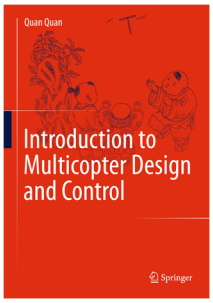

Introduction to Multicopter Design and Control

Q. Quan

Springer. 2017. xvii; 384pp. Illustrated. £79.99. ISBN 978-981-10-3381-0.

Miniaturisation of electronics and sensors, improved battery technologies and improvements in motor technologies have combined to create the recent explosion of interest in quadrotor air vehicles and multicoptors (or 'drones' in popular parlance). In particular, the very low cost and relative ease of making a quadcoptor almost from scratch has resulted in both hobbyists and university departments building and flying these vehicles. The fact that they can be flown indoors increases their attraction as a platform to test and evaluate many technologies, particularly in the control and vision processing domains.

For flight control engineers, this is a very welcome development because for manned platforms testing of a new control technology or algorithm requires certification. This is a prohibitive cost even for well-resourced laboratories that have access to manned aircraft. For unmanned aircraft, it foregoes the need for range flying, with the associated safety and regulation issues. The mechanical simplicity of quadrotor vehicles only adds to the attraction for hobbyists and control engineers. In addition, the recent pushes for autonomous vehicles and cyber-physical systems have only added to the appeal of these vehicles for university departments.

The book has sprung out of a course taught by the author at Beihang University as well as some of his research in the area. The introduction of problem-based learning and project-based learning into many undergraduate engineering courses has created a need for interdisciplinary problems that can be tackled by student groups. Multicoptor design and build provide an ideal such project. Hence, this text, aimed at undergraduates, is a timely addition to many reading lists.

The contents of the book appear to be driven partly by the research output of the author and partly by the nature of the technology. The book starts with an introduction that explains the basic principles of the operation of multicoptor aircraft and the author's view of their development phases. The subsection on performance evaluation and the 'bottlenecks' are particularly insightful. The book is divided into five subsequent Parts, each Part consisting of several chapters.

Part 1 is entitled Design'. Chapter 2 gives an overview of the various sub-systems and components of a small multicoptor, including the ground-station. Different configurations are discussed. Some of the available flight control computers are compared. Chapter 3 considers some of the configurations. Some simple analysis is introduced.

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There is a short section on the structural design. Chapter 4 'Modelling and Evaluation of Propulsion System' considers the performance of the propellers, motors, electronic speed controllers and battery. Thus, there is no dynamic modelling, as the purpose of the modelling should be for rotor sizing. Methods to calculate maximum climb acceleration, maximum horizontal speed and range are provided.

Part 2 is concerned with modelling, primarily the dynamics and kinematics of the aircraft; this being the foundation for the development of flight control and guidance. Chapter 5 considers rotations of rigid bodies. The standard aeronautics Euler angle rotations are described first. The rotation matrix is briefly described followed by a detailed description of the properties of quaternions. Chapter 6 derives the aircraft dynamics model in the three forms: Euler angles, rotation matrices and quaternions. The body velocity dynamics are extended later in the chapter to include some drag effects – but only in the x and y-directions. The control effectiveness matrix is derived and some actuator dynamics included. The last part gives some outlines of standard experiments to calculate the moments of inertia and centre of gravity. Finally, in a repeat of part of Chapter 4, a propulsion model experiment is described.

Part 3 'Perception' covers the sensing and estimation. Chapter 7 covers sensors and their calibration. The sensors described are mostly for small aircraft and are based on MEMS technologies. Basic principles are explained. Described sensors include three-axis accelerometers, gyroscopes and magnetometers, ultrasonic and laser range finders, barometers and GPS. There is also a brief section on cameras and vision. Chapter 8 contains an exposition on the concept of observability and its relevance to multirotor vehicles. There follows an explanation of the Kalman filter and the extended Kalman filter. These are developed without formal proofs, but with good and clear explanations and demonstrations of the concepts and how the algorithms work. Some examples support the exposition of the theory. Chapter 9 covers state estimation and data fusion. It covers some methods for attitude and position estimation. Then follows a section on SLAM (simultaneous localisation and mapping), optical flow and finally obstacle estimation.

Part 4 is dedicated to control. Chapter 10 commences with some fundamental theory on nonlinear stability. Then, follows a section devoted to a controllability analysis of multirotor vehicles subject to rotor failures; this is based largely on the author's research. Chapter 11 considers the control of the vehicle position and yaw via an inner-loop attitude controller combined with a control allocator. The outer-loop control is simple PID which is effective for most applications, whilst a variety of attitude methods are briefly explained. Standard pseudo-inverse control allocation is briefly explained. Much of this chapter is again based on the author's research. Chapter 12 looks at the problem of designing the outer loop controller for a system that already has inner loop attitude and velocity controls. PID control and linear dynamic inversion methods are described and simulation results presented.

The final section Part 5 is devoted to 'Decision'. This control level is often the distinction between 'automatic' and 'autonomous' control. Chapter 13 'Mission Decision-Making' gives an overview of mission and path planning, includes a path following method and details an obstacle

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avoidance method. Flight underground-pilot control is also described. Chapter 14 outlines some of the safety issues in drone operation and outlines how to conduct mode state modelling. The final chapter 'Outlook' gives the author's view on some of the potential future developments for multicoptor development.

The book is something of a curate's egg. It contains a great deal of very useful information for multicoptor developers and experimentalists. The book is admirably ambitious in the range of topics covered. However, this invariably means some aspects are sketchily covered. Some of the design aspects are not much more than high school level, whereas the chapters on dynamics and control are of a fairly advanced level suitable for graduate courses or a primer for researchers. Each chapter is supported by a set of exercises; some of these are vague and not clearly posed.

Unfortunately, the book suffers enormously from very poor editing and proof-reading by the publishers. The English is substandard in much of the book and there are a number of errors, many of which result from what seems to be poor translation from Chinese to English. For such a shoddy product to have come from a publisher with the history of Springer is very worrying. It is also a real disservice to the author, who with a firmer hand and guidance could have produced a teaching text of lasting value. Alas the opportunity has been missed.

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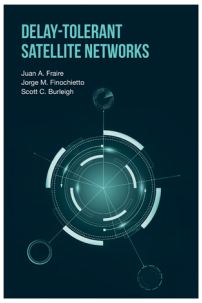

Delay-Tolerant Satellite Networks

J. A. Fraire *et al.*

Artech House, 16 Sussex Street, London, SW1V 4RW, UK. 2018, 249pp. Illustrated. £119 ISBN 978-1-63081-344-4.

Delay-Tolerant Satellite Networks addresses a significant and timely issue: will satellite systems allow us to move from a terrestrial world wide web with continuous connectivity to a space wide web with delay tolerant characteristics.

With the advent of mega-constellations, the potential exists for satellite networks that can transfer data in a far timelier fashion, as the book explains in the first few chapters. There is much information here on network theory, some of which seems a little pedantic, but the reader is left with a clear understanding of the challenges, from a communications perspective, of passing data through an intermittently connected network.

The predictability of satellite orbits means that it is possible to calculate a schedule of opportunities for data transfer and the text provides a comprehensive description of how

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