Designing human-drone interactions with the Paparazzi UAV System

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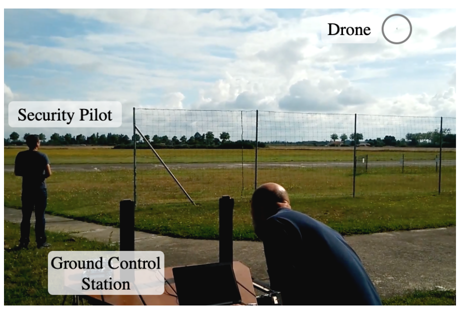

Figure 1: Flying drones outdoor with Paparazzi.

ABSTRACT

This paper presents the *Paparazzi* Unmanned Aircraft Vehicles (UAV) system and its use for designing novel interaction techniques for human-drone interactions. *Paparazzi* is a complete system of open source hardware and software for UAVs, including both the airborne autopilot as well as complete ground station mission planning and monitoring software utilizing a bi-directional data link for telemetry and control. We describe three examples of interactive systems built with *Paparazzi* to illustrate its capabilities to create new interactive UAV systems: augmented-reality glasses for safety pilots, adaptable interactions for pilots with disabilities and embedded interactions.

KEYWORDS

Human-Drone Interaction, Unmanned Aerial Vehicles, Paparazzi System

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Figure 2: Paparazzi System overview [10].

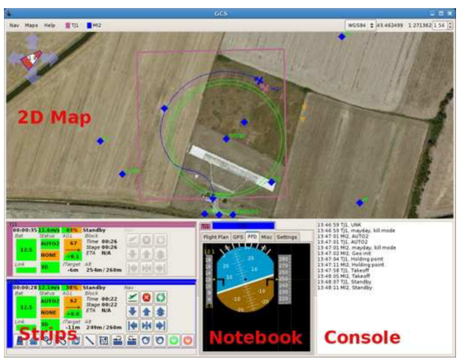

Figure 3: Ground Control Station Graphical User Interface [10].

INTRODUCTION

Human Drone Interaction (HDI) is gaining more and more interest due to the increasing number of affordable systems and research efforts in the field [2, 3, 5, 8]. However, designing and prototyping HDI remains challenging due to the distributed nature of such systems using both hardware and software platforms. As emphasized by Funk [8], building and prototyping interaction in this context requires: *controlling the drone, knowing where the drone is, and providing communication between the drone and other systems*. Unfortunately, existing technologies are often commercial products that offer little support for developers to tweak the systems or to adapt them to their needs.

In this paper, we first present the *Paparazzi* Unmanned Aircraft Vehicles (UAV) system [1, 10] and its architecture. We then describe three cases studies of new interactive systems built with *Paparazzi* which highlight its ability to support the prototyping of various HDI systems. Our case studies cover information visualization with Augmented Reality glasses, new control methods to support users with impairments and face tracking drones. Finally, we discuss the possibilities offered by *Paparazzi* to support HDI designers and possible improvements.

PAPARAZZI

Paparazzi [1, 10] is a complete system of open source hardware and software for UAV, including both the airborne autopilot as well as a ground station mission planning and monitoring software utilizing a bi-directional data link for telemetry and control.

Figure 2 details its global architecture which includes: 1) an airborne segment with the aircraft and its micro-controller, actuators and sensors to control the flight; 2) a ground segment to prepare flight plans, operate and monitor the drones during the mission but also to analyze the flights upon completion; 3) a communication segment that defines the various protocols that can be used between ground and airborne segments. Figure 1 illustrates a typical *Paparazzi* use case in which a drone performs an autonomous flight that is supervised by an operator near the ground station and a security pilot who keeps track of the drone's position at any point of the flight.

The airborne segment runs on the drone's autopilot board and features several modes: a manual mode, an assisted mode and a navigation mode. The manual mode allows the drone to be piloted using a controller. The assisted mode provides various automation routines to stabilize the drone or to limit its height or speed. The navigation mode interprets high level instructions that are described in flight plans. The flight plans can include various primitives such as waypoints, predefined navigation patterns (lines, circles) or conditional events. The flight plan is organized in blocks that are short sequences of elementary instructions performing tasks such as "make a circle around a waypoint" or "land here". The airborne segment can accept messages from the ground segment but also from embedded hardware or software via its API.

Figure 4: View from the security pilot with "Where is My Drone". 1) Gauges indicating the power and battery level, the air speed and the ground speed. 2) 3D model displaying the drone attitude 3) Drone's altitude and climb gradient. 4) The localization ring that helps finding the drone.

Figure 5: View from the security pilot with "Where is My Drone" second prototype. 1) to 4) as in Figure 4, 5) Radar view with the drone and pilot positions, 6) Line representing the current flight path.

The ground segment is made of several agents connected via the Ivy software bus [4]. This enables developers to use one or many of the existing agents such as the message monitoring agent or to develop new ones that can be integrated in the *Paparazzi* ecosystem. Two of our use-cases rely on this high level messaging system to process flight data and send commands to the drones. The ground control station provides a Graphical User Interface (Figure 3) to setup the flight plans and to operate them, i.e. to navigate in the collection of blocks and to adjust the flight parameters.

Paparazzi is versatile as it can accommodate rotor-craft UAVs as well as fixed wings UAVs, and can be used outdoors as well as indoors thanks to a positioning system. In our case studies, we used an Optitrack system [12] capturing markers fixed to any air-frame in a flight hall.

CASE STUDIES

Here, we describe three case studies illustrating new interactions with drones. For each use case we describe the interactions and how we leveraged the possibilities offered by the *Paparazzi* system to prototype them.

Where is my drone?: head-up display for safety pilots

Safety pilots must monitor the drone during the flight to ensure the safety of people and equipment. They have a dedicated remote control for each drone that allows them to manually control the drone if necessary. During observations of safety pilots at ENAC we found that they had trouble watching the drone with bad weather conditions or when there are several similar drones flying together. They also must constantly communicate with the operator near the ground control station to monitor critical information such as the battery level or the drone's expected flight plan. Figure 1 gives an example of such context.

Where is my drone? (Figures 4 and 5) is an Augmented Reality (AR) application that supports safety pilots in keeping the drone in sight and monitoring it in order to be able to regain control quickly if needed. It is a head-up display working on AR glasses. A localization ring centered on the drone's position facilitates its localization (see 4 in Figure 4). When the drone is not in the visible area, the ring stays on the border of the image, with its radius increasing proportionally to the angle between the drone and the pilot orientation, as with the Halo3D technique [13]. The application also features a radar view displaying the drone's position relatively to the pilot (see 5 in Figure 5). To help the pilot assess the status of the flight, several gauges display flight parameters such as battery level, throttle or altitude (see 1 in Figure 4). A 3D model of the drone is also displayed and rotated using the drone's attitude to help pilots better understand climbing and descending phases (see 2 in Figure 4).

Another feature that emerged from a workshop with pilots is the ability to visualize the programmed flight plan of the drone and to validate its current distance with respect to the flight plan. Figure 5.6 illustrates our first prototype implementation of this feature in which the current circular trajectory

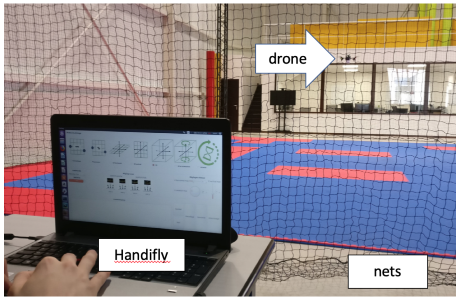

Figure 6: HandiFly in the flight arena [9].

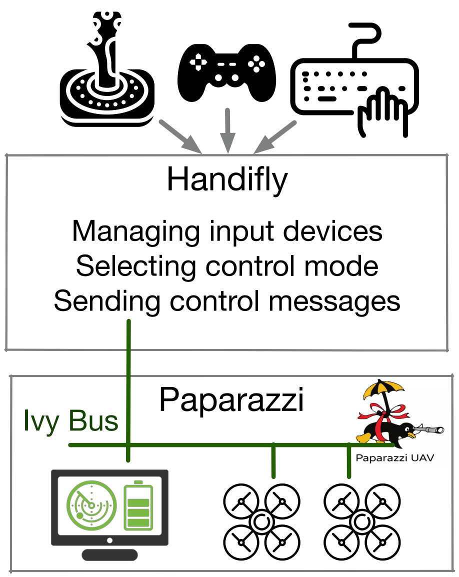

Figure 7: HandiFly Architecture [9].

is represented. The trajectory's color is updated according to distance between the drone and the expected trajectory. When reaching critical distance thresholds, it is colored in yellow (>5 meters) or red (> 10 meters) to alert the pilot. Representing the flight plan is important for situation awareness when using dynamic flight plans that can be modified by the operator. In the previous setup this required verbal communication between the pilot and the operator at the ground station and possibly led to confusions due to unexpected changes.

Where is my drone? is implemented in Unity and runs on EPSON Moverio Glasses [7]. It can be used with any type of UAV working with *Paparazzi*. The application listens to messages from the Ground Control Station via the Ivy bus. Position, speed and battery levels are included in messages that are parsed and displayed on the application. Positional information can be obtained from the glasses' sensors (compass and GPS when outside) or from the Optitrack agent if used in the flight arena. The latter requires to add markers on the glasses and to stream positional data via Ivy messages.

HandiFly: an adapted and adaptable application

HandiFly is an application to support pilots with disabilities who are flying drones as a leisure activity [9]. HandiFly features several adaptations to leverage diverse physical and cognitive abilities of the pilots, on the hardware, software and automation level. On the hardware level, we experimented using different physical controllers to match the users' motor skills, such as game controllers, keyboards or a DIY controller using makey makey [6]. On the software level, we provided a Graphical User Interface that allows to easily configure HandiFly depending on each user's needs, e.g. regarding the fine tuning of controls and the choice of physical controller. On the automation level, we implemented 6 piloting modes with different levels of assistance from fully automatic to manual control. This allows to simplify flying by restricting possible motions (e.g. limitation to a 2D plane, or turning off the yaw), and by (partially) automating the flight.

For this project, we used a Parrot ARDrone 2 modified to use *Paparazzi*'s autopilot (Figure 1) in our flight arena with Optitrack system. As explained above, HandiFly integrates with the existing *Paparazzi* ecosystem by exchanging messages on the Ivy bus [4] as illustrated in Figure 7. Thus it is possible to retrieve the drone's current position and data such as the battery level and to send control instructions to operate the drone.

In a pilot study, three users with motor and cognitive impairments were able to use HandiFly more successfully than their prior system and expressed enjoyment (Figure 8).

Look at me: face and marker based orientation

Look at me is an example application in which a drone stays at the same position and altitude but automatically orients itself towards a marker or a face as illustrated in Figure 9.

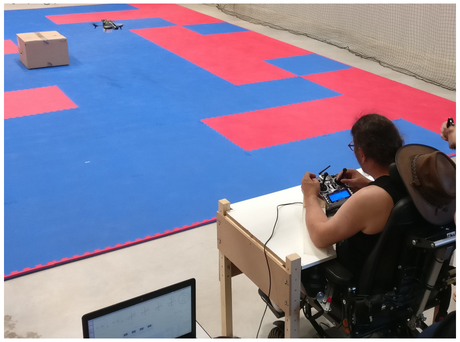

Figure 8: P4 trying landing the drone on a box [9].

Figure 9: Drone automatically orienting itself towards a marker.

We added a JeVois camera [11] which features computer vision tools processing on the drone. We implemented specific C code to get the data from the camera and call the autopilot API via the serial port to control the drone's orientation. This use-case is an example of enhancing drones' capabilities with additional sensors or computing modules that are directly embedded in the air-frame. Thus the system becomes autonomous and does not require the ground segment.

CONCLUSION AND DISCUSSION

We presented the *Paparazzi* UAV system and its use for designing three use cases. *Where is my drone?* provides data visualization for both autopilot modes with flight plan representations in addition to battery level or the drone's attitude. *HandiFly* builds upon the assisted mode to adapt the flying controls to various disabilities. *Look at me* embeds an extra sensor and its processing unit to create an autonomous system that does not require the ground segment.

The use-cases demonstrate how the system supports the necessary building blocks identified by Funk [8]: control, locate and communicate with the drone. *Paparazzi* also provides open-ended access to the autopilot (manual, assisted or navigation) via its API, both at hardware level via a serial port and at software level via network communication.

Designers and developers of HDI can use the existing software modules and the Ivy bus to build and integrate new visualization or control agents using any programming language. *Paparazzi* can be used for both outdoor and indoor applications, with fixed wings or rotor-crafts air-frames from several manufacturers. This makes it an extensible platform for creating new HDI.

While *Paparazzi* provides a wide number of tools and utilities, the online documentation still needs to be improved to make it easier for novice users to learn how to use it. However the active community of users can provide useful support thought the wiki, a forum and a gitter. Including safety oriented interactions to prevent damaging the material while prototyping interactions would be very valuable. In our use cases, we added safety settings such as setting a maximum speed. We also created emergency interactions such as "land here" or "stop engines" to avoid problems during tests phases. Such functionalities could be integrated in *Paparazzi* and exposed to designers and developers.

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REFERENCES

[1] Pascal Brisset, Antoine Drouin, Michel Gorraz, Pierre-Selim Huard, and Jeremy Tyler. 2006. The paparazzi solution. In *MAV 2006, 2nd US-European competition and workshop on micro air vehicles*. pp–xxxx.

[2] Anke Brock, Jessica R Cauchard, Markus Funk, Jérémie Garcia, Mohamed Khamis, and Matjaž Kljun. 2019. iHDI: First International Workshop on Human-Drone Interaction. In *CHI Conference on Human Factors in Computing Systems Extended Abstracts*. Glasgow, United Kingdom. https://hal-enac.archives-ouvertes.fr/hal-01990121

[3] Anke M. Brock, Julia Chatain, Michelle Park, Tommy Fang, Martin Hachet, James A. Landay, and Jessica R. Cauchard. 2018. FlyMap: Interacting with Maps Projected from a Drone. In *Proceedings of the 7th ACM International Symposium on Pervasive Displays - PerDis '18*. ACM Press, New York, New York, USA, 1–9. https://doi.org/10.1145/3205873.3205877

[4] Marcellin Buisson, Alexandre Bustico, Stéphane Chatty, Francois-Régis Colin, Yannick Jestin, Sébastien Maury, Christophe Mertz, and Philippe Truillet. 2002. Ivy: un bus logiciel au service du développement de prototypes de systèmes interactifs. In *Proceedings of the 14th French-speaking conference on Human-computer interaction - IHM '02*. ACM Press, New York, New York, USA, 223–226. https://doi.org/10.1145/777005.777040

[5] Jessica R. Cauchard, L. E. Jane, Kevin Y. Zhai, and James A. Landay. 2015. Drone & me: an exploration into natural human-drone interaction. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing - UbiComp '15*. ACM Press, New York, New York, USA, 361–365. https://doi.org/10.1145/2750858.2805823

[6] Beginner's Mind Collective and David Shaw. 2012. Makey Makey: Improvising Tangible and Nature-based User Interfaces. In *Proceedings of the Sixth International Conference on Tangible, Embedded and Embodied Interaction (TEI '12)*. ACM, New York, NY, USA, 367–370. https://doi.org/10.1145/2148131.2148219

[7] EPSON. 2019. https://www.epson.fr/products/see-through-mobile-viewer/moverio-bt-300. webpage. Retrieved February 14, 2019.

[8] Markus Funk. 2018. Human-drone Interaction: Let's Get Ready for Flying User Interfaces! *Interactions* 25, 3 (April 2018), 78–81. https://doi.org/10.1145/3194317

[9] Jérémie Garcia, Luc Chevrier, Yannick Jestin, and Anke Brock. 2019. HandiFly: towards interactions to support drone pilots with disabilities. CHI'19 Extended Abstracts. https://hal-enac.archives-ouvertes.fr/hal-02015415 Poster.

[10] Gautier Hattenberger, Murat Bronz, and Michel Gorraz. 2014. Using the Paparazzi UAV System for Scientific Research. In *IMAV 2014, International Micro Air Vehicle Conference and Competition 2014*. Delft, Netherlands, pp 247–252.

[11] Jevois. 2019. http://www.jevois.org. webpage. Retrieved February 14, 2019.

[12] Optitrack. 2019. https://optitrack.com/. webpage. Retrieved February 18, 2019.

[13] Patrick Perea, Denis Morand, and Laurence Nigay. 2017. Halo3D: a technique for visualizing off-screen points of interest in mobile augmented reality. In *Proceedings of the 29th Conference on l'Interaction Homme-Machine*. ACM, 43–51.