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Kolibri: Design of a Camera Stabilization inside a CubeSat

BACHELOR'S THESIS
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Abstract

This bachelor's thesis aims to stabilize a camera's movement on the vertical axis using a servo motor. The camera and its stabilization parts will be encased in a cubic structure and fly as part of the payload in the competition rocket HALCYON. After the nosecone with its payload is ejected and the parachute is released, the camera will record the rocket's descent out of the rotating nosecone. An inertial measurement unit records the nosecone's rotational movement and processes it in a microcontroller unit, which then sends control signals to a brushless DC motor to counteract the nosecone's spin, allowing the camera to record a clearer image. Designed and built by the Aerospace Team Graz, the rocket HALCYON launched in October 2023 at the European Rocketry Challenge in Portugal.

Kurzfassung

Ziel dieser Bachelorarbeit ist es, die Bewegung einer Kamera auf der vertikalen Achse mit Hilfe eines Servomotors zu stabilisieren. Die Kamera und ihre Stabilisierungsteile werden in einer kubischen Struktur untergebracht und fliegen als Teil der Nutzlast in der Wettbewerbsrakete HALCYON. Nachdem die Raketenspitze mit der Nutzlast abgeworfen und der Fallschirm ausgelöst wurde, zeichnet die Kamera den Abstieg der Rakete aus der rotierenden Raketenspitze auf. Eine Trägheitsmesseinheit zeichnet die Rotationsbewegung der Raketenspitze auf und verarbeitet sie in einer Mikrocontroller-Einheit, die dann Steuersignale an einen bürstenlosen Gleichstrommotor sendet, um der Drehung des Nasenkonus entgegenzuwirken, so dass die Kamera ein klareres Bild aufnehmen kann. Die vom Aerospace Team Graz entworfene und gebaute Rakete HALCYON ist im Oktober 2023 bei der European Rocketry Challenge in Portugal gestartet.

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CHAPTER 1

Introduction

This thesis is split into several chapters that will discuss different aspects of the project. We start with an introduction, in which we state the motivation and the goals. Afterward, we will continue in Chapter 2, where we review the scientific work relevant to this thesis. The main part will be the system design in Chapter 3, where we talk about the individual design decisions. The proof of concept in Chapter 4 will evaluate the design decisions taken, and the conclusion in Chapter 5 will compare the goals set in the introduction with the achieved results.
This chapter will introduce the thesis with the initial motivation in Section 1.1, follow up with the goal in Section 1.2, and conclude with the thesis structure in Section 1.3.

1.1 Motivation

The concept for this project emerged from a post-analysis discussion of the pitfalls encountered during the 2022 European Rocketry Challenge (EuRoC). During this discussion with the at that time Head of the Flight Computer team of the Aerospace Team Graz (ASTG)[1], we identified a critical issue: following an unsuccessful rocket recovery, only one onboard camera's video data survived the crash landing from a 3-kilometer free fall. This camera, located inside the nosecone, was subject to uncontrollable reciprocating rotation while suspended from the parachute. As a result, the camera's rolling shutter effect produced excessively blurry images, rendering the footage unusable for post-flight analysis.

Given that the camera was part of the bottommost CubeSat, we conceived the idea of stabilizing either the camera or the nosecone itself within a CubeSat to produce clear, high-quality video footage. This footage would be invaluable for accurate post-flight analysis.

The detailed "how" and "why" of this stabilization mechanism will be thoroughly explored in the subsequent chapters.

[1] https://astg.at/

1.2 Goal

The primary goal of this thesis is to demonstrate the development of a one-axis camera stabilization mechanism, integrating various engineering disciplines into the project. Key objectives include:

- Battery Management: Ensuring efficient and reliable power supply for the whole system.
- Microcontroller Programming: Developing robust firmware to process sensor data and control the stabilization mechanism.
- PCB Design: Creating compact and efficient printed circuit boards to support the electronic components.
- Motor Controller Configuration: Implementing and fine-tuning the Field Oriented Control (FOC) for the Brushless Direct Current Motor (BLDC) motor to achieve precise stabilization.
- Sensor Fusion: Integrating data from the Inertial Measurement Unit (IMU) to accurately counteract the nosecone's rotational movement.
- Power Supply for the Camera: Providing a stable and sufficient power source to ensure continuous camera operation.
- Low-Cost Manufacturing: Designing the system with cost-effective materials and methods to minimize production expenses.
- Fully Independent System: Developing a self-sufficient unit capable of operating autonomously during the rocket's flight.

The project also aims to address the challenges posed by the strict size requirements, ensuring that all components fit within the confined space of the CubeSat while maintaining functionality and performance.

1.3 Thesis Structure and Organization

This thesis is organized into several chapters, each addressing different aspects of the research.

Chapter 2 reviews the related work relevant to this study.

Chapter 3 provides a detailed explanation of the system design, divided into three sections: mechanical, electronic, and software. Each section discusses the design decisions made.

Chapter 4 presents the proof of concept, demonstrating the viability of the proposed system.

Chapter 5 concludes the thesis with a summary of the findings and suggestions for future work.