

AITA.AI applications to Testing Activities ETTC 2024

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Abstract:

Most test analyses are repetitive and therefore can be automated, instrumentation of prototypes is increasingly heavy and all parameters require validation. Most test analysis tasks are manual, time-consuming and prone to human error. Documentation grows exponentially, making it very difficult to find it when needed. Test tasks can be optimized, etc.

AITA is an Airbus R&T project with the aim of developing a framework based on AI to automate and facilitate most of these tasks.

Currently, the areas that are part of the AITA project are:

- Automatic FTI validation using a machine learning technique based on decision tree item [1].
- Automatic manoeuvre detection/validation using wavelets.
- NORDOC (Not Only Relational DOCument.Tool): Tool based on Natural Language Processing to find Test documentation.
- TABAI [2]: Chatbot to help Test Activities.

For each of these areas, proof of concepts has been developed with very promising results. The idea is to progress towards ultimately developing the AI-based framework.

This article describes the progress achieved in the AITA project in particular in the automatic detection of maneuvers, storage of maneuvers and analysis results in a non-relational database, Elasticsearch and finally the **AITAVIEW** tool will be presented, which is the interface used to find the manoeuvre information.

Key words: AI: Artificial Intelligence, decision tree, wavelets, CWT: Continuous Wavelet Transform, Elasticsearch, R2: correlation coefficient, pattern recognition.

Introduction

Airbus Defense and Space has grown significantly in recent time, particularly in the area of Flight Testing. With multiple prototypes to test and abundance of parameters to validate and analyze.

To address this challenge, ADS Test organization is developing a framework based on AI to streamline the process and make it more efficient.

The name of the project is AITA (Artificial Intelligence for Test Application).

The AITA project is an in-house software composed of a set of functions developed in Python and in C++ for reading data and heavy calculations.



Figure 1, AITA Logo

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This document will provide an overview of the project's advancements and enhancements in the area of automatic detection of manoeuvres, in the storage of this information in a no-SQL database, specifically Elasticsearch, and the manoeuvre visualization and search tool known as AITAVIEW will be presented.

Automatic Manoeuvre Detection

The Automatic Manoeuvre Detection is based on Pattern identification. The analysis methodology used consists of building adaptive wavelets in the sense of least squares to a specific pattern. Once the wavelet is available, the CWT (Continuous Wavelet Transform) is used to find the pattern in the time history.

This methodology is an improvement of the one included in the BMAD [3] (Big-data Manoeuvre Automatic Detection) project. Besides improving the pattern generation, including new parameters that help determine the manoeuvres validation, the data access and pattern search library has been optimized by migrating python library to C++ and parallelizing the process.

What is a wavelet?

Wavelet analysis is used in digital signal and image compression.

A wavelet is a mathematical function $\psi \in L^2(\mathbb{R})$ with zero average (i.e. $\int_{\mathbb{R}} \psi = 0$), normalized (i.e. $\|\psi\| = 1$), and centred in $t = 0$.

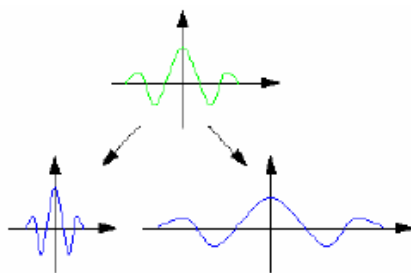


Figure 2.Harr Wavelet

Let $\psi_{u,s}$ be a family of translations u and dilations s of a wavelet ψ named wavelet mother.

$$\psi_{u,s}(t) = \frac{1}{\sqrt{s}} \psi\left(\frac{t-u}{s}\right), \quad u \in \mathbb{R}, s > 0. \quad (1)$$

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Given f , the Continuous Wavelet Transform (CWT) at time u and scale s is defined as:

$$Wf(u, s) = \int_{-\infty}^{+\infty} f(t)\psi_{u,s}^*(t)dt \quad (2)$$

The CWT is used to find the dilations and translations of the wavelet in the time series f .

Automatic Manoeuvre Detection Process

The steps to be followed are as follows:



Figure 3.steps

- Select a pattern to detect

The first step is to construct wavelets adaptable, as well as possible, in the least squares sense, to the specific pattern. The procedure is described in the chapter 7 of the item [3].

A Python application has been developed to generate the pattern library, which consists of XML files for each maneuver (GenWavelet.py). Initially, a time slice of a parameter that represents the maneuver is selected, as illustrated by the example of a Rapid Rolling maneuver during an actual Eurofighter flight. The lateral pilot stick serves as the parameter for defining the pattern.

The figure below depicts the interface of the application used to generate the patterns, specifically showcasing the Rapid Rolling pattern in this instance.

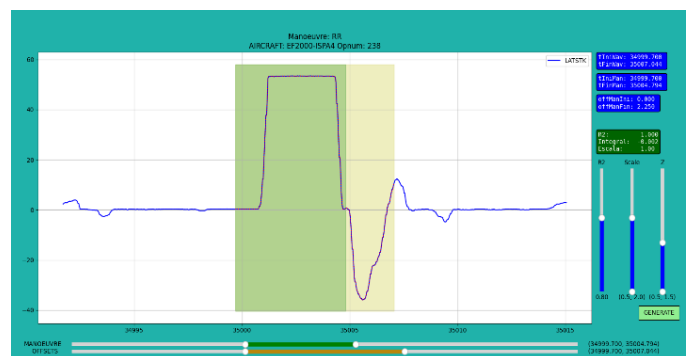


Figure 4.Rapid Rolling pattern

The time slice included in the dark green rectangle corresponds to the pattern that characterizes a Rapid Rolling, but this pattern doesn't meet the wavelet properties.

Hence, an additional light green rectangle is manually delineated by utilizing the lower slices until the pattern conforms to a wavelet shape.

$$\int_R \Psi = 0 \tag{3}$$

$$\|\Psi\|_{L2} = 1 \tag{4}$$

• Manoeuvre selection criteria

As previously stated, the Continuous Wavelet Transform (CWT) is employed to identify dilations and translations of a wavelet pattern within a time history, where horizontal and vertical dilations correspond to the scale and Z criteria, respectively.

In order to enhance the maneuver detection process, a new criterion has been introduced, which measures the R2 correlation between the actual data and the manoeuvre pattern.

Hence, within the application interface, the criteria for maneuver detection are outlined as follows:

- Scale: minimum and maximum horizontal axis scale applied to the wavelet pattern.
- Z: minimum and maximum vertical factor applied to the wavelet pattern.
- Minimum R2: between real data and the manoeuvre pattern in the dark green rectangle.

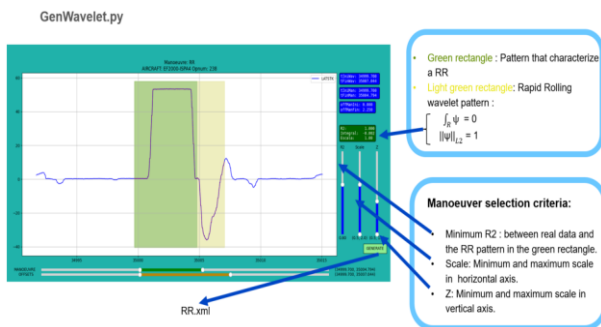


Figure 5. Manoeuvre Selection Criteria

• Add additional constrains and calculus

In the following figure, all the information contained in the XML file can be seen. This Information includes:

- Creation date.
- Name of the Pattern.
- Information of the flight, parameter used, time slice.

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- Wavelet characteristics: Integral value, wavelet pattern criteria, if is symmetric, R2 etcetera.
- Constraints can be imposed on parameters other than the one utilized to define the pattern. In the case of RR, the parameter phi (roll) is implicated and must complete a full turn within the manoeuvre.
- Calculations associated with the manoeuvre, such as the average MACH, Altitude and Airspeed, minimum and maximum of pitch and AOA angles within the manoeuvre.
- Numerical wavelet values.

The figure shows an XML file named 'RR.xml'. The XML content includes metadata like 'Date', 'Source', and 'Integral'. It contains sections for 'PREPROCESSING', 'CONSTRAINTS', 'CALCULATIONS', and 'DATA'. Annotations with arrows point to these sections: 'Pattern information' points to the metadata; 'constraints' points to the 'CONSTRAINTS' section; 'calculations' points to the 'CALCULATIONS' section; and 'wavelet' points to the 'DATA' section.

Figure 6 . RR.xml

Find pattern in flight

The continuous wavelet transform (CWT) is used to find the wavelet pattern in a flight. Findpatterninflight.py is a Python application that searches wavelet patterns in a flight.

The application is run by applying the following command.

```
python findPatternInFlight.py -ac EF2000-IPSA4 -opnum 240 -man RR -plot"
```

It can also be executed automatically, storing the results in an elasticsearch database.

```
python findPatternInFlight.py -ac EF2000-IPSA4 -opnum 240 -man RR -db"
```

In this case, the Rapid Rolling manoeuvre is searched in a real flight of the EF2000. The following figure shows the temporal data with the identified manoeuvres at the top and the spectrogram is represented at the bottom. Item [4].

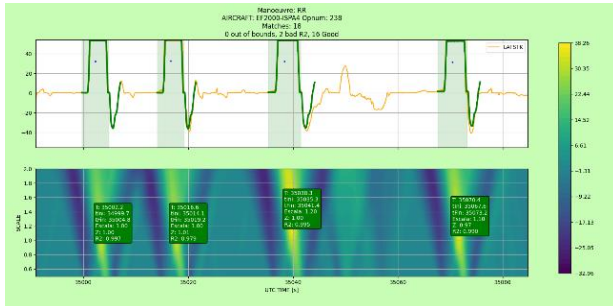


Figure 7. Find RR in flight

The relative maxima of the scalogram (yellow colour) indicate the temporal location of the wavelet, while the corresponding y-axis represents the horizontal scale applied to the wavelet pattern.

The green lines represent the detected wavelets, while the time slice encompassed by the green rectangles corresponds to the Rapid Rolling manoeuvre.

Validate patterns

The first step is to identify the wavelet pattern within the time series using CWT and then validate the detected manoeuvres. To do this, a section of the wavelet pattern that corresponds to the manoeuvre has been defined (manoeuvre pattern) and a minimum R2 value between the real data and the manoeuvre pattern.

Sometimes, this is not enough to detect all the real manoeuvres especially in cases where the wavelet pattern is much larger than the part corresponding to the manoeuvre.

The search for maneuvers has been enhanced as follows: once the center of the wavelet pattern is detected, the pattern moves along the x-axis, applying horizontal and vertical factors until identifying the maneuver pattern that best aligns with the real data.

Furthermore, by defining constraints with other parameters such as phi in the case of RR, the maneuvers are now perfectly identified.

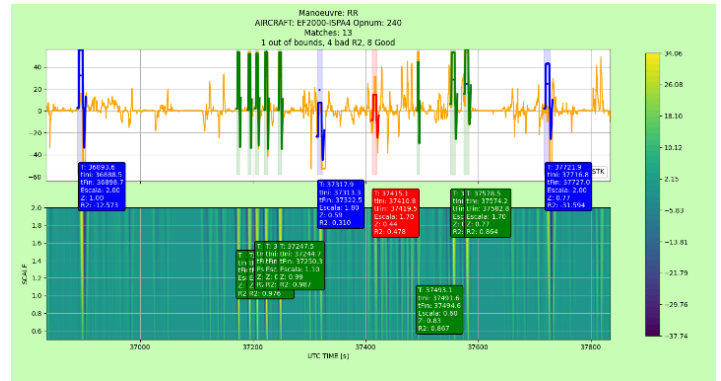


Figure 8. validate patterns

The green colour of the rectangle indicates whether the manoeuvre is well detected, in red if the R2 is lower than the required in the pattern definition, or in blue if it does not meet any of the constraints.

A 3D visualization of the manoeuvre has also included in the application by clicking on one of the rectangles.

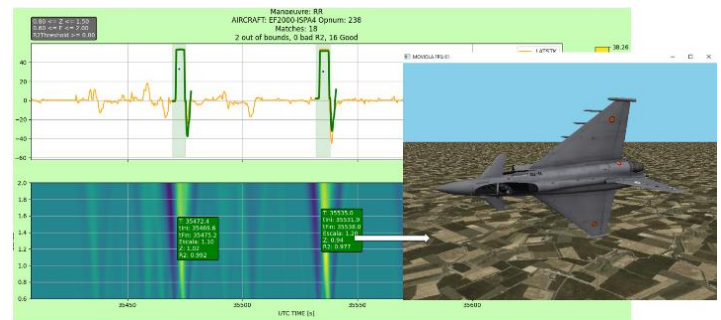


Figure 9. 3D manoeuvre visualization

Patterns Library

Currently the manoeuvres that are identified for each aircraft are:

Eurofighter: Rapid Rolling, Wind Up Term and Lateral-Directorial and Longitudinal manoeuvres generated by FBI (Function Bias Input).

C295: SHSS (steady Heading Side Slip), using DR (Rudder deflection) as pattern.

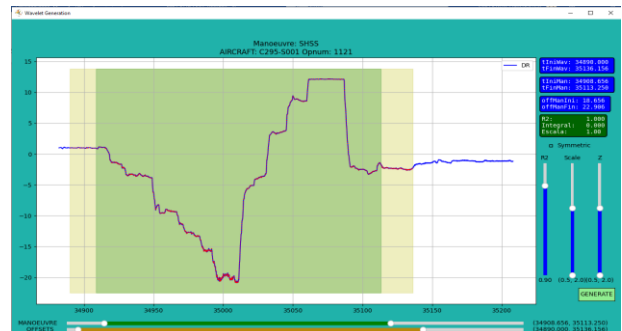


Figure 10. C295 – SHSS

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C295: BTB (Bank to Bank), using PHI (bank angle) as pattern.

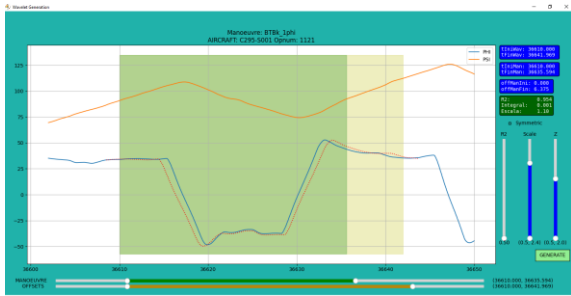


Figure 11. C295 – BTB

C295: TO (take off), using THETA (pitch angle) as pattern.



Figure 12. C295 TO

C295: DUCHROLL using DR as pattern.

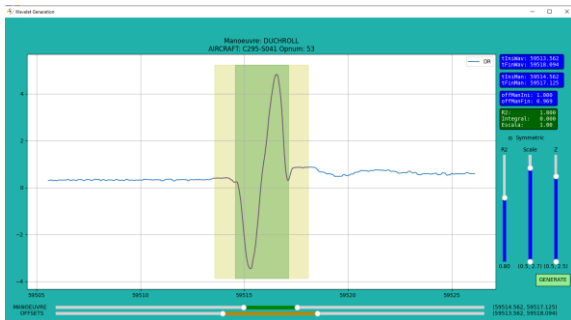


Figure 13. C295 DUCH ROLL

C295: STALL using AOA (angle of attack) as pattern.

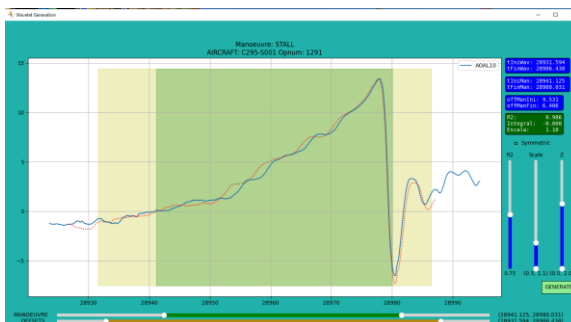


Figure 14. C295 STALL

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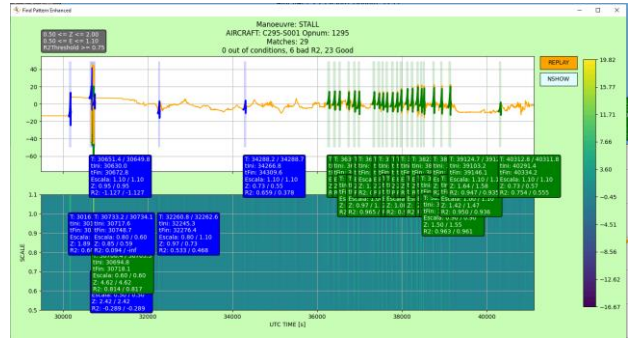


Figure 15. Find STALL in a flight

The following figure shows the 3D simulation of the manoeuvre.

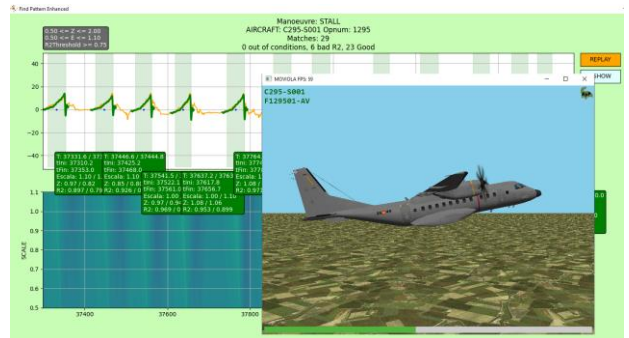


Figure 16. 3D manoeuvre visualization

By clicking on the NSHOW icon, a plotting tool will appear displaying the time histories of the key flight parameters of the manoeuvre, including all the time stamps corresponding to the manoeuvre.

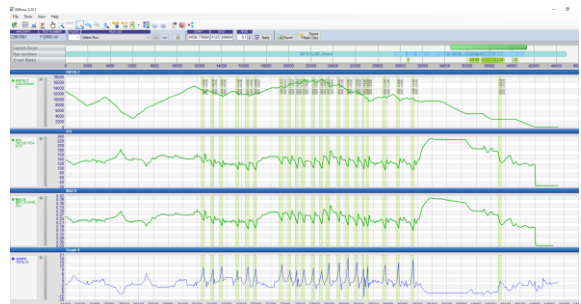


Figure 17. NSHOW

Store manoeuvres in an Elasticsearch

Initially, maneuver information was stored in relational database tables, but the data within these tables lacked relational structure. For instance, in-flight refuelling manoeuvres need storing data such as the fuel transferred, contact duration, or the aircraft receiver however these values do not make sense in other maneuvers such as aerial delivery tests.

What is elasticsearch?

- Elasticsearch is a distributed and document-oriented database
- Elasticsearch is an open, free and distributed search and analytics engine.
- Elasticsearch is commonly used for log analytics, full-text search, security intelligence, business analytics, and operational intelligence use cases.

The elasticsearch database had already been used in the NORDOC application, which is part of the AITA project based on Natural Language Processing, obtaining surprising results.

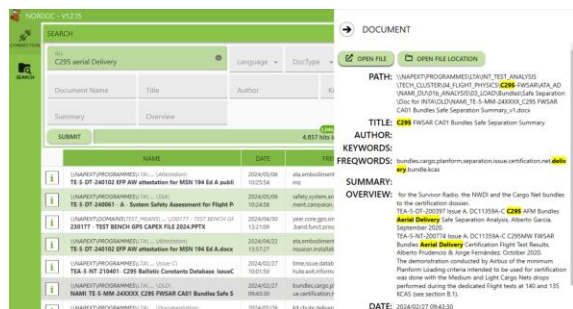


Figure 18. NORDOC

Elasticsearch databases have been created for each aircraft where all automatically detected maneuvers are stored with the fields that characterize each maneuver.

Kibana is the standard open-source data exploitation and visualization tool designed for Elasticsearch, but with the objective of facilitating access to maneuver databases and being able to connect them to Test applications and databases, it was decided to develop a specify tool: AITAVIEW.



AITAVIEW is an in-house Tool designed to access, visualize and filter maneuver databases.

Initially, you select the database you want to access. Currently, there are two options available, corresponding to Eurofighter and C295.

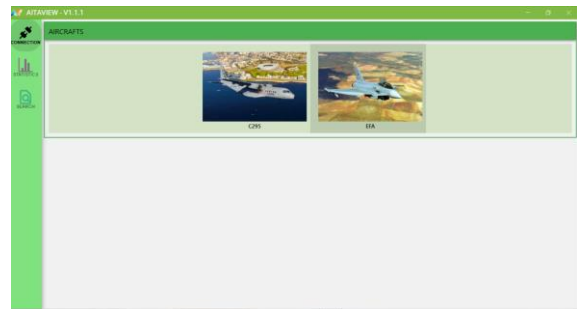


Figure 19. AITAVIEW. Database Selection

Once the database is selected, in this case C295, information regarding the number of aircraft and maneuvers contained within the database is displayed.

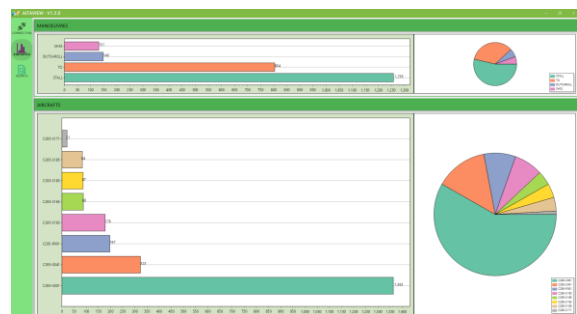


Figure 20. AITAVIEW Statistics

By clicking on the SEARCH button, searches can be performed by selecting aircraft and maneuvers.

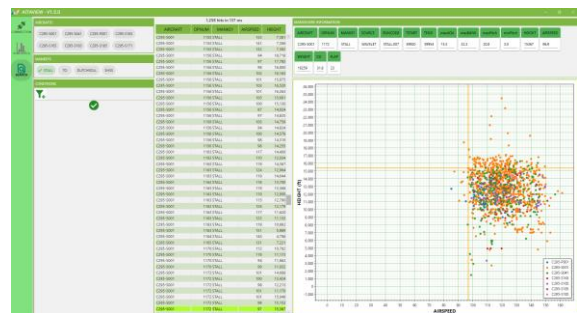


Figure 21. AITAVIEW SEARCH

In the center of the interface, the list of selected maneuvers appears, with a graph displayed on the right showing the airspeed versus altitude where these maneuvers were performed.

You can hover the mouse over the graphic, orange lines, and see the corresponding maneuver highlighted in green in the list, along with its characteristic parameters at the top of the interface.

Additionally, other filtering conditions can be defined using all available fields in the database.

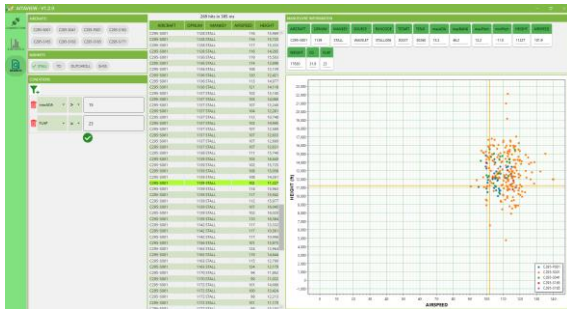


Figure 22. AITAVIEW Filter conditions

A 3D replay of a manoeuvre can be seen by selecting it with the right mouse button.

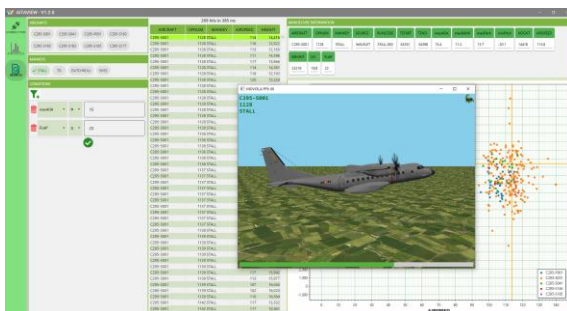


Figure 23. AITAVIEW 3D replay

You can also see the time history of the significant parameters of the manoeuvre using NSHOW plot Tool.

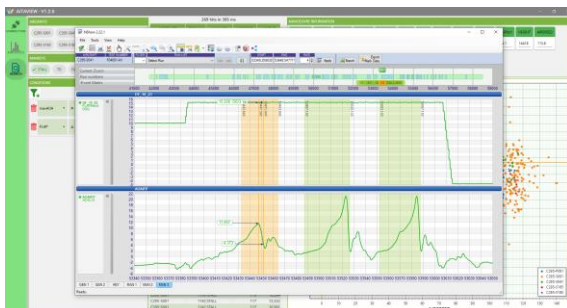


Figure 24. AITAVIEW NSHOW

Conclusions

The technique of automatic manoeuvre detection based on pattern recognition using Continuous Wavelet Transform has been optimized in accuracy and speed.

The method has been checked for some manoeuvres in Eurofighter (RR,FBI,WUT) and C295 (BTB,SHSS,TO,STALL,DR) with promising results.

An Elasticsearch database containing all the manoeuvres detected has been created.

A tool named AITAVIEW has been developed to view and filter the manoeuvre database.

The next steps are to store in Elasticsearch all the manoeuvres of all the aircraft, whether

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identified with patterns or other techniques, and to expand the functionalities of AITAVIEW.

References

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