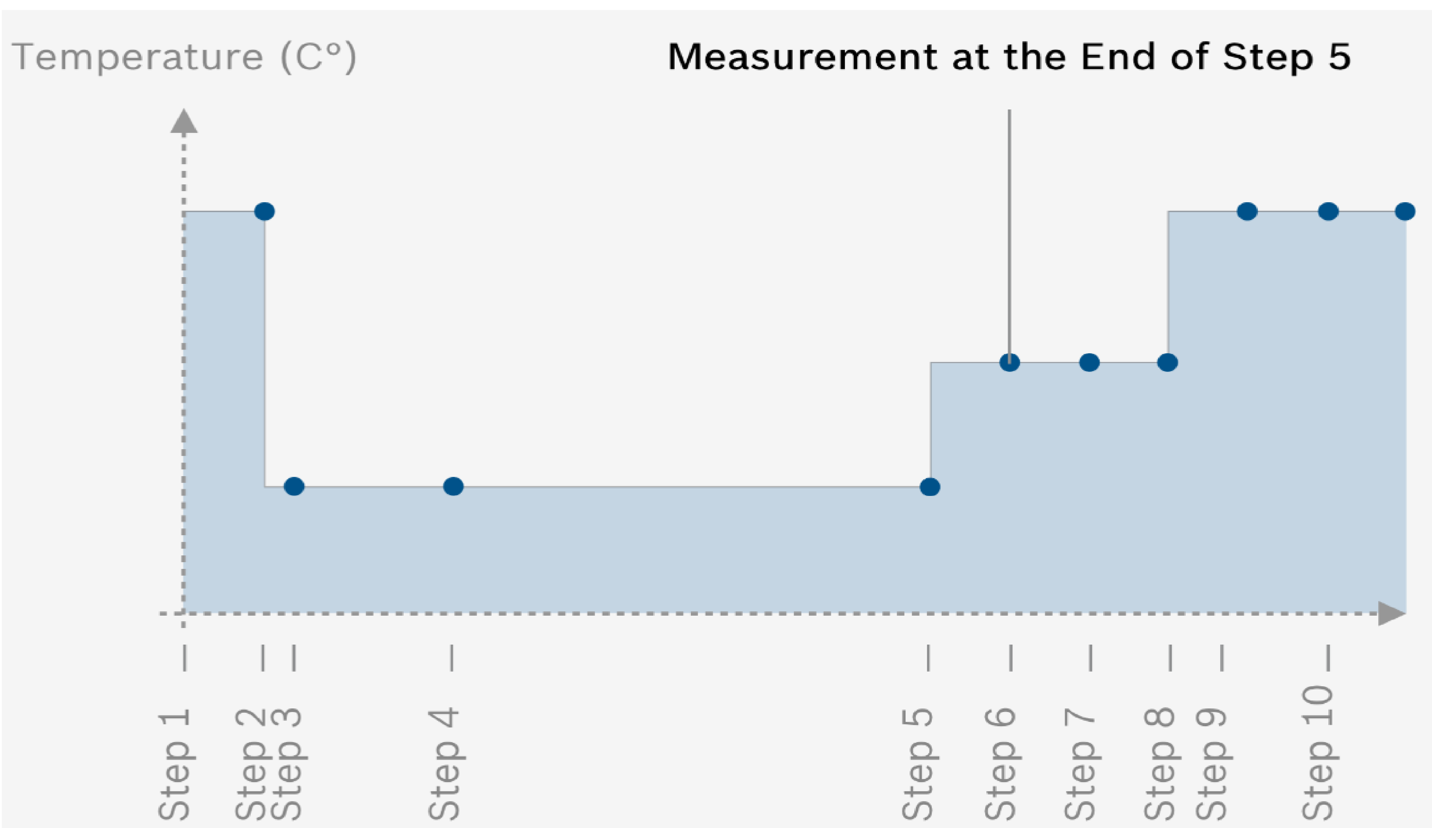
Insect-Scale, Low-Power, Olfactory-Based Sensing with Artificial Intelligence

Maitri Dedhia, Vikram Iyer, Kyle Johnson, Vicente Arroyos

Introduction: A "Electronic Nose"

The **BME688 sensor** is a low-power, 3 by 3 by 0.93mm sensor that demonstrates **gas selectivity with Artificial Intelligence**.

Gas selectivity is the ability to classify different gas compositions in different situations. The sensor's **metal oxide layer** heats at different temperatures to create a **unique fingerprint** for each gas composition.



Applications

- Detect and localize odors onboard small autonomous robots[1]
  - ❑Locate trapped natural disasters survivors
  - ❑Sense hazardous chemical leaks
  - ❑Locate explosives or chemical warfare
- Wildfire smoke detection in remote locations and impact on wildlife[3]
- Olfactory-based AR and VR systems[2]
- Spoiled food detection
- And much more!

Project Goal

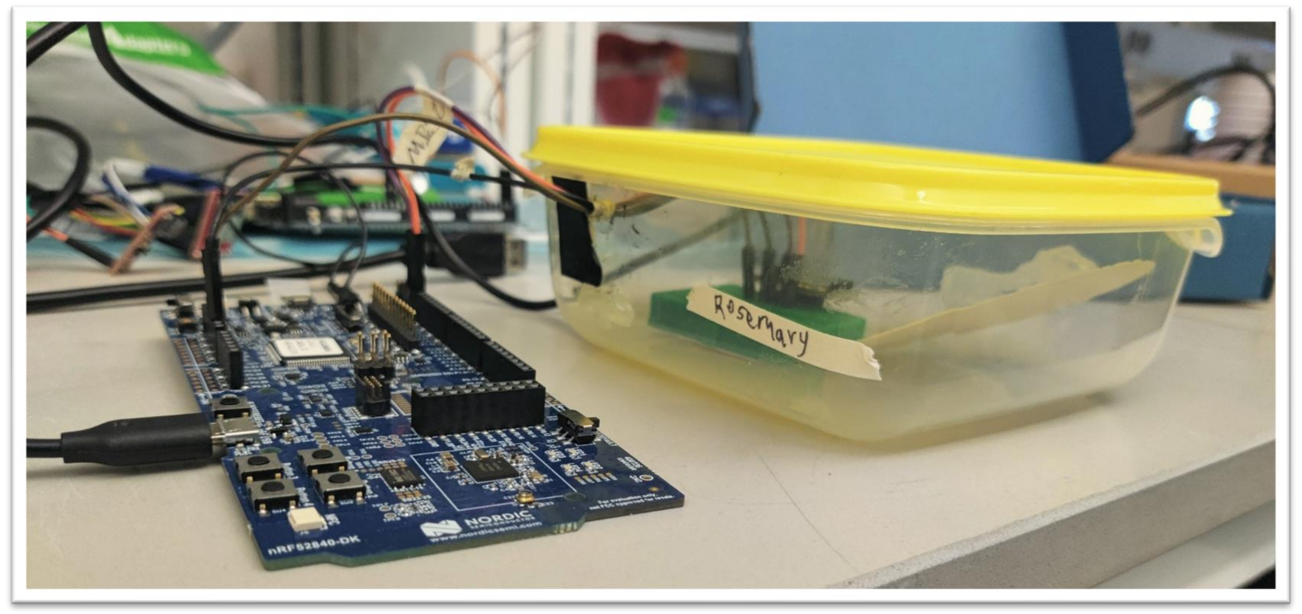
A single BME688 sensor is more suitable for **reduced power consumption** and **small-scale** applications.

We used Python and Arduino to **configure a single sensor to be compatible with the BME AI Studio** *(see right)* and demonstrate gas selectivity using ML.

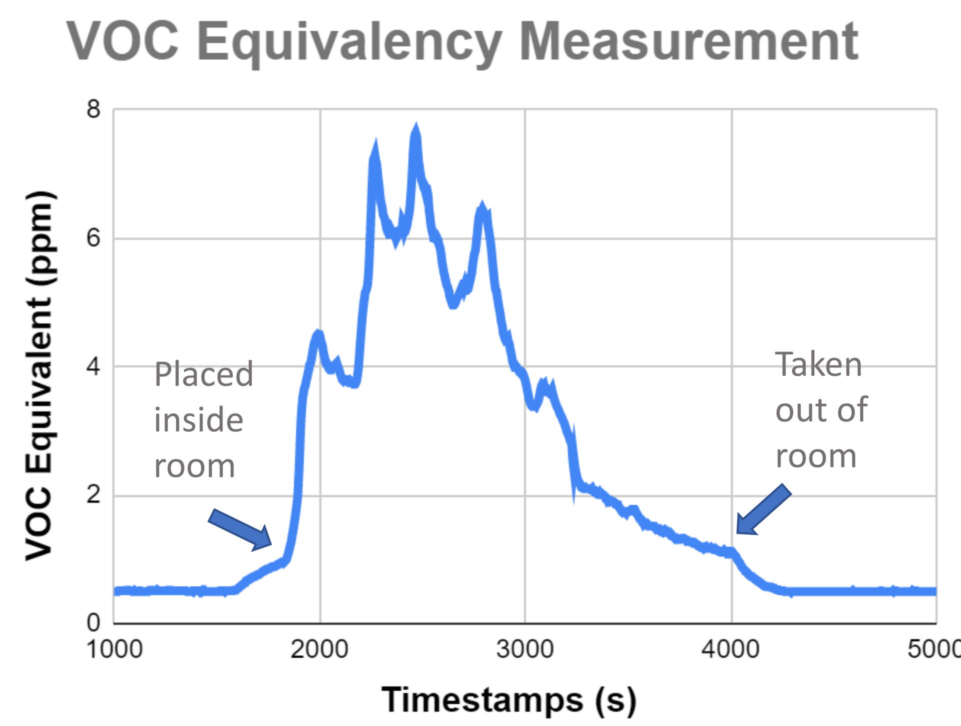
We also tested the sensor's air quality measurements.

Experimentation: Essential Oils

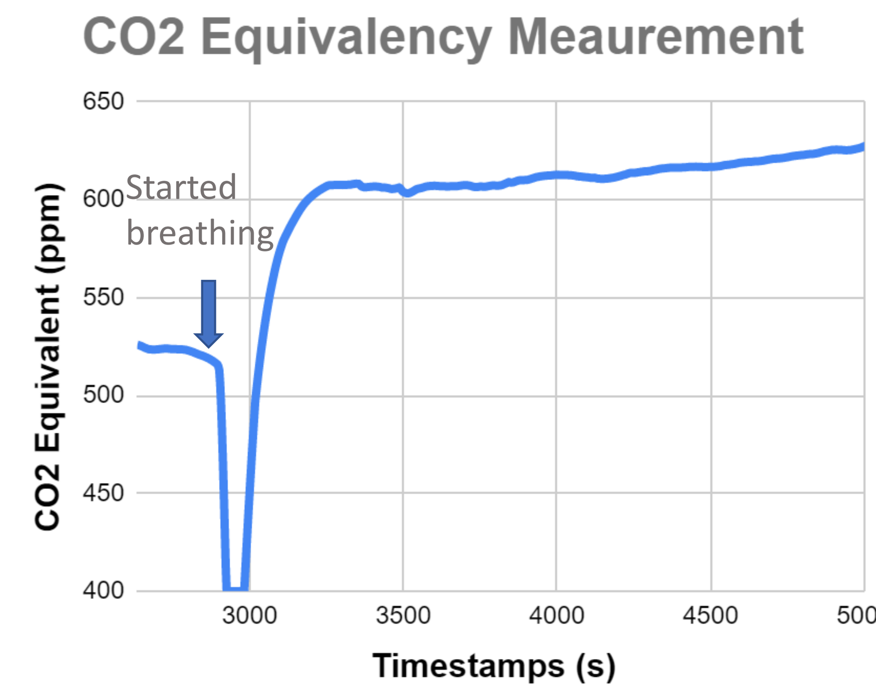
Using the set-up below, we collected data with Rosemary, Fir Needle, Grapefruit and Spearmint.



We measured Volatile Organic Compounds (VOC) and CO_2 concentrations.



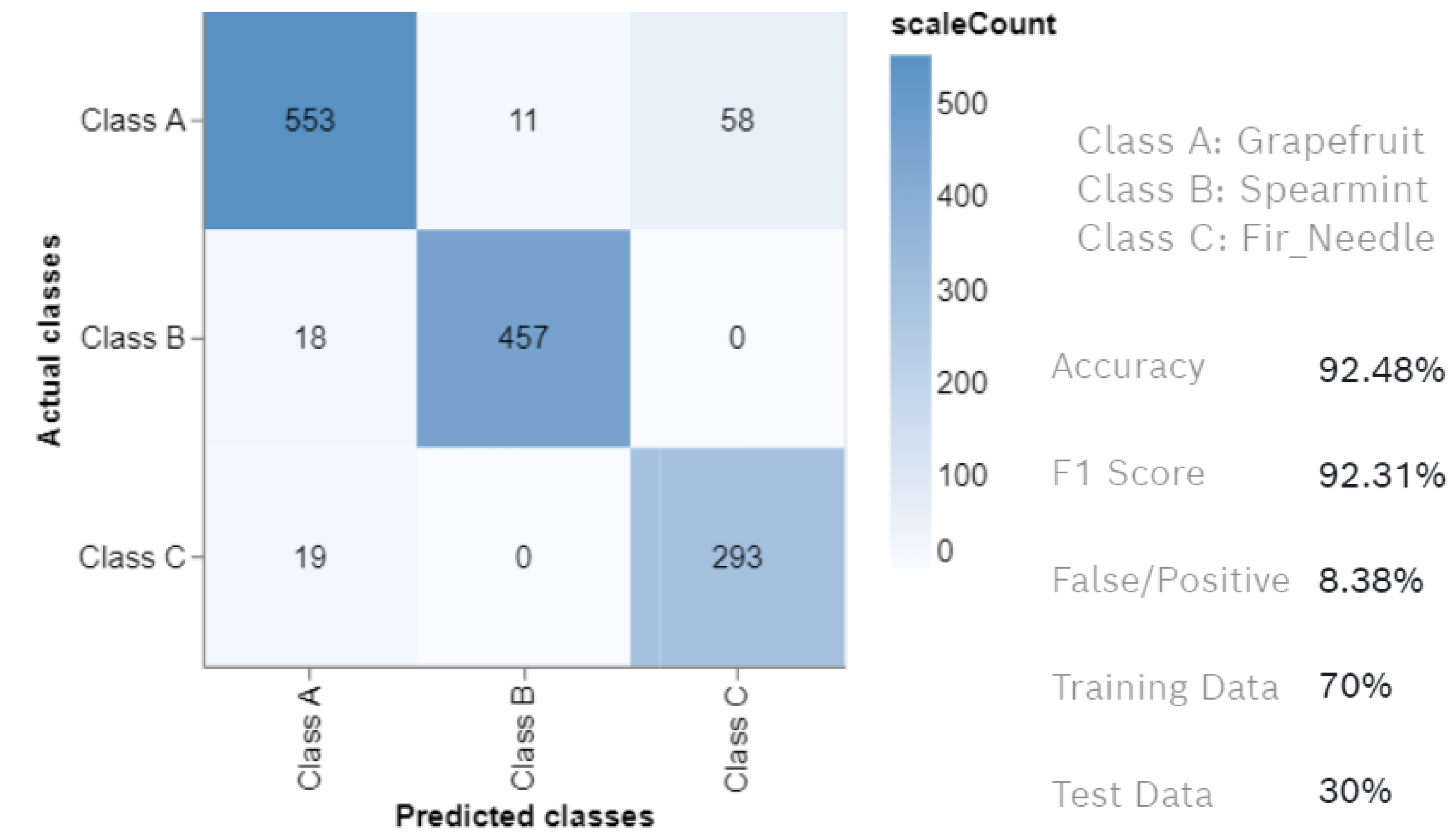
Outside and inside freshly painted room



Before and after breathing near sensor

Results: Gas Selectivity with AI

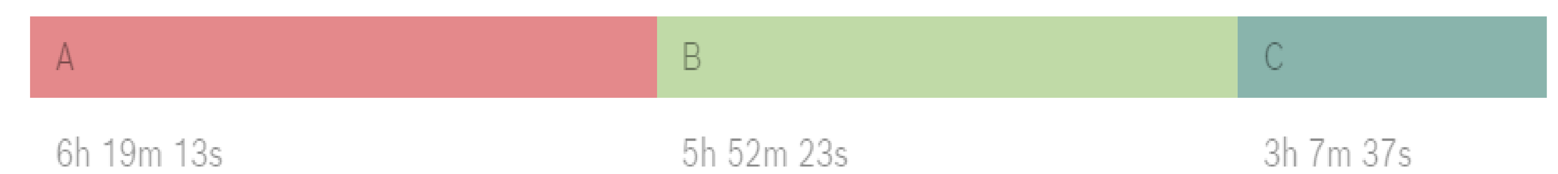
ML algorithms generated by Bosch's application, the BME AI-Studio, were used to configure and train a single sensor with **Bosch's BSEC Library**. Originally, the BME AI-Studio was only compatible with cumbersome 8 sensor boards. A **confusion matrix** *(below)* shows the accuracy of the algorithms.



Actual \ Predicted	Class A	Class B	Class C
Class A	553	11	58
Class B	18	457	0
Class C	19	0	293

Class A: Grapefruit
Class B: Spearmint
Class C: Fir_Needle

Accuracy	92.48%
F1 Score	92.31%
False/Positive	8.38%
Training Data	70%
Test Data	30%



Acknowledgements

I'm extremely grateful to Professor Vikram Iyer and graduate student mentors Kyle Johnson and Vicente Arroyos for giving me invaluable knowledge and feedback.

I'd like to thank NASA Space Grant for funding this research.

A big thank you to Raul, Tilboon, Choi, and Dennis from SSOL for all their help and support.

References:

[1]Anderson, Sullivan, J. G., Horiuchi, T. K., Fuller, S. B., & Daniel, T. L. (2020). A bio-hybrid odor-guided autonomous palm-sized air vehicle. *Bioinspiration & Biomimetics*, *16*(2), 26002–. https://doi.org/10.1088/1748-3190/abbd81

[2]Erkoyuncu, & Khan, S. (2020). Olfactory-Based Augmented Reality Support for Industrial Maintenance. *IEEE Access, 8*, 30306–30321. https://doi.org/10.1109/ACCESS.2020.2970220

[3]Sanderfoot, Bassing, S. B., Brusa, J. L., Emmet, R. L., Gillman, S. J., Swift, K., & Gardner, B. (2021). A review of the effects of wildfire smoke on the health and behavior of wildlife. *Environmental Research Letters*, *16*(12), 123003–. https://doi.org/10.1088/1748-9326/ac30f6