Development of a Compact, IoT-enabled Electronic Nose for Breath Analysis

A. Tiele[1], A. Wicaksono[1], S.K. Ayyala[1] and J.A. Covington[1,*]

[1] School of Engineering, University of Warwick, Coventry, CV4 7AL, UK.

* Corresponding author: Prof. James Covington, J.A.Covington@warwick.ac.uk, +44 (0) 24 7657 4494

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1 INTRODUCTION

- Modern breath analysis focuses on the detection of exhaled volatile organic compounds (VOCs) for the diagnosis and/or monitoring of disease. Breath VOCs are the by-products of normal metabolic activity, and in some cases, specific biomarkers associated with disease (e.g. cancer and COPD [1,2]).
- It has long been suggested that applications of diagnostic breath analysis must extend beyond laboratories and pilot studies to standard clinical practice and home-use [3]. The latter requires a compact, personal and portable diagnostic device, capable of sampling and analysing breath at any time or place.
- Most breath analysis technologies are "high-end" (expensive and complex). However, the latest generation of MEMS technology metal oxide (MOX) gas sensors could provide an alternative low-cost solution.
- While no single analysis technique can provide complete diagnosis of an individual, electronic nose (E-nose) technology has the advantages of being relatively low-cost, low-power, user-friendly and portable.
- In this work, we report on the design and development of a compact, internet-of-things (IoT) enabled E-nose for breath analysis.

2 MEMS MOX-BASED E-NOSE

The developed unit includes an array of 10 MEMS MOX-based gas sensors (Table 1), including many of the most relevant sensors currently available. Our system (Figure 1) is compact and uses a microcontroller with Wi-Fi capabilities (ESP32, Espressif Systems, China) for integration with future IoT infrastructure.

Figure 1: Warwick Breath E-nose

Sensor	Manufacturer
CCS811	ams
SGP30	Sensirion
BME680	Bosch
iAQ-Core C	ams
ZMOD4410	IDT
MiCS-6814	SGX
Dual Sensor	AlphaSense
TGS-8100	Figaro
TGS-2620	Figaro
AS-MLV-P2	ams

Table 1: Deployed Sensors

3 BREATH SAMPLING

Our E-nose design (Figure 2) includes an integrated sampling system, using a heated (35°C) sampling tube (50mL volume) with a CO_2/Temp/Hum gas sensor. This method samples end-tidal breath using the displacement principle.

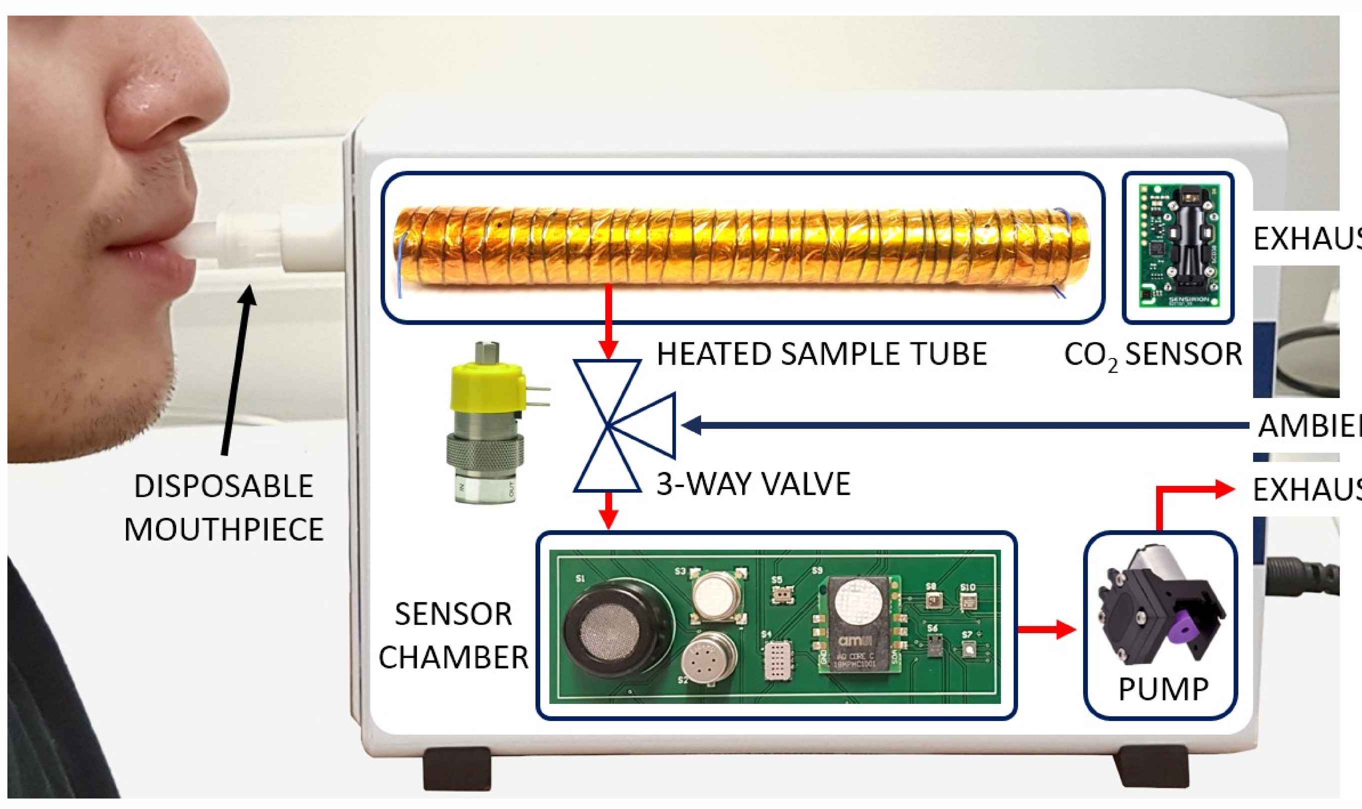

Figure 2: System Diagram

4 ANALYSIS & RESULTS

The device has been tested with chemical standards (acetone, isopropanol and 1-propanol). The PCA results for these tests are shown in Figure 3.

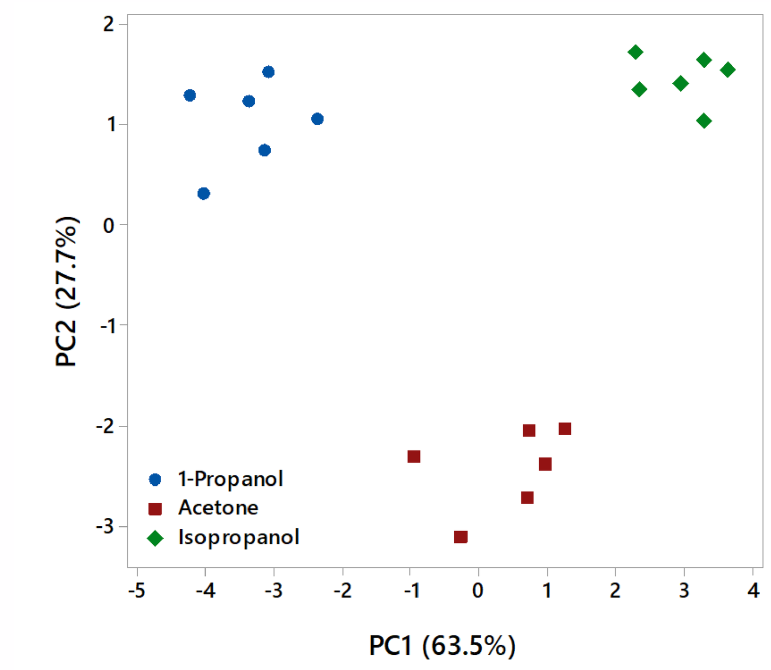

Figure 3: Chemical Standards PCA Results

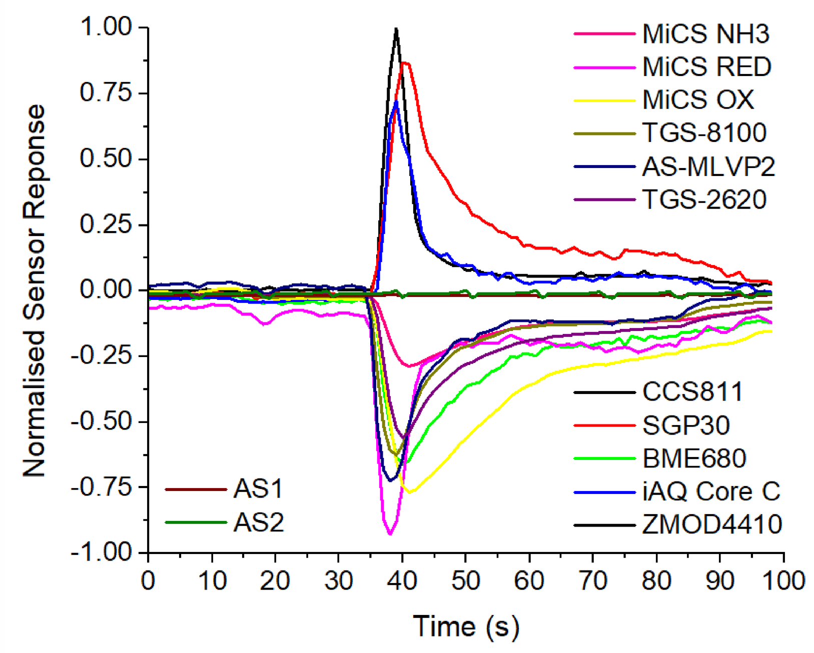

Figure 4: Typical Output Response

- Exhaled breath samples were collected from 18 volunteers (15 males, 3 females, ages 23-28). A typical output response is shown in Figure 4.
- To simulate a control vs. disease group case-control study, a peppermint breath test was conducted. Subjects provided breath samples pre- and post-consumption of a peppermint oil capsule. This produces a well-defined, but temporary, change in breath composition.
- Classification analysis demonstrates an AUC ± 95% = 0.80, sensitivity = 0.83 (0.59 – 0.96), specificity = 0.72 (0.47 – 0.90), p-value = 0.0007. These results were achieved using the Support Vector Machine (SVM) classifier.

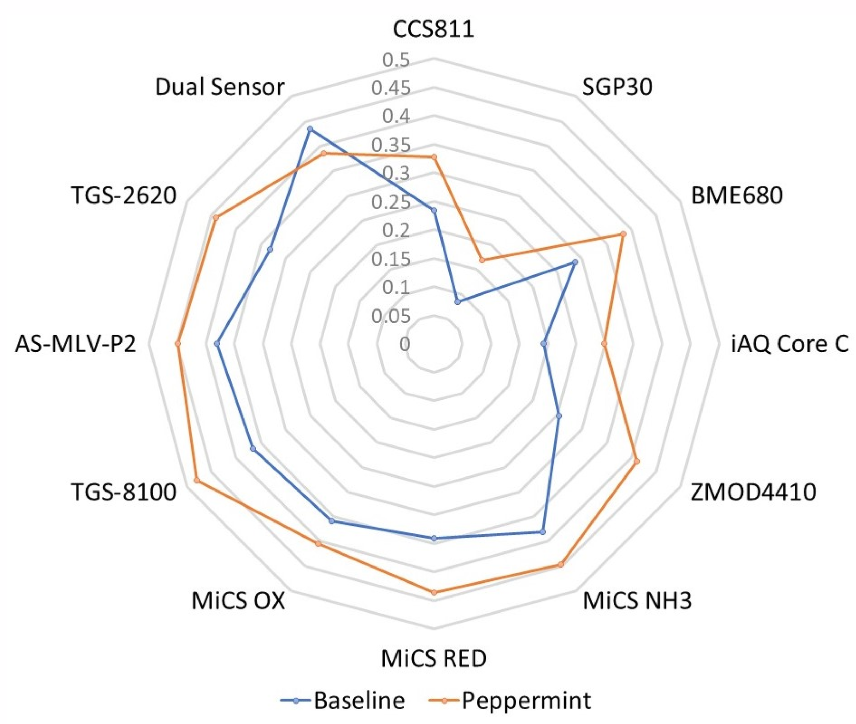

Figure 5: Radar Plot of Normalised Features

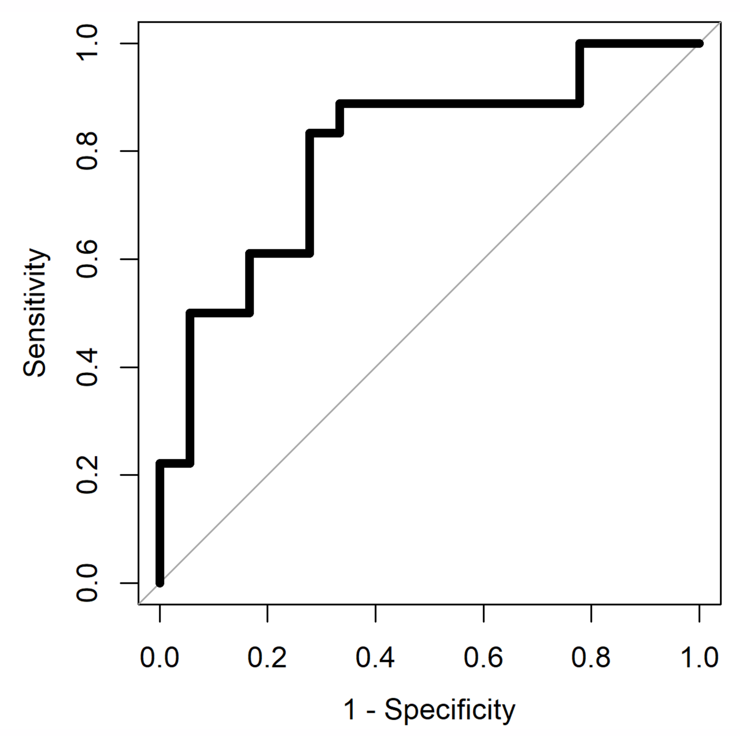

Figure 6: ROC Curve

A radar plot of normalised features is shown in Figure 5 and a generated ROC curve is shown in Figure 6. These results demonstrate that the developed unit is capable of detected changes in exhaled breath.

5 CONCLUSION

The functionality of the developed device was demonstrated with the testing of chemical standards and a simplified case-control study using peppermint oil. It is our intention to deploy this system in a UK hospital in upcoming breath research studies.

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