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MEMS based infrared spectrometry for measuring biogas composition

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Introduction

Catalytic sensors can suffer problems such as poisoning when exposed to compounds such as hydrogen sulphide [1]. Spectroscopy offers an alternative solution, whereby an infrared beam is passed through a substance, and the absorption is measured. The absorption profile can then be used to predict the properties of the substance. Spectroscopy can also offer an advantage over traditional two wavelength infrared measurements, as an absorption profile can be measured which can reduce the influence of other gases on the result. Spectrometers are typically costly and built for laboratory environments, this project is investigating the use of newly created MEMS spectrometers which are more suited for industrial applications.

Test Setup

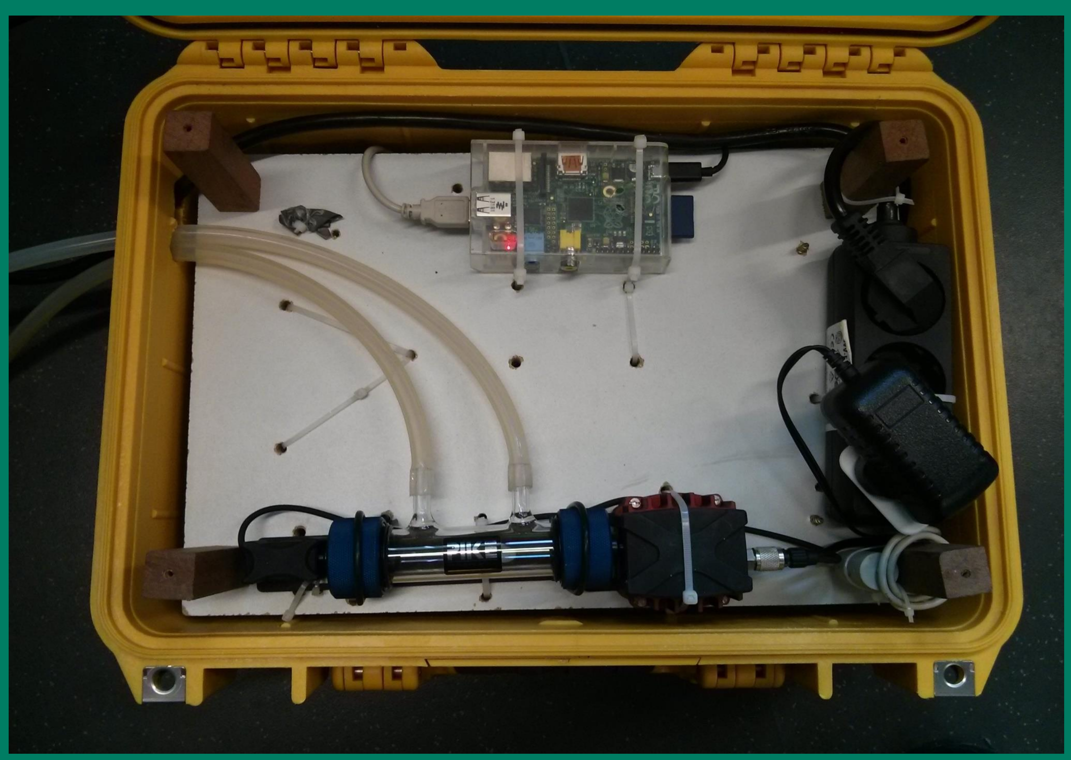

Figure 1 – Gas sensor and raspberry pi mounted in pelican case

A 3 - 3.7µm MEMS spectrometer was connected to a Raspberry Pi, both of which were fitted in to a pelican case shown in Figure 1. The system was installed in a pilot scale biogas digester, measuring the produced biogas. The pilot scale plant has a primary digester volume of 1000L, and is operated as part of the :metabolon research project [2]. The pilot scale digester is also fitted with an AwiFlexCool+ gas analysis unit, which measures Methane, Carbon Dioxide, Hydrogen Sulphide, and Hydrogen concentrations each hour. These measurement values were used to train and test machine learning algorithms. The algorithms are then used to calculate gas concentrations from the measured spectra. The system ran for 109 days, with the data from the first 76 days used for training, and the remaining 33 days for testing.

Results

Parameter estimation was performed using PLS-R (Partial Least Squares Regression), PCR (Principle Component Regression) and Random Forests. The results are shown in Table 1. PCR had the best performance, with an error of below 1% on the absolute scale. The predicted values and measured values are shown in Figure 2.

Regression Method	RMSEP	R^2
PLS-R	1.01%	0.986
PCR	0.95%	0.987
Random Forest	3.46%	0.873

Table 1 – Performance of selected regression models

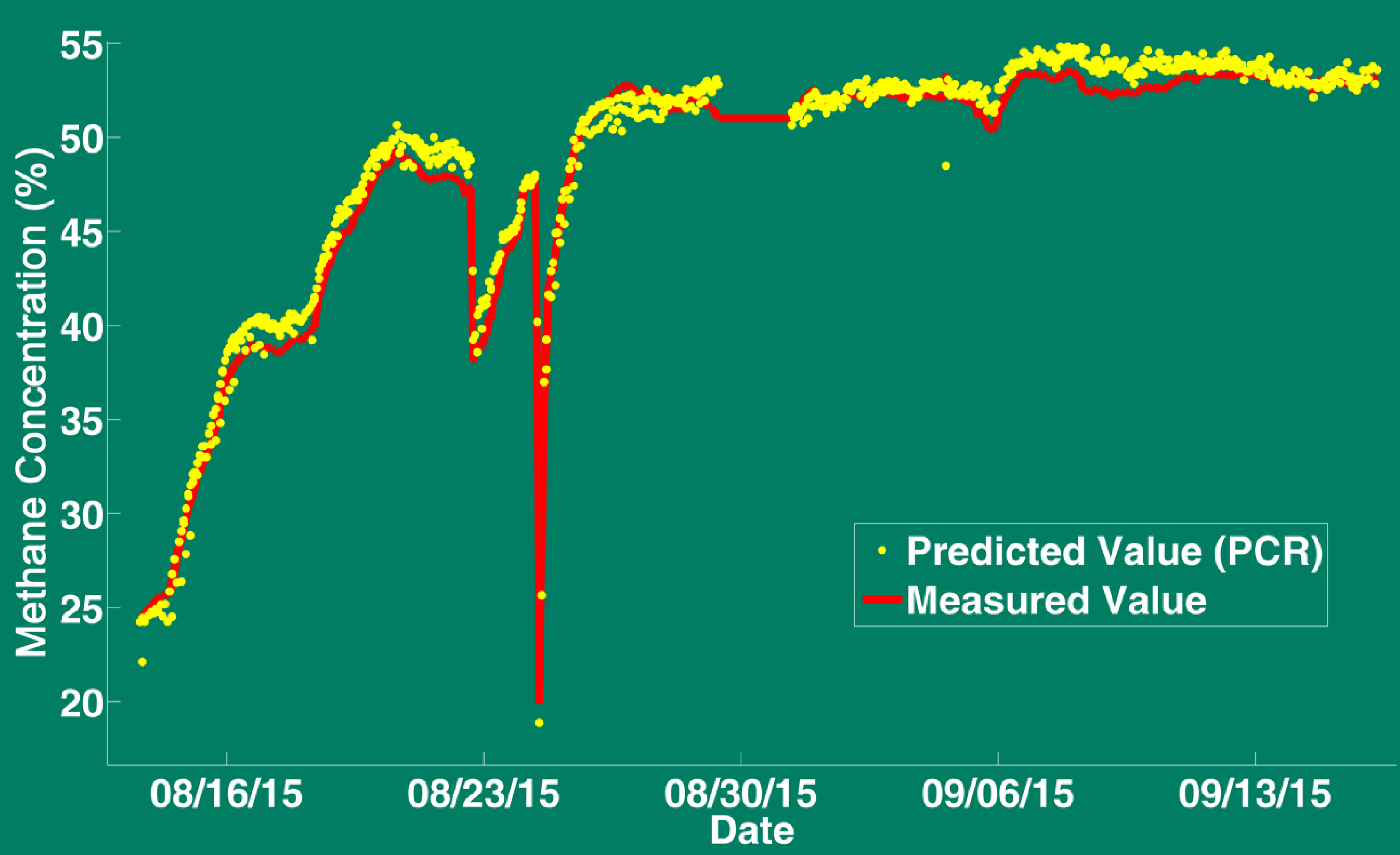

Figure 2 – Predicted methane concentrations plotted against measured test data.

Discussion

The sensor has good accuracy and can accurately estimate the methane concentration over a wide of values, including responding to rapid transients. Previous work [3] has successfully used the response to transient feeding impulses to estimate the process state and adjust the feeding rate. Planned further work is to combine this measurement system with a gas flow meter, and to use these measurements along with feeding data to optimise the anaerobic digestion process in a pilot scale digester.

Acknowledgements

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References

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