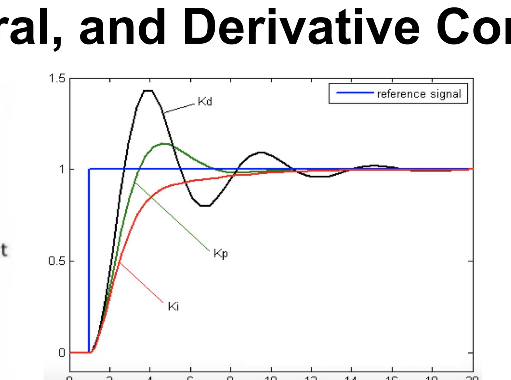
Main Objective:
Obtain **autonomous monitoring and control** of the ECMO system by implementing O2/CO2 sensors to assess patient vitals and maintain ideal patient conditions.

METHODS

Phase 1: Proof of Concept Design	Phase 2: Software and Hardware
• Incorporate sensors • Calibration • Simultaneous Readings • Sensitivity • Initial Control System	• Implement advanced control system via Arduino • Apply PID Feedback • Create case for controller considering materials and size

PID Design: Proportional, Integral, and Derivative Control





Fuzzy logic allows PID controller to make decisions based on “fuzzy” sets of rules. This makes it **more adaptable** to real-world conditions rather than binary decisions.

Quantitative Analysis and Modeling

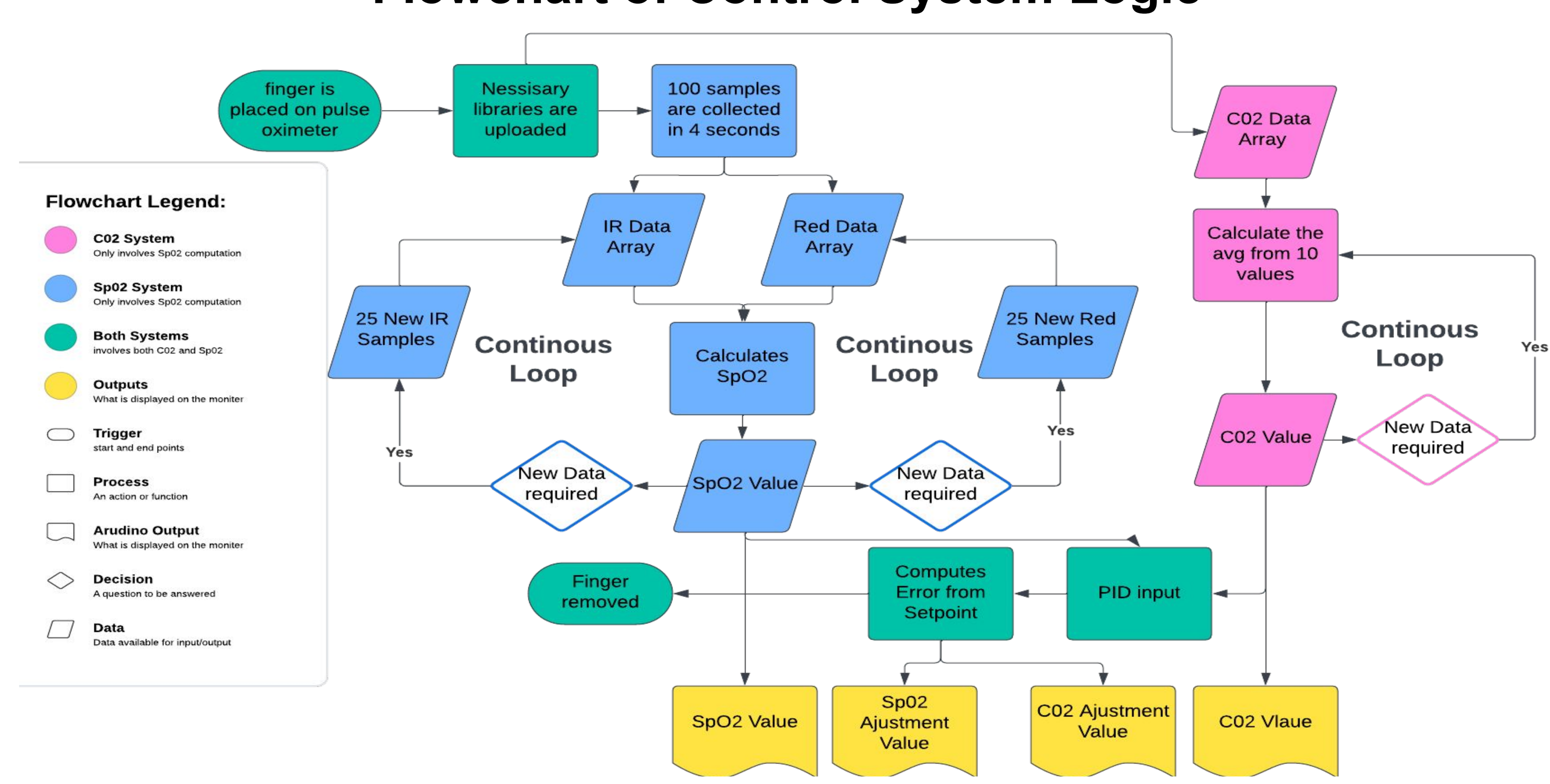
The arduino provides raw data which is transferred into the adjusted metric. The adjusted data will run through the feedback loop and the outputs will be to increase or decrease the gas flows so levels fall within the ideal range.

Using a MATLAB simulation, we plotted a base equation for CO2 removal need based on literature and plotted the ECMO response simultaneously. We accounted for catastrophic events of extremely low and high O2 levels to show our control system’s capabilities. The simulation is plotted in subplots to illustrate how proportional control and a PID design can minimize error and adjust the system.

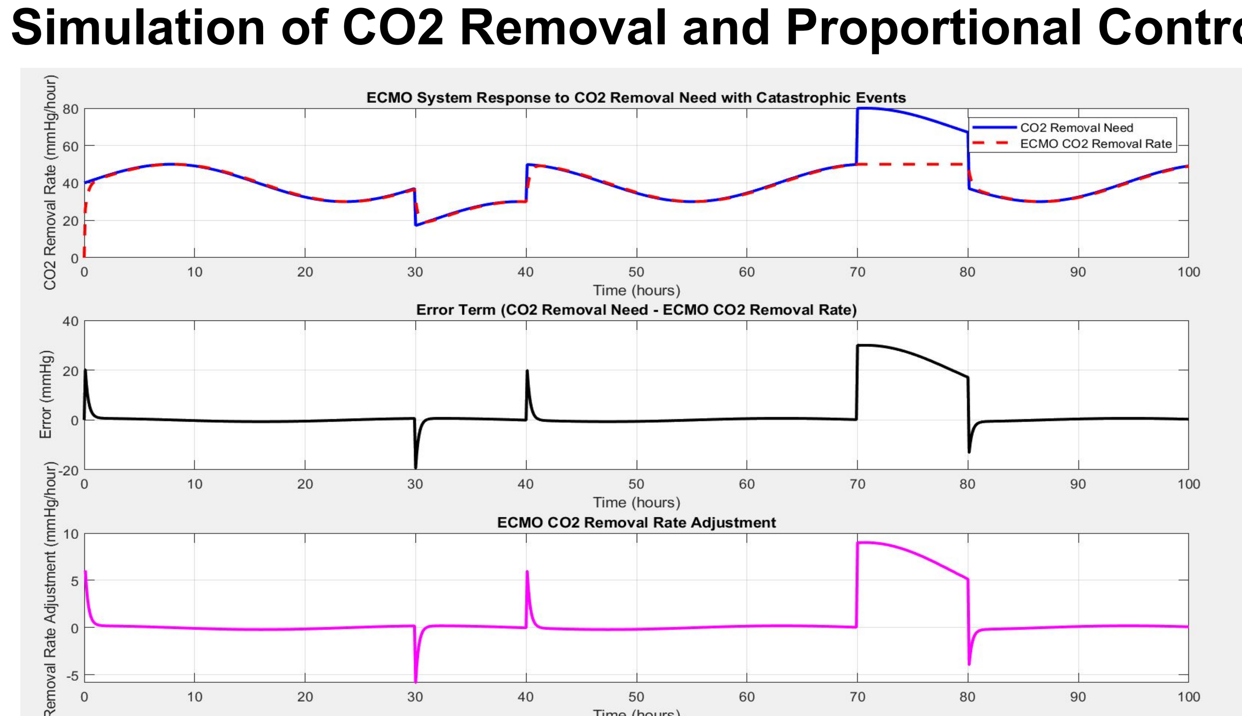
RESULTS

Using our PID control and sensors, we were able to create a proof of concept device that demonstrates the feasibility of autonomous VV ECMO application in clinical settings. We are able to maintain ideal values of simulated patient data, even through respiratory or mechanical failures. While we are limited due to lack of access to our OXY-1 VV ECMO machine, our simulated data acts as a proof of concept for further research to move forward in this field.

Flowchart of Control System Logic



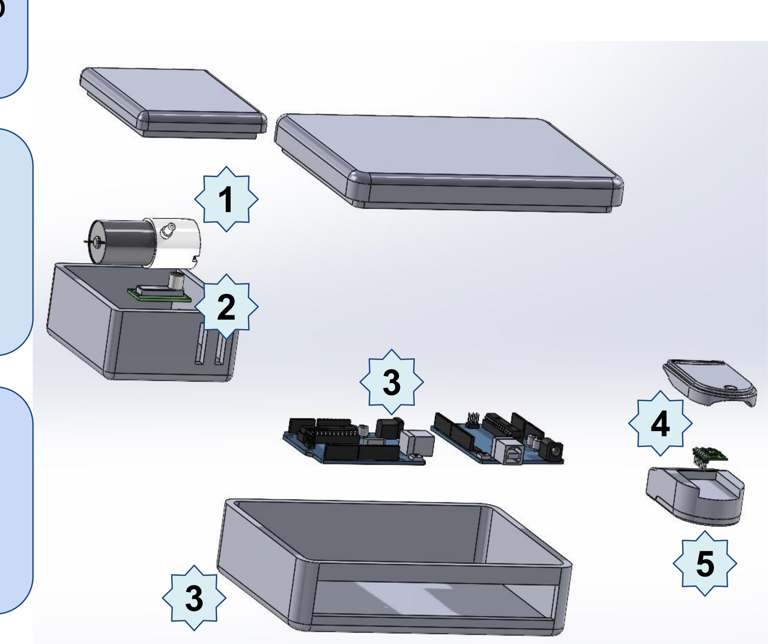
Simulation of CO2 Removal and Proportional Control



(1) Gas Pump
Directs gas flow into CO_2 sensor

(2) CO_2 Sensor
Outputs CO_2 concentration from gas pump

(3) Arduino / Case
Stores and executes code and control system



(4) spO_2 Sensor
Outputs beats per minute and oxygen saturation

(5) Pulse Oximeter
Contains spO_2 sensor, allows for pulse measurement

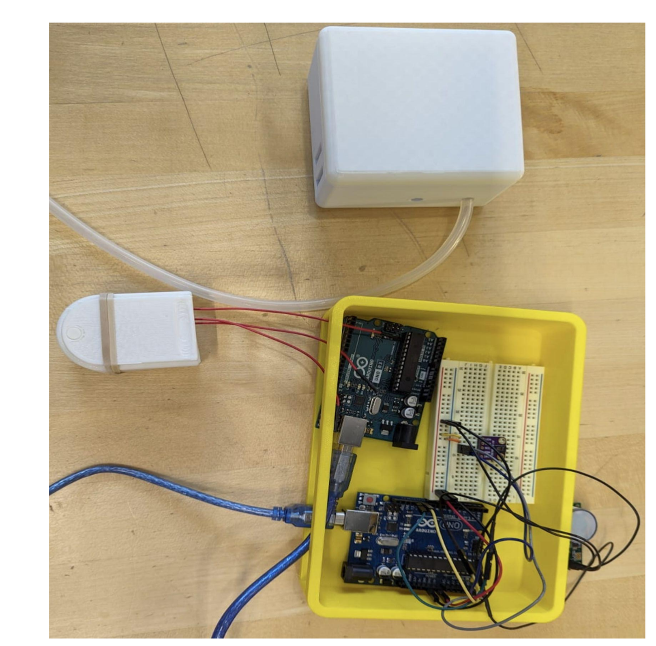
BIOETHICAL IMPLICATIONS

	Positive	Negative
Healthcare Workers	• Enhanced Decision Making • Reduced Workload	• Skill Atrophy
Patients	• Improved Outcomes • More Accessible	• Safety and Reliability of Automated Tech

CONCLUSIONS

We were able to build a system that autonomously controls Oxygen flow and Carbon Dioxide removal to reduce manpower needed for long term care of VV-ECMO patients. To do this, we used a closed loop control system and proportional control via Arduino IDE to calculate the adjustment a patient needs to return to baseline respiratory conditions.

The use of proportional control is beneficial for accurate adjustment, more than Integral or Derivative Control. This is due to its simplicity and its ability to immediately adjust with a low possibility of undershooting. While all humans have similar baseline respiratory requirements, these needs can adjust and we must ensure that our system can accurately change with them, especially in catastrophic conditions.



FUTURE WORK

Algorithm Optimization:
Refine optimize flow rates, pressure settings, and other parameters based on real-time patient data and feedback loops.

Real-Time Monitoring and Alerts:
Enhance the system to provide real-time monitoring of patient parameters and vitals. Implement alert mechanisms of deviations from ideal conditions.

Clinical Trials and Validation Studies:
Assess the performance and effectiveness of the system in real-world clinical settings. Gather feedback to identify areas for improvement.

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