Towards Human-Robot Interaction in Flying Robots : A User Accompanying Model and A Sensing Interface

その他のタイトル	飛行ロボットにおける人間・ロボットインタラクションの実現に向けて : ユーザー同伴モデルとセンシングインターフェース
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論 文 の 内 容 の 要 旨

Abstract

論文題目　Towards Human-Robot Interaction in Flying Robots: A User Accompanying Model and A Sensing Interface (飛行ロボットにおける人間・ロボットインタラクションの実現に向けて: ユーザー同伴モデルとセンシングインターフェース)

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Flying robots are one of the most important inventions in robot history. Widely known as drones or unmanned aerial vehicles (UAVs), flying robots have a wide range of applications and bring major impacts to academia, commercial sectors, government, and society.

Over the past few decades, flying robot research has focused on autonomy, which includes sensing, control, localization, mapping, and planning, while paying less attention to the sociability of the flying robots. This dissertation proposes the idea of companion flying robots, which the flying robots accompany and interact with us in our daily lives. To realize this goal, we focus on three topics in this work. Focusing on both autonomy and sociability, this thesis proposes the concept of *companion* flying robots, where the flying robots are expected to accompany and interact with us in our daily lives. Among all the challenging tasks involved, we believe that achieving a safe, intuitive, natural, and social flying behavior is of vital importance for a *companion* flying robot. Having this priority in mind, we focus on three topics to realize the goal of *companion* flying robots: (i) a holonomic hexacopter for human-robot interaction (HRI), (ii) a general model for human accompanying, and (iii) a sensing interface for human understanding.

First, we design a new form of hexacopter that has several merits for HRI in companion flying robots. As opposed to a conventional flying robot, the proposed holonomic hexacopter is able to maintain attitude while flying horizontally; it does not need to tilt. As a result, the holonomic hexacopter provides intuitive flight motions from the user's point of view and achieves better flight stability from the control perspective. The holonomic hexacopter also provides a stable video feed for high level tasks such as human detection without the need of an additional heavy gimbal platform. Moreover, thanks to its six degree-of-freedom motion, the holonomic hexacopter can produce 3D force naturally in the air and achieves safer physical interaction with user without a complex dynamic model.

Second, we design a general model to unify various human accompanying behaviors of a *companion* flying robot. Human accompanying, including human approaching, following, leading, and side-by-side walking are important behaviors of a *companion* flying robot. Robots to-date focus on one or two human accompanying modes; there is no existing work to unify these modes for robots to achieve natural and rich interaction with humans. In this work, we propose a two-level model to achieve this goal. At the top level, we adopt a hierarchical finite state machine (FSM) to organize the behavior flow of a *companion* flying robot. The hierarchical FSM has the merits of simplicity and expandability, where the robot, environment, and human states can be incorporated into the model to achieve a rich HRI behavior with a person. At the bottom level, we use a relative positioning control method for robots to achieve smooth and natural accompanying motions. While the top-level hierarchical FSM alone can be viewed as a rule-based approach, together with the bottom level relative positioning controller, they form a powerful hybrid approach that is able to achieve natural and rich HRI behaviors with minimal computational load.

Finally, we design a human sensing interface for *companion* flying robots to have a better understanding of user. We study, implement, and improve several human sensing techniques, such as human detection, human body orientation estimation, hand detection, hand shape recognition, facial expression recognition, and face alignment. While we only focus on human detection with our companion flying robot in this work, we aim to integrate multiple human sensing techniques for a more advanced *companion* flying robot in the future.