Detecting and Diagnosing Incipient HVAC Faults

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Challenges in Detecting HVAC Incipient faults

Motivation

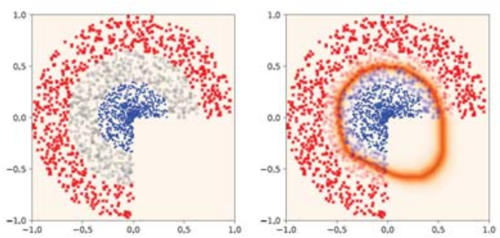
- Incipient faults (IF): reduce HVAC life-time and efficiency, & Increase maintenance costs.
- Detecting IF is challenging as they are less perceivable & not hinder regular operation (soft-faults).
- They affect the energy consumption, system performance & maintenance costs if left unattended.

Objectives: To develop methodology for detecting incipient chiller and air-handling unit faults (soft-faults) for data-sets that were not seen before.

Existing methods & FDD Challenges for HVAC systems:

- Data-driven models work well when labelled fault data are available and multi-class classification is done.
- Supervised learning methods require large amount of labelled data and they perform well on known data patterns.
- The incipient faults which are unseen could fool the classifier into wrong belief undesirable for FDD applications.
- Challenge in HVAC systems is to obtain comprehensive labelled fault-data for incipient faults with different severity levels.
- Consequently it is important to devise a method that can make full use of the available training data and detect unseen data-patterns.

Over Confidence Problem (2-D toy example)

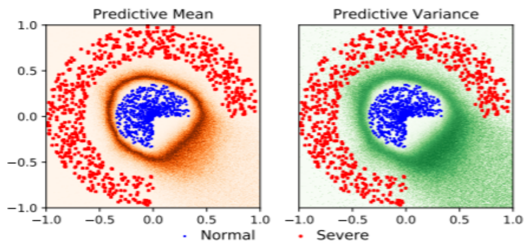


(a) Distribution of data points (b) Decision boundary

Monte-Carlo Dropout Approach

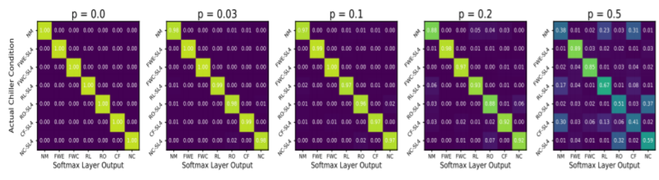
- MC dropout approach enhances supervised learning pipeline.
- A neural net trained with data-set comprising of normal and severe data-fault will be able to detect and diagnose unseen incipient fault that it has not seen before.
- Main ideas is to randomly drops units along with their connections during training and test-phases which provides intrinsic randomization to neural network models.
- The method leverages the intrinsic predictive uncertainty with MC-dropout networks to incipient faults.

MC Dropout on 2-D toy example

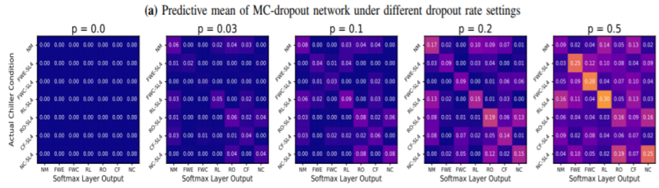


Results

- The MC-dropout approach was used to study incipient faults on the ASHRAE RP-1043 data-set on a 90-Ton chiller.
- 8 faults with 4 severity levels SL1-SL4 (slight to severe): Condenser fouling, water flow rate, reduced evaporator flow rate, refrigerant overcharge, excess oil & non-condensable refrigerant.



(a) Predictive mean of MC-dropout network under different dropout rate settings



(b) Predictive variance of MC-dropout network under different dropout rate settings

- The heatmap with normal and chiller fault condition for different dropout rates are shown in (a) and (b), respectively.
- Our results shows that the uncertainty information given by MC-dropout networks is useful in cases where there is lack of information on incipient faults & uncertainty is captured through predictive variance.

Conclusions

- Proposed a MC-dropout method for estimating deep-learning model's uncertainty in its decisions, to detect incipient or unknown faults on ASHRAE RP-1043 dataset.

References

1. Jin, B., Li, D., Srinivasan, S., Ng, S. K., & Poolla, K. (2019). Detecting and Diagnosing Incipient Building Faults Using Uncertainty Information from Deep Neural Networks. Presented at the Prognostics and Health Management Conference 2019.
2. Jin, B., Chen, Y., Li, D., Poolla, K., & Sangiovanni-Vincentelli, A. (2019). A One-Class Support Vector Machine Calibration Method for Time Series Change Point Detection, Presented at the Prognostics and Health Management Conference 2019.

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