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System integration of a miniature rotorcraft for aerial tele-operation research

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ABSTRACT

This paper describes the development and integration of the systems required for research into human interaction with a tele-operated miniature rotorcraft. Because of the focus on vehicles capable of operating indoors, the size of the vehicle was limited to 35 cm, and therefore the hardware had to be carefully chosen to meet the ensuing size and weight constraints, while providing sufficient flight endurance. The components described in this work include the flight hardware, electronics, sensors, and software necessary to conduct tele-operation experiments. The integration tasks fall into three main areas. First, the paper discusses the choice of rotorcraft platform best suited for indoor operation addressing the issues of size, payload capabilities, and power consumption. The second task was to determine what electronics and sensing could be integrated into a rotorcraft with significant payload limitations. Finally, the third task involved characterizing the various components both individually and as a complete system. The paper concludes with an overview of ongoing tele-operation research performed with the embedded rotorcraft platform.

1. Introduction

Compared to other UAV scenarios, indoor or highly confined operation sets stringent physical limitations. To operate indoors the vehicle must be small, maneuverable, and able to perform high-precision slow and stationary flight. To fulfill all these requirements and allow safe operation in the proximity of humans, miniature helicopters must be under 35 cm in diameter and weigh less than 300 g. In spite of their miniature size, vehicles of this scale inherit all the capabilities of full-sized helicopters enabling them to operate in environments that are difficult or impossible for other types of vehicles (like ground robots or fixed-wing aircraft). Examples of tasks that are well suited for this type of system include persistent surveillance, search and rescue, and exploration of complex 3D environments. With the appropriate tele-operation systems in place, miniature rotorcraft can operate in remote environments without risking the life of a pilot while still allowing human decision making. Miniature aerial vehicles like helicopters present unique challenges. These result from the types of operational environments and tasks that can be executed but also from the control challenges fundamental to rotorcraft flight, payload constraints and endurance limitations. A goal of the research described in this paper is to acquire a detailed understanding of the hardware and electronics, necessary software, operator interfaces and associated flight systems needed for operation of miniature rotorcraft platforms.

Indoor and confined operation scenarios require a combination of technologies that work in harmony both at the physical and algorithmic levels. The challenges in confined aerial tele-operations are mainly related to perceptual and guidance issues that arise when the UAV is free to translate and rotate in full 3-dimensional space under dynamic constraints. Successful tele-operation requires understanding how the human pilot maintains situation awareness and performs control actions for a given task. During tele-operation the visual information may be limited due to constraints on the camera field of view, therefore it is critical to understand the control and perception requirements for a task in order to build the type of augmentations that can help compensate for these limitations. Other challenges inherent to indoor operation include limited access to a Global Positioning System (GPS) and lack of information on the physical layout of the environment. To overcome these challenges the vehicle must carry a combination of sensors capable of perceiving the environment as well as its own motion. Finally, the delay in communication precludes the operator the use of high bandwidth feedback. Arriving at a functional system with robust performance requires a formal systems approach. The design and analysis has to encompass air frame dynamics, estimation, control, guidance and perceptual processes so as to exploit all information available from components and their interactions. This paper describes the platform that was developed to study the human interaction with the vehicle and environment.

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