

Measuring biogas composition with a compact MEMS based spectrometer

Eccleston, Robin.* and Bongards, Michael.

TH Köln (University of Applied Sciences), Institute for Automation & Industrial IT, Steinmüllerallee 1, 51643 Gummersbach, Germany

*robin.eccleston@th-koeln.de

Introduction

This project evaluates a newly developed MEMS (Micro-Electrical-Mechanical Systems) infrared sensor for use in the measurement of biogas. The performance of the sensor was tested for the measurement of Methane and Carbon Dioxide. Currently, the commercially available possibilities for measuring the composition of biogas in an industrial environment are either using a catalytic sensor or an IR sensor using either one or two wavelengths. Catalytic sensors have a drawback that high concentrations of Hydrogen Sulphide can damage the sensor. When compared to a conventional IR sensor, there is also a benefit as the MEMS sensor records a spectrum at multiple wavelengths, allowing a profile to be recorded. This profile is used for calculation of methane concentrations, and provides an improved robustness to the problem of cross sensitivity when compared to one or two measurement points.

Test Setup

The sensor was provided from Spectral Engines and measures mid infrared light from 3000nm – 3700nm using a MEMS tuneable Fabry-Perot Interferometer. This interferometer functions as a tuneable optical filter, and is combined with a wideband light source and wideband sensor which allows the system to function as a compact spectrometer. A gas measurement cell with a 10cm path length was used to hold the gas that was being measured. The spectrometer was connected to a Raspberry Pi, both of which were fitted in to a pelican case as 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 [1]. 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

For the data from the pilot scale reactor, methane prediction is performed with an RMSEP (Root Mean Square Error of Prediction) of 0.95% and carbon dioxide prediction with an RMSEP of 3.4%. Figure 2 shows a comparison of the predicted value vs the measured value. The gas concentrations ranged from 20% to 55%, with rapid changes due to maintenance allowing ambient air into the reactor. These fast transients were also well tracked by the sensor. The optimum machine learning technique for predicting methane concentration was PCR, and for predicting carbon dioxide was Random Forest.

Discussion

The sensor has good accuracy and can accurately estimate the methane concentration over a wide range of values, including responding to rapid transients. The capabilities of the sensor combined with a Raspberry Pi has enabled a powerful system to be built which is compact and portable whilst offering prediction for multiple gases. In the biogas application, the system can perform online measurement of both carbon dioxide and methane simultaneously, allowing it to fulfil the role of two different sensors with good performance. MEMS based sensors offer a new technology for monitoring of biogas composition which can be used for maintaining stable plant operation.

Acknowledgements

This work was completed as part of the ATBEST (Advanced Technologies for Biogas Efficiency, Sustainability and Transport) Marie-Curie Initial Training Network. The network has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement n. 316838. ATBEST is coordinated by the QUESTOR Centre at Queen's University Belfast <http://www.atbest.eu>

References

[1] <http://www.metabolon.de>

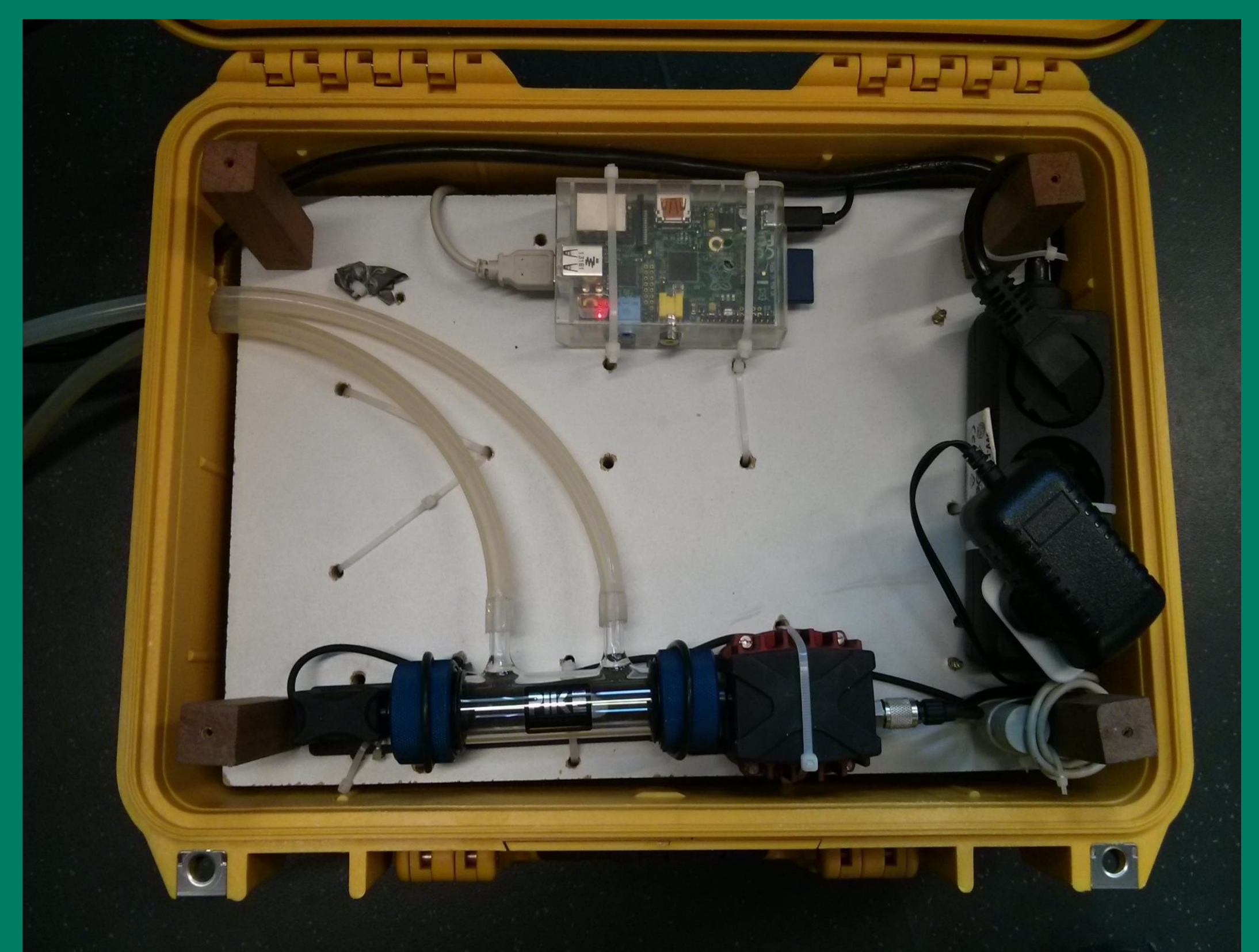


Figure 1 – Gas sensor and raspberry pi mounted in pelican case

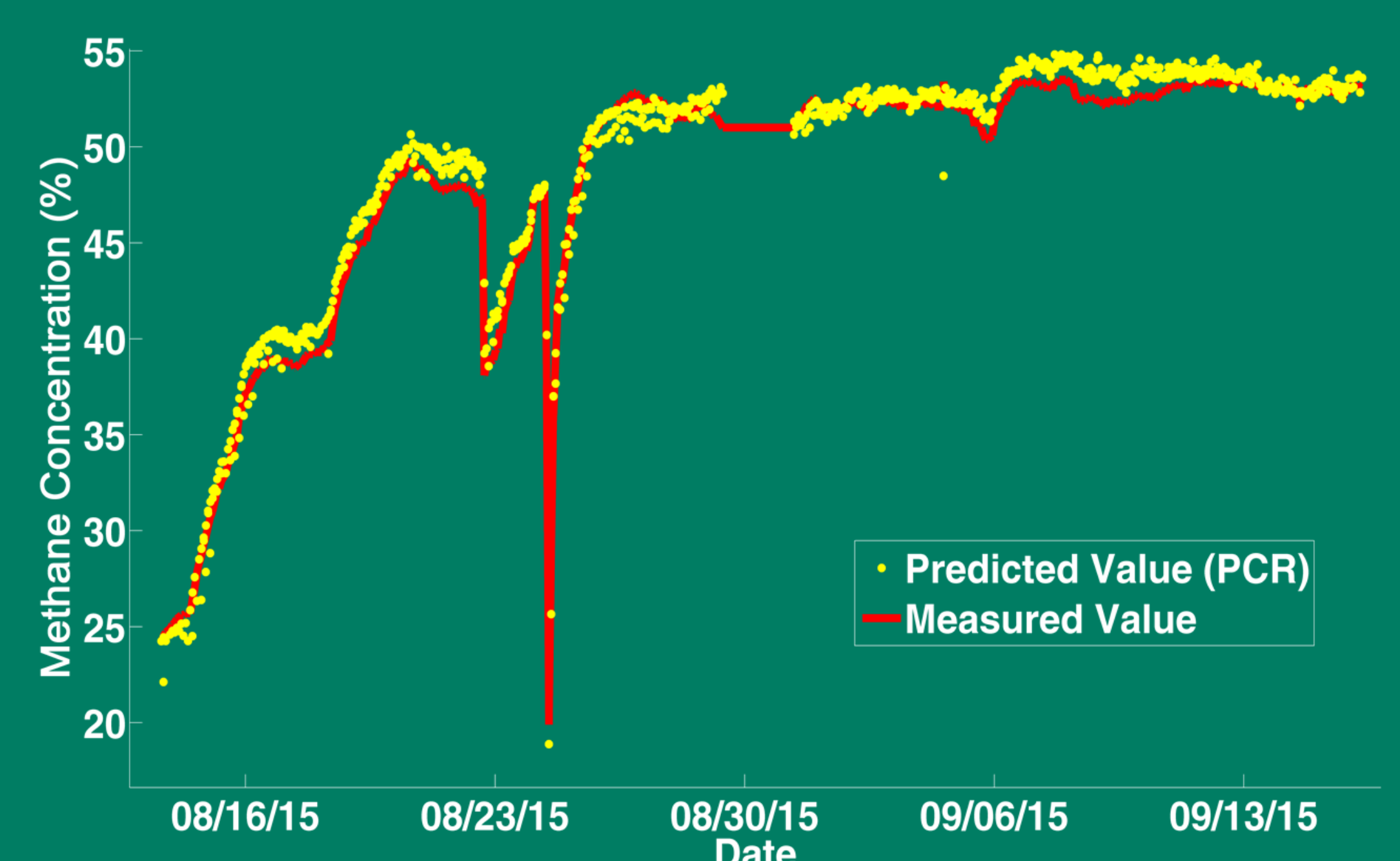


Figure 2 – Predicted methane concentrations plotted against measured test data.