Project Notes:

Project Title: **Novel Automated Carbon Monoxide Forecasting, Dead-Zone Detection, and Ventilation System for Homes**

Name: Venigalla, Abhiraam

Note Well: There are NO SHORT-cuts to reading journal articles and taking notes from them. Comprehension is paramount. You will most likely need to read it several times, so set aside enough time in your schedule.

Contents:

Knowledge Gaps:

This list provides a brief overview of the major knowledge gaps for this project, how they were resolved and where to find the information.

Knowledge Gap	Resolved By	Information is located	Date resolved
NDIR (Non-Dispersive Infrared) Sensors	Reading article from Analog Devices about NDIRs work	https://www.analog.com/en/resources/analog-dialogue/articles/complete-gas-sensor-circuit-using-nondispersive-infrared.html	8/27/25
MEMS emitters	Read MIT article on MEMS emitters and different types of emitters	https://www.mtl.mit.edu/sites/default/files/attachments/mems_nems.pdf	9/03/25
Optical filtering	Read article on how optical filters work and what they do	https://www.edmundoptics.com/knowledge-center/application-notes/optics/optical-filters/?srsltid=AfmBOooxiFVrEYdnzfIY6B4mA6Kz2ABQyTA1qXUS893SKIkf7-VCNaxG	9/07/25
Optical Coupling Efficiency	Read article on how optical coupling efficiency works and how it is used in gas sensors	https://optics.ansys.com/hc/en-us/articles/42661682185107-Single-mode-fiber-coupling-in-OpticStudio#:~:text=Aberrations%20in%20the%20optical%20system,fiber%20and%20wavefront%20amplitude%2C%20T%20:	9/15/25
TDLAS and their applications in gas sensors	Read research article on TDLAS through science direct and their applications	https://www-sciencedirect-com.ezpv7-web-p-u01.wpi.edu/topics/engineering/diode-laser-absorption-spectroscopy	9/27/25
Pope's Equations	Read article on PDF and Pope's equations	https://tcg.mae.cornell.edu/pubs/Pope_NACM_91.pdf	10/9/25

Literature Search Parameters:

These searches were performed between (Start Date of reading) and XX/XX/2019.
List of keywords and databases used during this project.

Database/search engine	Keywords	Summary of search
Google	CO detector + NDIR	NDIR systems are commonly used in CO detectors as an alternative to electrochemical based sensors, but they also tend to be very expensive, which is why electrochemical sensors are more suited for residential environments

Tags:

Tag Name	
carbon_monoxide	ndir_sys
electrochemical_sensor	health_monitoring

TEMPELATE FOR NOTES ON ARTICLES

Article notes should be on separate sheets

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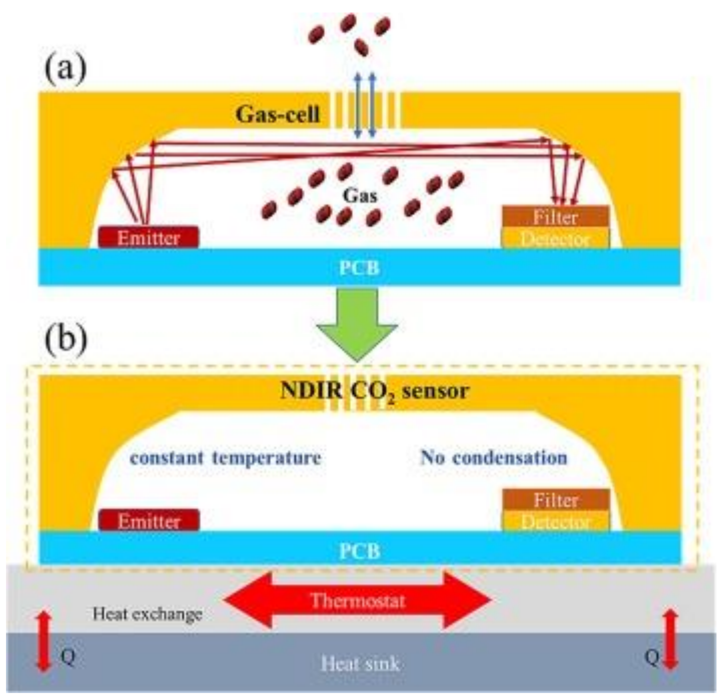
Source Title	
Source citation (APA Format)	
Original URL	
Source type	
Keywords	
#Tags	
Summary of key points + notes (include methodology)	
Research Question/Problem/ Need	
Important Figures	
VOCAB: (w/definition)	
Cited references to follow up on	
Follow up Questions	

Article #1: Development of a compact NDIR CO2 gas sensor for harsh environments

Article notes should be on separate sheets

Source Title	Development of a compact NDIR CO2 gas sensor for harsh environments
Source citation (APA Format)	Xu, M., Xu, Y., Tao, J., Wen, L., Zheng, C., Yu, Z., & He, S. (2024). Development of a compact NDIR CO2 gas sensor for harsh environments. *Infrared Physics & Technology*, *136*, 105035. https://doi.org/10.1016/j.infrared.2023.105035
Original URL	https://doi.org/10.1016/j.infrared.2023.105035
Source type	Journal Article
Keywords	Carbon Monoxide, NDIR, Gas Sensing
#Tags	carbon_monoxide, ndir_sys, gas_sensing
Summary of key points + notes (include methodology)	This article focuses on solving common challenges with Non-Dispersive Infrared CO2 gas sensors for harsh environments. This study proposes an NDIR gas sensor design that uses a MEMS emitter integrated with a broadband radiation spectrum with an optical filter for high coupling efficiency. The result of this study was a CO_2 NDIR gas sensor that detects CO_2 relatively cheaply among other gases and impurities in the environment very accurately.
Research Question/Problem/ Need	How can NDIR-based CO_2 gas sensor help detect CO_2 levels in harsh environments?
Important Figures	 Diagram comparing different scenarios of novel gas cell during constant temperature and no condensation (b) versus non-constant temperature and

	gas flow.
VOCAB: (w/definition)	**NDIR:** Non-Dispersive Infrared Sensors that have novel applications in gas sensing technology. They work using a sensor that shoots about a beam of IR radiation, which is then absorbed by gas molecules, in which sensors detect that absorption and measure the remaining infrared light. The less light detected, the higher the concentration of the gas there is. **TDLAS: Tunable-diode laser absorption spectroscopy --> relies on a tunable diode that adjusts to the wavelength absorption of the gas. When the lasers pass through the gas, the molecules of that gas absorb a specific wavelength, in which the amount of light passed through the gas is measured by a detector and reports the ppm or ppb of that gas.**
Cited references to follow up on	Hannon, A., & Li, J. (2019). Solid State Electronic Sensors for Detection of Carbon Dioxide. *Sensors*, *19*(18), 3848–3848. https://doi.org/10.3390/s19183848 Tipparaju, V. V., Mora, S. J., Yu, J., Tsow, F., & Xian, X. (2021). Wearable Transcutaneous CO_2 Monitor Based on Miniaturized Nondispersive Infrared Sensor. *IEEE Sensors Journal*, *21*(15), 17327–17334. https://doi.org/10.1109/jsen.2021.3081696
Follow up Questions	- How can NDIRs be adapted to detect multiple gases instead of one gas? - What improvements can be made to NDIRs so that they better detect levels of gases within the environment among other gases? - How can NDIR sensors coupled with biological reactions help detect and convert poisonous gasses like CO into O_2

Article #2: Understanding the effect of temperature and relative humidity on sensor sensitivities in field environments and improving the calibration models of multiple electrochemical carbon monoxide (CO) sensors in a tropical environment

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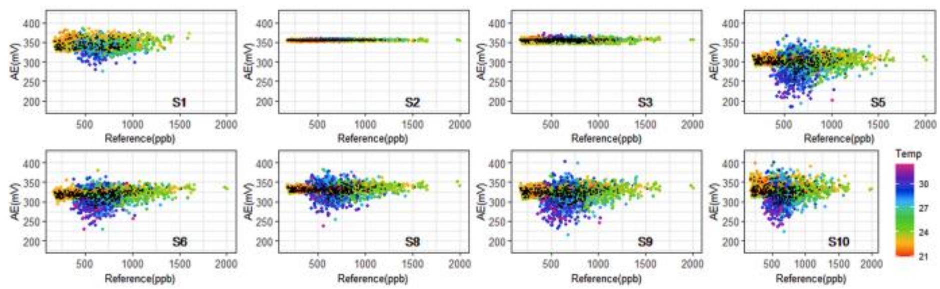
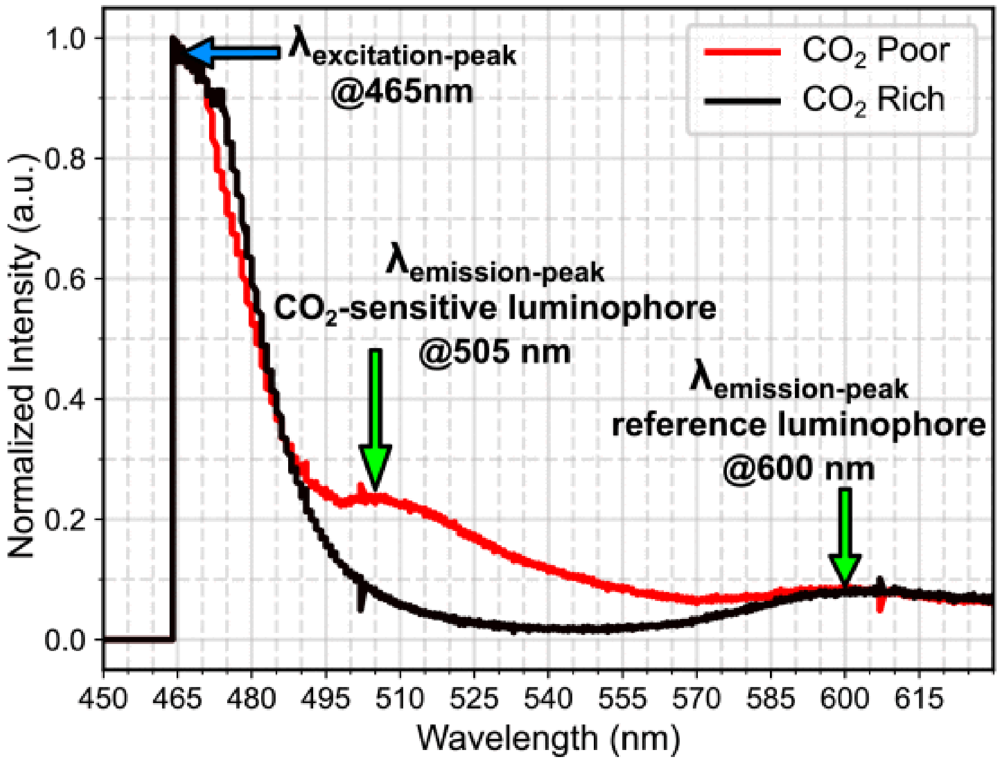
Source Title	Understanding the effect of temperature and relative humidity on sensor sensitivities in field environments and improving the calibration models of multiple electrochemical carbon monoxide (CO) sensors in a tropical environment
Source citation (APA Format)	Rajitha A, M.A. Elangasinghe, Z, Karunaratne, D. G. G. P., A. Manipura, K.B.S.N. Jinadasa, & K.H.N. Abayalath. (2023). Understanding the effect of temperature and relative humidity on sensor sensitivities in field environments and improving the calibration models of multiple electrochemical carbon monoxide (CO) sensors in a tropical environment. *Sensors and Actuators B Chemical*, pg 390, 133935–133935.
Original URL	https://doi.org/10.1016/j.snb.2023.133935
Source type	Journal Article
Keywords	Electrochemical sensors; Carbon monoxide; Sensor calibration; Sensor sensitivity; Linear regression
#Tags	electrochemical_sensors
Summary of key points + notes (include methodology)	This article talks about different calibration methods of electrochemical carbon monoxide detectors and how prone they are to environmental factors like humidity. The study focused on improving the calibration models of several linear regression calibration models of Alphasense-B4 CO detectors. They evaluated their

	sensitivities to their respective environment. They then introduced a novel averaged calibration method that was found to reduce the effect of temperature and humidity on sensor outputs.
Research Question/Problem/ Need	How does temperature and humidity effect sensor sensitivity and how can the calibration of these sensors be improved in such environments?
Important Figures	 Fig. 4. AE voltage values (mV) by reference CO concentration (ppb). Average voltage values (mV) compared to the carbon monoxide concentrations of the reference detector in parts per billion.
VOCAB: (w/definition)	Calibration: The process of tuning an instrument or sensor based on current, known, true values.
Cited references to follow up on	J. Rozante, et al., Variations of carbon monoxide concentrations in the megacity of Sao ˜ Paulo from 2000 to 2015 in different time scales, Atmos. (Basel) vol. 8 (81) (2017), https://doi.org/10.3390/atmos8050081. C. Reboul, et al., Carbon monoxide exposure in the urban environment: an insidious foe for the heart, Respir. Physiol. Neurobiol. vol. 184 (2) (2012) 204–212, https://doi.org/10.1016/j.resp.2012.06.010. A. Aslam, et al., Mitigation of particulate matters and integrated approach for carbon monoxide remediation in an urban environment, J. Environ. Chem. Eng. vol. 9 (4) (2021), https://doi.org/10.1016/j.jece.2021.105546.
Follow up Questions	How do you think CO detectors within closed environments would do with the proposed calibration methods? Why don't you consider polynomial regression as your calibration model? Why did you choose an averaged model instead of a more precise polynomial regression model?

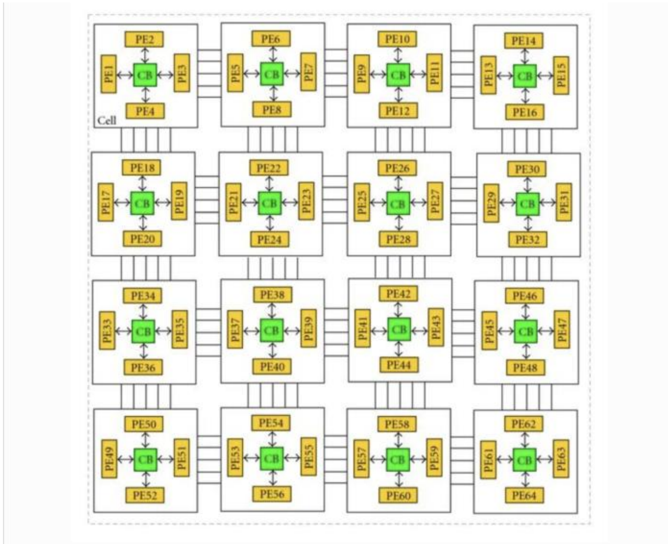
Article #3: A Transcutaneous Carbon Dioxide Monitor Based on Time-Domain Dual Lifetime Referencing

Source Title	A Transcutaneous Carbon Dioxide Monitor Based on Time-Domain Dual Lifetime Referencing
Source citation (APA Format)	Tufan, T. B., & Guler, U. (2023). A Transcutaneous Carbon Dioxide Monitor Based on Time-Domain Dual Lifetime Referencing. *IEEE Transactions on Biomedical Circuits and Systems*, *17*(4), 795–807. https://doi.org/10.1109/tbcas.2023.3277398
Original URL	https://doi.org/10.1109/tbcas.2023.3277398
Source type	Journal Article
Keywords	Continuous remote monitoring, dual lifetime referencing, luminescent carbon dioxide sensing, partial pressure of carbon dioxide, physiological monitoring, ptcCO2, respiration monitoring, transcutaneous carbon dioxide, vital signs, wearable.
#Tags	Carbon_dioxode, health_monitoring
Summary of key points + notes (include methodology)	The main point of this article is to describe a novel, wearable carbon-dioxide detector that detects the partial pressure of arterial carbon dioxide, which plays a role in assessing the acid-base and respiratory status of the human body. The study uses a luminescence sensing film and a time-domain dual lifetime referencing method. They tested their detector with a human test subject and found that the detector detected changes as small as 0.7% during hyperventilation. The wearable wristband is compact with dimensions of 37 x 32 mm, making it efficient and portable at the same time.
Research Question/Problem/ Need	How can a hybrid TDDLR-luminescence sensing film detect changes in arterial carbon dioxide and monitor changes in acid-base and respiratory status of the human body.

Important Figures	 Graph that compares the emission spectra of the sensing film under CO_2 rich and CO_2 poor conditions.
VOCAB: (w/definition)	t-DLR: A time domain dual lifetime referencing model is a technique that measures the lifetime of fluorescence between two separate fluorophores to get information about a sample. It works by using a short pulse of light emitted from n LED, then two images are taken from the excitation and decay period, and then the luminescence helps correct for intensity changes.
Cited references to follow up on	U. Guler, D. Sen, I. M. Costanzo, T. B. Tufan, and L. Rhein, Sensors for neonatal monitoring, Encyclopedia of Sensors and Biosensors, R. Narayan, Ed., 1st ed. Amsterdam, The Netherlands: Elsevier, 2023, pp. 423–448, doi: 10.1016/B978-0-12-822548-6.00104-7.
Follow up Questions	What made you (directed to authors) think of using luminescence and a t-DLR system in terms of detecting carbon dioxide in the body? How does a peak wavelength of 465nm excite the CO_2 luminescence film?

Article #4: SmartCell: An Energy Efficient Coarse-Grained Reconfigurable Architecture for Stream-Based Applications

Source Title	SmartCell: An Energy Efficient Coarse-Grained Reconfigurable Architecture for Stream-Based Applications
Source citation (APA Format)	Liang, C., & Huang, X. (2009). SmartCell: An Energy Efficient Coarse-Grained Reconfigurable Architecture for Stream-Based Applications. *EURASIP Journal on Embedded Systems*, *2009*, 1–15. https://doi.org/10.1155/2009/518659
Original URL	https://jes-eurasipjournals.springeropen.com/articles/10.1155/2009/518659
Source type	Journal Article
Keywords	Reconfigurable architecture, control process, architecture design
#Tags	Smart_architecture, hardware_manufacturing
Summary of key points + notes (include methodology)	This paper presents a smart, course-grained reconfigurable architecture that is able to provide high performance for stream-based applications. This paper describes the innovative structural design of the computer hardware they propose, while also talking about the main research gap that this study resolves: bridging the flexibility and performance gap between ASIC and FPGA. They show that this architecture, capable of achieving more gains than standard computer architecture, shows its potential as a promising alternative to current computer architecture.
Research Question/Problem/ Need	The problem statement is that current stream-based applications, such as media and telecommunications are the dominant workloads, but they have stringent energy and performance requirements, and they cannot meet the increasing requirements of energy, cost and performance in current computer architecture.

Important Figures	 Diagram showing configuration of architecture in this unique circuit prposed by the researchers.
VOCAB: (w/definition)	ASIC: Application-Specific Integrated Circuit. They are custom designed microchips that perform very specific tasks, different from CPUs that follow software for instructions. FPGA: Field Programmable Gate Array. They are a type of integrated circuit that can be programmed and reprogrammed after manufacturing to perform a wide range of custom digital logic.
Cited references to follow up on	Singh, H., Lee, N. M.-H., Lu, N. G., F.J. Kurdahi, N. Bagherzadeh, & Filho, E. M. C. (2000). MorphoSys: an integrated reconfigurable system for data-parallel and computation-intensive applications. *IEEE Transactions on Computers*, *49*(5), 465–481. https://doi.org/10.1109/12.859540
Follow up Questions	How do you think integrated circuits like this improve the efficiency of gas sensor hardware design and thus make gas sensors more concise?

Article #5: Investigation of Sprinkler Sprays on Fire Induced Doorways

Article notes should be on separate sheets

Source Title	Investigation of Sprinkler Sprays on Fire Induced Doorways
Source citation (APA Format)	Crocker J. P., Rangwala A. S., Dembsey N. A., & LeBlanc D. J. (2010). Investigation of Sprinkler Sprays on Fire Induced Doorway Flows. *Fire Tech,* Vol. 46 (2), 347-362. https://doi.org/10.1007/s10694-009-0081-0
Original URL	https://doi.org/10.1007/s10694-009-0081-0
Source type	Journal Article
Keywords	Fluid Mechanics, Fire Science, Hazard Control, Building Safety, Origin firing, Thermal Process Engineering, Wetting, Hydraulic Engineering
#Tags	Sprinkler_systems, fire_protection_modelling
Summary of key points + notes (include methodology)	This paper talks about the effect of sprinkler sprays on the smoke that exits the residential environment. The researchers hypothesized that a sprinkler spray would reduce the mass flow out of the doorway by cooling the upper gas layer. As air enters an environment, hot air rises while cool air lowers in elevation towards the ground. To test this, the researchers set up 24 full-scale fire tests in a 10m x 5m x 2.5m compartment with a single doorway. They tested with a single tyco TFII residential sprinkler. They measured temperature and velocities using thermocouples and bidirectional velocity probes. Tests were conducted in pairs: one with and without a sprinkler system. They found that sprinklers reduced mass flow by about 20%.
Research Question/Problem/ Need	Research problem: There are very few practical engineering tools that exist for predicting the effects of sprinkler sprays on fire scenarios, and existing methods are too complex for everyday use

Important Figures

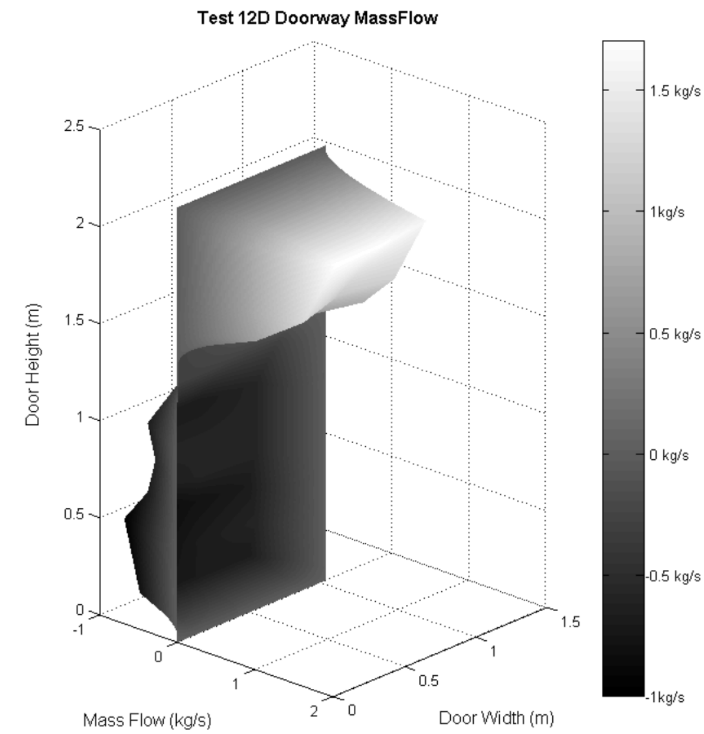


Figure 3: Surface plot of doorway mass flow. Negative mass flows represent flow into the compartment and positive mass flows represent flow out of the compartment.

Diagram shows the mass flow of gasses without the sprinkler system, with regions representing negative mass flow (flow into the compartment) and positive mass flow representing flow out of the compartment.

VOCAB: (w/definition)

Thermocouples: Thermoelectric sensors used to measure temperature
Bidirectional velocity probes: A device that measures the speed of fluid flow in two directions
Mass flow: In this case, it refers to the flow of smoke (matter)

Cited references to follow up on

You, H.Z., Kung, H.C., Han, Z., The Effects of Spray Cooling on the Ceiling Gas Temperature at the Door Opening of Room Fires, Fire Safety Science, *Proceedings of*
the Second International Symposium, Hemisphere, NY, pp. 655-665, 1989.

Morgan, H.P. Heat Transfer from a Buoyant Smoke Layer Beneath a Ceiling to a Sprinkler Spray. 1. An Experiment, *Fire and Materials*, Vol. 3, pp 34-38, 1979.

Follow up Questions

Do you think that the results would be different if a different type of sprinkler was tested?

Article #6: Gas and radiation sensor array for deployment on UAV, ROV and as a handheld standalone device

Article notes should be on separate sheets

Source Title	Gas and radiation sensor array for deployment on UAV, ROV and as a handheld standalone device
Source citation (APA Format)	Duck, A., Munasinghe, K. & Reakes T., Gas and radiation sensor array for deployment on UAV, ROV and as a handheld standalone device, *2017 Eleventh International Conference on Sensing Technology* (ICST), Sydney, NSW, Australia, 2017, pp. 1-5, doi: 10.1109/ICSensT.2017.8304519.
Original URL	https://ieeexplore.ieee.org/document/8304519
Source type	Journal Article
Keywords	Sensor arrays; Prototypes, Gas detectors, Tools, Unmanned aerial vehicles, CBRNE sensor array prototype, gas, radiation, sensors, graphical visualization
#Tags	#gas_detector, #prototyping, #sensors

Summary of key points + notes (include methodology)	- Introduction
	  o The goal of this project is to develop a CBRNE sensor array that can be used or deployed on its own on a UAV or ROV
	- Related Works
	  o UAV technologies have been really important in the past few years, as they are used in rescue, surveying, agriculture, and forestry
	  o Portable, deployable gas sensor arrays are important for UAVs to detect pollutant gases and help maintain ecological sustainability
	  o Refers past projects that used different types of gas sensors
	    ▪ MQ-2, which is sensitive to natural gas and liquified petroleum
	    ▪ MiCS-5121 and MiCS5255, which both detect VOCs and CO respectively
	    ▪ CdZnTe-based xray detector was developed for radiation detection
	    ▪ Project describes next step of other projects that have incorporated gas sensors in high specialized cases, and this project is the next step for that
	- System Components
	  o Engineering requirements

	- Ability to function as a multi-purpose, multi-gas radiation sensor array - Lightweight to the point where it can accommodate the weight requirements of UAVs o Microprocessor Board - Controlled by a USB-programmable microprocessor board that receives, stores, and transmits gas data, radiation and other ancillary data for graph visualization o Radiation Sensor Board and LND-712 Geiger Tube - Attached Geiger tube becomes active when ionizing radiation that passes through tube - Results in short intense pulses that flows from positive to negative electrode - Sensor delivers pulse that will activate an interrupt on the CBRNE array, increasing pulse counter by one - Pulses are collected and stored in memory for further analysis to obtain dosage of radiation - Selected to operate on UAV because of its compactness and most availability o BME280 Temperature and Humidity Sensor - Delivers high accuracy readings for temperature, humidity, and pressure - Data collected will be crucial variable that is part of the calculations for the gas sensor readings o Gas Sensors - Includes CO sensor and a molecular O_2 sensor, with a methane and combustible gas sensor that operates on a Pellistor AFE Board - Sensor types operate by returning an integer value to ADC (Analog-Digital Converter) and then communicates findings with CBRNE, with takes the average of those variables while compensating for other variables such as ambient temperature o GPS Sensor - GPS enables CBRNE to obtain time and geo-locational data specific to the CBRNE - Current work will investigate how to implement Klv video metadata with the geo-locational mapping data o LCD Screen to display necessary information and used for debugging - Testing o Researchers used the iBrid MX6, which is used to calibrate the CBRNE gas sensor array o Both sensors were exposed to a compound gas o Compound gas contained - 18% volume of O_2 - 100 ppm CO

        - 3500 ppm pentane (25% LEL)
    - Both units were tested and validated separately, with the CBRNE achieving a margin of error of only +/- 5%
- Graphical Visualization
    - Used processing IDE
    - Tool supports visualization of all 4 onboard sensors and is flexible, adjusting for the output depending on the number of sensors installed

Research Question/Problem/ Need

The research need was a portable gas sensing module for easy deployment on UAVs and ROVs for efficient environmental monitoring.

Important Figures

Test	O_2 (% Vol)	CO (ppm)	CH4 (LEL %)
Test 1	17.6	99	23
Test 2	17.6	98	24

Test	O_2 (% Vol)	CO (ppm)	CH4 (LEL %)
Test 1	19.02	100.26	23.74
Test 2	18.96	104.73	24.54
Test 3	18.86	101.86	23.87

Calibration of the CBRNE gas sensor array vs industry standard gas detection system. The baseline test included an 18% volume of O_2, a CO concentration of 100 ppm, and a methane LEL percentage of 24% (minimum concentration of methane required to explode)

VOCAB: (w/definition)

LEL (Lower Explosion Limit): The minimum concentration of combustible gas or vapor in the air that will support flame propagation in the presence of an ignition source.

Pellistor AFE Board: Analog front-end that is used to connect to a pellistor gas sensor to collect gas sensor readings.

CBRNE: Acronym that stands for Chemical, Biological, Radiological, Nuclear, and Explosive.

Geiger Tube: Type of radiation detector filled with low-pressure gas with a central wire anode and an outer cylindrical cathode.

KLV video metadata: KLV --> (Key-Length Value) metadata is information that comes in the form of video feeds. Key-length value is an organizational technique that measures video feeds using the type-length and value encoding scheme.

Cited references to follow up on

M. R. Brust and B. M. Strimbu, A Networked Swarm Model for UAV Deployment in the Assessment of Forest Environments, in IEEE Tenth International Conference on Intelligent Sensors, Sensor Networks and Information Processing, Singapore, 2015.

A. Khan, D. Schaefer, B. Roscoe, K. Sun, L. Tao, D. Miller, D. J. Lary and M. A.

	Zondlo, Open-Path Greenhouse Gas Sensor for UAV applications, in Lasers and Electro-Optics, San Jose, USA, 2012. A. Khan, T. Schaefer, D. J. Miller, K. Sun, M. A. Zondlo, W. A. Harrison, B. Roscoe and D. J. Lary, Low Power Greenhouse Gas Sensors for Unmanned Aerial Vehicles, Remote Sensing, vol. 4, no. 5, pp. 1355–1368, 2012. A. Malaver, F. Gonzalez, N. Motta, A. Depari and P. Corke, Towards the Development of a Gas Sensor System for Monitoring Pollutant Gases in the Low Troposphere U sing Small Unmanned Aerial Vehicles, in Workshop on Robotics for Environmental Monitoring, Queensland, Australia, 2012.
Follow up Questions	Is averaging the gas sensor readings and then compensating an effective measurement system? How does the gas module not have an error of more than 17% if it doesn’t even use machine learning? How reliable is the study’s method of data collection and gathering results? Where did they test both detectors? In an enclosed, controlled environment or outdoors with other inhibiting factors?

Article #7: Autonomous Gas Detection and Mapping With Unmanned Aerial Vehicles

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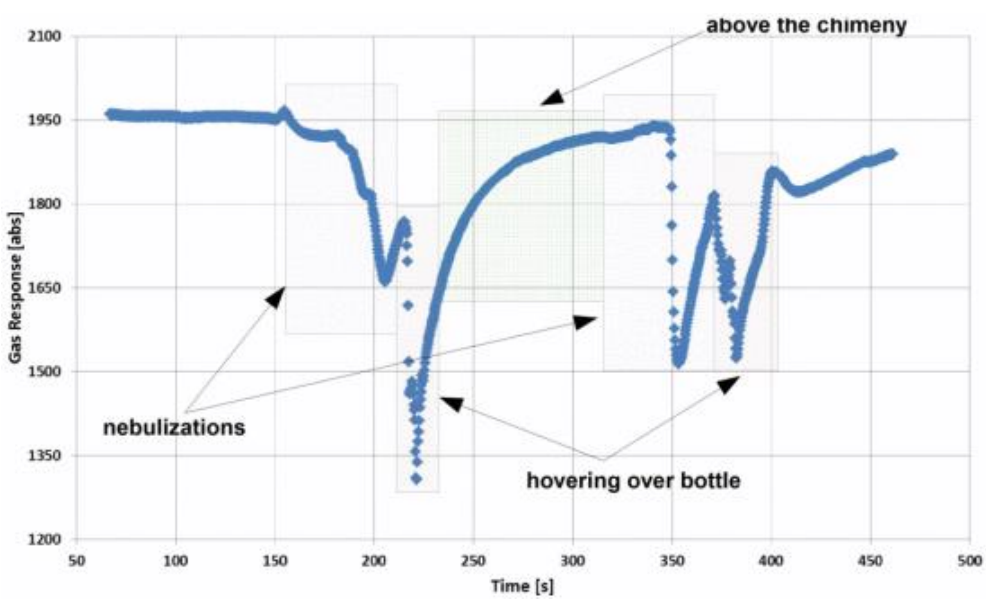
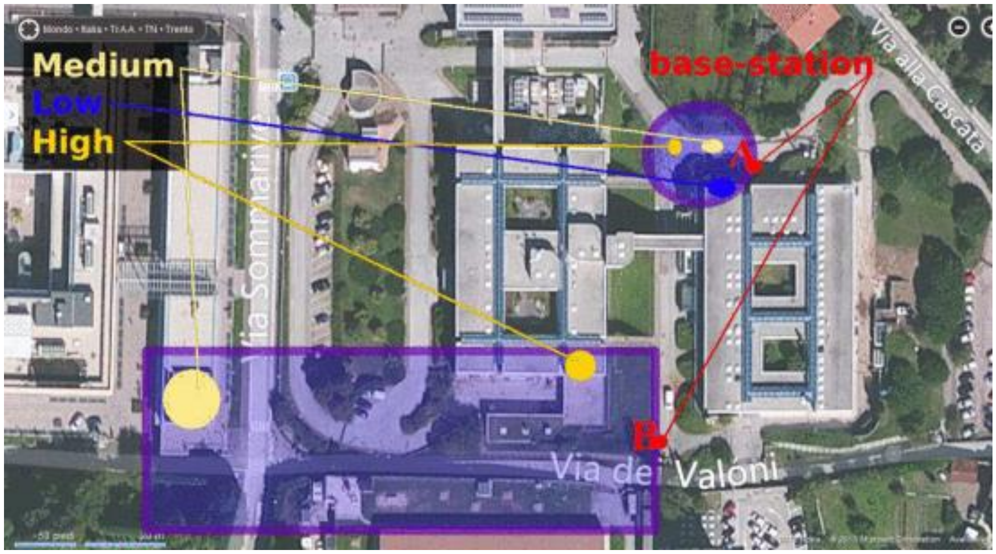
Source Title	Autonomous Gas Detection and Mapping With Unmanned Aerial Vehicles
Source citation (APA Format)	Rossi, M., Brunelli. D Autonomous Gas Detection and Mapping With Unmanned Aerial Vehicles, *IEEE Transactions on Instrumentation and Measurement*, vol. 65, no. 4, pp. 765-775, April 2016, https://doi:10.1109/TIM.2015.2506319
Original URL	https://ieeexplore.ieee.org/document/7369958
Source type	Journal Article
Keywords	Chemical sensors, Gas detectors, Chemicals, Sensor phenomena and characterization, Monitoring, Robot sensing systems
#Tags	#gas_detection, #chemical_sensing, #environmental_robotics
Summary of key points + notes (include methodology)	- Proposal o Proposed a drone with a chemical sensing system for environmental monitoring, gas leakage detection, and pollution mapping applications o Lightweight, electronic system that uses microcontroller unit (MCU) that manages a global system for mobile communications o Used 16 cm^2 compact battery system that weighs a total of less than 30 grams o Uses MOX gas sensors

- Allows it to be applicable to any kind of autonomous system, not just UAVs
- Engineering embedded sensing and algorithm that uses adaptive sampling to measure and locate gas leakage by minimizing the energy required by the sensing elements

- Decided to use chemo-resistive sensors for this type of implementation as it offers fast responsivity and has great longevity and long-term stability even when their power consumption is not negligible
- The study used to off the shelf sensors
    - MiCS-5121 for CO and VOC detection
    - MiCS-5255 for CO measurement solely
    - MiCS-5255 is basically the same except it has an embedded charcoal filter
        - Even though charcoal filter was found to lower sensor reaction time and reduce sensor sensitivity, it actually enhanced sensitivity
- Considered using machine learning to separate different concentrations of different gasses
    - Thought that it would impair the weight of the system since it requires a chip or module that can store an ML model on the hardware side, which adds more weight to the gas module system
    -
- Considering the complexity of gas mixtures and turbulent flows, the researchers ran 2 tests on the MOX sensors
    - Tested heatmap generation of gas concentrations using bottles of acetone and isopropanol to test whether the MOX sensors would pick up the different amounts at different places of the room that the drone was tested in
    - Tested indoor vs outdoor environments and found out that the MOX sensors were able to pick up gas concentrations despite the inhibiting factors of the outdoors
- Hardware + Circuitry
    - 32-bit RISC microprocessor
    - 128 KB ROM, 128 KB RAM
    - Multiple peripherals: SPI, UART, timers, and ADC
    - Communication
        - SIM-9083 with integrated GPS/GSM transceiver for location tracking
        - Sends data via GRPS in web server using TCP/IP
    - Design features:
        - Interface with MCU using 4 lines
            - 2 for supply
            - 1 for digital enable
            - 1 for analog output
        - Interchangeable socket for different MOX sensors
        - MOX sensors driven at ~76 mW, operating at ~340°C

	▪ Sensing resistance (Rs) varies inversely with gas concentration (higher concentration = lower resistance) ▪ Range: few megaohms to tens of kilohms ▪ Uses 12-bit ADC for high-resolution measurements o Power Management ▪ n-type MOSFET switch to turn sensor ON/OFF ▪ Gas sensors are the highest power consumers in the system ▪ Requires careful algorithm optimization to maximize battery life - Testing + Results o Tested gas sensing module on DJI hexacopter o Drone is suited for limited region gas distribution o Used the MiCS-5121 VOC-targeted sensor o Found out that environmental sensitives played a big role on the MOX sensor's response to the gasses o In response, the researchers switched to a different sensor system that added on to the MOX sensor system to account for the environmental sensitivities
Research Question/Problem/ Need	Currently, there is a lack of autonomous monitoring systems that lack of a dynamic system of sensors that communicate with each other and present valuable data to the user about their surroundings and concentrations of surrounding gases.
Important Figures	 This graph represents the MOX sensor's gas response at different moments in time. A decrease in gas response correlates to an increase in the sensor's sensitivity, which is supposed to happen as they come closer to

	the isopropanol alcohol and acetone on different parts of the field. This was indoors.  Gas distribution maps of aerial view of test location for drone.
VOCAB: (w/definition)	MOX (Metal Oxide) Sensors - Chemo-resistive gas sensors that detect gases by changing electrical resistance when exposed to target compounds; operate at high temperatures (~340°C) and offer fast response times with good longevity. Chemo-resistive - A sensing mechanism where the electrical resistance of a material changes in response to chemical interactions with gas molecules, used as the detection principle in these sensors. Adaptive Sampling - An algorithm approach that dynamically adjusts measurement intervals and patterns to minimize energy consumption while maintaining effective gas detection and localization. GPRS (General Packet Radio Service) - A mobile data communication protocol used to transmit sensor data from the drone to a web server via TCP/IP networks. VOC (Volatile Organic Compounds) - Carbon-based chemicals that easily evaporate at room temperature; one of the primary target pollutants detected by the MiCS-5121 sensor in this system.
Cited references to follow up on	V. Gallego, M. Rossi, and D. Brunelli, Unmanned aerial gas leakage localization and mapping using microdrones, in Proc. IEEE Sensors Appl. Symp. (SAS), Apr. 2015, pp. 1–6. M. Rossi, D. Brunelli, A. Adami, L. Lorenzelli, F. Menna, and F. Remondino, Gas-drone: Portable gas sensing system on UAVs for gas leakage localization, in Proc. IEEE SENSORS, Nov. 2014, pp. 1431–1434.

	P. P. Neumann, S. Asadi, A. J. Lilienthal, M. Bartholmai, and J. H. Schiller, Autonomous gas-sensitive microdrone: Wind vector estimation and gas distribution mapping, IEEE Robot. Autom. Mag., vol. 19, no. 1, pp. 50–61, Mar. 2012.
Follow up Questions	Why were isopropanol alcohol and acetone as the testing chemicals to see whether the sensors picked up gases in the environment? How is this accurate to compare modern, dangerous gases with potentially different characteristics than that of the testing compounds?

Article #8: Autonomous gas-sensitive microdrone: Wind vector estimation and gas distribution mapping

Source Title	Autonomous gas-sensitive microdrone: Wind vector estimation and gas distribution mapping
Source citation (APA Format)	Neumann P., Asadi. S, Lilienthal A. Bartholomai M., & Schiller J., (2012) Autonomous gas-sensitive microdrone: Wind vector estimation and gas distribution mapping, *IEEE Robot Autonomous Magazine*, vol. 19, no. 1, pp. 50–61, https://doi: 10.1109/MRA.2012.2184671
Original URL	https://ieeexplore.ieee.org/document/6155597
Source type	Journal Article
Keywords	Robot sensing systems, Real time systems, Gas detectors, Delta modulation Mobile communication, Delta modulation
#Tags	#environmental_monitoring #environmental_robotics
Summary of key points + notes (include methodology)	Objective of paper - Engineered an autonomous system that is used for autonomous gas-validation and wind-vector estimation using the onboard control unit of the microdrone and the performing gas distribution map - Problem: There are many sites where gas pollution is at high levels and the release of hazardous gases is an acute threat that dangers human beings o Gas can be released in different ways, which is why it is important to detect it precisely - This is why a quick, deployable measurement device is needed for efficient gas monitoring to protect humans

	- MUAVs are suitable for this task --> identified by the researchers o Focuses more specifically on quadcopters - Decided to utilize a mobile system instead of a grid of stationary networks - Used kernel DM discretizes available space into grid cells and computes an estimate of the distribution mean for each cell using a symmetric Gaussian kernel - Gaussian kernel weighs importance of each reading in relation to the heatmap as a whole - Used Drager Xm gas sensor, which is a catalytic, electrochemical and infrared gas sensor - Wanted to make drone compact and lightweight to maximize flight time - However, they faced a serious problem o Gas Transport Diffusion ▪ Some solutions include • Passive Gas Transport • Semiactive Gas Transport (found most useful) • Active Gas Transport - Decided to focus on wind vector optimization since it determines the speed and mixing of different poisonous gasses like CO, meaning that it can account for the mixing of those gasses - Used wind triangle and drone altitude to calculate inclination angle, which has a quadratic relationship with flight speed - Derived flight vector and measured ground vector from this information - Tested algorithm and drone in wind tunnel --> 1-8 m/s in 0.5 m/s steps o Tested different drone orientations o With and without 200-gram payload o Found out that inclination angle and flight speed is constant all across the experiments - Used kernel DM + V / W for 2-D gas distribution mapping - Results from error o Wind speed RMSE o Wind direction RMSE o Inhomogeneous wind field o Other factors that the researchers didn’t account for
Research Question/Problem/ Need	The research need for this study is that there is a lack of autonomous systems that accurately and autonomously detect dangerous gas concentrations in dangerous environments, and that there is a need for quick, deployable machines that can achieve this task.

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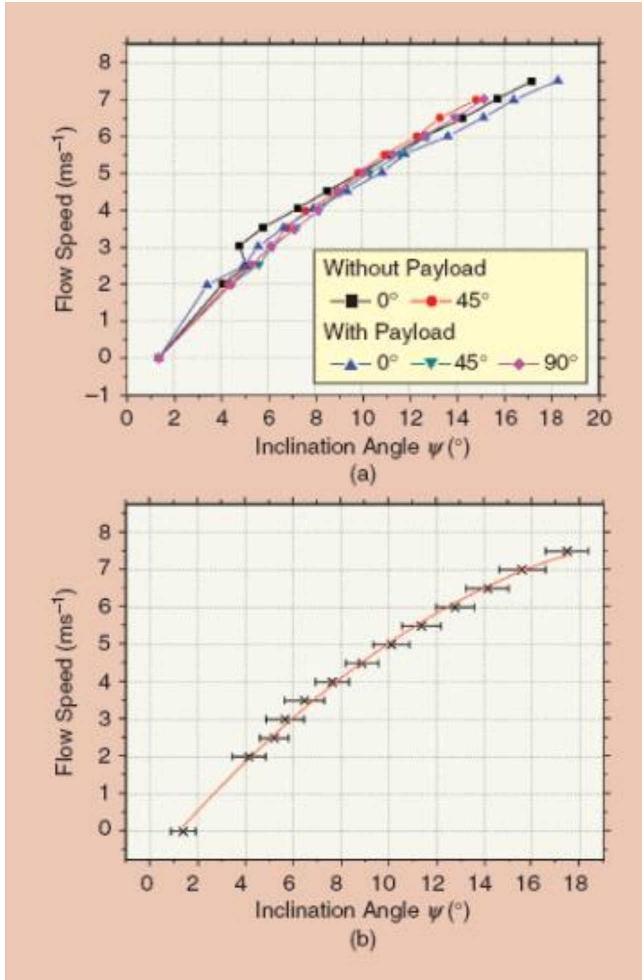
<tr>
<td>Important Figures</td>
<td>


Figure shows the inclination angle versus the wind speed when testing the drone in the wind turbine. (a) shows the different conditions the drone was tested under when running these tests while (b) shows the line of best fit for the relationship between inclination angle and wind flow speed, showcasing a strong positive relationship with only a little margin of error
</td>
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<td>VOCAB: (w/definition)</td>
<td>
MUAV: MIcro Unmanned Aerial Vehicle, a small autonomous flying robot that is described as a 1m diameter quadcopter

Quadcopter: Aircraft with four motors arranged in a square pattern

Payload: Weight that the drone had to carry

Waypoint: Specific coordinate that the drone has to navigate through

Flight Envelop: Range of speeds, altitudes and conditions an aircraft can safely operate in

Kernel DM + V / M: An algorithm that estimates gas concentrations at each
</td>
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</table>

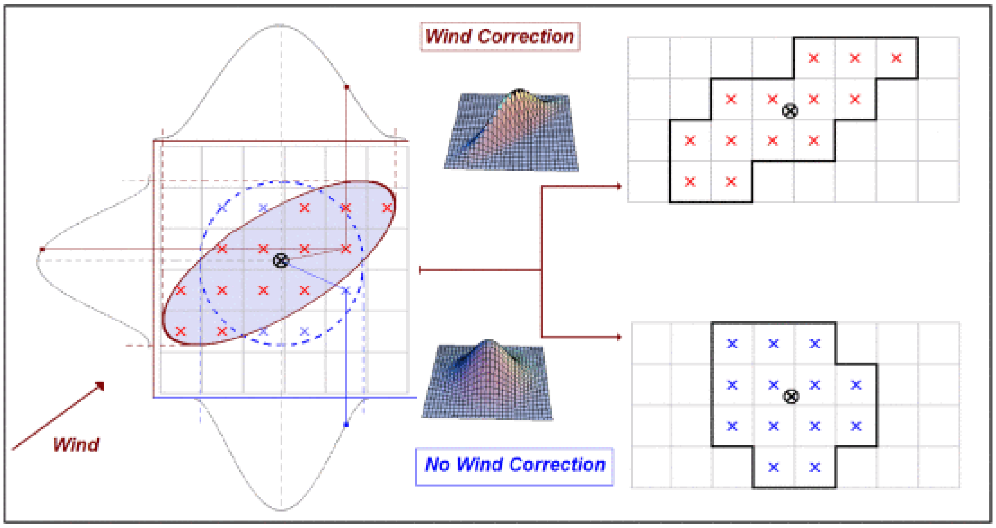
	grid cell as a weighted average of all measurements, where each measurement's weight is determined by a Gaussian kernel (proportional to wind speed × γ), and simultaneously calculates variance and confidence based on measurement density and distance.
Cited references to follow up on	H. Ishida T. Nakamoto T. Moriizumi Remote sensing and localization of gas/odor source and distribution using mobile sensing system Proc. Int. Conf. Solid State Sensors and Actuators 1 559 562 Proc. Int. Conf. Solid State Sensors and Actuators 1997 P. Pyk S. Berm údez i Badia U. Bernardet P. Knusel M. Carlsson J. Gu E. Chanie B. S. Hansson T. C. Pearce P. F. J. Verschure An artificial moth: Chemical source localization using a robot based neuronal model of moth optomotor anemotactic search Auton. Robots 20 3 197 213 2006 A. Hayes A. Martinoli R. Goodman Distributed odor source localization IEEE Sensors J. 2 3 260 271 2002 A. J. Lilienthal M. Reggente M. Trincavelli J. L. Blanco J. Gonzalez A statistical approach to gas distribution modelling with mobile robots-The kernel \${\rm DM} +{\rm V}\$ algorithm Proc. IEEE/RSJ Int. Conf. Intelligent Robots and Systems (IROS) 570 576 Proc. IEEE/RSJ Int. Conf. Intelligent Robots and Systems (IROS) 2009-Oct. 11–15 M. Reggente A. J. Lilienthal Using local wind information for gas distribution mapping in outdoor environments with a mobile robot Proc. IEEE Sensors 1715 1720 Proc. IEEE Sensors 2009
Follow up Questions	How many different types of gases can the UAV pick up? Has the UAV been tested in the real-world environment? How accurate would it be with a lot of other factors?

Article #9: Using local wind information for gas distribution mapping in outdoor environments with a mobile robot

Source Title	Using local wind information for gas distribution mapping in outdoor environments with a mobile robot
Source citation (APA Format)	Reggente M., and Lilienthal A., Using local wind information for gas distribution mapping in outdoor environments with a mobile robot, (2009) *IEEE SENSORS*, Christchurch, New Zealand, pp. 1715-1720, doi:10.1109/ICSENS.2009.5398498.
Original URL	https://ieeexplore.ieee.org/document/5398498
Source type	Journal Article
Keywords	Mobile robots; Pollution measurement; Kernel; Monitoring; Shape measurement; Ultrasonic variables measurement; Gas detectors; Computational fluid dynamics; Wireless sensor networks; Computational modeling
#Tags	#environmental_monitoring #compututational_environment_analysis
Summary of key points + notes (include methodology)	- Intro o The problem identified is the lack of current gas distribution modelling system and the cost of current methods like computational fluid dynamics o Researchers turned to computational side of modelling ▪ Researchers noticed that wind had a strong influence on the advective transport of gasses that lead to the chaotic gas mixtures ▪ Instead of relying on CFD, they modified the algorithm to take into account the wind levels as they play a valuable role in the advection of gasses. • Old algorithm: KM + v • New Algorithm: KM + V / W

- New algorithm can use the information provided by the wind to determine source of gas leak
- Use similar kernel extrapolation methods to incorporate wind info in gas distribution model to create gas distributional model

- Kernel DM + V / W
  - Central idea of kernel extrapolation methods is to understand gas distribution as a density estimation
  - First, the algorithm computes individual weights, representing the information content of a sensor measurement *i* at grid cell *k*
  - After calculating all weights, researchers computed a weight map that indicates high confidence for cells for which a large number of readings close to center of the respective grid cel is available
  - Depends on 4 parameters
    - Zero-kernel width
      - The kernel width governs the amount of extrapolation on individual readings and the cell size determines the resolution at which different predictions can be made.
    - Cell size
    - Confidence scaling parameters
      - The confidence scaling parameter defines a soft margin on the confidence estimate, which is used to decide whether sufficient information is available to estimate the concentration mean and variance for a given grid cell.
    - Stretching coefficient
      - The stretching coefficient is related to the certainty about the wind estimate and to the duration over which the local airflow v→ can be assumed constant.
- Testing
  - Used SICK LMS 200 laser scanner range for localization
  - Electronic noise filtering using Figaro TGS 2620 gas sensors
  - Active ventilation system with fans creating constant airflow towards sensors to minimize effects of external airflow
- Experimental Setup
  - Test Environment
    - Used an 8 by 8 m play area
    - Ethanol source placed on the floor near the center
    - Sensor response is then normalized to a value between 0 and 1
    - This system assumes a single targe gas (no interferents or simultaneous odors)
    - Perfect position knowledge
    - Single sensor response is sufficient
    - Used anemometer to take measurements of wind to

	factor into algorithm - Results ○ Overall, the algorithm extends the current KM + V algorithm by adding a bivariate Gaussian weighting function to model the information provided by the gas sensors while incorporating the information from the anemometer ▪ Can be used in the software for deployable gas-sensing UAVs
Research Question/Problem/ Need	The problem identified is the lack of current gas distribution modelling system and the cost of current methods like computational fluid dynamics.
Important Figures	 The graph describes the process of how wind is translated in the algorithm. The algorithm corrects wind by superimposing an ellipse onto a 2-D plane and therefore, corrects for that tilt in the 3-D as seen in the diagram when compared to no wind correction.
VOCAB: (w/definition)	ATRV-JR - The mobile robot platform used Laser range scanner - Device for robot localization (position tracking) Electronic nose - Array of gas sensors for detecting chemical compounds Metal oxide sensors - Type of gas sensor that heats up to detect gases Ultrasonic anemometer - Device that uses sound waves to measure wind speed and direction Weight: Learnable parameter that quantifies the importance or significance of that variable when determining the outcome
Cited references to follow	A. Lilienthal and T. Duckett, Building gas concentration gridmaps with a mobile

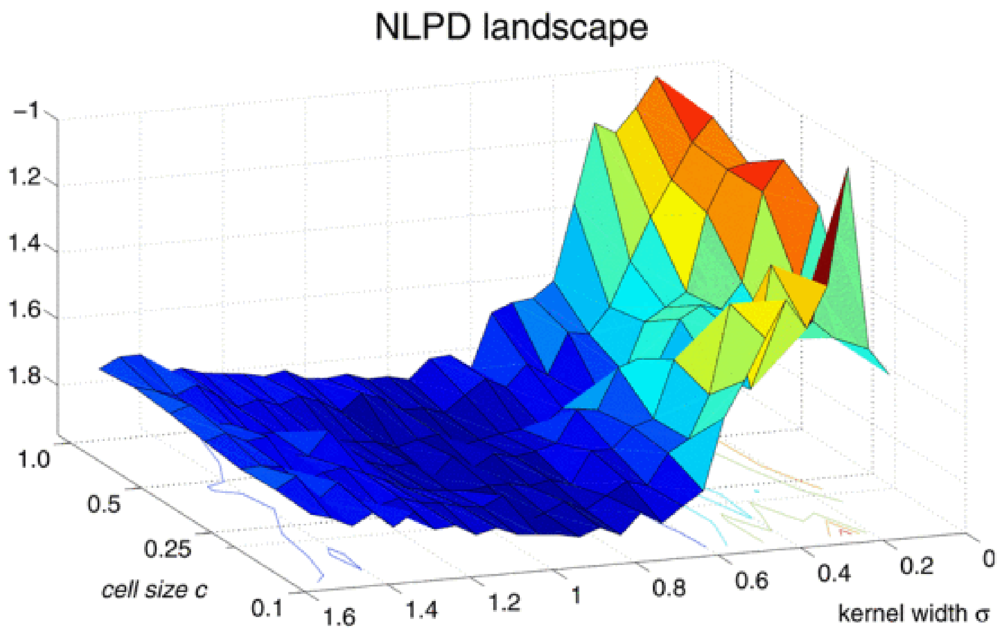
up on	robot, Robotics and Autonomous Systems, vol. 48, no. 1, pp. 3–16, August 2004.
Follow up Questions	How would the algorithm perform if there were interferant gasses? How would the model need to be finetuned in order to account for that?

Article #10: A statistical approach to gas distribution modelling with mobile robots - The Kernel DM+V algorithm

Source Title	A statistical approach to gas distribution modelling with mobile robots - The Kernel DM+V algorithm
Source citation (APA Format)	Lilienthal A., Reggente M., Trincavelli M., Blanco J., Gonzalez J., (2009) A statistical approach to gas distribution modelling with mobile robots-The kernel DM + V algorithm Proc. IEEE/RSJ Int. *Conf. Intelligent Robots and Systems* (IROS) pg 570-576, https://doi: 10.1109/IROS.2009.5354304.
Original URL	https://ieeexplore.ieee.org/document/5354304
Source type	Journal Article
Keywords	Mobile robots; Kernel; Intelligent sensors; Gas detectors; Pollution measurement; Intelligent robots; Predictive models; Atmospheric modeling; Intelligent networks; Robot sensing systems
#Tags	#Robotic_gas_sensing

Summary of key points + notes (include methodology)	- Researchers proposed new algorithm called DM + V algorithm for gas distribution modelling
	  - The algorithm learns a statistical 2D gas distribution model from localized gas sensor measurements without strongly considering assigning high importance to sensing locations or environmental conditions when making its predictions. Unlike previous approaches, it models both the distribution mean and the predictive variance.
	- Key Advantages
	  - Problem: Ground truth evaluation for gas distribution modelling
	    o Algorithm estimates predictive variance to solve this problem, which other models don't have
	  - The algorithm makes no assumptions about the distribution's functional form. In other words, it's non-parametric.
	  - Lower computational complexity compared to alternative methods like Gaussian Process Mixtures
	- Experimental Validation
	  - Experiments were conducted in three environments (enclosed 3-room indoor space, corridor, and outdoor area) using a mobile robot equipped with the gas sensor module built in the study

	- Mobile Robot:
	  ○ Mobile robot contained electronic nose (Figaro gas sensors)
	  ○ Equipped with SICK laser scanner for pose correction
	  ○ Anemometer for wind measurements
	  ○ Active ventilation for consistent airflow
	- Results demonstrated consistency between maps created from stationary and mobile sensor measurements, with comparable performance to the GPM approach

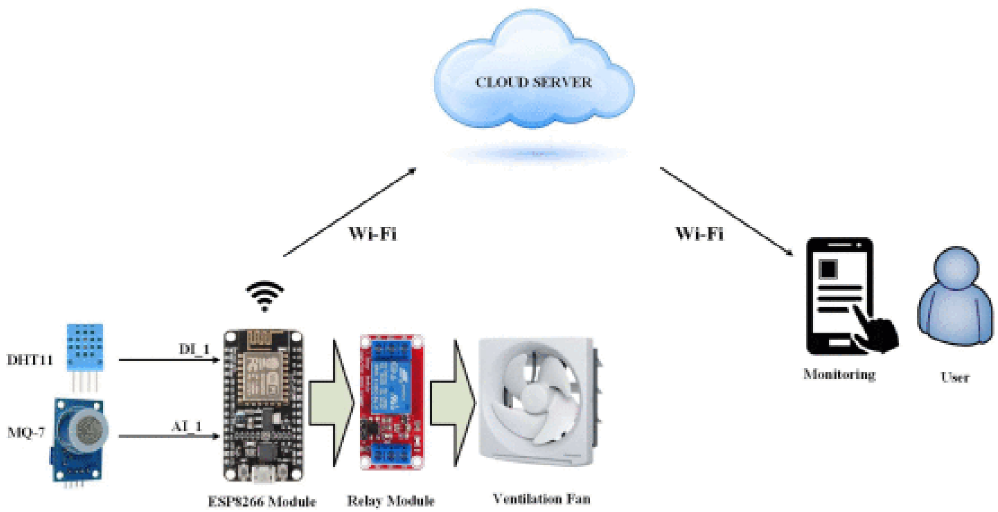
Research Question/Problem/ Need	The problem is that gas distribution modelling with mobile robots is challenging because turbulent air flow creates chaotic gas packets, resulting in fluctuating, intermittent concentration patches rather than stable readings.
Important Figures	 The graph shows the different parametric input combinations (all combinations of kernel width and cell size) and the model's overall gas concentration. The blue regions represent optimal gas concentration prediction of gas distribution, meaning that high kernel widths correlate to better predictions.
VOCAB: (w/definition)	Negative log property landscape diagram: Criterion that evaluates the different combinations of parameters to analyze how well the model predicts unseen measurements Nonparametric: Makes no assumption about the functional form of the distribution. More specifically, past studies don't account for wind vectors when calculating gas concentration and assume a direct relationship between 2 sources. Predictive variance: Estimation of fluctuation and variability in gas readings Kernel width: Controls amount of spatial extrapolation/smoothing

	Gaussian Process Mixture: Alternative statistical approach for comparison
Cited references to follow up on	H. Ishida, T. Nakamoto, and T. Moriizumi. Remote Sensing of Gas/Odor Source Location and Concentration Distribution Using Mobile System. Sensors and Actuators B, 49:52-57, 1998.
Follow up Questions	How accurate was the robot equipped with gas modules under terrible wind conditions? What about other inhibiting gases such as CO_2, H_2, N_2, etc.

Article #11: Wireless Carbon Monoxide Level Control and Monitoring System

Article notes should be on separate sheets

Source Title	Wireless Carbon Monoxide Level Control and Monitoring System
Source citation (APA Format)	Rerkratn A., Riewruja, V., Petchmaneelumka A., Tammaruckwattana S., (2025), Wireless Carbon Monoxide Level Control and Monitoring System*, International Conference on Control, Automation,* and Robotics (ICCAR), pg 537-541, doi: 10.1109/ICCAR64901.2025.1107303
Original URL	https://ieeexplore.ieee.org/document/11073038/authors#authors
Source type	Journal Article
Keywords	Temperature measurement; Temperature sensors; Fans; Humidity; Control systems; Carbon monoxide; Internet of Things; Relays; Monitoring; Testing; Carbon Monoxide (CO); Internet of Things (IoT); MQ-7; ESP8266; Ventilation System
#Tags	#ventilation #co-monitoring
Summary of key points + notes (include methodology)	- Proposes online CO measurement system to alarm users when CO gas leak levels exceed setting value - CO values are then used to control the ventilation system to maintain CO at a low level - Materials used o CO MQ-7 gas sensor for CO level monitoring o Relay module to operate with low voltage control signals and to control the ventilation fan module o ESP8266 module to support IoT devices --> used to read CO levels

	and humidity levels from the sensors ○ ThingSpeak: IoT platform providing cloud data storage and analysis in IoT projects. In this case, it was used to create different gauges of CO (in ppm), humidity level (%), temperature (in Celsius), and ventilation fan output. Provides an opportunity for an HMI. - Results ○ Results show that the proposed system can operate with design, as presented in these figures when the detector is in different states
Research Question/Problem/ Need	Current carbon monoxide measurement systems are local and offline, and don't account for CO filtration.
Important Figures	 Figure above shows system architecture for the entire monitoring system. Data is collected from the DHT-11 and MQ-7, when transmitted to the ESP32 which is then sent to Wi-Fi and a relay module which is connected to a fan that is activated when the module sends the fan voltage.

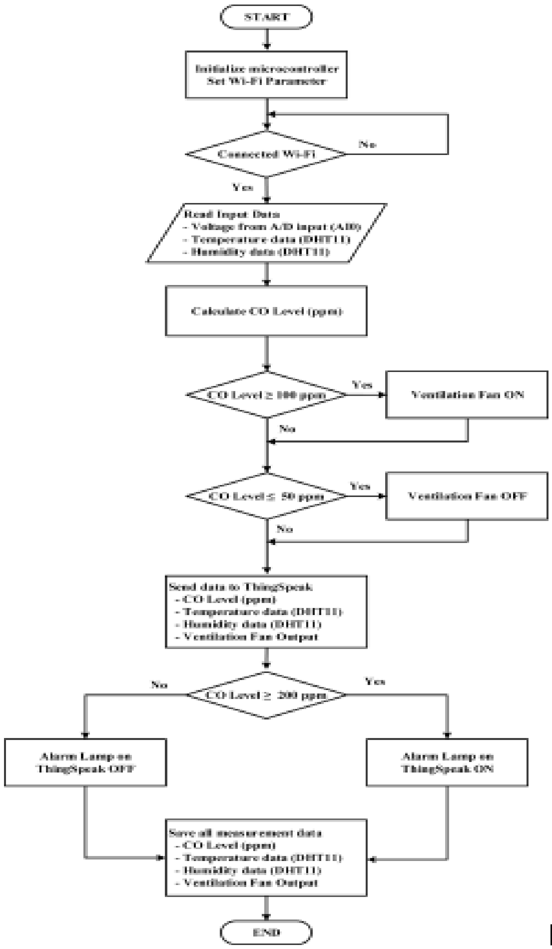


Diagram represents control flow of the software used inside the system

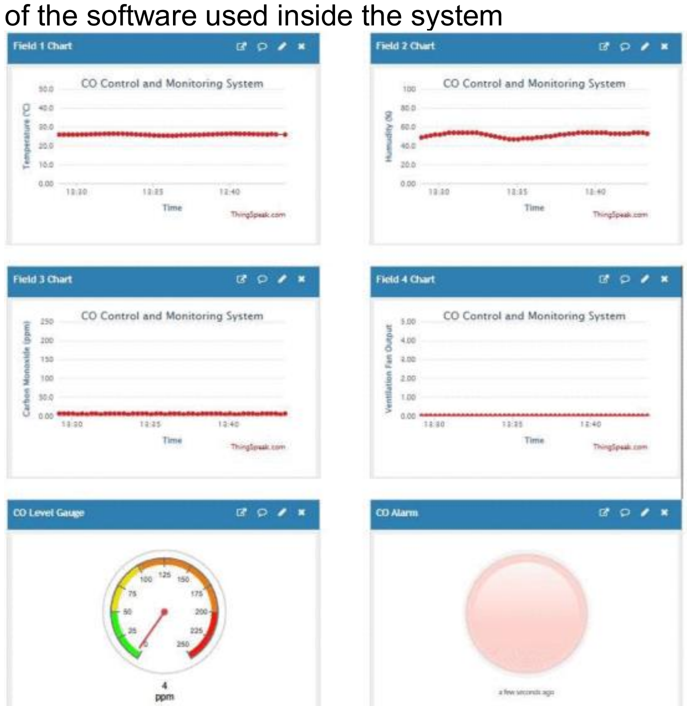


	Figure above represents how the user-interface looks in one certain condition (when CO levels are not as high)  FIgure above represents CO detection when levels are very high, displaying high amounts of danger to the user
VOCAB: (w/definition)	HMI: Human-Machine Interface; another word for user interface as used in the journal MQ-7: Carbon monoxide gas sensor used for building Arduino/IoT projects DHT-11: Humidity and temperature sensor for monitoring humidity (in %) and temperature in Celsius
Cited references to follow up on	J. A. Raub, M. Mathieu-Nolf, N. B. Hampson, and S. R. Thom, Carbon monoxide poisoning-A public health perspective, TOXICOLOGY, Vol. 145 (1), pp. 1–14, 2000. A. A. Ibrahim, Carbon dioxide and carbon monoxide level detector, 2018 21st International Conference of Computer and Information Technology (ICCIT), Dhaka, Bangladesh, pp. 1–5, 2018. L. Das, R. Raman Chandan, P. Kaur, A. Singh, A. Rana and B. D. Shivhare,

	Advancements in wireless network technologies for enabling the (IoT): a comprehensive review, 2023 6th International Conference on Contemporary Computing and Informatics (IC3I), Gautam Buddha Nagar, India, pp. 807–814, 2023.
Follow up Questions	Can the system forecast future CO levels and predict danger from earlier trends?

Article #12: Development of Carbon Monoxide Gas Leakage Detector in Vehicles Using IOT

Article notes should be on separate sheets

Source Title	Development of Carbon Monoxide Gas Leakage Detector in Vehicles Using IOT
Source citation (APA Format)	Azhar N., Hussin Z., Mohammad S., (2024) Development of Carbon Monoxide Gas Leakage Detector in Vehicles Using IOT. *International Conference on Engineering Technology and Technopreneurship (ICE2T)*., pp. 330-334, doi: 10.1109/ICE2T58637.2023.10540501.
Original URL	https://ieeexplore.ieee.org/document/10540501/authors
Source type	Journal Article
Keywords	GSM; Packet radio networks; Internal combustion engines; Carbon monoxide; Automobiles; Internet of Things; Gas detectors; Carbon Monoxide detection; MQ-7 sensor; Internet of Things (IoT)
#Tags	#IoT #gas_sensing #car_sensing

Summary of key points + notes (include methodology)	- Sensor that detects the presence of carbon monoxide, then activates a power window to open and release the carbon monoxide into the air
	- Proposes a system that automatically sends a notification to a user's phone and automatically switches off ignition in the car
	- It will also have an emergency response algorithm that if it doesn't detect user feedback, it will call emergency services after the alert is sent to the user's phone
	- Materials
	  o MQ7 --> Arduino MEGA (connected to power supply)
	    ▪ Arduino MEGA connected to:
	      • Servo to power window down
	      • LCD display to display CO levels
	      • GSM900a to send alerts to the user's phone
	- Results
	  o The proposed system appears to work in every single condition

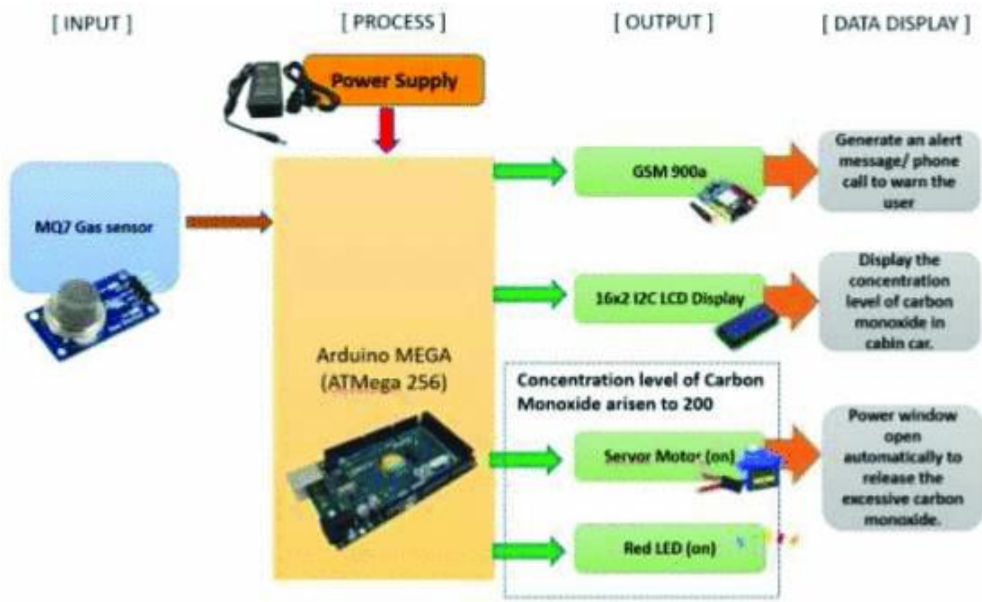
<table>
<tr><td></td><td>and edge case presented, signifying that this system can reduce carbon monoxide poisoning in cars.</td></tr>
<tr><td>Research Question/Problem/ Need</td><td>Carbon monoxide leakage can often happen in a car due to the original exhaust system not working, and carbon monoxide leakage within cars can be very dangerous due to it being poisonous, orderless, and essentially undetectable by cars. Current sensors don’t exist in cars to detect carbon monoxide.</td></tr>
<tr><td>Important Figures</td><td>


Figure above shows the electrical diagram of the different components of the circuit, including the MQ7 gas sensor picking up CO levels, then sending data processed by the Arduino MEGA that is then connected to a power supply. It is then connected to a servo that turns powers a window open and LEDs to display to the user what level the CO is in the car.</td></tr>
<tr><td>VOCAB: (w/definition)</td><td>GSM900A Module: It is a popular Arduino-based model used in IoT to enable cellular communication, such as sending and receiving SMS, making calls, and transmitting data.</td></tr>
<tr><td>Cited references to follow up on</td><td>A. C. Soh, M. Hassan, and A. Ishak, Vehicle gas leakage detector, The Pacific Journal of Science and Technology, vol. 11, no. 2, pp. 66–76, 2010.

B. Miles, S. Chikhi, and E.-B. Bourennane, Carbon monoxide detection: an iot application used as a tool for civil protection services to save lives, in Proceedings of the 3rd International Conference on Future Networks and Distributed Systems, 2019, pp. 1–4., doi: 10.1145/3341325.3341998.

M. S. Shamsudin and A. S. M. Zain, Low-cost iot based carbon monoxide (co) monitoring system, INOTEK 2021, vol. 1, pp. 179–180, 2021.</td></tr>
<tr><td>Follow up Questions</td><td>What if there is a malfunction in the car windows (something got stuck or something is jammed so that the window is not opening)? Could that be a</td></tr>
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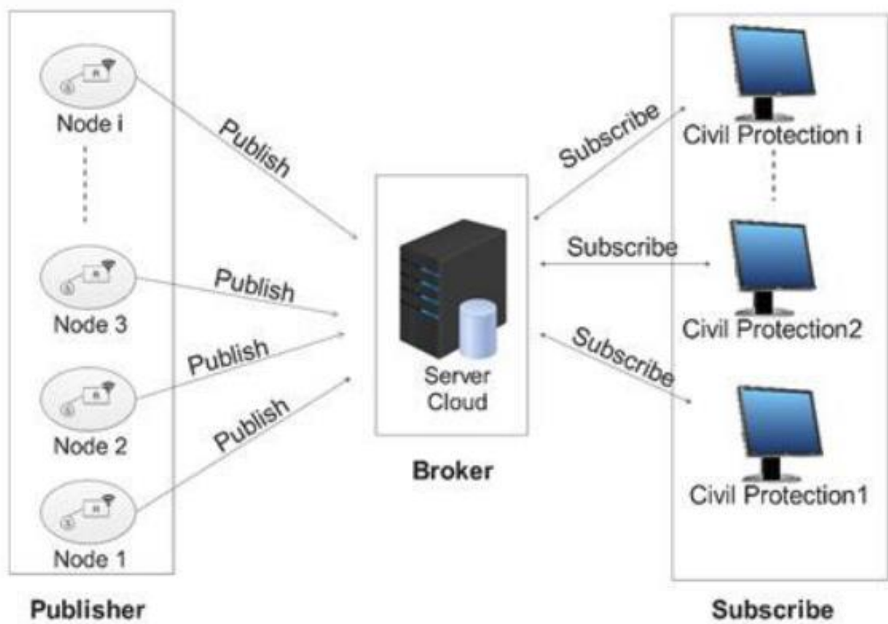
	limitation of the study?

Article #13: Carbon monoxide detection: an IoT application used as a tool for civil protection services to save lives

Article notes should be on separate sheets

Source Title	Carbon monoxide detection: an IoT application used as a tool for civil protection services to save lives
Source citation (APA Format)	Miles B., Chikhi S., Bourennane E., (2019, July 1).,Carbon monoxide detection: an IoT application used as a tool for civil protection services to save lives. *Proceedings of the 3rd International Conference on Future Networks and Distributed Systems (ICFNDS '19)* pp. 1-4., https://doi.org/10.1145/3341325.3341998.
Original URL	https://doi.org/10.1145/3341325.3341998
Source type	Journal Article
Keywords	#IoT, #Carbon monoxide
#Tags	#Automated detection, #efficient_monitoring

Summary of key points + notes (include methodology)	- Proposed to integrate automated carbon monoxide detection IoT system to manage alerts of high levels of carbon monoxide poisoning in homes
	- Designed civil protection communication system to inform users about the CO levels in multiple environments
	- Used MQTT communication protocol when developing whole-house communication system
	- Uses CoAP protocol as well to meet IoT requirements that HTTP lacks
	    o Uses request/response type structure for resource discovery and HTTP interaction and security
	- MQTT contains 3 components
	    o Subscriber
	        ▪ User Interface
	    o Publisher

	▪ Sends new info to the broker o Broker ▪ Provides security by verifying authorization of publishers - Used a raspberry pi microcontroller and MQ-7 for CO detection + monitoring - Results o Appeared to work in every tested scenario, showcasing its promise in protecting citizens' lives from carbon monoxide poisoning
Research Question/Problem/ Need	Lack of civil intervention protection systems to let authorities know about high CO level environments to take affirmative action
Important Figures	 Flowchart of proposed architecture used in the study, combining the carbon monoxide nodes and MQTT architecture

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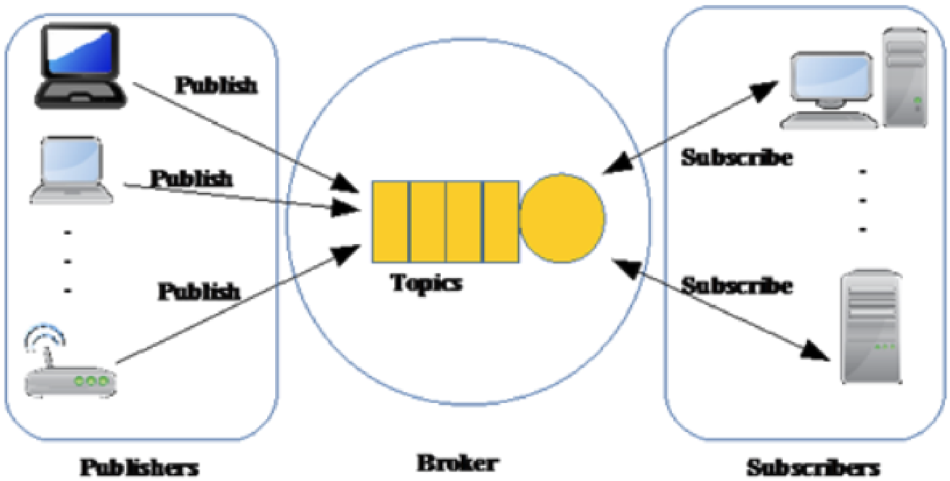

Figure 2: MQTT architecture [5].

Flowchart describing MQTT architecture with the publisher, broker, and subscriber model

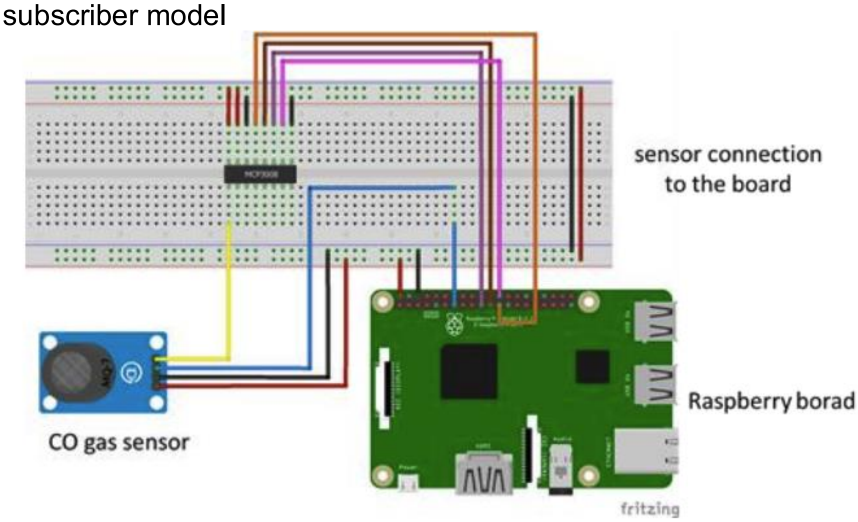

Figure 5: CO Intoxication Detection Node.

Electrical diagram describing carbon monoxide node

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VOCAB: (w/definition)

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MQTT: MQTT, which stands for Message Queuing Telemetry Transport, is a lightweight, publish-subscribe messaging protocol designed for machine-to-machine communication, especially on the Internet of Things (IoT). In this context, it is used to let civil protection services know about dangerously high levels of CO (carbon monoxide).

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Cited references to follow up on

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<td>

L. Belli, S. Cirani, L. Davoli, A. Gorrieri, M. Mancin, and M. Picone, Design and Deployment of an IoT Application Oriented Testbed, IEEE Computer., vol. 48, no. 9, pp. 32–40, 2015.

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	R. Hat, OASIS Advanced Message Queuing Protocol OASIS Standard, no. October, pp. 0–124, 2012. P. Saint-Andre, Extensible messaging and presence protocol (XMPP): Core, Internet Engineering Task Force (IETF), Request for Comments: 6120, 2011. .
Follow up Questions	Do you think that this system is susceptible to interference between the publisher and broker or the broker and the subscriber? How would this system combat that or is that a limitation that can be addressed?

Article #14: Full-scale validation of CFD simulations of buoyancy-driven ventilation in a three-story office building

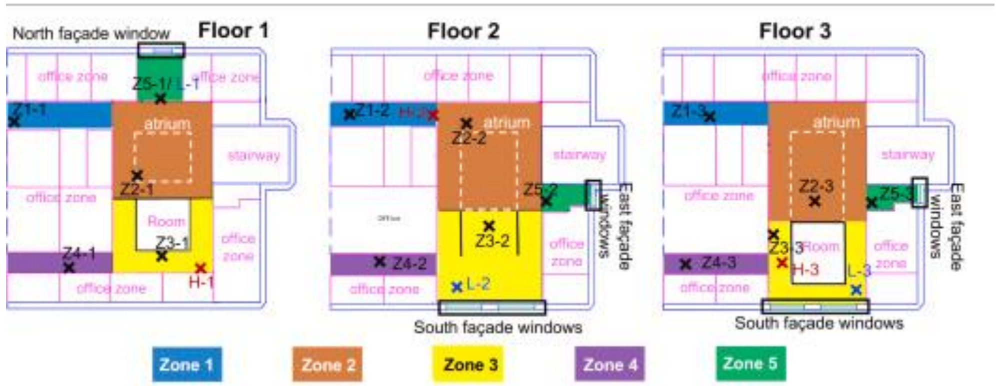
Article notes should be on separate sheets

Source Title	Full-scale validation of CFD simulations of buoyancy-driven ventilation in a three-story office building
Source citation (APA Format)	Chen, C., & Gorle, C. (2022). Full-scale validation of CFD simulations of buoyancy-driven ventilation in a three-story office building. *Building and Environment*, *221*. https://doi.org/https://doi.org/10.1016/j.buildenv.2022.109240
Original URL	https://doi.org/https://doi.org/10.1016/j.buildenv.2022.109240
Source type	Journal Article
Keywords	Buoyancy-driven ventilation; Computational fluid-dynamics; Full-scale validation; Sensitivity analysis
#Tags	#CFD #model_validation
Summary of key points + notes (include methodology)	- The study used CFD and a URANS simulation approach to simulate buoyancy-driven ventilation in a 3-story office building - Validated CFD simulations with real-time sensors placed in different parts of the building, with windows schedule to open at certain times to allow outdoor air to flow in as they are accounting for that as well - UQ and sensitivity analysis considers uncertainties in initial and final

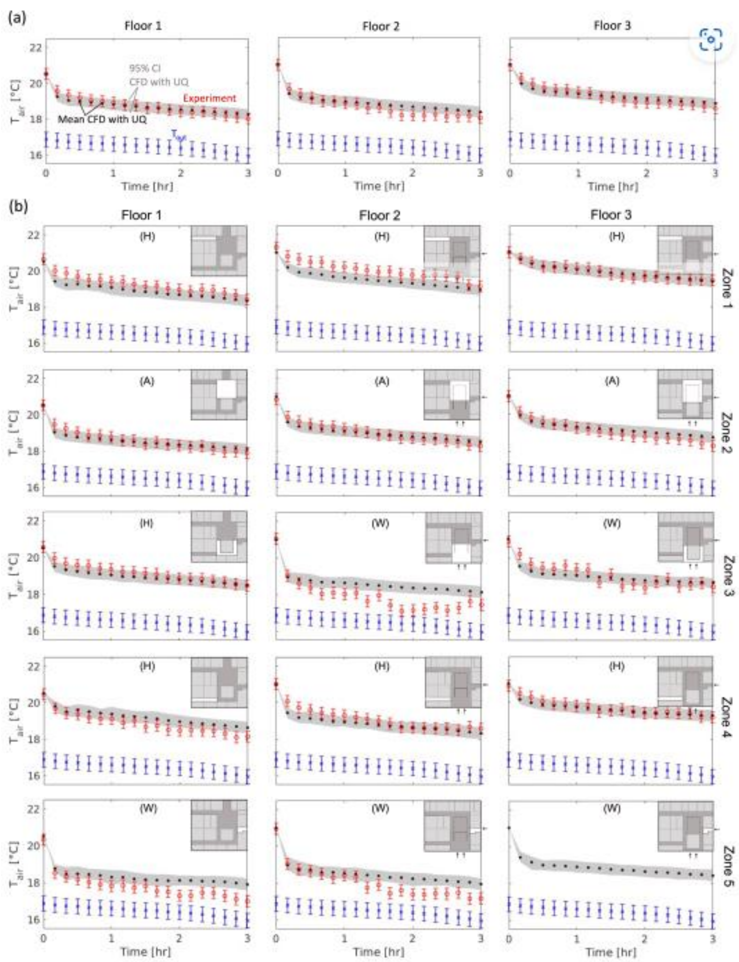
	boundary conditions for the temperatures
	- Temperature sensors were calibrated with a margin of error of only about 0.3 degrees Celsius
	- Measurements were performed over 8 nights, with the first half hour used to measure the initial conditions, with the building's outdoor temperature sensor and Stanford's wind and weather data providing alternative wind and temperature data
	- Validation approach
	    o Simulations were validated against full-scale experimental data for one night where buoyancy was the driving force
	        ▪ Validation compared
	            • Floor-averaged air temperatures
	            • Zone-averaged air temperatures in different regions of each floor
	            • Temperature range on each floor
	    o UQ (Uncertainty Quantification) was used to represent uncertainties in the measured initial and boundary conditions
	    o Sensitivity analysis using Sobel indices were performed to identify the dominant uncertain parameters that the CFD model failed to account for
	- Results
	    o CFD models could predict temperatures very accurately (RMSEs almost less than 0.3)
	    o RMSEs ranged from 0.1 to 0.81 for overall zone-averaged temperature ranges, indicating good overall agreement
	    o Most uncertainties occurred in the zones nearest to the window openings
	    o Sensitivity Analysis results
	        ▪ Boundary conditions for thermal mass surface temperature and outdoor temperatures --> internal heat gains had a smaller effect
	        ▪ Zones adjacent to windows were most affected by the outdoor temperature uncertainties

Research Question/Problem/ Need	Validation of CFD model modelling buoyancy-driven ventilation conditions tend to make simplistic assumptions while ignoring important uncertainties that greatly affect the size of the discrepancies between CFD models and real-life.

Important Figures



Map of zones where temperature sensors were placed at where lower, average and higher temperatures are marked by black, red and blue crosses respectively



Graphs of temperatures outputted by CFD model vs experimental temperatures gathered by calibrated temperature sensors in different zones in different floors of the building (A = Atrium, H = Hallway, W = Window zones)

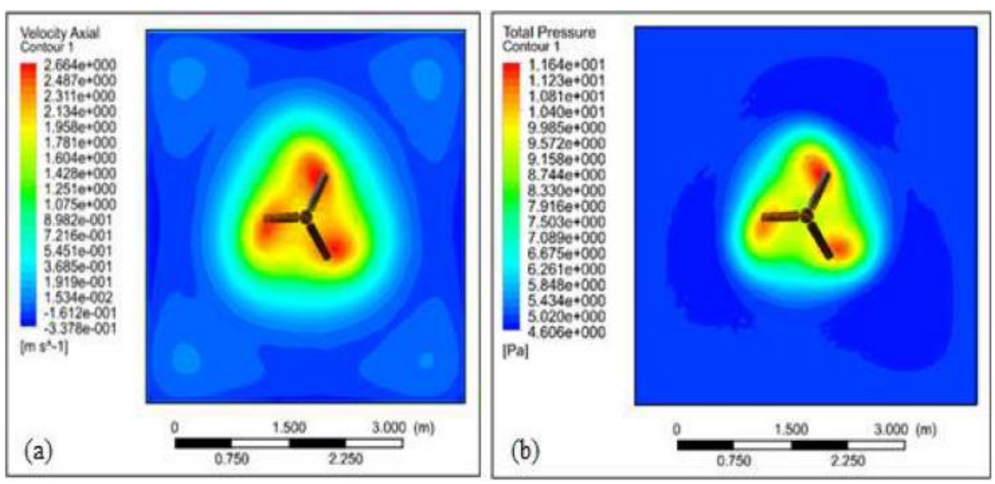
VOCAB: (w/definition)	**URANS:** Type of simulation method that account for outside air flow to predict the mean air flow and other turbulence properties **UQ:** Method of quantification used to represent uncertainties in input parameters (buoyancy conditions, internal heat gains, etc) in the CFD model **Sobel Indices:** A method of index-based quantification that informs the researcher about the dominant input parameters to the variance in the model outputs **Buoyancy-driven ventilation:** Natural ventilation strategy that accounted for the buoyancy force created by the difference between indoor and outdoor air temperatures
Cited references to follow up on	Omrani S., Garcia-Hansen V., Capra B.R., Drogemuller R. Effect of natural ventilation mode on thermal comfort and ventilation performance: Full-scale measurement. *Energy Build*., 156 (2017), pp. 1-16, 10.1016/j.enbuild.2017.09.061
Follow up Questions	Do you think that these results would differ if measured in a different season (winter vs summer?) where the outside air temperature would be different?

Article #15: Influence of ceiling fan induced mass flow rate to create uniform temperature distribution in a closed room: A CFD investigation

Article notes should be on separate sheets

Source Title	Influence of ceiling fan induced mass flow rate to create uniform temperature distribution in a closed room: A CFD investigation
Source citation (APA Format)	Yadav A., Dewangan A., Khan O., Sharma P., Kumar N.,
Original URL	[Influence of ceiling fan induced mass flow rate to create uniform temperature distribution in a closed room: A CFD investigation - ScienceDirect]
Source type	Journal Article
Keywords	Velocity profile; CFDk- ε model; Axial velocity; Mass flow rate; Fan
#Tags	#cfd, #airflow
Summary of key points +	- Presents CFD investigation of a newly developed ceiling fan named “New

notes (include methodology)	Breeze”
	- Aim is to determine mass flow rate, velocity profile, and total pressure of ceiling fan to measure its efficiency. Contours were plotted to visualize air flow
	- Mainly attached fan on ceiling
	- CFD simulations show that the rate of air created by the ceiling fan is 222.99 kg/s, while experimental rate of air in lab-tested chamber was around 215 kg/s
	- Air velocity was measured at 64 different points in simulated room using an anemometer
	- Used ANSYS fluent to create a 3D model of test chamber and perform the CFD analysis
	- Model had 4 different zones
	    o Inner fluid
	    o Outer fluid
	    o Roof Domain
	    o Rotating domain
	- A mesh of around 3 million cells was created, with unstructured mesh for the rotating domain and structured mesh for the rest of the domain.
	- K-epsilon model was employed, along with moving reference frame for rotating fan domain
	- Boundary conditions like temperature, pressure, and velocity were specified for different zones

Research Question/Problem/ Need	How does the mass flow rate, velocity profile, and total pressure of a newly designed ceiling fan compare CFD simulation and experimental measurements in a closed room environment?
Important Figures	 Right graph shows the axial velocity contour at 1.5 m above surface and total gauge pressure contour at 1.5 m above surface
VOCAB: (w/definition)	Axial velocity: Vertical component of velocity of fan (air blowing downwards towards the floor from the fan on the ceiling) Gauge Pressure: Difference in pressure between measure pressure and

	surrounding atmospheric pressure Mesh: Refers to the discretization of computational data into small, interconnected cells --> plays a crucial role in the accuracy and convergence of CFD models Unstructured Mesh: Type of mesh that uses regular, non-uniform elements to model complex geometries Anemometer: Device used to measure the speed of wind (can also be used to indirectly measure airflow)
Cited references to follow up on	Thanushan, R., Ranasinghe, R. A. C. P., Rajapakshe, P. D. M. P., & Mapa, M. H. H. G. (2015). Investigating Aerodynamic Performance of a Ceiling Fan.
Follow up Questions	Why didn't you need to use a more complicated model to simulate all these parameters? How did you decide whether to use k-epsilon or SST k-omega model

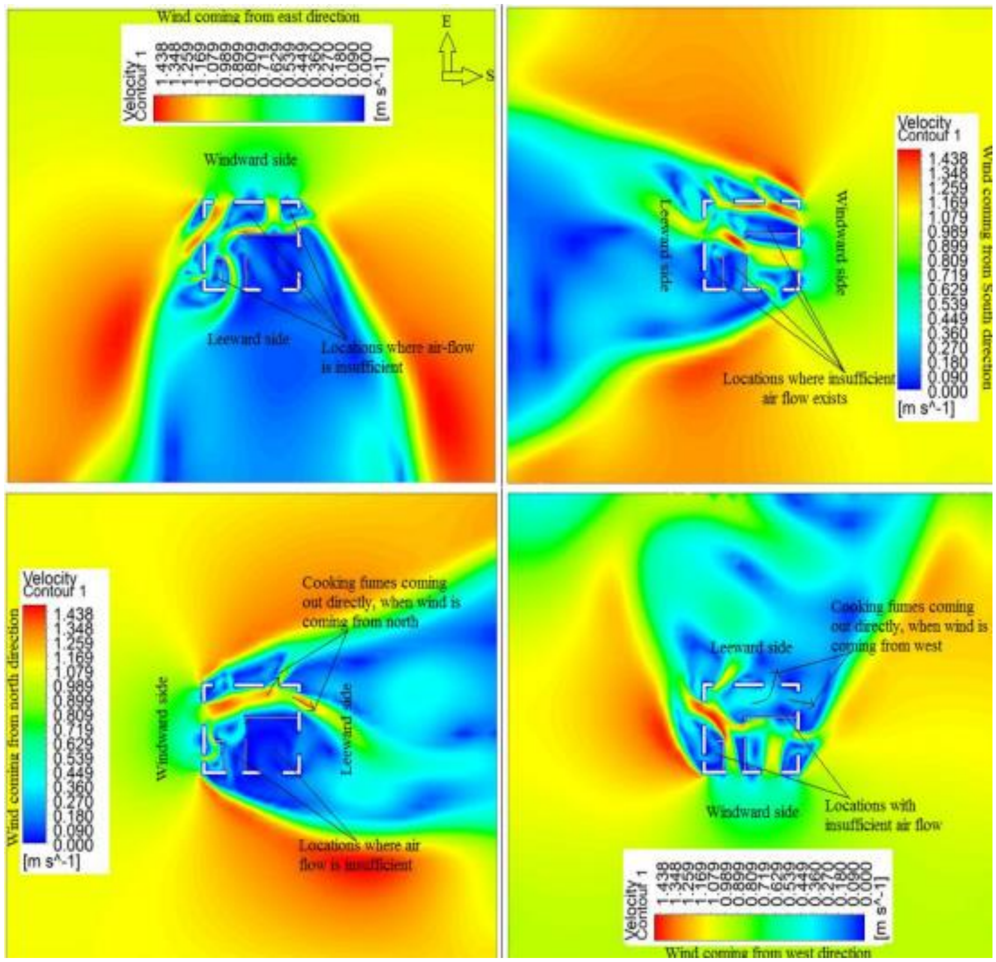
Article #16: Computational Fluid Dynamics Analysis of Airflow Distribution in Conventional Residential Buildings

Article notes should be on separate sheets

Source Title	Computational Fluid Dynamics Analysis of Airflow Distribution in Conventional Residential Buildings
Source citation (APA Format)	Kummitha, O. R., Kumar, R. V., & Krishna, V. M. (2021). CFD analysis for airflow distribution of a conventional building plan for different wind directions. Journal of Computational Design and Engineering, 8(2), 559–569. https://doi.org/10.1093/jcde/qwaa095
Original URL	https://doi.org/10.1093/jcde/qwaa095
Source type	Journal Article
Keywords	Computational fluid dynamics; ventilation; airflow distribution; air change rate
#Tags	cfd, air_flow
Summary of key points + notes (include methodology)	- Primary challenge/goal: Maximize ACH (air change rate) or AEE (air exchange effectiveness) in a room per hour solely through wind-driven forces (no other environmental sensors) - Research incorporates CFD through ANSYS fluent through the use of the RANS simulation technique to simulate airflow patterns

	- A domain size of 4H / 4W was employed to prevent blockage effects --> fluid domain (blockage ratio = 1.2%)
	- A hybrid mesh (tetrahedral/hexahedral) was subjected to grid independence. A medium mesh (of around 191,000 cells) was employed due to its optimal balance in computational cost and accuracy
	- Inlet velocity was set to 1 m/s based on local weather data to isolate geometric effects
	- Main factor being analyzed: Wind direction (North, South, East, West) and its impact on airflow to better optimize indoor air circulation
	- Tested different wind orientations
	    o West wind
	    o North wind
	    o South wind
	    o East wind
	        ▪ Results
	            • Found out that west wind resulted in the greatest ACH out of al the configurations
	- Ventilation is derived by the pressure differential between windward and leeward forces
	- West wind scenario generated max driving force of 1.65 Pa, whereas all the other directions –1.1 Pa
	- Pressure coefficients for west facade created strong stagnation pressure, maximizing push-pull effect required by deep-plan ventilation

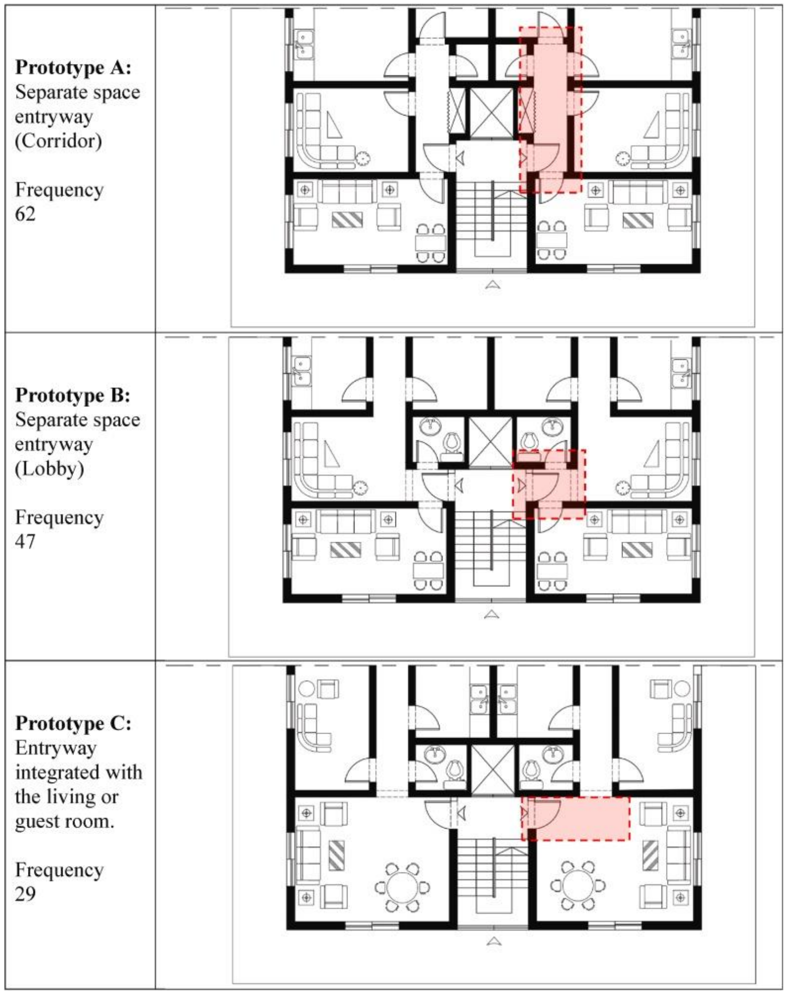
Research Question/Problem/ Need	Built environment accounts for 40% of the CO_2 emissions, meaning that optimizing natural ventilation patterns in residential environments is crucial for optimal air flow

Important Figures	 Figure of airflow of different wind direction optimizations. West Wind (blue-green section pointed towards west) showcased the greatest ACH (3-4) while East, North and South wind showcased ACHs of below 1
VOCAB: (w/definition)	Grid Independence Study: Verification process where simulation is run with increasing mesh densities Discretization: The process of converting PDEs of the fluid motion to a system of algebraic equations using the second order upwind scheme Pressure coefficient (C_p): A dimensionless number that describes the relative pressure at a point on the building surface. Positive values on the windward side and negative values on the leeward side create the pressure difference that drives natural ventilation
Cited references to follow up on	Calautit, J. K., & Hughes, B. R. (2014). Wind tunnel and CFD study of the natural ventilation performance of a commercial multi-directional wind tower. Building and Environment, 80, 71–83.
Follow up Questions	Would the results have been more accurate if more environmental data such as humidity, temperature and pressure was involved?

Article #17: Evaluating airflow dynamics in common vertical circulation spaces of a multi-floor apartment building for mitigating airborne infection risks: A CFD modeling study

Article notes should be on separate sheets

Source Title	Evaluating airflow dynamics in common vertical circulation spaces of a multi-floor apartment building for mitigating airborne infection risks: A CFD modeling study
Source citation (APA Format)	Obeidat, B., & Al-Zuriqat, M. H. (2024). Evaluating airflow dynamics in common vertical circulation spaces of a multi-floor apartment building for mitigating airborne infection risks: A CFD modeling study. *Heliyon*, 10(5). https://doi.org/10.1016/j.heliyon.2024.e26596
Original URL	https://doi.org/10.1016/j.heliyon.2024.e26596\
Source type	Journal Article
Keywords	Indoor air flow, Stair design, Natural ventilation, Apartment building, Airborne infection, Jordan
#Tags	#cfd #airflow
Summary of key points + notes (include methodology)	- Statistical data and a field survey of 138 buildings in Amman established the dominant typology: four-story buildings with glazed, non-operable stairwells. - A model was created in DesignBuilder v6 (coupling EnergyPlus and CFD). The study simulated winter conditions (worst-case scenario) using the k-epsilon turbulence model and a verified grid sensitivity analysis. - The study measured ACH, Relative Humidity (RH), and calculated CO_2 concentrations based on occupancy loads (6 people/unit). - Optimization: The model tested mitigation strategies, comparing varying Window-to-Wall Ratios (15–30%) against permanent vents and aerodynamic louvers - Successfully increased ACH to 12.5

Research Question/Problem/ Need	Can increasing the window-to-wall ratio (WWR) or retrofitting spaces with fixed louvers effectively enhance natural ventilation to meet the CDC's recommended safety standard of 12 ACH?
Important Figures	 Figure above describes 3 prototyped designs of certain corridors, for example floorplans. The first design is a long, narrow corridor that connects to the main living area. The second design is a small, enclosed foyer for slower air velocity. The third design is where the apartment door opens directly into the living area.
VOCAB: (w/definition)	Chimney Effect: Vertical movement of air driven by temperature differences. For example, warm air rises, creating suction at the bottom, and exhaust at the top. Reason why contaminants were pumped from lower to upper floor apartments. WWR (Window-Wall Ratio): Percentage of the exterior wall area that is covered by glazing windows (installation of glass panes inside of a window) Louvers: Ventilation device containing angled slats (vertical or horizontal) that allows air to pass through while blocking rain or direct sun. Identify that fixed louvres are the best solution. RH (Relative Humidity): Amount of water vapor relative to the maximum it can

	hold at the detected temperature Metabolic Rate: Unit to estimate body heat, as heat emissions from any source can affect the airflow within the environment. A metabolic rate of 0.8 was assumed for simplicity.
Cited references to follow up on	Wang, C. C., Prather, K. A., Sznitman, J., Jimenez, J. L., Lakdawala, S. S., Tufekci, Z., & Marr, L. C. (2021). Airborne transmission of respiratory viruses. *Science*, 373(6558). Yang, F.-J., & Aitken, N. (2021). People Living in Apartments and Larger Households Were at Higher Risk of Dying from COVID-19 during the First Wave of the Pandemic. *Statistics Canada.* World Health Organization (WHO). (2020). *Modes of Transmission of Virus Causing COVID-19: Implications for IPC Precaution Recommendations.*
Follow up Questions	Do you think that if you accounted for differing metabolic rates, would the results support another design apart from this current design?

Article #18: Simulation-aided development of a compact local ventilation unit with the use of CFD analysis

Article notes should be on separate sheets

Source Title	Simulation-aided development of a compact local ventilation unit with the use of CFD analysis
Source citation (APA Format)	Zelenský, P., Zmrhal, V., Barták, M., & Kučera, M. (2024). Simulation-aided development of a compact local ventilation unit with the use of CFD analysis. *Building Simulation*, 17, 2233–2247. https://doi.org/10.1007/s12273-024-1183-9
Original URL	https://doi.org/10.1007/s12273-024-1183-9
Source type	Journal Article
Keywords	Decentralised ventilation; Local ventilation unit; Heat recovery; Computer fluid dynamic (CFD); Numerical analysis; Design improvement; Multiple Reference Frame
#Tags	#cfd #building #airflow
Summary of key points + notes (include methodology)	- Used ANSYS fluent with k-epsilon realizable model to conduct simulations - Focused on product development of a compact, decentralized ventilation unit with a regenerative heat exchanger to improve airflow and quality of living - Moved from initial cad design --> CFD analysis --> geometry optimization --> prototype manufacturing - Sub-study tested four air outlet designs (no diffuser, perforated cover, fixed vanes, and

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<td>adjustable nozzles)

Physical prototype was built, and its airflow rates were measured using an orifice plate setup to validate CFD predictions
Results

Initial design showed high velocity and low noise risks in the supply channel
Improvements included fans with profiled blades and rotating the fan orientation by 90 deg
Sub-study concluded that adjustable nozzles were superior

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<td>Research Question/Problem/ Need</td>
<td>As research buildings are becoming more airtight to save energy, air quality gets poorer. This study is using CFD to optimize decentralized ventilation units’ internal geometry to reduce pressure and aerodynamic noise.</td>
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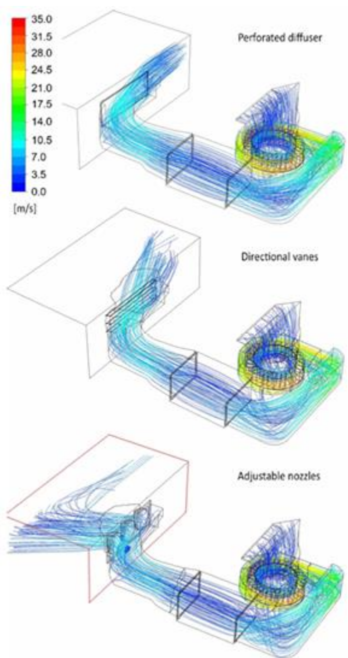
<td>Important Figures</td>
<td>

Figure showcases CFD airflow analysis of different designs proposed in the study</td>
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<td>VOCAB: (w/definition)</td>
<td>Decentralized Ventilation (Local Ventilation): A ventilation strategy where individual units are installed directly in the building envelope (e.g., through a wall) to serve specific rooms. Unlike centralized systems, they do not require extensive ductwork, making them ideal for renovating existing buildings to improve air tightness and energy efficiency.

Regenerative Heat Exchanger (Rotary): The specific heat recovery mechanism used in the DC40 unit. It features a storage mass that periodically rotates 180° to alternate between the warm exhaust stream and the cool supply stream. This cycle allows for the transfer of heat and moisture, and critically, facilitates condensate removal and de-icing in winter, allowing the unit to operate independently year-round.

MRF (Multiple Reference Frame): A steady-state CFD modeling technique used to approximate the rotation of fans (often called the "frozen rotor" approach). In this study, the authors used MRF to simulate the radial fans but noted a key limitation: it consistently underpredicted airflow</td>
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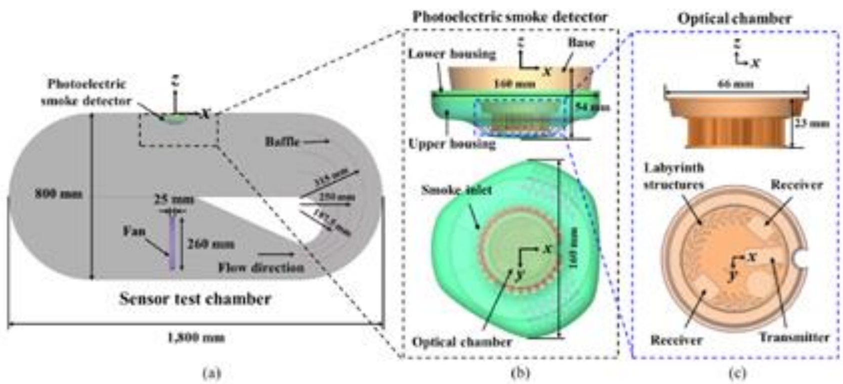
	rates by approximately 10% compared to physical measurements.
Cited references to follow up on	Justo Alonso M, Liu P, Mathisen HM, et al. (2015). Review of heat/energy recovery exchangers for use in ZEBs in cold climate countries. *Building and Environment*, 84: 228–237. Bianco N, Fragnito A, Iasiello M, et al. (2023). A CFD multi-objective optimization framework to design a wall-type heat recovery and ventilation unit with phase change material. *Applied Energy*, 347: 121368.
Follow up Questions	Have you tried testing fans that move/rotate in place and how effective they are?

Article #19: Computational design of a smoke detector with high sensitivity considering three-dimensional flow characteristics

Article notes should be on separate sheets

Source Title	Computational design of a smoke detector with high sensitivity considering three-dimensional flow characteristics
Source citation (APA Format)	Huang Y. W., Lee J. Hyung., Jin J., Ryou. S. H., Choi. K. C., Hong. H. S., Lee H. S., (2024), Computational design of a smoke detector with high sensitivity considering three-dimensional flow characteristics., *Case Studies in Thermal Engineering*., https://doi.org/10.1016/j.csite.2023.103896.
Original URL	https://doi.org/10.1016/j.csite.2023.103896
Source type	Journal Article
Keywords	Photoelectric smoke detector, Computational fluid dynamics (CFD), Detection, Internal flow fields, Activation time.
#Tags	#smoke_detector #cfd
Summary of key points + notes (include methodology)	- Study explores how smoke-inlet geometry and flow direction affect the sensitivity of a photoelectric smoke detector - CFD simulations show that reversing the external flow hinders smoke energy through certain compartments of the detector - Larger inlet lengths increase CO concentration inside the detector and improve sensor detection - Redesign was developed because of how the researchers found out that faster mainstream flow into the optical chamber of the sensor enhances performance of detector - Number of smoke inlets raised from 26 to 29 due to this finding

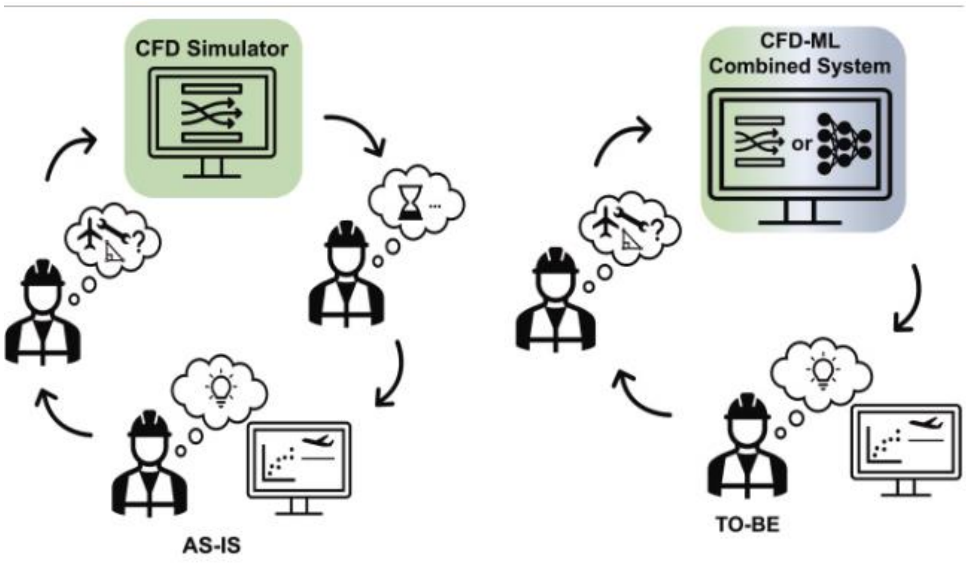
	- Redesign achieved nearly a 30% reduction time in activation time for both forward and backward flow directions compared to baseline
Research Question/Problem/ Need	How do different flow directions affect the performance of photoelectric smoke detectors
Important Figures	 Fig. 1. Computational domain: (a) sensor test chamber, (b) photoelectric smoke sensor, and (c) optical chamber. Figure above showcases the experimental setup of the study. Panel A shows rectangular sensor chamber where sensor was placed and also where a fan was placed to create a uniform air flow. Panel b describes the installation of a photoelectric smoke sensor. This experimental setup was simulated and solved in ANSYS fluent.
VOCAB: (w/definition)	Photoelectric smoke detector: Type of smoke detector that sense smoke through the scattering of light within an optical chamber Optical Chamber: Internal housing area where sensing process in the photoelectric smoke detector occurs Activation Time: Elapsed time before the detector triggers an alarm once the CO concentration reaches the threshold Labyrinth Structure: Length/area of the smoke-inlet port
Cited references to follow up on	M. McNamee, et al., IAFSS agenda 2030 for a fire safe world, Fire Saf. J. 110 (2019), 102889, https://doi.org/10.1016/j.firesaf.2019.102889. [2] V. Kodur, et al., Fire hazard in buildings: review, assessment and strategies for improving fire safety, PSU Research Review (2019) 1–23, https://doi.org/ 10.1108/PRR-12-2018-0033. [3] S.J. Chen, et al., Fire detection using smoke and gas sensors, Fire Saf. J. 42 (8) (2007) 507–515, https://doi.org/10.1016/j.firesaf.2007.01.006. [4] Z. Liu, et al., Review of recent developments in fire detection technologies, J. Fire Protect. Eng. 13 (2) (2003) 129–151, https://doi.org/10.1177/ 1042391503013002003. [5] Y. Hu, J. Zhan, G. Zhou, A. Chen, W. Cai, K. Guo, Y. Hu, L. Li, Fast forest fire

	smoke detection using MVMNet, Knowl. Base Syst. 241 (2022), 108219, https://doi. org/10.1016/j.knosys.2022.108219.
Follow up Questions	How would factors like temperature and humidity affect the flow rate and thereby, indirectly affect the performance of the photoelectric smoke detector

Article #20: CFD-ML: Stream-based active learning of computational fluid dynamics simulations for efficient product design

Article notes should be on separate sheets

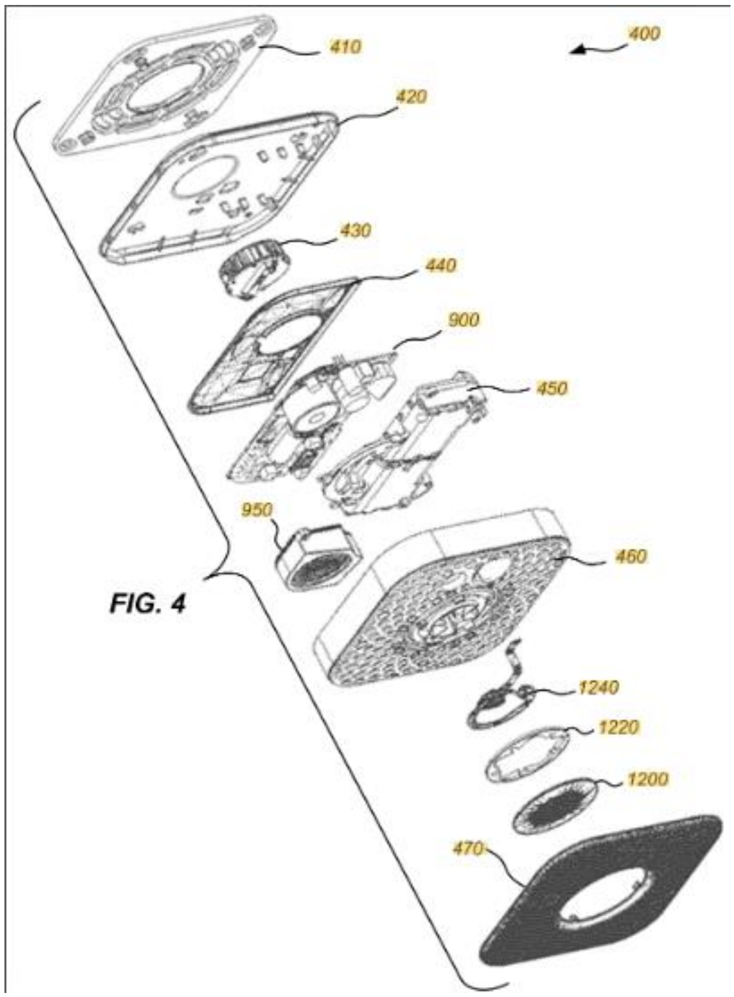
Source Title	CFD-ML: Stream-based active learning of computational fluid dynamics simulations for efficient product design
Source citation (APA Format)	Bae Y, Nam K. Kang S. (2024). CFD-ML: Stream-based active learning of computational fluid dynamics simulations for efficient product design. *Computers in Industry*. https://www.sciencedirect.com/science/article/abs/pii/S01663615 24000502
Original URL	https://www.sciencedirect.com/science/article/abs/pii/S0166361524000502
Source type	Journal Article
Keywords	Airborne infection; Apartment building; Indoor air flow; Jordan; Natural ventilation; Stair design.
#Tags	#air_flow #cfd
Summary of key points + notes (include methodology)	- Study proposes a hybrid model switching CFD/ML model for stream-based active learning - Strengths of CFD model can combine withs strengths of ML model - When an engineer queries a new design, the system calculates the Predictive Uncertainty of the ML model for that specific design. - High Uncertainty: The system recognizes it doesn't "know" this design well. It triggers the CFD Simulator to calculate the ground truth. This new data is then used to update and retrain the ML model (making it smarter for future queries). - Low Uncertainty: The system is confident. It bypasses the CFD simulator and uses the ML Model to provide an instant approximation. - Results

	○ Significant cost reduction ○ System yielded higher accuracy than standard, static models ○ Alternating approach is effective for workflow and product development
Research Question/Problem/ Need	In real-world product development, engineers must evaluate many design instances. Running full CFD simulations for every single design is too expensive and slow. While Machine Learning (ML) surrogates can approximate CFD results quickly, they suffer from low accuracy when predicting new designs that deviate significantly from the training data (out-of-distribution data). Existing "Active Learning" research typically uses a "pool-based" approach (selecting data from a pre-existing large batch), which does not match the real-world engineering workflow where designs are created and queried sequentially (stream-based). Methodology
Important Figures	 (a) Typical usage scenario. (b) Proposed CFD-ML combined system. Image above showcases traditional CFD simulation process vs proposed CFD-integrated ML analysis process.
VOCAB: (w/definition)	Active Learning: Process of ML where ML model selectively queries most important pieces of data to learn from to achieve higher accuracy with fewer data points
Cited references to follow up on	Chabanet S., El-Haouzi H.B., Thomas P. (2021). Coupling digital simulation and machine learning metamodel through an active learning approach in industry 4.0 context. *Comput. Ind.* https://www.sciencedirect.com/science/article/pii/S0166361524000502#bib1
Follow up Questions	Is there a way you could include deep learning into this system and integrate cameras into this system to solve DL-related issues?

Patent #1: Smart-home control system providing HVAC system dependent responses to hazard detection event

Article notes should be on separate sheets

Source Title	Smart-home control system providing HVAC system dependent responses to hazard detection events
Source citation (APA Format)	Sloo D., Webb U. M., Fisher J. E., Matsuoka Y., Fadell A., Rogers M., (US Patent No. 10540864B2)., *Smart-home control system providing HVAC system dependent responses to hazard detection events*., US Patent and Trademark Officer., https://patents.google.com/patent/US10540864B2/en?q=(CO+detector+%2b+ventilation+system)&oq=CO+detector+%2b+ventilation+system
Original URL	https://patents.google.com/patent/US10540864B2/en?q=(CO+detector+%2b+ventilation+system)&oq=CO+detector+%2b+ventilation+system
Source type	Patent
Keywords	Ventilation, HVAC
#Tags	#ventilation, #hvac, #smoke_detection
Summary of key points + notes (include methodology)	- Patent describes of a novel smart-home control system to detect and prevent hazards such as smoke and CO presence - Systems contains a network of interconnected devices (thermostats, CO detectors, etc) communicating with each other - Workflow ○ First it detects elevated levels of CO or smoke in the environment ○ Queries the smart thermostat to check if HVAC heater is a fossil-fuel based and if it is currently active ○ Intervention: System turns heater and other devices off to respond to the danger ○ Observation: System monitors CO trend when it turned off the heater compared to when it was turned on --> from that, it determines if the heater was the main source of CO --> leads to more accurate, false-positive filtering ○ Utilizes pellistor sensor for detection of natural gasses such as CH_4
Research Question/Problem/ Need	Traditional hazard detectors are prone to false hazard detections and are isolated, leading to inaccurate results. They alert the user of danger but are not able to identify the source.

Important Figures	 Figure above showcases the design layout of the components of the detection module. It features a smoke chamber, protective plate, and circuit board all combined into one compact module.
VOCAB: (w/definition)	Pellistor sensor: A type of gas sensor used in the system specifically for detecting Natural Gas (CH_4) within a range of 0 to 100% (gas, temp, humidity) that exceeds a dynamically established base threshold.
Cited references to follow up on	Street, T. T., & Alexander, J. I. (n.d.). Processor-aided fire detector.
Follow up Questions	How would this system to different seasonal variations (how would it compare in the summer vs during the winter)

Patent #2: Smart-home control system providing HVAC system dependent responses to hazard detection event

Article notes should be on separate sheets

Source Title	Smart-home control system providing HVAC system dependent responses to hazard detection events
Source citation (APA Format)	Sinkevicius V., Curran A. P. (US Patent No. 20090273470A1). Environmental monitoring and control system. US Patent and Trademark Office. https://patents.google.com/patent/US20090273470A1/en?q=(CO+detector+%2b+ventilation+system)&oq=CO+detector+%2b+ventilation+system
Original URL	https://patents.google.com/patent/US10540864B2/en?q=(CO+detector+%2b+ventilation+system)&oq=CO+detector+%2b+ventilation+system
Source type	Patent
Keywords	Ventilation, HVAC
#Tags	#ventilation, #hvac, #smoke_detection
Summary of key points + notes (include methodology)	○ Patent describes a three-tier wireless environmental monitoring system designed to address the inaccuracies of standalone detectors. ○ Monitor Unit (20): Installed in the target space (e.g., garage, apartment). It contains sensors (CO, CH4, Humidity, Temp), an alarm, and crucial to this invention, a Relay Output to trigger external mechanical devices. ○ Server Unit (40): An intermediary microprocessor that facilitates wireless communication (using ISM 2.4 GHz) between the local monitors and the internet. ○ Remote Monitoring Centre (60): A centralized processor that receives data from the monitors and, uniquely, pulls live weather data from Regional Government Sources (70). ○ Unlike standard alarms with fixed trigger points, this system constantly receives real-time data (temperature, pressure, humidity) from regional government stations. It pushes this data to the local Monitor Units to adjust their "base threshold levels." Prevents false alarms caused by natural weather shifts (e.g., a spike in humidity due to rain vs. a pipe leak). ○ The system moves beyond passive alerting to active control. When an "Anomalous Environmental Condition" is confirmed, the Monitor Unit's Relay Output physically activates mitigation equipment. ○ Examples: If Carbon Monoxide (CO) is detected, it triggers a relay to open a garage door or turn on exhaust fans.

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- The Remote Centre tracks the "operational parameters" (aging/sensitivity) of the sensors themselves, allowing it to interpret readings more accurately as the hardware degrades over time.

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<td>Research Question/Problem/ Need</td>
<td>Traditional hazard detectors are prone to false hazard detections and are isolated, leading to inaccurate results. They alert the user of danger but are not able to identify the source.</td>
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<td>Important Figures</td>
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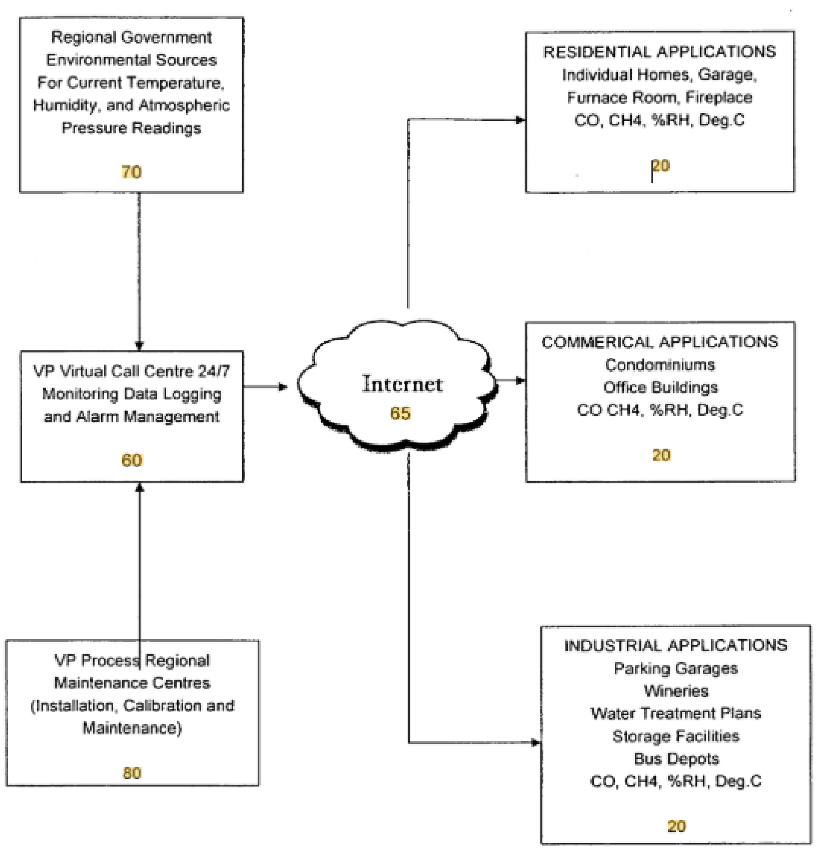

FIG.1

Figure above showcases the control system of the environmental monitor, with it being connected to governmental environmental sources, 24/7 monitoring algorithms, and commerical and industrial applications.

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<td>VOCAB: (w/definition)</td>
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Relay Output: An electromechanical switch integrated into the Monitor Unit that closes a circuit to trigger an external device (fan, door opener, valve) when an alarm threshold is breached.

Anomalous Environmental Condition: A deviation in measured variables (gas, temp, humidity) that exceeds a dynamically calculated base threshold (derived from regional weather data) rather than a fixed static limit.

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Cited references to follow up on	Kates, L. (2008, February 26). System and method for variable threshold sensor.
Follow up Questions	How would this sensor differentiate from other types of gasses such as CO_2 or CO? Is there some type of material that helps with this?