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## Preface

The flight is always the dream of mankind. The kite was invented in China, possibly as far back to the fifth century. Beginning with the last years of the 15th century, Leonardo da Vinci wrote about and sketched many designs for flying machines and mechanisms, including ornithopters, fixed-wing gliders, rotorcraft, and parachutes. On December 17, 1903, the Wright brothers invented and built the world's first successful airplane and made the first controlled, powered, and sustained heavier-than-air human flight. Since 1903, in the following one hundred years, many types of aircraft emerged. However, not too many people tried to pilot and enjoy their flying. Aircraft and pilots were still mysterious until small and micro multicopters were approaching consumers via the Radio Controlled (RC) toy market. This mainly due to the huge improvement on the user experience via their salient features: ease-of-use, high reliability, and easy maintainability. It hardly finds an aircraft as simple as multicopters. They do make more and more people really pilot and enjoy flying. Besides as an RC toy, multicopters demonstrate other commercial applications as drones, including surveillance, search, and rescue missions. So far, multicopters have taken and consolidated their dominance in the market of small aircraft. No matter defined as an RC toy or a drone, the multicopter is definitely an appropriate research target for students. This is because students have a chance to experience all phases from design to flight testing within a short time. One more reason is that students can read and interact with the open-source code of multicopters to understand the underline principle.

As an outcome of a course developed at Beihang University (Beijing University of Aeronautics and Astronautics, BUAA), this book is intended as a textbook or introductory guide for senior undergraduate and graduate students, and as a self-study book for practicing engineers involved in multicopters. With the intention of covering most design phases on hardware and algorithms of multicopters, it has fifteen chapters which is divided into five parts, including multicopter airframe and propulsion system design, modeling, perception, control, and decision. This book can also be used for a supplementary reading material for other unmanned flying systems. It aims to organize the design principles adopted in engineering practice into a discipline and to emphasize the power of fundamental concepts. This book is featured with four salient characteristics.

- (1) *Basic and practical.* The most contents related to multicopters are self-contained, aiming at making this book understandable to readers with the background of Electronic Engineering (EE). For such a purpose, the components are introduced starting from their functions and key parameters. The introduction to the design process starts with the principle, while the modeling section starts with the theoretical mechanics. The state estimation section starts with the measurement principle of sensors. Before talking about the control, the notions of stability and controllability are introduced. In addition, most of basic and practical methods are presented. These methods are closely related to open-source autopilots which are often used now.
- (2) *Comprehensive and systematic.* This book hopes to give a complete picture of multicopter systems rather than a single method or technique. Very often, the role of a single method or technique is not sufficient to meet the users requirements or to solve a practical complex problem. On the other hand, improving other related methods or techniques will reduce the difficulty in a single method. For example, the improvement of the state estimation performance or the mechanical structure can avoid dealing with delay or vibration as a control problem. Through this, some complex controller design can be avoided. For an undergraduate student, basic knowledge has been obtained, such as mathematics, aerodynamics, materials, structures, electronics, filtering, and control algorithms, which correspond to numerous courses. This book is hoped to combine them together to lay foundations for full stack developers.

The preparation and writing of this book have suffered me a lot. Fortunately, the Software and Control Lab, I stayed as a student (I have been staying here as a faculty since 2010), started to support the research on multicopters since about 2007. Ruifeng Zhang and I devoted ourselves to building quadcopters then. This made me almost witness the gold development period of small multicopters. Moreover, fortunately, public documents are shared selflessly by developer teams of open-source autopilots, such as APM and PX4, and numerous technique dissertations and papers are contributed by scholars all over the world. More importantly, this book could never have been written without the support and assistance from my students from BUAA Reliable Flight Control Group <http://rfly.buaa.edu.cn/>, which is a part of Software and Control Lab. Deep thanks go to graduate students Jinrui Ren, Zhiyao Zhao, Guang-Xun Du, Xunhua Dai, Zibo Wei, Heng Deng, Dongjie Shi, Yangguang Cai, Jiang Yan, Hongxin Dong, Jianing Fu, Zhenglong Guo, Jing Zhang, Yao Luo, Shuaiyong Zheng, Baihui Du and Xiaowei Zhang for material preparation, chapter revision, and simulations. I would like to thank my colleague Prof. Zhiyu Xi, graduate students Usman Arif and Hanna Tereshchenko, and undergraduate student Kun Xiao for their comments and hours of tireless proof reading. I would like to thank Prof. Wei Huo, Prof. Dawei Li at Beihang University, Mr. Yun Yu at DJI-Innovations,

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