Novel Automated Carbon Monoxide Forecasting, Dead-Zone Detection, and Ventilation System for Homes

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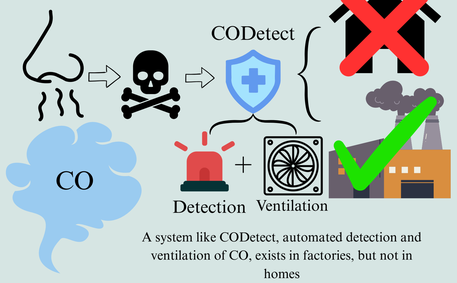
Main Takeaway:

CODetect has a **positive effect** on residential carbon monoxide detection and ventilation, displaying an **increased performance** in carbon monoxide forecasting and ventilation of dead zones compared to standard hazard mitigation systems

Abstract



A system like CODetect, automated detection and ventilation of CO, exists in factories, but not in homes

Problem Statement

Current residential carbon monoxide prevention systems fail to automatically monitor and ventilate CO.

Engineering Need

Smart safety system that predicts CO levels and dynamically optimizes air quality.

Background

- Carbon monoxide (CO) = **poisonous, tasteless, and colorless** gas, → **difficult** to detect and ventilate out
- CO → **hypoxia** (lack of oxygen) → death
- **Dead Zones:** Areas with low circulation and high CO levels → **primary driver** of CO level increase
- **SimScale:** Software to simulate fluid flow within a room
- **AEE (ACH):** Average Exchange Effectiveness or a way to quantify the quality of ventilation.

Engineering Goals

Detector must forecast 15-minute CO trends with **>90% accuracy**

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Detector must **communicate** values with ventilation system

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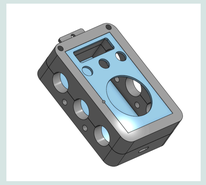
Ventilation must reduce CO dead-zones by 94%

Handheld Detector

+

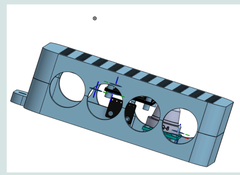
Ventilation System

Handheld Detector



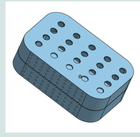
- ✓ Portability
- ✗ No Blockage

⇩



- ✓ Portability
- ✓ No Blockage
- ✗ Key-fob sized

⇩



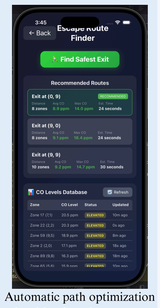
- ✓ Portability
- ✓ No Blockage
- ✓ Key-fob sized

The 3rd design allows for maximized portability, while retaining important features throughout each iteration

Mobile App

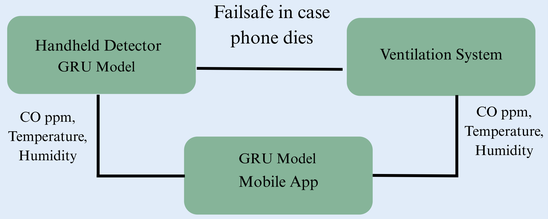
Environmental dashboard to record environmental values

Escape route map of building plan

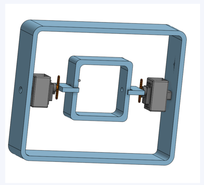


Automatic path optimization algorithm based on average CO level

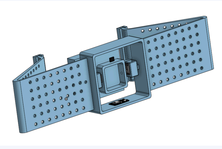
Control System



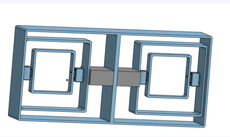
Ventilation System



- ✓ Modularity
- ✗ Filtration



- ✓ Modularity
- ✓ Filtration
- ✗ No Heat Blockage

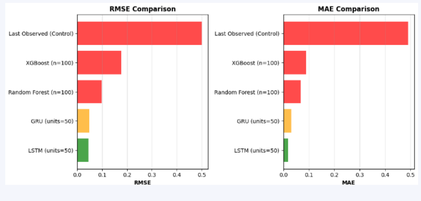


- ✓ Modularity
- ✓ Filtration
- ✓ No Heat Blockage

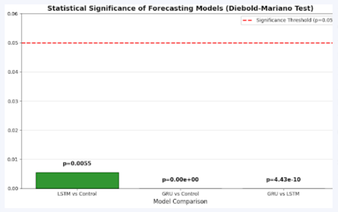
The 3rd design allows for effective utilization of exhaust and filtration for the effective guidance of CO from dead zone to filtration system

Predictive CO Modelling

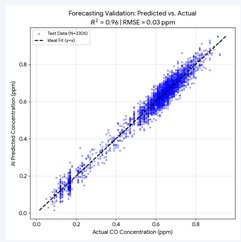
RMSE, MAE, and R2 value were graphed for 4 different models



Results: LSTM and GRU have similar + best performances

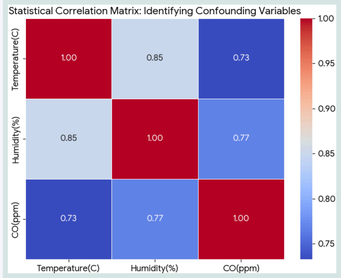


Result: GRU performed better than the LSTM in all the 3 performance metrics. A p-value < 0.05 (4.43e-10) indicates highly significant results

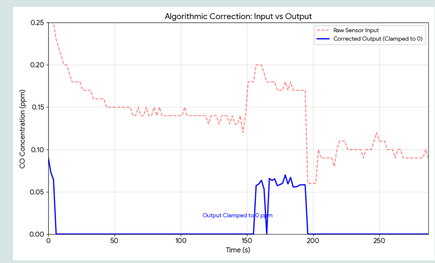


Results: Parity plot demonstrates significant accuracy to gas sensor concentrations. GRU achieved an R^2 of 0.96, indicating **96% accuracy,** and **RMSE of only 0.03 ppm,** indicating highly reliable forecasting accuracy

Multivariate Sensor Characterization

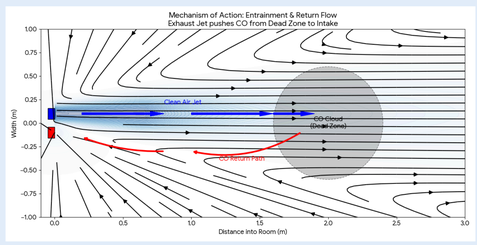


Significant correlation between CO and Tempearture **(r = 0.77)** as well as CO and Humidity **(r = 0.73)**



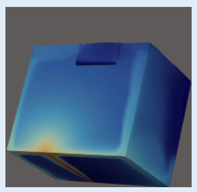
Auto-correction algorithm to correct for environmental sensitivities such as humidity and temperature

In-Silico Validation

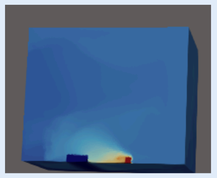


Visualization combines the physics of the jet (Blue) and the return flow (Red) to show how CO is moved from the dead zone to the suction.

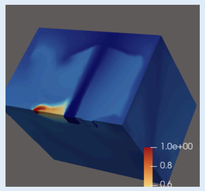
SimScale CFD Simulations



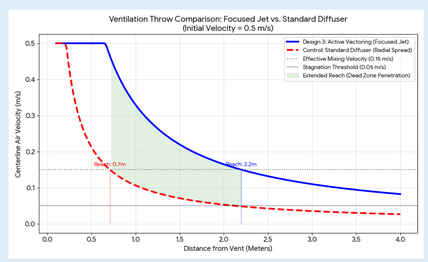
CONTROL
Moran's I: 0.78



ASHRAE
Moran's I: 0.46



CODetect
Moran's I: 0.05



Graph above shows how far air reaches from design 3 compared to a standard diffuser through python simulation. Results show how design 3 has a greater reach than the control

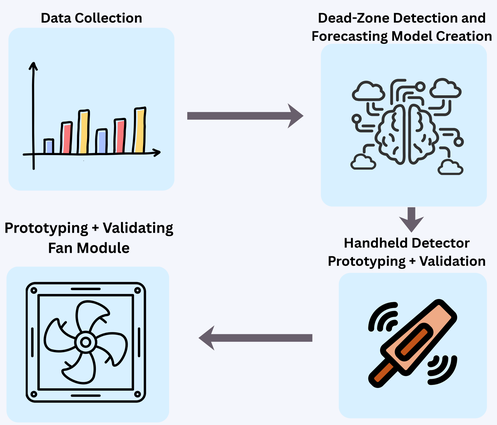
Competitior Analysis

Score: (1-10)

Criteria	CODetect	Electrochemical Detectors + Standard Ventilation	Google Nest Protect Smoke Alarm	Zeta Alarm System
Accuracy in CO detection (Weight: 4)	8	7	8	8
Ability to forecast future levels of CO (Weight: 3)	10	0	5	6
Ability to communicate with ventilation system (Weight: 4)	9	0	7	8
Dynamic ventilation (Weight: 5)	9	1	4	7
CFD (Computational Fluid Dynamics) informed and validated (Weight: 3)	10	5	3	8
Total Score: (Weight × Score)	**173**	**48**	**104**	**141**

Decision matrix that compares CODetect to existing systems in the market

Methodology



Highlights

CODetect resulted in a CO forecasting accuracy of **96%** while **decreasing** dead zones by nearly **94%**

Future Steps

- Implement real-time spatial learning for CODetect mobile app to map buildings and surroundings while tracking CO ppm.
- Continue to test handheld detector in terms of CO sensitivity and CO dead zone detection and forecasting (experiment with 2 other designs as well and iterate as needed
- Validate simulations with thermally buoyant tracer (solder smoke) using closed, proportionally dimensioned container

References

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