Accurate model identification of quadcopters with moments of inertia uncertainty and time delay

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Abstract. Development of a reliable high-performance quadcopter requires an accurate and practical model of the vehicle dynamics. Generally, the key physical parameters of an object with six degrees of freedom (6-DOF) are mass and moments of inertia, where mass is easily obtainable while it is difficult to identify moments of inertia considering that it is not always measurable by static tests. In this paper, a precise and fast system identification technique in the frequency domain is proposed, which is directly applicable to the control system design. This technique has been experimentally implemented to two quadcopters. Transfer functions are extracted and the moments of inertia are identified. The process has been firstly applied in a captive form to a quadcopter attached to the three degrees of freedom laboratory test stand. In addition, the tests are repeated for F450 quadcopter and the extracted dynamic models are verified. Moreover, delays of the rotors are also identified.

Introduction

With the increase of interest in Quadcopters, the necessity of establishing a precise and fast mathematical model has been risen in order to simulate dynamic behavior and estimate dynamic characteristics with the aid of computers, which lead to the cost and time reduction in the development of flight controllers [1]. Mathematical model of quadcopters can be derived in many ways one of which is the system identification or the art of extracting mathematical model from measured input and output data [2] which not only is used to establish the dynamic model equations but also is useful to determine the constant parameters in the equations [3] or to obtain the dynamic of the subsystem of quadcopter like its rotors [4]. With regard to controller design, however, it is necessary that the main parameters to be known especially the moment of inertia since it is not measurable through static tests[5]. However, analytical methods or CAD software can be used for geometrically simple objects which are impractical for quadcopters due to complexity in the equations and also the possibility of change from one mission to another due to payload requirements. Therefore, flight tests would be more convenient to obtain moments of inertia.

Results and discussion

Experimental tests for transfer function extraction of both quadcopters are presented. Single-input single-output (SISO) system identification is just implemented with regard to the cross control talk in control mechanism, which results in an intense control coupling because of gyroscopic effects. However, multi-input single-output (MISO) analysis can be neglected due to great difference between the main or on-axis input and other correlated off-axis inputs. The process of identification starts with the chirp signal known as a frequency sweep which consists of a sinusoidal function. In order to excite all different modes of the system, this signal starts at a low frequency and slowly increase to higher frequencies [6]. After performing experimental tests with different frequency sweeps for test cases, the adequate range of excitation is found. CIFER program is used to extract a bare airframe model using the motor speed as an input and orientation angle as an output with the control system in the loop due to marginal stability/instability of the system. Therefore, the extracted model was compared against flight test data in a maneuver not used in the process of system identification to examine the validity and accuracy. On the top of that, identified moment of inertia shows a comparing results with the outcomes acquired from the SolidWorks modeling. It is found that the proposed method is a precise, fast and simple in comparison with traditional modeling techniques. Here, the data acquisition rate plays a key role in the identification process and should not be less than 10 HZ for common quadcopters. It is notable that dynamics identification of quadcopters in frequency domain is immense because applying the periodic input is tough on these systems. Hence, identification of a captive quadcopter attached to the laboratory stand is a more attractive option.

References

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