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AUTONOMOUS NEURO-FUZZY SOLUTION FOR FAULT DETECTION AND ATTITUDE CONTROL OF A 3U CUBESAT

Abstract

In recent years, thanks to the increase of the know-how on machine-learning techniques and the advance of the computational capabilities of on-board processing, algorithms involving artificial intelligence (i.e. neural networks and fuzzy logics) have began to spread even in the space applications. Nowadays, thanks to these reasons, the implementation of such techniques is becoming realizable even on smaller platforms, such as CubeSats.
The paper presents an algorithm for the fault detection and for the fault-tolerant attitude control of a 3U CubeSat, developed in MathWorks Matlab & Simulink environment.
This algorithm involves fuzzy logic and multi-layer feed-forward online-trained neural network (perceptron).
It is utilized in a simulation of a CubeSat satellite placed in LEO, considering as available attitude control actuators three magnetic torquers and one reaction wheel. In particular, fuzzy logics are used for the fault detection and isolation, while the neural network is employed for adapting the control to the perturbation introduced by the fault. The simulation is performed considering the attitude of the satellite known without measurement error.
In addition, the paper presents the system, simulator and algorithm architecture, with a particular focus on the design of fuzzy logics (connection and implication operators, rules and input/output qualificators) and the neural network architecture (number of layers, neurons per layer), threshold and activation functions, offline and online training algorithm and its data management.
With respect to the offline training, a model predictive controller has been adopted as supervisor. In conclusion the paper presents the control torques, state variables and fuzzy output evolution, in the different faulty configurations.
Results show that the implementation of the fuzzy logics joined with neural networks provide good robustness, stability and adaptibility of the system, allowing to satisfy specified performance requirements even in the event of a malfunctioning of a system actuator.