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A Fixed-wing UAV Capable of Vertical Take-off and Landing for Aerial Mapping and Photogrammetry.

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Este relatório foi julgado no contexto da disciplina

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Curso de Engenharia de Controle e Automação

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Prof. Ubirajara Franco Moreno

Orientador

Fly, you fools!

<div style="text-align: right">

J. R. R. Tolkien

</div>

Abstract

This work proposes the usage of a VTOL (Vertical Take-Off and Landing) fixed wing aircraft for aerial photograpy and mapping. It entails the gathering of requisites, design, protyping, and testing of the proposed UAV.

Palavras-chave: otimização sem derivada, poços de petróleo, simulação, sintonia automática .

Abstract

Aerial mapping is one task that got revolutionized by the arrival of drones on the latest years. The manual job of taking pictures, printing and assembling them together was changed into putting coordinates into a software, and the pictures into another after the flight.

Depending of the task at hand, the operator can chose a multicopter for smaller areas, or a fixed-wing aircraft for larger ones. Both categories have their quirks: While multirotors are precise and can take-off/land virtually anywhere, their autonomy suffers as they generate all their lift by using propellers, Fixed-wing aircrafts, on the other hand, can cover large areas quickly with a smaller power consumption, but are harder to position, and require larger areas for take-off an landing.

This work prososed an aircraft in between these two worlds. The prototype designed is a tail-sitting fixed-wing aircraft, able to take-off as a multicopter and transition into fixed-wing mode for more efficiency, enabling it to cover larger areas while needing a small area for take-off or landing and no additional apparatus for take-off.

results!

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1 Introduction

1.1 Motivation

Technology and auomation have been changing and improving a lot of tasks on last few decades. One of the tasks is aerial mapping, which started with balloons, then manned airplanes, and now, for smaller areas, is done mostly with drones

citation needed, improvent needed

1.2 Objectives

The final objective of the work is to have a working prototype of a VTOL fixed-wing UAV able to autonomously take off vertically, transition into fixed-wing mode, follow a planned path taking pictures, transition into hover mode, and land autonomously. It's planned to have a smaller prototype to test and tune the hover mode before testing the larger, heavier and more powerful final prototype, for safety and practicity reasons. The possible on-board electronics will be briefly described and one of them chosen. An overview will be given of the control systems in place and their tuning. The requisites for the job will be gathered, and the eletro-mechanical structure designed and built around it. It's expected that the prototype fulfills the hole between rotating-wing and fixed-wing aircraft by being able to land in tight spaces, but having a perfomance close to that of fixed-wing aircrafts.

1.3 Structure

This report is structured in 5 chapters. Chapter 1 gives an introduction to the report. Chapter 2 describes the fields of aerial mapping and photogrammetry. Chapter 3 explains the requisites imposed on the aircraft. Chapter 4 delves into the flight mechanics and the UAV's mechanical design. Chapter 5 shows the electronics involved. Chapter 6 shows the control structure and it's tuning.

2 Aerial Mapping and Photogrametry

2.1 The need for mapping the land

The first known map (actually a painting of a city) dates up to the 7th millenium BCE,[1], while the oldest surviving world maps are from 9th centursy BCE Babylonia[2].

In the past, maps were used mostly for localization and navigation [citation needed], and were made without special tools, mainly by sight. During the Age of Exploration, new tools such as the sextant and magnetic compass helped improve accuracy, while remaining as a navigational tool.

On the last centuries, maps began being used to precisely map properties, natural landscapes, and cities. Mapping properties, for example, requires high dimensional accuracy, hard to get with regular tools. This is usually the job of land surveyors, professionals who use a multitude of tools, such as total stations, robotic total stations, GPS receivers, retroreflectors, 3D scanners, radios, handheld tablets, digital levels, subsurface locators, drones, GIS, and surveying software.

2.2 Aerial Mapping

Aerial mapping consists of using photographs taken from the air, usually with the camera facing straight downwards, correcting the perspective transformation, and assembling them into an orthomosaic, as seen on Figure 1.

2.3 Aerophotogrammetry

Aerophotogrammetry takes the job on step further. By knowing the cameras lens intrinsics, software are capable of matching a number of pictures, detecting features on the environment, and locating the point used to take each of the pictures. With this information, it's possible to rebuild in 3D most of the environments, enabling the operator to interact with the area as a 3D mesh. By using precise GPS information(such as RTK/PPK data, or total stations) or known landmarks, it's possible to accurately measure distances, areas, volumes, angles and elevations, simplifying the surveyors' job.

Aerophotogrametry can also rebuild in 3D buildings and other structures,

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[1] Stephanie Meece (2006). "A bird's eye view of a leopard's spots. The Çatalhöyük 'map' and the development of cartographic representation in prehistory". Anatolian Studies. 56: 116. JSTOR 20065543.

[2]   Kurt A. Raaflaub; Richard J. A. Talbert (2009). Geography and Ethnography: Perceptions of the World in Pre-Modern Societies. John Wiley & Sons. p. 147. ISBN 1-4051-9146-5.

Figure 1 – Orthomosaic. source: Indonesian Redcross/OpenAerialMap

3 The Requisites

3.1 Objective

The final objective of the work is to have a working prototype of a VTOL fixed-wing UAV able to autonomously take off vertically, transition into fixed-wing mode, follow a planned path taking pictures, transition into hover mode, and land autonomously. It's expected that the prototype fulfills the hole between rotating-wing and fixed-wing aircraft by being able to land in tight spaces, but having a perfomance close to that of fixed-wing aircrafts.

3.2 Requisites

For the design, a few conditions have been imposed by the available material and desired performance:

- The flight time should be between 1 and 2 hours.

- The cruise speed must be around $15m/s$.

- The batteries used will be 6s lithium-polymer packs of XXXXX mAh. capacida

- The motors should preferably be the ones already in use at the company, MK3538, Mk3638, or MK3644

- The UAV must be able to take of and land autonomously.

3.3 Functional Requisites

4 Flight Mechanics and Design

4.1 Brief Introduction to Flight Mechanics

Flight mechanics deal with a vehicles interaction with propulsional, aerodynamic, and gravitational forces.

In order to achieve proper flight, a vehicle needs an upwards force, and means of maneuverability.

4.2 Fixed-Wing Mechanics

In fixed-wing aircrafts, the force responsible for cancelling the gravitational pull and keeping the vehicle aloft is the lift generated in the wings.

In a simplified explanation, two main principles are responsible for generating lift:

4.2.1 Flow deflection and Newton's laws

Most wings have an angle of attack (to be hereafter called α) such that $\alpha > 0$, which means the air passin through it gets deflected down. According to Newton's second law, an opposite force is necessary on the wing. This force is the generated lift.

4.2.2 Increased flow speed and Bernoulli's principle

Bernoulli's principle states that within a steady airflow of constant energy, when the air flows through a region of lower pressure it speeds up and vice versa. Implying there is a direct mathematical relationship between the pressure and the speed, meaning if one knows the speed at all points within the airflow, on can calculate the pressure and vice versa. For a cambered airfoil (where the chord at the top is longer that the chord at the bottom) the/home/will/Pictures/Screenshot from 2017-11-13 11-03-27.png air needs to take a longer path, moving faster, thus lowering the pressure on the top, and generating lift.

4.2.3 Airfoil Shape

How much lift is generated depends on the chosen airfoil. An cambered airfoil (longer chord on the upper surface than in the lower one) generated lift even when the angle of attack α is zero. Simmetric airfoils need a positive angle, and the lift is generated by deflecting the air downwards. Other properties that depend on the airfoil shape are
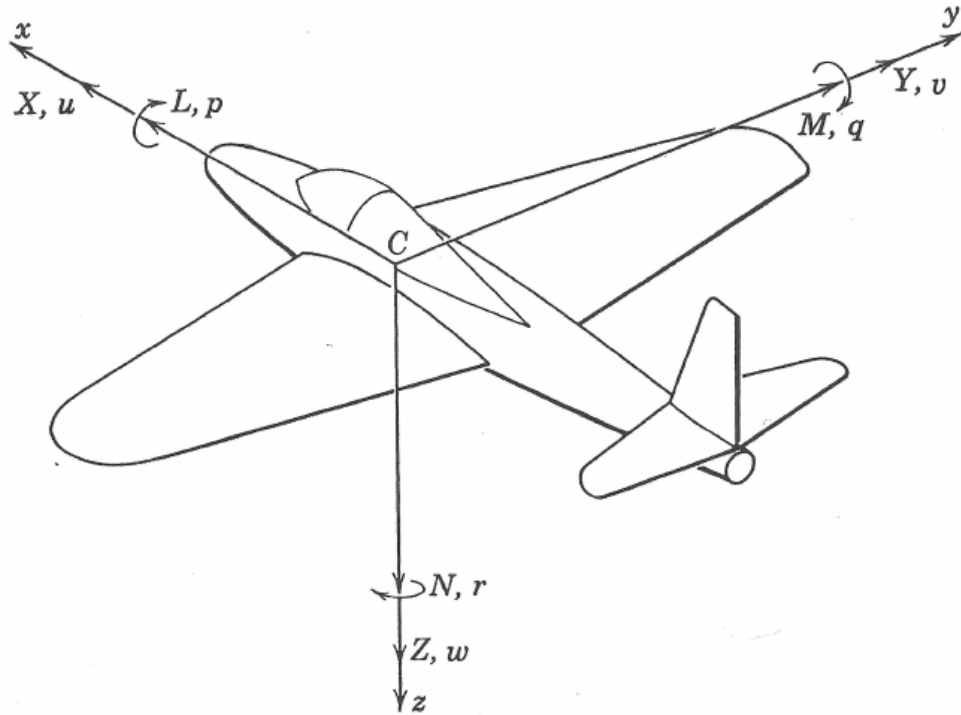
Figure 2 – Coordinates system and relevant variables.

the drag (air force pushing agains the direction of movement) and angular moment it generates on the aircraft.

4.2.4   The Coordinate System and Nomenclature

The coordinate system, when dealing with the fixed-wing mode, is as shown in figure 2

Where:

- x, y, and z are the coordinates, with the origin in the vehicle's center of mass.

- u, v, and w are the linear velocities in each of the x, y, and z coordinates, respectively.

- X, Y, and Z are the components of the aerodynamic force in each of the x, y, and z coordinates, respectively.

- p, q, and r are the linear velocities in each of the x, y, and z coordinates, respectively.

- u, v, and w are the linear velocities in each of the x, y, and z coordinates, respectively.

- Although not indicated in the figure, the variables ϕ, θ, ψ represent the angular rotations, relative to the equilibrium state, about the x, y, and z axes, respectively. Thus, $p = \dot{\phi}$, $q = \dot{theta}$ and $r = \dot{\psi}$ where the dots represent time derivatives.

  ϕ, θ, and ψ can also be referred, respectively, as *yaw*, *pitch*, and *roll*.

4.3 VTOL Mechanics

4.4 XFLR5

4.5 Design

5 The Eletronics

5.1 Propulsion

5.2 Batteries

5.3 The Control Surfaces

5.4 The Flight Controller

6 The Control Structure

7 Conclusions