Classifier with incremental learning ability for fault diagnosis – an aerospace application

Supervising team

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Context of the work

Europe is developing reusable launchers in the framework of different projects. To ensure launcher reliability, it is necessary to evaluate the state of health of the different parts of the launcher once it comes back to earth without dismantling it. This master thesis should contribute to a research project that addresses the development of a systematic methodology for the health monitoring of the electromechanical actuators (EMAs) used to orientate the nozzle and the fins notably.

A classifier for detecting and identifying defects in an electromechanical actuator (EMA) is currently used based mostly on physical models of EMAs and common faults. The current classifier has several limitations which the present master thesis is aimed at overcoming.

Objective of the thesis

The goal is to improve the current model-based fault detection and isolation (FDI) system. While additional ideas are welcome, different sub-goals have already been identified:

- Automated adaptation to new data by incremental learning (no need for re-training from the complete database)
- Automated definition of a new type of fault (i.e. generation of a new class)
- Provide explanations on the decision taken (i.e. choice of classification; likelihood or belief associated to each class)
- Account for the unbalanced database (many more data in healthy mode than in the different faulty modes)

An existing classifier based on support vector machines is available[1] and the possibility to equip this type of classifier with the above properties should be evaluated. Possibly other types of classifiers could also be investigated if they offer more flexibility for achieving the indicated goals. Work on this topic has been ongoing for quite some time, notably for image processing[3] [4] [5]. In the present case, it is also important to come up with a solution with low computing cost and to provide an explanation for the decision taken[2]. Those constraints are essential as the approach is aimed for aerospace applications. It must therefore guarantee the performance of the classifier even after the inclusion of new data. The need for certification of the approach should be kept in mind, which means that interpretability of how the method operates is required.

Work to be done

The student should

1. perform a bibliographic search on classifiers with adaptability to new data (incremental learning ability) and/or explainability features.

2. study the EMA models in healthy and faulty states and get acquainted with the current simulator in MATLAB/Simulink and FDI system[6].

3. Get acquainted with the methodology to generate fault indicators and the associated features

4. Compare the most promising data-driven approach for this application in terms of performance and learning ability

Requested skills

- Quick & autonomous learner in a dynamic environment
- Team player, creativity
- Good acquaintance with MATLAB/SIMULINK
- Good mastery of the bases in in control theory and digital signal processing

References :

[1] Wauthion, Benjamin, et al. "Monitoring based on analytical redundancy and classification for a primary flight surface electromechanical actuator." *IFAC-PapersOnLine* 55.6 (2022): 790-796

[2] Carlevaro, Alberto, et al. "Probabilistic safety regions via finite families of scalable classifiers." *arXiv preprint arXiv:2309.04627* (2023).

[3] Michael D. Muhlbaier, Apostolos Topalis, and Robi Polikar, Learn++.NC: Combining Ensemble of Classifiers With Dynamically Weighted Consult-and-Vote for Efficient Incremental Learning of New Classes, IEEE TRANSACTIONS ON NEURAL NETWORKS, VOL. 20, NO. 1 (2009).

[4] Liu Yu, Sarah Parisot, Gregory Slabaugh, Xu Jia and Ales Leonardis and Tinne Tuytelaars. More Classifiers, Less Forgetting: A Generic Multi-classifier Paradigm for Incremental Learning, European Conference on Computer Vision (ECCV), 2020

[5] Da-Wei Zhou , Yang Yang and De-Chuan Zhan, Learning to Classify With Incremental New Class, IEEE TRANSACTIONS ON NEURAL NETWORKS AND LEARNING SYSTEMS, VOL. 33, NO. 6 (2022).

[6] Massager, Louise, Geoffrey Postal, and Michel Kinnaert. "Three-phase motor drive fault detection and isolation based on multi-model dual extended Kalman filtering." Benelux Meeting on Systems and Control, 2025.