FOLDAWAY DroneSense, a controller for haptic information encoding for drone pilots

Marco Salerno
Reconfigurable Robotics Laboratory
Swiss Federal Institute of Technology
Lausanne, Switzerland
marco.salerno@epfl.ch

Jamie Paik
Reconfigurable Robotics Laboratory
Swiss Federal Institute of Technology
Lausanne, Switzerland
jamie.paik@epfl.ch

Stefano Mintchev
Reconfigurable Robotics Laboratory
Swiss Federal Institute of Technology
Lausanne, Switzerland
stefano.mintchev@epfl.ch

ABSTRACT

Over the last decade, the number of drones has significantly increased. In parallel, researchers have started to investigate new human-drone interaction paradigms for a more natural and immersive piloting experience. The use of haptic feedback to establish a bidirectional interaction with a remote drone is a promising yet not fully exploited paradigm. In this article we introduce FOLDAWAY DroneSense, a portable controller with multi-directional force feedback for drone piloting. We also discuss four haptic interaction paradigms with the aim of boosting immersion and safety during teleoperation, and to simplify the training of first-time users.

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KEYWORDS

Human-machine interaction; Drones; Haptics

INTRODUCTION

The recent years have witnessed an exponentially increase in the use of drones. Miniaturization of electronic components and advances in perception algorithms enabled commercial and recreational applications like inspection, delivery and imaging [1]-[3].

As these applications are becoming ubiquitous, the number of naïve users that interact with drones has exponentially increased. With this respect, the quest for new human-machine interfaces to make the control of drones more natural and intuitive is becoming a significant research challenge. Indeed, despite the recent advances in sensing and autonomy, there are several scenarios where a direct control of the drone is still desirable or even needed. Notably, in aerial imaging and inspections, users often need to teleoperate drones to reach a point of interest or the best perspective. In these scenarios, users fly the drone using controllers, and receive a video feedback from onboard cameras. However, screens or googles are overfilled with data on drones' attitude, battery status, location of nearby obstacles (see Fig. 1). As a consequence, users get overwhelmed by a multitude of visual information and piloting becomes a challenge that requires a continuous cognitive effort and a long practice to be mastered.

In this paper, we introduce FOLDAWAY DroneSense a new controller equipped with force feedback for bidirectional interactions with drones. We discuss different user-interaction paradigms where haptic feedback can complement visual feedback to achieve a more immersive and safe flight control.

RELATED WORK

Control in human-drone interactions

The control strategies for drones can be broadly divided in two main categories: non-gestural and gestural. Non-gestural control usually relies on electroencephalography signals or gaze detection [4]-[6]. In gesture-based control the movements and poses of the pilot are translated into commands for the drone. The gestures can be tracked using external cameras [7], robotic platforms [8], exosuits [9], or hand-held controllers [10][11]. Every type of control approach and associated interface has specific advantages and disadvantages, a detailed discussion can be found in [8]. In this work, we use a hand-held controller as it is the most commonly used interface for commercial drones, and we discuss the integration of haptic feedback.

Figure 1. Visual interface of a DJI drone during the flight in close proximity to obstacles.

Figure 2. Example of use of kinesthetic haptic feedback to increase spatial awareness during the teleoperation of drones

Feedback in human-drone interactions

The teleoperation of drones relies in most cases on the visual feedback through screens or googles. The images captured by onboard cameras are streamed with low latency to the pilot. Using visual feedback, experienced pilots can perform high speed and aggressive maneuvers, for examples in drone racing. However, there are scenarios where relying only on visual feedback could hinder the user experience. In the examples in Fig. 1, while it is clear that the top icon warns the pilot about obstacles in front of the drone, the bottom icon could signal obstacles either behind or below the drone causing a misunderstanding. In addition, the considerable amount of information in the display can overwhelm the visual channel of the pilot.

Previous studies have shown that haptic feedback, namely convening information through the sense of touch, is an effective solution to complement vision and increase safety and efficiency during teleoperation [12]-[14]. For example, force feedback can help the pilot to better perceive the attitude, dynamics, and interactions of the drone with the local environment, for example for obstacle avoidance 0-[17]. As illustrated in Fig. 2 haptic interfaces can render directional forces and the pilot can intuitively understand the position of obstacles with respect to the drone.

However, the use of force feedback for drone piloting is currently hindered by the lack of portable and affordable haptic interfaces. On the one hand, the aforementioned studies have been performed with bulky and heavy haptic devices (e.g. Omega, Force Dimension), which are not suited for field operations where portability is a primary requirement. On the other hand, currently available controllers for drones are equipped at most with vibration feedback on the thumbsticks, which is suited to send alerts to the user (e.g. low battery level, or stall), but fails to convey more complete information about the status of the drone.

In this work we present a bimanual controller for drones with directional force feedback on the thumbsticks.

IMPLEMENTATION

FOLDAWAY DroneSense

FOLDAWAY DroneSense is a force feedback controller for drones. Each thumbstick integrates a miniaturized origami robot that can deliver kinesthetic feedback to the fingers of the user. Like a conventional controller, the thumbsticks can be pinched by the user and rotated in two directions (i.e., pitch and roll [21][19]) to send commands to the drone. In addition, the thumbsticks can actively generate rotations and forces that can be used to provide kinesthetic feedback to the fingers of the user.

Figure 3. FOLDAWAY DroneSense is a controller with force feedback thumbsticks. It is conceived to establish a bidirectional interaction with drones.

By doing so, FOLDAWAY DroneSense allows to establish a bidirectional interaction with a drone. The pilot can use the thumbsticks to send commands, but also to receive haptic feedback that renders the status of the drone while flying (Fig. 3)

Haptic modes

We envisage four strategies to enrich the teleoperation of drones through haptic feedback:

- **Personalization mode**. Each pilot has different preferences for the stiffness of the thumbsticks. Nowadays pilots who want to adapt the mechanical response of controller have to physically replace a set of springs connected to the thumbsticks. With haptic thumbsticks, the stiffness profile can be regulated via software. Furthermore, it can self-adapt to different flight conditions and tasks. For example, during the transition from free flight to the inspection of an infrastructure, the thumbsticks can stiffen to maximize the accuracy of the input provided by the user.
- **Immersion mode.** Force feedback thumbsticks can provide real-time information about the dynamic behavior of the drone. For example, the thumbsticks can stiffen when the drone flies faster, or can move replicating the oscillations induced by turbulences.
- **Training mode.** Today training relies on visual or oral instructions form manuals or instructors. Actively moving thumbsticks can be used for haptic training while flying. The drone could enter a "tutorial mode" and autonomously perform standard flight maneuvers that are replicated by the thumbsticks to ease the learning process. Once the training is completed, haptic feedback can be used to further refine the skills of the user by correcting wrong inputs during flight.
- **Obstacle mode.** The thumbsticks can apply forces to alert the pilot about obstacles nearby the drone. Directional forces can help to increase the spatial awareness of the pilot and prevent collisions.

We are developing a flight simulator where we are implementing and testing the aforementioned haptic modes. Fig. 4A depicts a cluttered environment where we test the "obstacle mode". The pilot can fly a drone with assisted obstacle avoidance. When the drone is heading toward an obstacle, it autonomously executes an avoidance maneuver which is reproduced by movements of the thumbsticks to increase spatial and situational awareness. In Fig. 4B we test the "training mode" with first-time users. In this experiment, we ask participants to fly a simulated quadcopter through the red targets. The controller provides a haptic guidance to correct the pilot when the drones deviates from the nominal path represented by the red line.

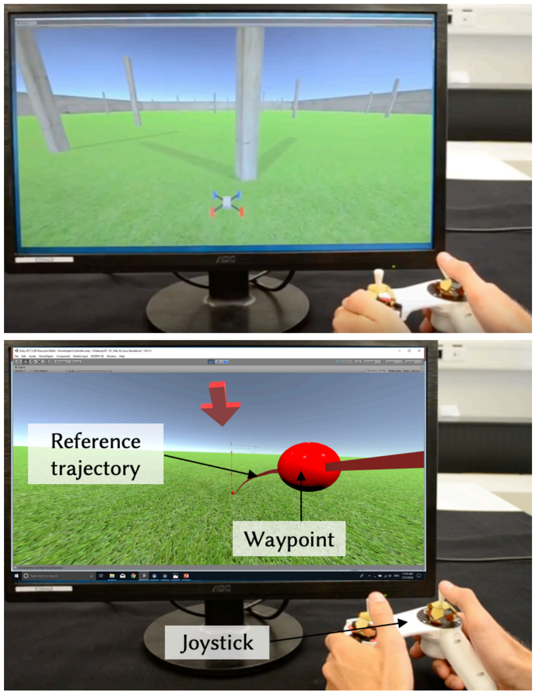

Figure 4. Different haptic modes tested in simulation. Top, obstacle mode. Bottom, training mode.

DISCUSSION

The increasing number of naïve users that approach drone piloting is calling for a new generation of natural and intuitive user interfaces [20]. In this context, multisensory feedback is fundamental to increase awareness about the status of the drone. Yet drone piloting rely almost entirely on visual feedback. The lack of portable and affordable force-feedback joysticks is hindering the use of haptic feedback in commercial applications. With the FOLDAWAY project, the authors are tackling the challenge of developing ultra-portable and low-cost haptic interfaces by investigating new design and manufacturing solutions based on origami micromachining 0. FOLDAWAY DroneSense is a prototype of drone controller that will be used to test and evaluate different haptic feedback paradigms for drone piloting. The goal is to develop a new generation of portable interfaces to create a bidirectional interaction between the pilot and the drone to increase intuitiveness and safety during teleoperation.

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