STOP! Enhancing Drone Gesture Interaction with Force Feedback

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ABSTRACT

Gesture interaction is a common way to control drones. Often it is done by mid-air gestures i.e. the operator does not need to hold any controller. Hence, such interaction is lacking force feedback while the other senses are overloaded by the noise of the drone or occupied by following the behavior of the drone. Therefore, we present an approach in which we use electrical muscle stimulation (EMS) to provide force feedback for controlling drones. We build on existing gesture sets and discuss different feedback options for operating drones.

KEYWORDS

Drone, Gesture Interaction, Force Feedback, Electrical Muscle Stimulation (EMS)

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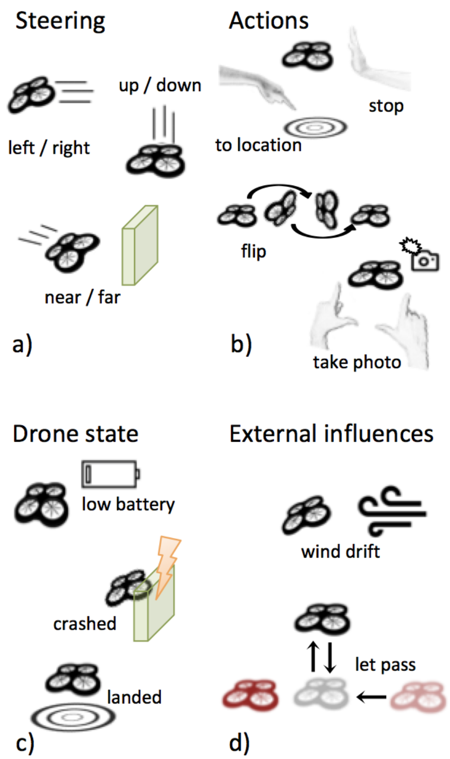

Figure 1: Drone feedback space: a) Steering commands, b) action commands, c) state of the drone, and d) external influences

INTRODUCTION

Nowadays, drones are available in various sizes and are used for different application scenarios, indoors as well as outdoors. In many cases, drones share the physical space with their users (their operators) and other people to fulfill specific tasks. The main actions operators use to control drones are for performing simple movements (e.g., up, down, left, right, near, far, rotate) and specific action commands for drones such as take-off, landing, or photo and video recording [11].

One popular way to perform such inputs is to use gestures [11, 12, 16]. Users perform gestures in mid-air either with their hands [10], arms [16], or their full body [1]. Cauchard et al. [2] explored how users interact with drones in a natural way. They found that users treat drones either like individual persons, a group, or as a pet. The replication of [2] study showed that Chinese participants also treated drones similar to their US counterpart. Jane et al. [5] investigated the social impact on such gesture sets. An overview of hand and upper body gestures is given by Peshkova et al. [12].

When interacting with drones, the user can immediately see the result of the command (i.e., the drone moves in the intended way) as long as the drone is within the line of sight. As soon as the drone is not in the user's field of view, the user can not receive any feedback on the movement of the drone directly. One way of enhancing the feedback associated with mid-air gestures is to introduce force feedback via electrical muscle stimulation (EMS) [8, 9, 13, 14, 18]. This approach has already been explored for mid-air input on public displays [14]. Moreover, EMS has been used to notify [3] users about important events, communicate affordance of objects [9], and support mid-air target selection [15] of 3D objects.

In this work, we introduce a novel way to provide force feedback for gesture-controlled drones using EMS. We use gesture sets proposed in related work and extend them with feedback. We discuss how such feedback can be designed and what benefit it might provide.

DRONE FEEDBACK

Drones provide feedback to users on several different occasions. This includes feedback as a response to commands performed by the user and feedback generated proactively by drones.

Steering Commands. While controlling a drone in a restricted area (e.g., inside a building, in a forest), an operator can perform commands that might result in crashing the drone into an obstacle. This could happen through any steering command e.g moving the drone up or further away (see Figure 1 a). Thus, this crash potential needs to be communicated to the operator so that the operator can stop the command prior to an incident.

Action Commands. Besides steering commands, operators also perform action commands such as controlling a camera or another adjacent device (e.g., taking a picture, starting a video) or doing a

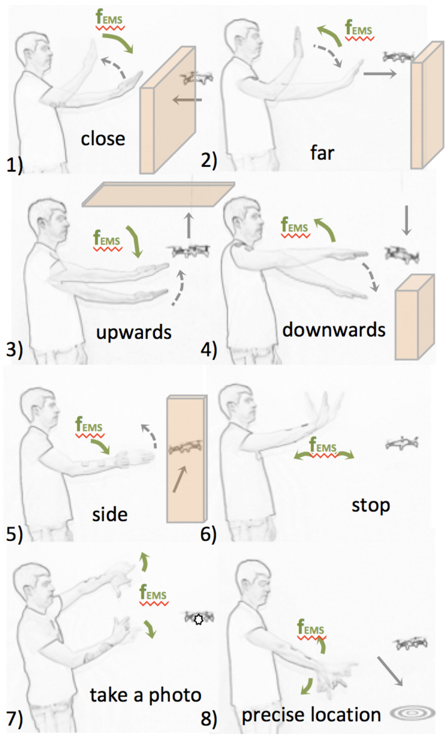

Figure 2: EMS force feedback (f_{EMS}) for gesture-based drone control: 1) Close, 2) far, 3) up (including taking off), 4) down (including landing), 5) side, 6) stops, 7) take a photo, and 8) flight to a location

special move (e.g., fly to a location, land or flip the drone) as shown in Figure 1 b. For each command, the operator needs to perceive feedback [17].

State of the Drone. The current state of the drone is also important information that needs to be communicated to the user (see Figure 1 c). The level of the battery, the connectivity, or the selected flight mode might need to be communicated to the user in certain situations. To provide this information, one option would be that the operator triggers the feedback. For example, the operator could request the current flight mode. Another option could be that the drone proactively provides such feedback if e.g. the battery level becomes low. The type of information that needs to be communicated differs from state to state. While a proactive message of a low battery might be binary information, an operator request for the battery level might rather be a continuous value.

External Influence on the Drone. Drones are influenced by their environment (see Figure 1 d). For example, the wind might influence the drone so that it needs to compensate. Another external influence could be a moving object (e.g., other drones, other people) the drone has to avoid. The drone might communicate this maneuver to the operator in a proactive way.

EMS FEEDBACK FOR GESTURE-BASED DRONE CONTROL

In the first step, we identified gestures for drone control and combined them in a set. We derived the gesture set from related work (i.e., Peshkova et al. [12], Obaid et al.[11]). The used gesture set is depicted in Figure 2 and contains eight gestures for the most common commands. Next, we identified EMS movements suited as feedback for this gesture set.

Feedback for Steering Gestures. Steering gestures include gestures controlling the drone on each axis in 3D space. This is done by moving the arm in a dedicated direction (cf., Figure 2 1-5).

The general idea of the EMS feedback group for these gestures is to generate a counter movement to the gesture performed by the operator to slow down, stop or invert the gesture. As soon as the drone comes too close to an obstacle (e.g., a wall when flying indoors or the operator him-/herself when the drone is flying towards him or her), EMS actuates the arm of the operator in the opposite direction. This either stops the drone or brings it back to its previous position.

Note that, with EMS, the operator is still able to override the force feedback and to further perform the respective gesture command. The *closer* and *further* commands require the user to move his hand closer or further away from him-/herself (Figure 2 1-2).

For the *closer* command, the counter force feedback is generated by actuating the triceps muscle. This stops the operator from moving the drone towards him-/herself or an obstacle (Figure 2 1). The biceps is actuated to induce counter force feedback of the *further* command (Figure 2 2).

Accordingly, the *up* command requires the operator to raise his/her whole arm which involves muscles in the shoulder, in particular, the deltoid muscle. Thus, the counter-movement would be to pull the arm down, which could be realized by actuating the infraspinatus muscle (Figure 2 3). Similarly, for the *down* command, the operator decreases the tension of the muscles of the shoulder and lets gravity sink down the arm. By actuating the deltoid, this movement could be slowed down or stopped, or the arm could even be raised again (Figure 2 4). For moving the drone *left* or *right*, the operator needs to move his/her hand to the left or right. The movement to the inside (i.e., left for right-handed operators) is achieved using the flexor digitorum profundus muscle, thus the counter movement (i.e., right for right-handed operators) can be created by actuating the extensor digitorum muscle. The other way around, the counter-movement to the outside of the operator (i.e., right for right-handed operators) could be generated (Figure 2 5).

Feedback for Action Gestures. We propose using the following feedback for action gestures. The *stop* gesture is done by raising the arm and the hand in front of the operator (Figure 2 6). This action may be triggered when the operator wants to stop the drone immediately. If the command was executed successfully, the hand of the operator can be moved slightly forward and backward by actuating the flexor digitorum profundus muscle and the extensor digitorum muscle alternating.

The *take a photo* or *'selfie'* gesture is done by opening the thumb and index finger of both hand and forming the shape of a frame in front of the operator (Figure 2 7). The EMS-based force feedback after the drone takes the photo could be realized by opening the hands slightly by actuating the flexor carpi ulnaris muscle and extensor carpi ulnaris muscle.

The *fly to a location* gesture involves a pointing gesture to a certain location [2] (Figure 2 8). The EMS feedback could be similar to the response for the stop gesture. The hand could be moved slightly forward and backward. In general, this type of *'acknowledge'* feedback could function to confirm certain action gestures but also enhance flight control gestures, such as confirming a successful landing or take-off maneuver.

This considered gesture sets does not include gestures for requesting feedback on the *state of the drone* or reacting to *external influences* [11, 12, 16]. The feedback that describes the *state of the drone* could be an *'acknowledge'* gesture as a response to the user's request gesture. In the case of a simple response, as discussed in the work of Duente et al. [4]. In the case a discrete value or progress is communicated, the hand of the user could be raised to indicate the value similar to the work of Lopes et al. [8]. For more complex output [6, 9] or disambiguation, gestures [7] could be used to represent the state or the behavior of the drone.

For *external influences* on the drone, feedback could be designed to be similar to the motions of the locomotion system. For example, if the drone is drifting due to wind while the operator controls the direction of the drone, the operator's arm could be stimulated to slightly follow this drift, as discussed above.

CONCLUSION

We propose EMS as a force feedback technology for drone-controlling gestures. For the existing gesture sets, counter-movements through EMS feedback could be used to slow down, stop, or revert the operator's gestures. However, the operator should always be able to override the EMS feedback with his or her own muscle force e.g. if the operator would like to fly closer to an obstacle than the system allows. EMS is particularly suited for this situation since it is light-weighted and could be included in wearable devices [13]. Upcoming electrode suits, such as the Tesla suit[1], and auto-calibration using electrode grids will reduce the time to set up such a force feedback system. In the future, a full working prototype should be implemented and tested with drone operators.

[1]Tesla-suit: https://teslasuit.io/

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