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Design of the autonomous micro helicopter muFly

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ABSTRACT

In this paper, the design of two prototypes of the autonomous micro helicopter muFly is introduced. These prototypes have been built and flown in untethered test flights. The rotor configuration and steering principle selection of the prototypes are discussed according to the specifications, and the selection of a coaxial configuration with a swash plate steering of the lower rotor is justified based on dynamic simulation results. The two prototype designs are shown and discussed with special attention paid to their respective system integration issues, which are solved. Finally, the prototypes are compared and conclusions for future designs of autonomous micro helicopters are drawn.

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1. Introduction

Nowadays, Unmanned Aerial Vehicles (UAV) and Micro Aerial Vehicles (MAV) are subject to a growing interest from researchers, but also as actual products, mainly in the defense sector. While autonomy, which in our case is considered to be automatic attitude and position control, has been reached for outdoor UAVs with large payload margins, it is still a challenging problem for small indoor MAVs, which are intended to operate in GPS-denied environments. The small payload margins, and the need for a small and lightweight, yet useful position sensor are in fact among the largest problems in MAV design.

In order to solve some of these problems, the European framework project muFly started in 2006. Its goal is to design and build an autonomous indoor helicopter MAV that is comparable to a small bird in size and mass, i.e. a rotor diameter of less than 20 cm and a take-off mass of less than 100 g. Possible fields of application for such systems could be surveillance of buildings or large indoor areas (airports, train stations, exhibition halls), the search phase of search and rescue missions in partially collapsed buildings, plant surveillance and inspection, exploration and mapping of mines and caves, as well as police and military operations in urban terrain.

Among other challenges, like low Reynold's number aerodynamics, or implementation of effective navigation and control algorithms, the actual prototype design and especially the integration of all the sensors and computing power without violating the mass constraint pose a serious problem.

In this paper, we want to illustrate the solution to this problem in several ways: first of all, the rotor configuration and the steering principle, which are the two most important properties of the helicopter itself, are selected based on quantitative dynamic simulation results from an existing model [1,2]. Then, the two prototypes, which have been designed, built, and tested in untethered flight, are introduced. While the first one follows a design paradigm of highest possible modularity at the cost of a high total mass, the second prototype is designed in a highly integrated manner, in order to reduce its mass and allow for a full sensor set to be integrated. This second paradigm however, comes at the cost of a loss of modularity. Finally, the two prototypes are compared, and the largest potential in terms of mass saving is identified.

For work in other fields of the same project, we refer to the following publications: [1,2] present a complete and modular simulation model for different steering principles derived from first principles. Ref. [3] shows flight test data and an identification model suitable for model based controller design, while in [4] the model based controller for muFly and several approaches to modeling of the low Reynold's number coaxial rotor system are shown.

The paper is organized as follows: after a review of the state of the art in Section 2, the rotor configuration for the muFly helicopter is selected based on simulation results in Section 3. Also based on quantitative evaluation by simulation, the steering principle is chosen in Section 4. After these theoretical considerations, two muFly prototype designs are introduced and discussed in Section 5. Finally, the paper is concluded in Section 6.

2. State of the art

There are several works in the robotics domain that report on actual prototype building and which handle component integration and sizing challenges. In [5], the integration of a center of

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