Designing an aicraft

With open-source tools

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Contents

Note

The following document uses some of the more advanced features of the pdf format. Advanced features like buttons, animations and 3d files.
For these to work they need to be opened in an environment that can read them.
Adobe reader is recommended: https://get.adobe.com/reader

Introduction

I am Tobias Jacobsen, and I undertook the ambitious endeavor of conceptualizing and designing an aircraft. The intricate task of aircraft design unfolds as a multifaceted process, drawing upon the principles of aerodynamics, thermodynamics, chemistry, and mechanics. The interconnected nature of these disciplines adds a layer of complexity to the design process, as developments in one field inevitably reverberate across others.

To navigate through this intricate web of knowledge, a structured approach is imperative. Recognizing this, I embarked on the creation of a set of simulation tools, meticulously crafted within the programming language Python. This collection of tools serves as a strategic foundation, allowing for a more systematic and manageable exploration of the intricacies involved in the design of an aircraft.

1 Python

The selection of Python as my programming language of choice stems from its renowned accessibility, making it a conducive platform for rapid and comprehensive learning. This inherent ease of learning has propelled Python to the forefront, establishing it as one of the most widely adopted programming languages in various domains.

Within the Python ecosystem, I have harnessed the power of several captivating libraries, each contributing indispensably to the intricacies of aircraft design.

1.1 CAD modelling with python

Recognizing the significance of geometry in aircraft design, I focused on developing tools using the CadQuery package for constructing essential components. This allowed me to create the basic structure of an aircraft, with the added functionality of automatic dimension updates as the aerodynamic formulation progresses. Below is an example of an aircraft model entirely crafted in Python.

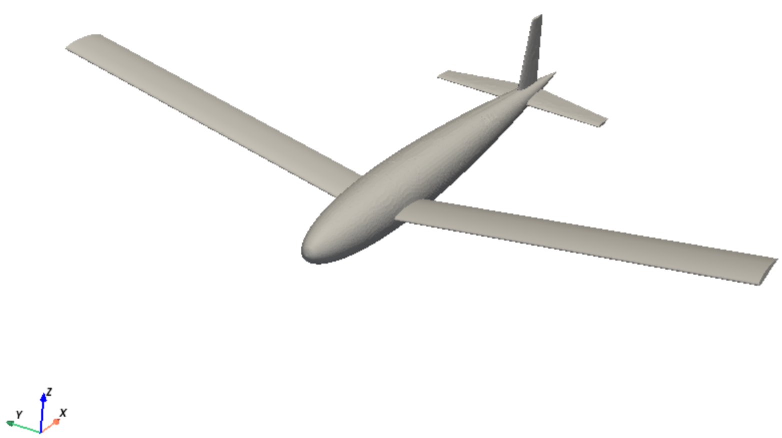


Figure 1: Basic aircraft designed in python

There has also been an entire IC engine which can be seen in the Blender chapter.

1.2 Thermodynamic analysis

Comprehending the intricacies of the engine is paramount in the aircraft design process. Python, as it happens, incorporates a substantial repository of thermodynamic data, proving to be a valuable asset in this aspect of the design journey. This built-in wealth of information within Python significantly aids in unraveling the complexities associated with engine dynamics, contributing essential insights to inform and refine the overall aircraft design.

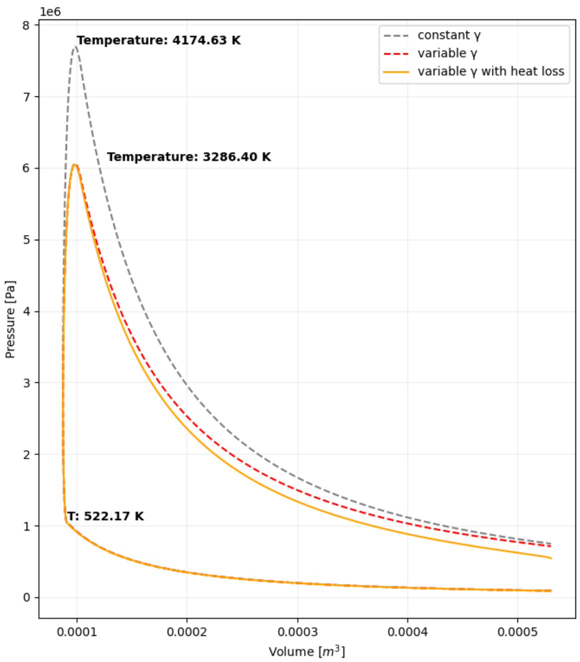


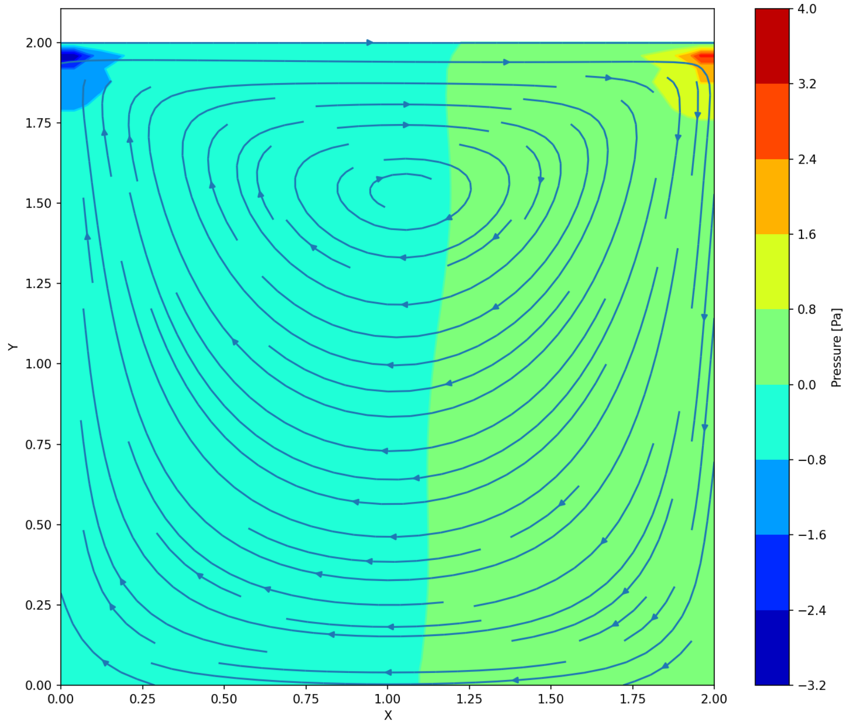
Figure 2: IC engine analysis

1.3 CFD with python

Recognizing the pivotal role of airflow in aircraft design, I dedicated considerable effort to simulating fluid movement. My exploration led me to delve into Lorena Barba's 12 steps to Navier-Stokes, providing me with a comprehensive understanding of the finite difference method.

Adopting the finite difference method involves breaking down the domain into discrete points and subsequently applying discretization schemes between these neighboring points. This systematic approach allows for a nuanced examination of fluid dynamics, unraveling the intricacies of airflow around the aircraft.

The insights gleaned from this methodology serve as a cornerstone in refining the design process, ensuring a more informed and scientifically grounded approach to addressing the challenges posed by fluid dynamics in aircraft engineering.



Cavity | Circle | Airfoil

I ran some simulations that gets fairly close to reality, although it lacks a turbulence model.
To view the simulations click the three buttons above.

1.4 Simulation model

Prior to taking flight, comprehending the behavior of an aircraft is crucial, with particular emphasis on ensuring stability. The potential dangers associated with an unstable design underscore the importance of rigorous testing before actual flight operations.
In pursuit of a suitable test model, I adopted a 6-degree-of-freedom (6-DOF) simulation model. This model, rooted in the RCAM (Research Civil Aircraft model), provided a robust framework for evaluating the aircraft's dynamic response in various flight conditions. By leveraging this simulation model, I could systematically assess and refine the design, enhancing the safety and predictability of the aircraft's performance before it takes to the skies.

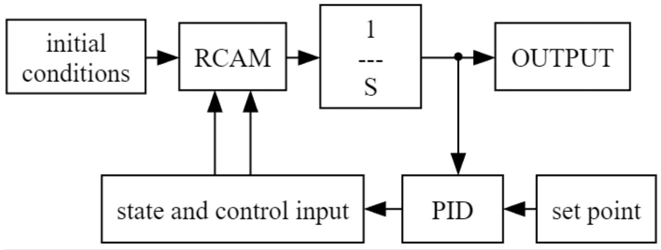


Figure 3: Block diagram of simulation model

I am currently trying to design an autopilot that can control the RCAM aircraft. For the time being I have control over the pitch of the aircraft.

1.5 Running the simulation

WIth the RCAM model formulated I ran a simulation with some simple demands to aircraft.
Maintain the wings level, which mean roll = 0
Have the nose, at pitch = 5, then aim for pitch = 10, then aim for pitch = 0.

Basically, keep the aircraft level, raise the nose and then lower it.

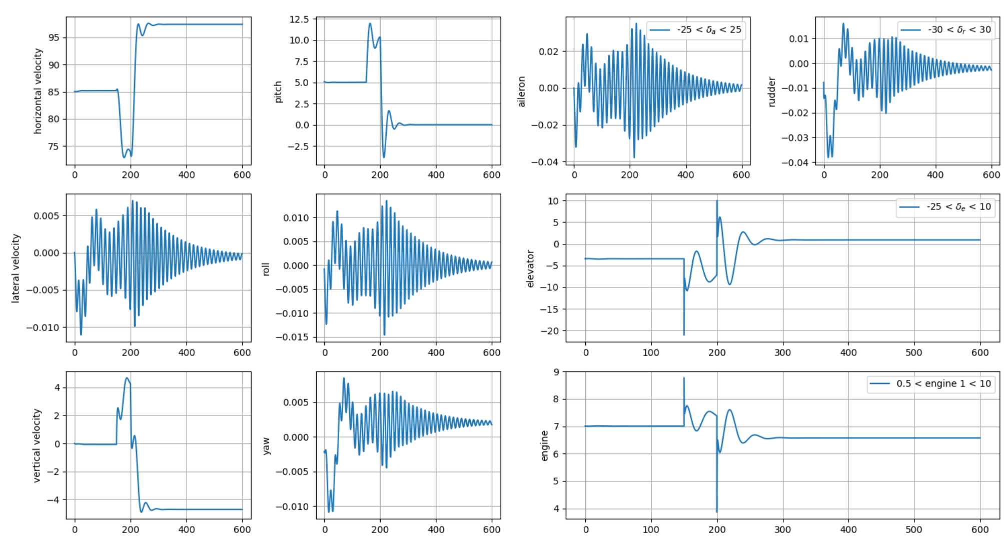


Figure 4: state vector to the left, control inputs to the right

The results of the simulation does indicate quite a good control over the pitch, but there seems to be a fair amount of noise on the roll and yaw. This will have to be worked.

1.6 Post analysis

Given the extensive data generated from simulations, deciphering meaningful insights can be a daunting task. To address this challenge, I opted to create a replica of an aircraft's instrument panel. This strategic decision has significantly enhanced the interpretability of the data, consolidating the myriad metrics onto a single display.
The instrument panel replica not only simplifies the process of data analysis but also provides a more intuitive and comprehensive overview of the aircraft's performance. By centralizing key information on a singular display, it streamlines the task of monitoring and understanding the simulation data, offering a more efficient and user-friendly approach to extracting valuable insights from the complex array of generated information.

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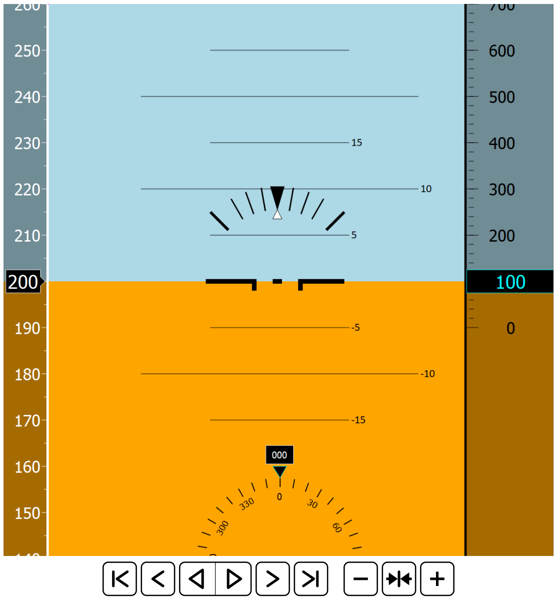

This animation only shows a test case, but it will be integrated into the simulation later on.

2 OpenFOAM

OpenFOAM, an acronym for Open Field Operation And Manipulation, is a versatile suite featuring an array of valuable numerical solvers. Among these, the Computational Fluid Dynamics (CFD) program has particularly captured my attention. This program serves as a potent tool for simulating and analyzing fluid dynamics in complex systems.

My intention is to leverage OpenFOAM as a means to comprehensively analyze a finalized aircraft design. The CFD capabilities offered by OpenFOAM enable a detailed examination of how air flows around and interacts with the aircraft structure. This analytical approach is pivotal in refining and optimizing the aerodynamic performance of the aircraft, ensuring that the design meets stringent criteria for stability, efficiency, and safety. OpenFOAM's robust numerical solvers provide a sophisticated framework for gaining deeper insights into the fluid dynamics of the aircraft, contributing to the overall refinement of the design.

2.1 Wing analysis

Here is an example of a wing section moving through the air.

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2.2 Combustion

Combustion plays a major part in many thermodynamic engine. Combustion is a very difficult process to describe in simulations, but OpenFOAM is able to do this.

2.2.1 Constant volume

In the simulation a gas is ignited from a high energy source, which originates from the circle in the top middle.
The hope is that I can use this to gain insight into the combustion of an internal combustion engine.

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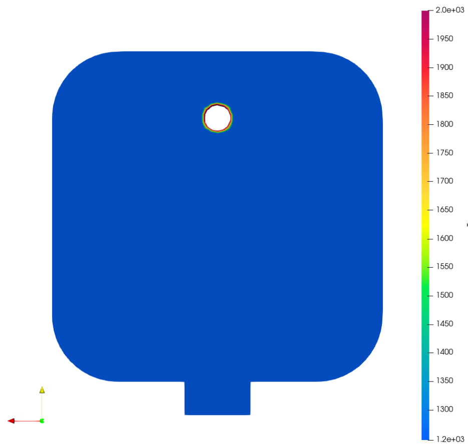

2.2.2 Constant pressure

With systems such as an gas turbine the flow is constant through the combustion chamber. The simulation below is the the early results of simulating an combustion chamber.

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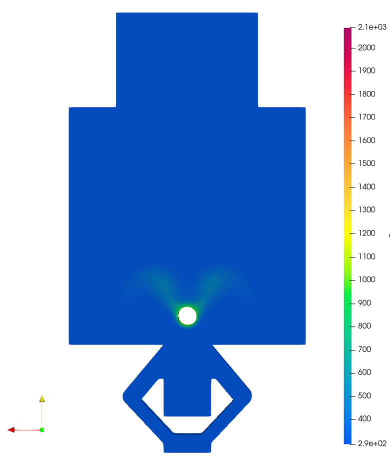


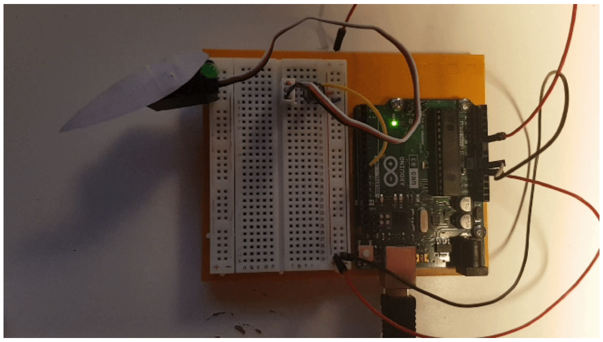
3 Arduino

Before flying the the actual aircraft, I want to make sure the design and simulation in fact is correct.

To test the design I am planning to build a smaller scaled model of the design that can be controlled remotely. I plan on using Arduino to design a control system.

3.1 Servo

Here is the concept of a servo that is going to manage the flight controls. .



3.2 IMU

In the animation below the inertial measurement unit has been programmed to be able to read pitch and roll. Based on the output of the IMU, the servos will act accordingly.

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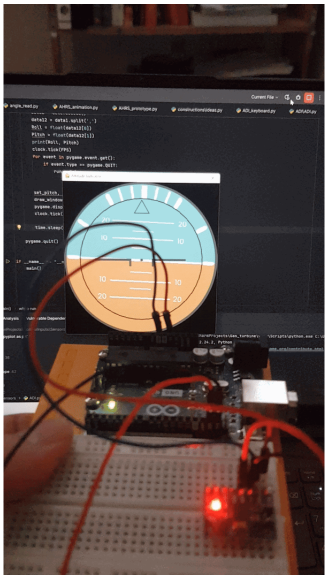

4 Blender

I wanted something that could make beautiful rendering and animation, which is very possible to do within the program called Blender.

4.1 Organic design approach

To learn Blender I followed a tutorial which instructed me in designing the ornithopter from the movie Dune.

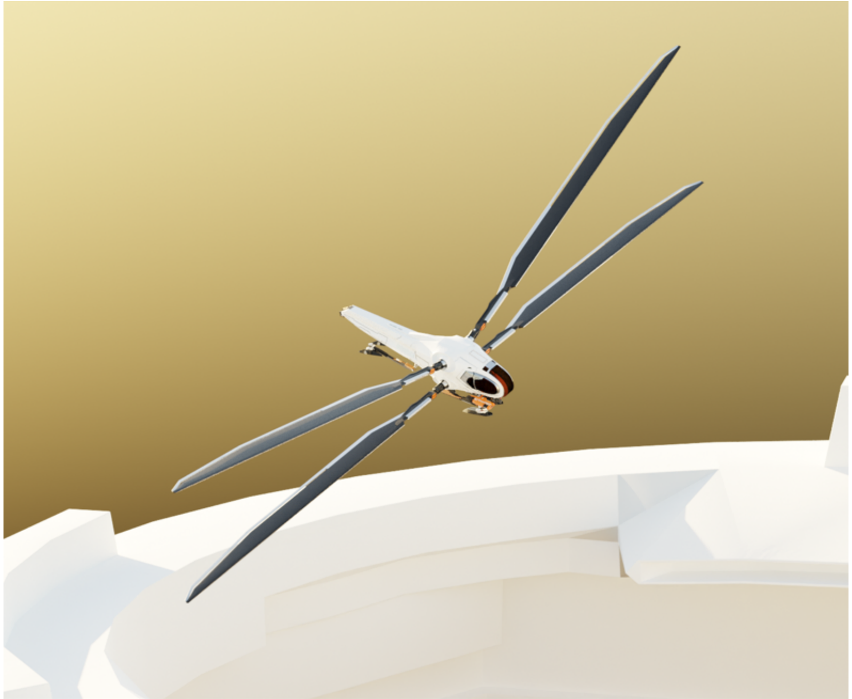

Figure 5: Complex geometry

Blender is a direct modelling software. This design allows for an incredible freedom and can make far more complex geometries.

4.2 Animation design

It is even possible to use the files made by python in Blender.
in the animation below the components are made by python but assembled in Blender. These components have then been rigged to follow an animation design.

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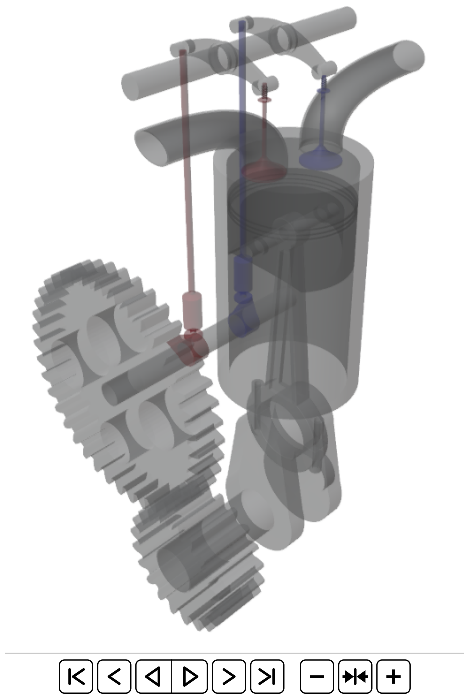

5 3D files

Capturing all the nuances of a design in a single image can be challenging. However, employing a 3D file facilitates a more comprehensive understanding, allowing the object to be rotated and observed from various angles. This dynamic approach provides a more immersive and detailed exploration of the design.
For instance, an example is showcased below, where Adobe Reader is utilized to navigate the 3D model. Granting permission to the document enables the user to interact with the design, rotating it to gain insights from different perspectives. This interactive feature enhances the visualization of the object, offering a more holistic and insightful experience in comprehending the intricacies of the design.

Figure 6: A propeller blade of a piper 28

6 Udemy

To gain the skills required for this project I had to take some extra courses outside of DTU. This courses was taken on the website: udemy

Certificate no: UC-1f95d58a-4036-4fa4-9c48-d8c646c2393d
Certificate url: ude.my/UC-1f95d58a-4036-4fa4-9c48-d8c646c2393d
Reference Number: 0004

CERTIFICATE OF COMPLETION

BLENDER: Creating the Dune Ornithopter from start to finish

Instructors **Mrawan Hussain**

Tobias Jacobsen

Date **March 17, 2023**
Length **49.5 total hours**

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