Federated approaches for Remaining Useful Life prognosis

Raúl Llasag Rosero, Catarina Silva and Bernardete Ribeiro
Universidade de Coimbra, CISUC - Centro de Informática e Sistemas, FCTUC-DEI - Departamento de Engenharia Informática

1. Introduction

Condition-Based Maintenance (CBM) using intelligent prognostic strategies that estimate Remaining Useful Life (RUL) has been applied in real scenarios to reduce maintenance costs and down times of machinery [1]. When applied to aircraft maintenance, these models have also been developed in collaborative platforms that make use of data from similar components both in the same and different aircraft [2].
Even though RUL predictors have been presenting potential opportunities for developing federated scenarios after aggregating Machine Learning models, accuracy improvements of these models have not been evaluated yet, mainly due to absence of aircraft data.
In this work, we propose two collaborative federated approaches to determine RUL prognosis. The first approach aggregates models of **equivalent subsystems** located in the same airplane, while the second approach aggregates equivalent subsystems on different airplanes. We analyse 2 different systems from the airplane Boeing 787: **Integrated Cooling System (ICS)** and **Cabin Air Conditioning and Temperature** Control System (CACTCS).

2. Proposed Approach

In order to reduce the distance between the theoretical and the estimated RUL, a recent collaborative paradigm named Federated Learning has been integrating machine learning models based on neural networks [2].
Using the global loss function of the next Equation, federated techniques based on Gradient Descent minimization have been improved the accuracy of equivalent prognostics systems in private aggregations of machine learning models [3].

$$F(w)\frac{\sum_{j=1}^{N} n_j F_j(w)}{n}$$

Accuracy improvements have done after **iterative averaging prognostic models (F_j) on a Federated Server**, obtaining a central model ($F(w)$) which contains the knowledge of a defined number of federation participants (n). In the present work, due to we are using and Health Indicator (HI) methodology previously to RUL estimation, those participants correspond to HI predictors of equivalent aircraft subsystems.

References

[1] V. Atamuradov and et. al. Prognostics and health management for maintenance practitioners-review, implementation and tools evaluation. *International Journal of Prognostics and Health Management*, 8:31, 2017.

[2] R. LLasag Rosero, C. Silva, and B. Ribeiro. Remaining useful life estimation in aircraft components with federated learning. *Proceedings of the European Conference of the PHM Society*, 5(1):1–9, 2020.

[3] Q. Yang and et. al. Federated machine learning: Concept and applications, 2019.

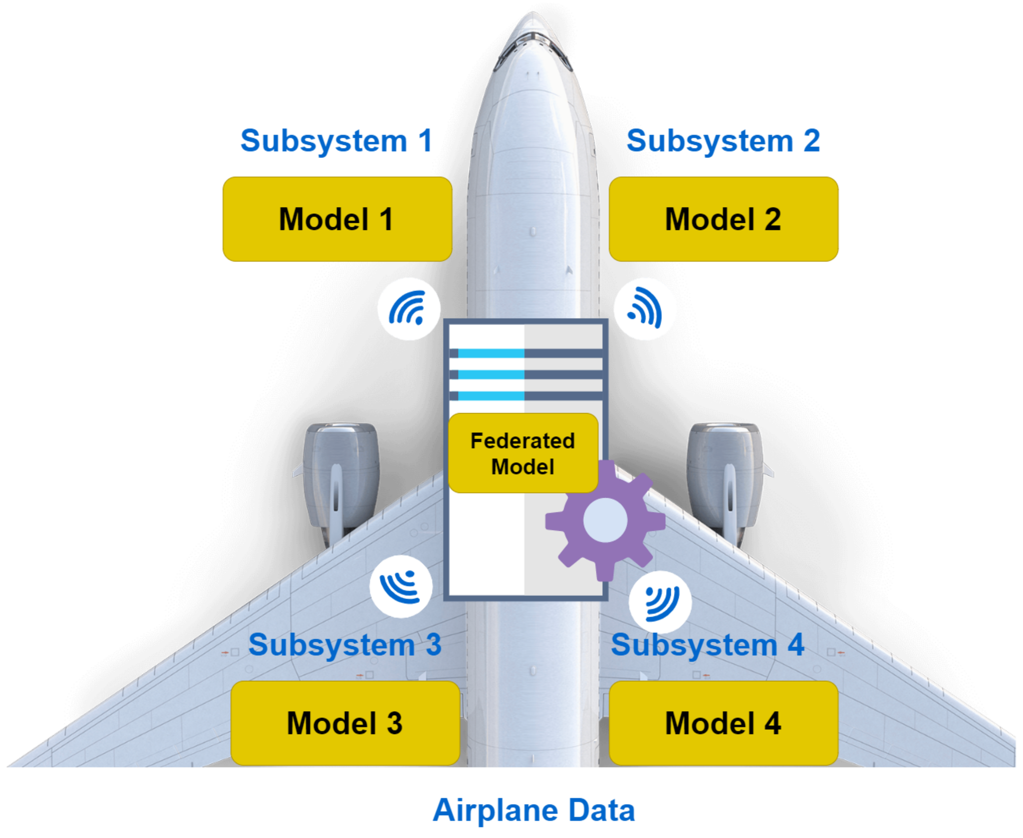
3. Aircraft Subsystems

To aggregate HI estimators of equivalent components of CACTCS andICS with federated techniques, Boeing 787 systems terminology has to be generalized to describe the federated approaches.

Fed. Learning	CACTCS	ICS
Subsystem	Component	Unit
Model	HI of Comp.	HI of Unit
Fed. Model	Fed. Comp.	Fed. Unit

CACTCS dataset is composed of sensor data obtained by different components, while ICS dataset contains units. Thus, in order to adopt the same terminology in a Federated context, **systems correspond to the dataset and subsystems correspond to components or units**, respectively.

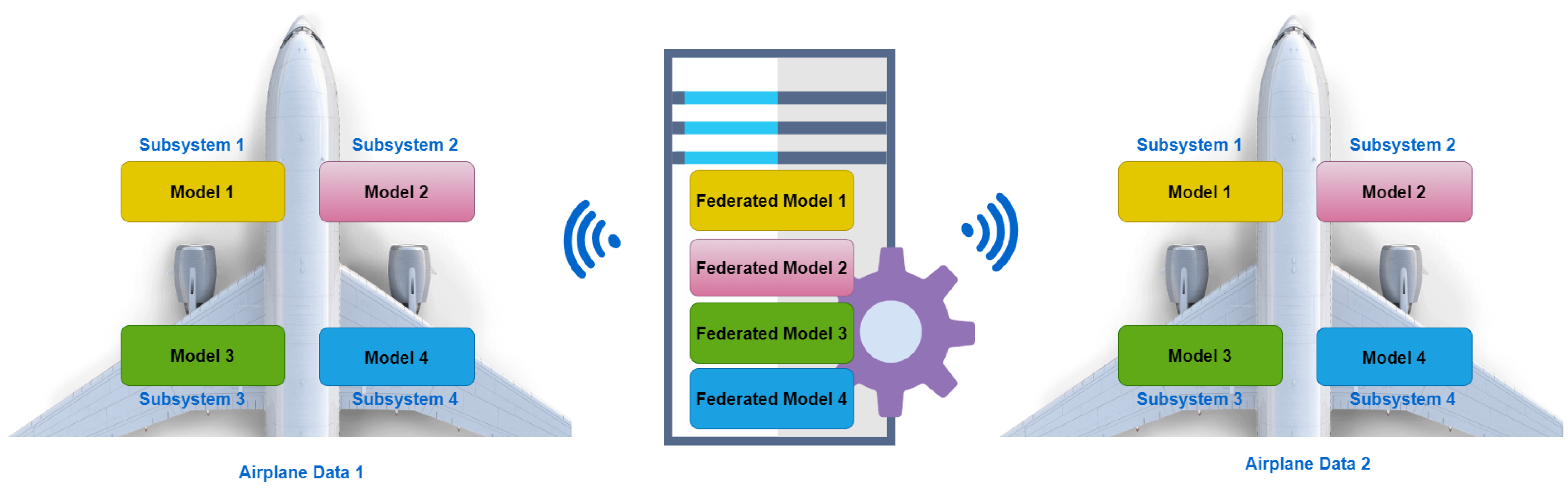
4. Federating subsystems of the same airplane



This federated approach assumes that some subsystems (same color boxes) per airplane are equivalent. In other words, the health of the 4 Charge Air Cooling (CAC) components of CACTCS or 4 Suppplement Colling Units (SCU) of ICS can be prognosticated using the same model.
Federation of equivalent subsystems does not require sharing models of different airplanes, but doing that, the prognosis accuracy of the federated model could be already improved.

5. Federating subsystems of different airplanes

In this federated approach, equivalent subsystems (same color boxes) of different airplanes can be aggregated. This approach generates one Federated Model per subsystem after aggregating models of different airplanes.



In the case of CACTCS, is assumed that the RUL of the 4 CACs of the left and the right packs can not be foreseen with the same model, i.e., the input sensors' data could be different for each subsystem.

6. Conclusions and Future Works

For the federated approach described in the *Section 4*, 10 CACTCS models and 9 ICS models contains the information of a same subsystem but located in different airplanes, while for the federated approach described in the *Section 5*, the number of federated components varies according each L-*th* and SCU-*th* subsystem. Therefore, after developing and federating HI predictors, improvements of federated approaches will be evaluated in future work.

Dataset	CACTCS	ICS
Subsystems	CAC (L1,L2,L3,L4)	SCU(1,2,3,4)
Airplanes	13	17
Failures	24	22
1st Fed. Approach	10	9
2nd Fed. Approach	6, 6, 4, 5	7, 4, 6, 2

Acknowledgements
This work is funded project from the European Union's H2020 research and innovation programme under grant agreement No. 769288.