Fault Tolerant Solutions for Multirotor Unmanned Aerial Vehicles in NVIDIA® Jetson™ TX2

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Introduction

- In unmanned aerial vehicles, particularly multirotors, dealing with possible rotor failures is a must to ensure safe operation.
- Fault Detection and Identification (FDI) modules are tasked with fast and accurately detecting the origin of the failure to take adequate measures.
- Fault tolerant control algorithms then must decide how to proceed after the failure occurred for best performance.

Fault tolerant multirotor vehicle

- In multirotor vehicles, it has been proved that, to keep attitude and altitude control even if an actuator completely fails, a minimum of six motors is needed. This is the definition of fault tolerance adopted here.
- As the standard hexarotor is not fault tolerant, several designs have been proposed to achieve it. Among them, reconfigurable designs based in rotor tilting have shown good maneuverability even after a failure.

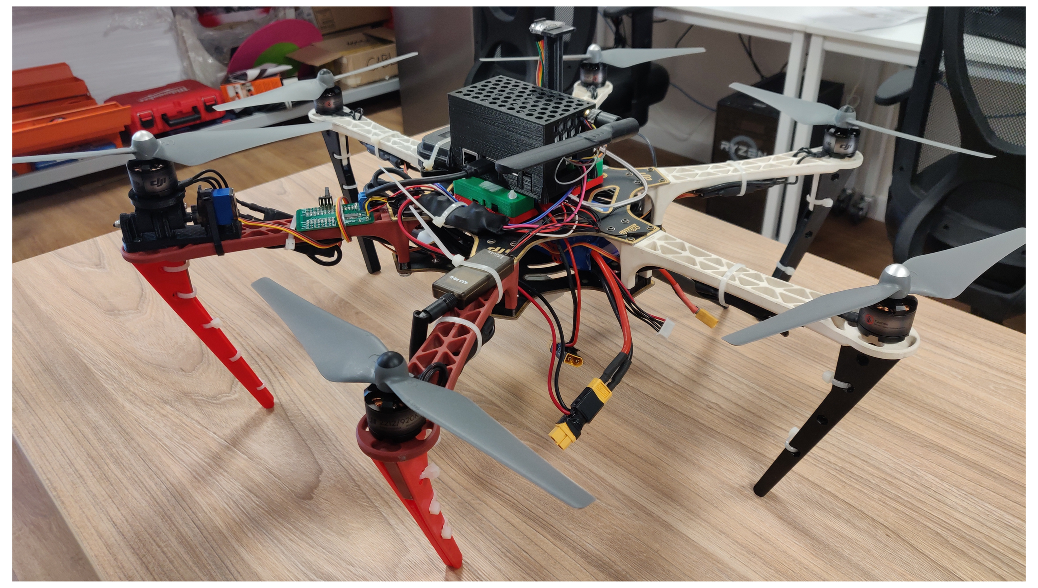

Fig. 1: Fault tolerant hexarotor with NVIDIA® Jetson™ TX2 mounted.

Fault detection and identification

- For motor failures, bank of observers are usually used, which are able to detect and identify the cause in around $250\,\mathrm{ms}$.
- Techniques based in supervised learning don't need to identify the system and may rely on recorded flight data.
- Random Forest and Support Vector Machines classifiers approaches yielded good and robust FDIs.

Fault detection and identification

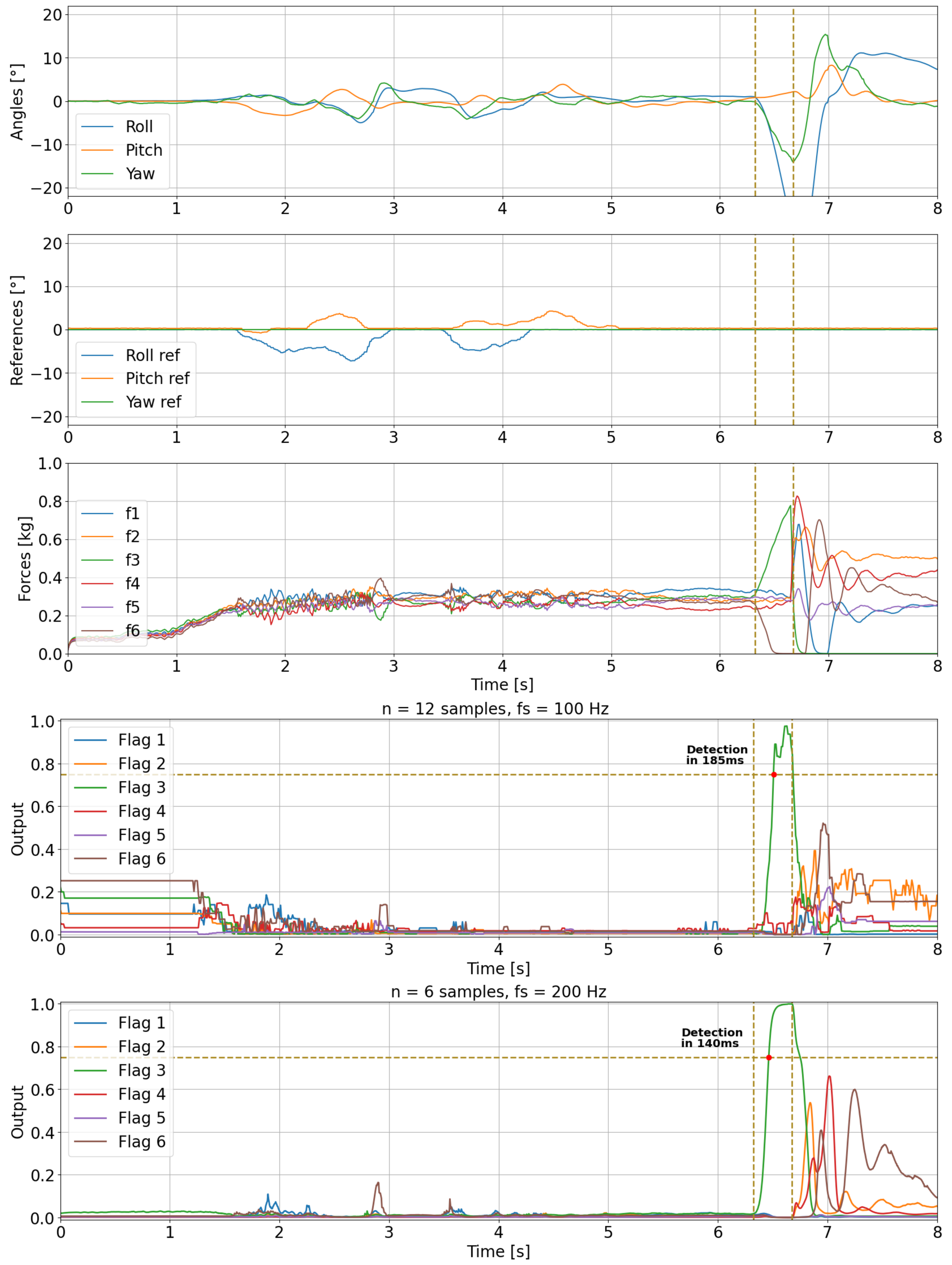

Fig. 4: Input data, Random Forest output and SVM output

- In the event of failures, fast and accurate fault detection and identification (FDI) of the cause improves the system's response.
- Random Forest (with 20 trees and depth 8) provided similar detection delays to bank of observers but with much lower processing loads, allowing to be implemented in low-resource microcontrollers.
- SVM solutions required much more processing power, required to be implemented in the NVIDIA® Jetson™ TX2.
- Low processing classification times in the SVM case (with around $0.7\,\mathrm{ms}$ - $0.82\,\mathrm{ms}$ per sample) allow to execute the algorithm at high sensor data acquisition rate. Detection times showed to be lower than those of the bank of observers.

Autonomous Landing

- When failures occur, non-critical missions may allow for an immediate landing to prevent further problems.
- Camera-based navigation comes in handy to search for feasible landing points.
- Intel® RealSense™ camera was used to detect ground fiducial marker and land within its perimeter.
- Achieved good precision even with failure present in one motor.

Fig. 5: Intel® RealSense™ mounted in hexarotor and fiducial marker.

References

1. Giribet, Juan I., Ricardo S. Sánchez-Peña, and Alejandro S. Ghersin. "Analysis and design of a tilted rotor hexacopter for fault tolerance". In: IEEE Transactions on Aerospace and Electronic Systems 52.4 (2016), pp. 1555–1567.
2. Pose, Claudio D., Juan Ignacio Giribet, and Ignacio Mas. "Fault Tolerance Analysis for a Class of Reconfigurable Aerial Hexarotor Vehicles". In: IEEE/ASME Transactions on Mechatronics 25.4 (Aug. 2020), pp. 1851–1858