

Instructions for PA28 Flight Test Data Processing

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November 2020.

# Introduction

In order to complete my thesis I had to reprocess PA28 flight test data that was initially done by Flavio Ferrari. Mostly all calculations are done by Flavio, I modifyied and simplifyied his code. All my comments, modifications, removals, shortcomings of the scripts, possible improvements and comparison and validation are written here as well.

# Structure

Files are structured as it follows:

* David\_MT
  + Data
    - Flights
      * *Flight\_1\_and\_3.mat*
      * *Flight\_2\_and\_4.mat*
      * ...
    - Manoeuvres
      * *FID\_1.MID\_53.CG\_FWD.Mass\_M.Alt\_M.S\_M.P\_M.Mnvr\_Phugoid.mat*
      * *FID\_1.MID\_85.CG\_FWD.Mass\_M.Alt\_M.S\_L.P\_M.Mnvr\_DutchRoll.mat*
      * *...*
  + Data Processing
    - Flight Test Data
      * Flight\_1\_and\_3\_raw
      * Flight\_2\_and\_4\_raw
      * ...
    - Manoeuvre Data
      * *cutManoeuvre\_1\_and\_3.csv*
      * *cutManoeuvre\_2\_and\_4.csv*
      * *...*
    - *Utilities*
      * *All\_Data\_processing.m*
      * *Single\_flight\_data\_processing.m*
      * *processData.m*
      * *organizeData.m*
      * *cutToManoeuvres.m*
      * *calibration.csv*
      * *signal\_mapping\_flight.xlsx*
      * *signal\_mapping\_manoeuvre.xlsx*
      * *Masterfile.xlsx*

In order for all the matlab files to work user should position himself in the 'Davit\_MT' directory.

# Directories

## Data

Contains all the *MATLAB* processed data files ready for further analisys. They are divided in two folders based on whether it is a flight test data or cut into manoeuvres data. When reprocessing the data, all new data is saved in these folders in a way that the old data is replaced by the new. But to be extra sure, maybe it is better to delete the old data prior to reprocessing.

## Data Processing

Contains all files and folders necessary to process the data.

**Flight Test Data** contains all single flight raw flight test data folders. Each of them has:

* a original *pdf* file from after the flight
* 3 *excel* files containing IMU data
* 4 excel files, along with the original *tdms* files, containing cRIO data
* *Excel* file containing starting times of cRIO data (replacing Flavio's *read\_cRIO\_csv* function)
* Synchronization *excel* file (representing Flavio's text files with synchronization values)

*Excel* files are numerated in a way for the matlab fuction to select them in order.

**Manoeuvre data** contains *excel* files with specific manouvre information, they are used to properly cut the data to manoeuvres and add samo parameters like fuel and trim to the data. They contain start and end times of each of the manoeuvres.

# Utilities

**Scripts**

*All\_Data\_processing.m* script processes all the flight data and saves it in the corresponding folder. For the start, it is necessary to select the folder with all the raw flight data folders – 'Flight Test Data'. It also has the option to organize the data and cut the data to manoeuvres which both, if not wanted, should be commented in the code.

*Single\_flight\_data\_processing.m* is mostly there to check the modifications and not needing to process all the flights. It is needed to specify the raw data folder of a single flight.

**Functions**

*procesData.m* is the main function composed of Flavio's *A\_AfterFlightProcessing\_v3.m* and *B\_fromRaw2Values\_V2.m* scripts. It imports the raw data, merges it, applyies delays and synchronization shift, converts the cRIO data to physical values (calibration), applyies the error models and adds additional calculated parameters. The function producess a *FT\_Data.m* file for specifying a folder with all the raw flight data files. Data (without organizing it) comes in 3 different groups with 2 different prefixes. IMU data starts with *imu,* cRIO data has a *crio* prefix and there are also data starting with *calc* that are calculated from IMU and cRIO data. When data is converted to physical values it gets the suffix *corr* except the AOA, AOS, and dynamic and static pressure that get the suffix *conv* and after aplying error models they also become *corr.*

Changes I made: Importing of all the data is changed, unnecessary parameters like additional date and time and marker data are removed, automatic synchronization is implemented, calculations of density, TAS and pressure altitude are changed.

Shortcoming I noticed but did't change to have the same data like Flavio:

- First rows of original data are not imported (neglectable). Probably Flavio didn't notice, but I kept it the same not to mess up his synchronization.

-Retiming, synchronizing and shifting of the tables could be done better (it is done few times in a different places in the code).

- Synchronization by markers between cRIO and IMU is also done in a manual and strange way where Flavio changed (rounded?) the seconds value of the cRIO marker cause matlab was giving him some errors when retiming and synchronizing. I guess that could be done just by substracting the corresponding marker times without changing the seconds value and retiming the tables more correctly.

-There was a sensor error sometimes giving the dynamic pressure values as negative, so these values are set to NaN.

-When importing cRIO data of 1613 Hz and 1000 Hz, sample rates are set to correspond with 1651.6 Hz and 1005 Hz (not sure if the written Hz values are just rounded and the cRIO samples with good rates or this is an error ).

*organizeData.m* uses corresponding *signal\_mapping excel* file to rename and keep only the selected parameters. Funcion works only if the data is not organized and renamed prior. Usually, data is organized before cutting to manoeuvres and then it is suitable for everyone to use. But, there is also option to reprocess and cut the data without organizing it and then select what to keep when loading each of the manouvres (that is why there are 2 *signal\_mapping* files).

*cutToManoeuvres.m* cuts manouvres out of each of the flight data based on the proper excel file. From original Flavio's *D\_cutManoeuvres.m,* I removed all mass values and all of the plots because they take 10 minutes more to print and they are not actually needed.

Data is saved with a descriptive name in the 'Manoeuvres' folder but when loaded it is a structure named *FT\_MData.*

**Other**

*Calibration.csv* contains all the calibration data (gain and offset) necessary for the *processData.m* function to work, it is done by Flavio.

*Signal\_mapping\_...xlsx* is the file for data organization. Parameters to keep should be assigned with value 1.

*Masterfile.xlsx* contains all the informations from test flights, it is not needed for data processing.

# Validation/Comparison

All the data was compared with Flavio's processed files. It is needed to say that all of his flights are processed manually one by one and there is a lot of inconsitencies.

In his files, after-applying-error-model parameters, come after the calculations of additional parameters while in the script they are calculated before. Also, in some flight there are \_*Old* versions of these parameters that dont exist in the script.

All of the parameters, except after-applying-error-model parameters, in all of the flights are exactly the same or acceptable. Only flight 7 have some differences (neglectable), but in his flight 7 there was no pressureAltitude variable and his whole flight 7 data looks critical.

While AOA is also exactly the same everywhere except flight 7, dynamic and static pressure final values (after EM) are slightly different and the cause of that is nowhere to be found since the \_*conv* values of the same parameters are identical and the error models are copyied from Flavio's script.

AOS values are in some flights acceptable, with the same issue like the pressures. In some other flights, the values are opposite sign, due to opposite sign calibration values (*\_conv*). Flavio said that he found out, during the FPR that the rudder is inverted and then he changed it directly in the FPR without touching the original data. Now he doesn't remember whether he adjusted the calibration part back in the script or not.

To sum up, comparing the dates when Flavio's files where created, the newer files (November 2019.) are also more alike and consistent while the older ones are a bit different from mine.

# For future data analisys

When doing flight path reconstruction, Flavio discovered an offset between ADB and IMU data. Like stated in his thesys, this offset is due to the different instalation pitch angle between ADB and IMU. IMU was mounted on the floor of the baggage compartment while the ADB was aligned to the level points of the aircraft. In his thesys he states that the angle is about 6 deg like in the following figure.

Diagram, engineering drawing

Description automatically generated

**Figure 1**. *Angle between IMU and ADB*

Measuring the angle on the actual aircraft, I measured the angle of 4.75 deg so that value is taken over. How flavio got 6 deg is not sure.

This should be taken into account when using FT data keeping in mind that IMU axes are not aligned with the body coordinates. IMU data should be rotated around y axis by -4.75 deg.