Chapter 17
Robust and Intelligent Control Techniques for Twin Rotor System

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ABSTRACT
During recent decades, popularity of unmanned aerial vehicles has increased throughout academics, engineers, as well as students because of their wide range of application areas such as inspection, communication, and transportation. The twin rotor system represents the nonlinear and coupled dynamics of a helicopter to a certain extent. Therefore, it provides a good test bed for engineering students’ education on dynamics of aerial vehicles and control of mechatronic systems. In this study, sliding mode and fuzzy logic controllers are designed to control hovering motion of this highly nonlinear system. A robust sliding mode controller is preferred since it is insensitive to external disturbances, and intelligent fuzzy logic control is preferred since it is applicable to nonlinear systems where exact model of the system is not needed. Designed controllers, which are robust and intelligent, are then applied to the twin rotor system in real time. Then, experimental results are presented and discussed in terms of control performances of the designed controllers in detail.

INTRODUCTION
Twin rotor system which is usually called as twin rotor multiple-input multiple-output (MIMO) system (TRMS), is a laboratory experimental setup generally utilized to simulate and to control hovering motion of a reduced helicopter model. It possesses two degrees of freedom which correspond to pitch and yaw motions respectively. It is also well-known with its highly nonlinear cross coupled rotor dynamics. As a result of involved limitations of TRMS, it is a challenging system for modelling and implementation.

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of new control algorithms for academicians, researches and educators as well. In 2001, Ahmad et al. modelled a 2 DOF MIMO TRMS in hover by applying linear system identification techniques (Ahmad, Chipperfield, & Tokhi, 2001). A suitable modelling approach is concluded from their investigation for complex new-generation air vehicles. In 2004, (Aldebrez, Darus, & Tokhi, 2004) and (Darus, Aldebrez, & Tokhi, 2004) had proposed dynamic and parametric modelling of a twin rotor system using a multi-layer perceptron neuro-model and a genetic algorithm model respectively. Rahideh et al. utilized Newtonian and Lagrangian methods in order to model the TRMS in terms of vertical and horizontal 1DOF dynamics (Rahideh, Shaheed, & Huijberts, 2008). In another work, a complete dynamic model of the TRMS derived explicitly through application of the Euler–Lagrange approach that was contributed by Tastemirov et al. (Tastemirov, Lecchini-Visintini, & Morales-Viviescas, 2017). Most of above researches were done with commercially available setups. In 2015, Bayrak et al. published a paper on design and development of a TRMS in an academic setting (Bayrak, Dogan, Tatlicioglu, & Ozdemirel, 2015). This work demonstrated that the total cost of a TRMS could be lowered during the design stage compared to the commercial systems available in the market.

In general, TRMS models and experimental installations are used to evaluate and develop controller designs. There are many works published in the literature contributing to this purpose from classical to robust and intelligent techniques. Azarmi et al. proposed a simple analytical method for designing fractional order PID controller (Azarmi, Tavakoli-Kakhki, Sedigh, & Fatehi, 2015). The designed controller was implemented on a laboratory scale helicopter platform. Chemachema and Zeghlache utilized an output feedback linearization method in order to derive control laws without decoupling the TRMS into horizontal and vertical subsystems (Chemachema & Zeghlache, 2015). Choudhary proposed an H∞ optimal feedback controller for TRMS in the presence of cross-coupling effects with MATLAB simulation results (Choudhary, 2017). Witczak et al. presented a robust fault estimation approach for a class of nonlinear discrete-time systems with the application to a case study based on the TRMS (Witczak, Buciakowski, Puig, Rotondo, & Nejjari, 2016). As a nonlinear control strategy, Ilyas et al. considered sliding mode and backstepping controllers in order to achieve limitations of TRMS due to unstable, nonlinear and coupled dynamics with simulation results (Ilyas et al., 2016). In another work, Rashad et al. proposed a robust tracking controller for an experimental TRMS setup by combining a backstepping approach with a sliding mode disturbance observer to an integral sliding mode controller (Rashad, El-Badawy, & Aboudonia, 2017). Yang and Hsu designed an adaptive control approach based on the backstepping concept since the system parameters are assumed to be unavailable and are estimated on-line (Yang & Hsu, 2009). When the mathematical model and system parameters are not known exactly, fuzzy logic can be preferred to design an intelligent controller with expert knowledge related with the dynamics of the system. In (Taskin, 2014), (Hacioglu, 2015), and (Che Soh, Abdul Rahman, Md. Sarkan, & Yeo, 2013), numerical and experimental studies were published about fuzzy logic controller implementations to TRMS. Fuzzy logic is a powerful tool of which is applied to many fields not only as a controller approach but also as system analysis and synthesis approaches. In order to better and more understand the fuzzy systems and their applications, the following references can be taken into account (Burrascano, Callegari, Montisci, Ricci, & Versaci, 2015; Versaci et al., 2015b, 2015a, 2015c; Versaci, La Foresta, Morabito, & Angiulli, 2018; Versaci, Morabito, & Angiulli, 2017).

In this chapter, robust and intelligent control techniques that are implemented to a twin rotor system in real time are briefly described. The remainder of the chapter is arranged as follows. In next section, twin rotor model and experimental set-up are introduced. Design of sliding mode and fuzzy logic con-