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Development of an onboard system for flight data collection of a small-scale UAV helicopter

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ABSTRACT

This paper presents the development of an onboard system of a small-scale Unmanned Aerial Vehicle (UAV) helicopter. Both the hardware and software parts of the system have been developed. In the hardware part, several components are carefully selected or custom made for five separate systems including PC/104 computer system, sensor system, telemetry system, power system and bypass circuit system. The constructed hardware exhibits low weight, small size, anti-vibration, low power consumption, and easy interfacing. In the software part, the onboard software periodically manipulates the hardware components in a specified order. In every cycle, the system collects data from an Inertial Measurement Unit (IMU) and a Counter/Timer (C/T) card, and records them in a Compact Flash (CF) card as well as sends them to a ground station. The onboard system has been tested in actual flight, and the reliability and feasibility are evaluated. The results are plotted and analyses have shown that the collected data is sufficiently accurate for modeling the helicopter.

1. Introduction

Development of Unmanned Aerial Vehicle (UAV)s is an increasingly popular research in both academic and industrial fields. There is a wide range of applications performed by UAVs, such as traffic surveillance [1], reconnaissance [2], search and rescue [3], fire detection [4], cinematography, and exploration. Compared with fixed-wing UAVs, helicopters are capable of performing missions in high risk and demanding environments with exclusive capabilities including hovering, vertical takeoff and landing in limited launching spaces, and extremely agile maneuvering. With the growth of electronic technology, onboard avionics are shrinking in size and weight which decreases the payload of the helicopter. Thus, the development of a UAV with a small-scale low-cost helicopter becomes possible and has been investigated by a number of research institutes. For example, the robotics institute at Carnegie Mellon University (CMU) [5], the MIT UAV team [6,7], the University of Berkeley [8], Georgia Tech [9] and the Stanford University [10] have developed fully or partially autonomous helicopters over the past decade. More recently, National University of Singapore (NUS) UAV team has made great progress on designing small-scale UAV helicopters and reported a series of research results on both hardware and software designs [11,12]. To realize a reliable automatic control, the related work has been conducted with success in different stages of the UAV helicopter development, such as software design and integration [12,19,20], model identification [18,20–22], control law design and implementation [23–28].

During the 1990s, conventional control systems were adopted by most UAVs. The controllers were designed with the single-input–single-output (SISO) method and their parameters were tuned empirically. Whereas, the most recent UAVs are designed with multivariable controller synthesis approaches which require an accurate dynamics model of the helicopter. The bare airframe helicopter exhibits complex dynamics characteristics which makes the modelling difficult. For most useful analysis and control design tools, a well-designed controller depends on a sufficiently accurate model of the rotorcraft dynamics. Mettler et al. [13] introduced a system identification approach to precisely model and identify the system characteristics of a small-scale UAV helicopter. One of the most important steps in system identification process is to collect flight data during specific flight experiments. The practical flight test data is utilized to identify the mathematical model of UAV helicopters.

The objective of the current effort is to design an onboard system to collect enough flight data for obtaining high fidelity linear dynamic model with system identification technology and also to use the model as a basis for autonomous flight. Both the hardware and software parts are developed. The integrated hardware exhibits compact, light weight and low power consumption attributes. The software integrates high-level functionalities to schedule the I/O tasks and manipulate the onboard hardware in real time.

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