Small scale F16 model and simulation

ECE Capstone

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Background and Motivation

Who wouldn't want to fly in an F-16 fighting falcon? How about a scale model RC F-16? Yeah, us too! This capstone is about developing software to discover the flight dynamics of a scale model RC F-16 aircraft for the purposes of developing trusted flight control software. Why, because, let's face it, we don't want to crash this awesome bird![1] Your mission, if you choose to accept it, is to design a real time software package that runs in parallel with an autopilot, stores data at real time, and leverages novel machine learning algorithms to get an accurate model of the RC F-16 dynamics. Don't worry, we'll help you get started and we won't let your approach "take-off" without plenty of simulation.

Galois is participating[2] in DARPA's Assured Autonomy program, and has developed a tool for rapid control system development and testing, called Control System Analysis Framework (CSAF). This tool will be publicly available in the next few weeks.

To demonstrate the capability of our tool, we want to show an end-to-end development of a new control system, including flight testing. F16 Falcon is of particular interest to our client, but flight testing a real fighter jet is complicated. To circumvent the inconvenience of flight testing a real aircraft, we want to use a remotely-controlled and scaled down model of F16 instead. This 64mm ducted fan model seems to be a good platform.

Full scale F16 model is well understood, and high fidelity system equations are available in the literature[3], but system equations for the scaled down model are not known, making simulation of such a system impossible.

We want the capstone team to develop equations describing the scaled down F16 model and incorporate them into an existing simulation tool. Based on your model, we will develop an autopilot for autonomous flight of the scaled down F16.

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[1] Freewing F-16C Super Scale 90mm EDF Jet - ARF PLUS
https://www.motionrc.com/products/freewing-f-16c-super-scale-90mm-edf-jet-arp?variant=19073422726&currency=USD&utm_medium=product_sync&utm_source=google&utm_content=sag_organic&utm_campaign=sag_organic&gclid=EAIaIQobChMIhYHT8dK26wIVEz2tBh29Xw3ZEAQYASABEgJbXfD_BwE#description-tab

[2] Full blog post:
https://galois.com/blog/2020/08/providing-safety-and-verification-for-learning-enabled-cyber-physical-systems/

[3] https://github.com/stanleybak/AeroBenchVV

Objectives

Our goals with this capstone are as follows:

1. **Defining the parameters of interest.**. In this objective, you will study the materials provided, both the simulation and the textbook resources. You will identify the appropriate flight control variables that need to be observed and recorded during either simulated runs or flight tests.
    a. Aircraft Control and Simulation by Brian L Stevens
    b. Introduction to feedback and control - BYU Tim McLane

2. **Develop the test plan.** The next objective is to develop a test plan that describes how to "excite" the system such that the variables of interest can be observed. You will also be required to, given a Pixhawk software stack, identify where in the software stack the particular input variables can be accessed and logged.

3. **The creation of an accurate model of the system.** We prefer if the team measures/calculates the aerodynamic coefficient and other constants, using aerodynamic equations from the literature.[4] As a backup, a System Identification approach can be taken.

4. **Flight testing the scaled down F16 to gather data:** We expect the team to instrument the F16 model with additional sensors/hardware to gather flight data, which is necessary both for system identification and for validation of your equations. This is also an important step towards an autonomous flight of the model (which can be a stretch goal for the team).

5. **[Stretch Goal]** Perform a real flight validation. This optional step is to compare simulated data with flight data[5]

6. **[Stretch Goal]** Design an autopilot to adjust flight characteristics of the model, so the model is easier to fly.

7. **[Stretch Goal]** Perform an autonomous flight with the model.

Learning Outcomes

The team will gain expertise in the following:

- Aircraft design and modelling

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[4] https://onlinelibrary.wiley.com/doi/book/10.1002/9781119174882
[5] https://scihubtw.tw/10.1109/red-uas.2015.7440998

- Flight testing of small UAV
- Hardware and software for small UAV

Milestones

The project consists of the following milestones:

- Gain understanding of kinematics and dynamics of aircraft motion
    - [Stevens: Aircraft control and simulation book]
- Develop set of test and measurements necessary for calculating the aerodynamic coefficients for the small F16 model
    - We expect some test to be static, some might need to be dynamic, and some data will be gathered from flights
- Instrument the model with necessary hardware/software
    - Adding an autopilot, such as PX4 might be necessary to record in flight data at sufficient fidelity
- Gather flight data using the instrumented airplane
- Develop a model describing the scaled down F16
- Compare your model with a real flight test, and quantify the accuracy of your model

Student skills

We realize that this capstone requires you to learn material that is outside PSU's curriculum, and while we do have some aircraft modelling expertise in-house, you might have to consult additional resources at or outside PSU. We believe that a PSU team will be very solid on the hardware and software instrumentation side, and we do have a lot of experience doing it as well, so we can support you as needed. Having experience flying RC airplanes would be very helpful, because flying a ducted-fan model of a fighter jet is much more difficult than flying a quadcopter.