1. By end of July complete an up to date literature review of prior work on **machine learning or expert systems (consider various terminology)** on **industrial air compressors**.  Identify **suitable rules**.

* Previous work – restrict to last 15 years – in particular last 5 years
* Expert systems / machine learning – come up with list of different terminologies
* Industrial air compressors – narrow scope to just this

Literature Review

# Adaptive Clustering

(Petković et al. 2012) presented a method for feature identification

# (Cortés et al. 2009)

(Cortés et al. 2009) presented the paper *“Optimization of operating conditions for compressor performance by means of neural network inverse”*.

In this paper an artificial neural network method was applied to a gas turbine’s compressor. It was therefore different to an air compressor as the fluid being compressed was a fuel-air mixture with a different pressure and temperature requirement than normally expected from an air compressor. The compressor type is given as “axial”.

An artificial neural network was first developed with an input layer (10 neurons), a hidden layer (12 neurons) and an output layer (four neurons). The inputs for developing this model were obtained by experimental measurement of 59,049 samples. The outputs were then calculated using a thermodynamic model. Once the neural network was created an inverse neural network was developed. The compressor cooler temperature drop was then optimised with respect to efficiency using the Nelder–Mead simplex method. An advantage of this method was noted to be the low time required to find the ideal cooler temperature drop for a given efficiency (<0.5 s). This would allow the method to be used for on-line operation.

# (Yu et al. 2007)

(Yu et al. 2007) presented the paper *“Neural-network based analysis and prediction of a compressor's characteristic performance map”*.

In this paper neural networks are used to develop characteristic performance maps of a gas turbine’s axial compressor when operating in off-design conditions. It was desired to know the relationship between four of the compressor’s key parameters. These four parameters were the same as those defined as outputs in the neural network of (Cortés et al. 2009). If these four parameters are known, then the compressor’s characteristic performance map may be drawn. This map may be used to determine an accurate state of the compressor’s operation if two of the four parameters are known.

Normally characteristic performance maps are created either experimentally or from manufacturer provided data. In an off-design condition measuring the required parameters experimentally can be difficult. Therefore it was desired to find an easier method of determining the compressor’s characteristic performance map. A tri-layer back-propagation neural network model was developed to give the compressor’s characteristic performance map. While the position of the inlet guide vanes of an air compressor affect its performance map, this variable was ignored in this work. This paper differed from (Cortés et al. 2009) in that the structure of the neural network (i.e. number of neurons in the input and second layer) was not readily given.

# (Ghorbanian & Gholamrezaei 2009)

(Ghorbanian & Gholamrezaei 2009) presented the paper *“An artificial neural network approach to compressor performance prediction”*.

In this paper different neural network model types were reviewed for accuracy in generating a gas generator’s compressor performance characteristic map. The four types reviewed were:

* General regression neural net-work (GRNN)
* Modified GRNN
* Multilayer perceptron network
* Radial basis function network

The two types of neural network found to be most effective in reconstructing a compressor’s performance map were modified or rotated GRNN and multilayer perceptron. Rotated GRNN was found to be most accurate in terms of closest agreement of results with training data, it was limited as a method to predicting the compressor performance map within the limits of training data given to it, and i.e. it is limited to interpolation. Multilayer perceptron networks are more suited to predicting a compressor’s performance characteristic at any operational point of the compressor, i.e. it can extrapolate to outside the given experimental training data. It was determined that multilayer perceptron neural networks are the most powerful of those reviewed in reconstructing compressor performance characteristic maps.

A key accuracy measure was that the performance map of a compressor was able to be reconstructed to 92% accuracy using 50% of available training data. Also by using the output of one neural network together with one measured parameter (corrected mass flow rate of air) as the inputs of another neural network the efficiency of the compressor could be predicted to an extremely high accuracy.

The authors had the same opinion as (Yu et al. 2007) in that neural networks provide an effective means of reconstructing a compressor’s characteristic performance curve when experimental or manufacturer’s data is not available, e.g. in off-design conditions.

Cortés, O., Urquiza, G. & Hernández, J. a., 2009. Optimization of operating conditions for compressor performance by means of neural network inverse. *Applied Energy*, 86(11), pp.2487–2493. Available at: http://dx.doi.org/10.1016/j.apenergy.2009.03.001.

Ghorbanian, K. & Gholamrezaei, M., 2009. An artificial neural network approach to compressor performance prediction. *Applied Energy*, 86(7-8), pp.1210–1221. Available at: http://dx.doi.org/10.1016/j.apenergy.2008.06.006.

Petković, M. et al., 2012. On-line adaptive clustering for process monitoring and fault detection. *Expert Systems with Applications*, 39(11), pp.10226–10235.

Yu, Y. et al., 2007. Neural-network based analysis and prediction of a compressor’s characteristic performance map. *Applied Energy*, 84(1), pp.48–55.