# Chapter 3
# Multimodal Human Aerobotic Interaction

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## ABSTRACT

*This chapter discusses HCI interfaces used in controlling aerial robotic systems (otherwise known as aerobots). The autonomy control level of aerobot is also discussed. However, due to the limitations of existing models, a novel classification model of autonomy, specifically designed for multirotor aerial robots, called the navigation control autonomy (nCA) model is also developed. Unlike the existing models such as the AFRL and ONR, this model is presented in tiers and has a two-dimensional pyramidal structure. This model is able to identify the control void existing beyond tier-one autonomy components modes and to map the upper and lower limits of control interfaces. Two solutions are suggested for dealing with the existing control void and the limitations of the RC joystick controller –the multimodal HHI-like interface and the unimodal BCI interface. In addition to these, some human factors based performance measurement is recommended, and the plans for further works presented.*

## INTRODUCTION

This chapter discusses the interfaces used in the control of small multirotor aerial robotic systems. In order to aid the discussion of these interfaces, a novel classification model for autonomy called the 'navigational control autonomy (nCA)' model, was presented and discussed intensively. This sets the background for discussing the RC joystick-controller control range and the control void existing beyond the tier-one nCA model. The limitations of the RC joystick controller were presented in the result section of this chapter. This chapter suggests two solutions that could address this control void revealed by the nCA model, as well overcome the limitation of the RC joystick controller. The first method suggests

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the development of an interface that emulates multimodal human-to-human communication methods to address higher-level interaction problems. The second method extends the first solution into a beyond normal human interaction of mind control via brain-computer interfaces. The limitations of these suggestions are also presented under the discussion section. It then concludes by suggesting some further research works resulting from this chapter's investigation.

This section briefly discusses the background of the unmanned aerial vehicle and introduces the term 'aerobot', which is used to refer to aerial robotic systems in this chapter's discussion. Some aerial robot applications are also presented in this section.

## BACKGROUND

A particular class of unmanned aerial vehicles (UAVs) gaining wide popularity with applications cutting across diverse fields, is the small unmanned multirotor aircraft system. The most common application of this system is cost-effective image or data acquisition from remote locations, high altitudes, hazardous environments, or positions that are difficult or more expensive for a human to reach. Another rising application is drone delivery of goods, medical, or military supplies. However, in this research, a particular application of interest for these small multirotor aircraft systems is in aerial robotics. This research focuses on control for these aerial robots. Control for delivery applications or data/image acquisition can be achieved via a combination of manual or automatic control. However, for aerial robotic application, some higher-level control methods may be required. This chapter explores a few relevant control concepts.

### Aerobot

The term aerobot was derived from the following two words 'AERial rOBOT', as a way of referring to small unmanned multi-rotor aircraft robotic systems (Abioye, Prior, Thomas, & Saddington, 2016). The term, as adopted in this chapter, is used to give these multi-rotor aircraft systems (often seen as toys) an elevated status of a proper robotic system. Some researchers who seem to share this position are Kim et al. (2016), Muscio et al. (2016), and Verma (2016). Kim et al. (2016) demonstrated the concept of a vision-guided flying robotic arm (aerial robotic manipulator). Muscio et al. (2016) developed a control model for aerial robotic manipulators. The authors particularly identified the industrial applications of these multi-rotor aircraft as Unmanned Aerial Vehicle-Manipulator (UAVM), when equipped with grippers or multi-joint robotic arm manipulator. Verma (2016) also presented the idea of a flying robotic projector system that can be used to convert any plain surface as a display screen. Clearly, these are multi-rotor UAV systems acting as robots. Therefore, aerobots can be considered as unmanned multi-rotor aircraft systems with actuators, able to perform tasks analogous to fixed industrial robot manipulators. They are robot manipulators with an innate ability to hover or fly.

The applications of aerial robots are vast. Aerobots are being creatively adopted in many practical application scenarios such as working in human hazardous or radioactive environment, aiding search and rescue missions, performing military ISR (intelligence, surveillance, and reconnaissance) missions, undertaking logistics and transportation (DHL and Amazon examples), conducting space exploration missions (potential Mars rover attached aerobot missions), and videography/photography. Some civilian applications of aerial robots have been presented in Table 1, although some of these applications may be limited by current technological constraints.

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