

# Preface

The book addresses the coordinated motion control problem of a team of unmanned aerial vehicles (UAVs). The problem is particularly challenging due to the complex nonlinear dynamics governing this type of systems, which are often underactuated. As such, coordinated control schemes developed for linear multi-agent systems cannot be directly applied to this type of systems. This has motivated our research in this area in the past few years. In particular, we were interested in the attitude synchronization problem of multiple rigid-body systems and the formation control of a class of UAVs with vertical take-off and landing capabilities, referred to as VTOL UAVs for short.

The attitude synchronization problem is generally considered in deep space applications where replacing traditionally large and complex spacecraft with clusters of simpler micro-satellites was shown to present several advantages regarding mission performance and cost. In the majority of the current research relevant to spacecraft attitude synchronization, it is assumed that the state variables are available for feedback. Designing efficient controllers with a minimum number of measured state variables is a common theoretical challenge yet with important practical implications. It is of a great interest to design controllers that do not involve the measurements of some crucial variables that require complex, expensive, and/or prone-to-failure sensors. From this perspective, the design of attitude synchronization schemes without velocity measurements stands out as an important and challenging problem.

VTOL UAVs include several types of thrust propelled aircraft such as helicopters, quadrotor, and ducted fan vehicles. They constitute an important class of flying systems due to their ability to hover and maneuver in confined or restricted environments. This makes them suitable for a broad range of applications requiring stationary flights such as surveillance, search and rescue missions, and monuments/bridge inspection. The coordinated control of this class of underactuated mechanical systems is quite challenging, especially, when some state variables are not available for feedback.

Information exchange between aircraft involved in the formation plays an important role in achieving a successful motion coordination. This information exchange

is generally subject to delays that are inherent in communication systems. The effects of communication delays in linear multi-agent systems, with first and second order dynamics, have been discussed in many interesting research papers. The application of these results to the attitude synchronization of spacecraft is hampered by the complex nonlinear attitude dynamics of a rotating rigid body. In addition, the underactuated nature of VTOL UAVs introduces several control design difficulties. Moreover, in most of the research dealing with multi-agent systems, delayed communication is only considered in the full state information case. This was a motivating factor for the development of new approaches that handle communication delays in the case where only part of the system state variables are available for feedback.

Our objective in writing this research monograph is to summarize our recent developments related to coordinated control problems. Different control design approaches for the attitude synchronization problem are presented. The synchronization schemes require only attitude measurements and the neighbor-to-neighbor information exchange, which can be delayed. In addition, by integrating new control design techniques with some concepts from multi-agent systems, a new theoretical framework is developed for the motion coordination of VTOL UAVs.

The book is primarily intended to researchers and engineers from robotics, control engineering, and aerospace communities. It also serves as a complementary reading for graduate students pursuing research in these fields.

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Attitude Synchronisation and Formation Control

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