HandiFly: towards interactions to support drone pilots with disabilities

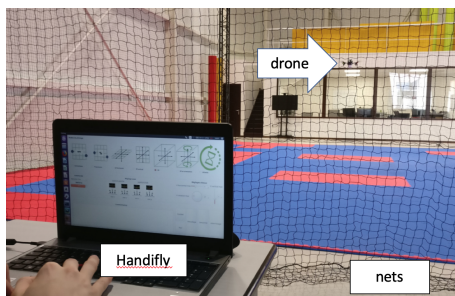Jérémie Garcia, Luc Chevrier, Yannick Jestin, Anke Brock

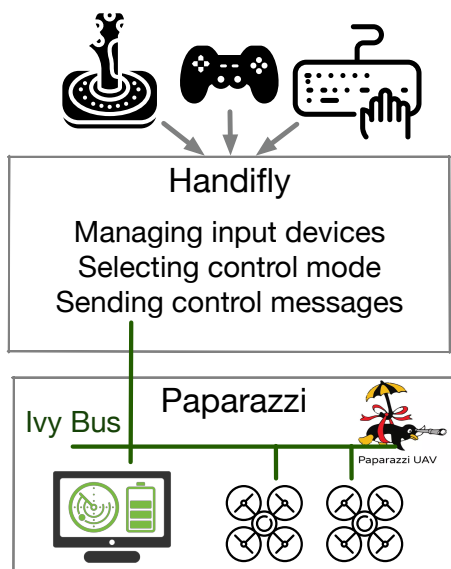**Figure 1: HandiFly in the flight arena**

Figure 2: HandiFly Architecture.

HandiFly: Towards Interactions to Support Drone Pilots with Disabilities

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ABSTRACT

This paper describes two studies with people with sensory, cognitive and motor impairments flying drones as a leisure activity. We found that despite several adaptations to existing technologies that match their abilities, flying remains very difficult due to the required perceptual and motor skills. We propose an adaptation space at hardware, software and automation levels to facilitate drone piloting. Based on this adaptation space, we designed HandiFly, a software for piloting drones which is adaptable to users' abilities. Participants were able to fly and emphasized its ability to be tailored to specific needs. We conclude with future direction to make drone piloting a more inclusive activity.

P1: Girl (~10 years old) in wheel chair with congenital motor and cognitive impairments, as well as attention and speech disorders.
P2: Adult male (~20 years old) with congenital cognitive impairments. He has a limited attention span and 3D visual perception difficulties.
P3: Adult male (~20 years old) with congenital motor impairments in the hands and mild cognitive deficits. Experienced video game player.
P4: Adult male (~45 years old) with cognitive, speech and motor impairments following a recent accident. Wheel chair user.
T1: Occupational therapist.
T2: Psychomotor therapist.
ELHEVA: https://elheva.jimdo.com/
Artilect: https://artilect.fr/

Sidebar 1: Participants description

Cognition Calmness, attention. Easy matching of directions in space and on remote. Simplify remote control. Limit drone movement and orientation (e.g. remove yaw).
Perception Possibility to limit flight to vertical 2D plane or visible range.
Motor skills Physical support to reduce fatigue. Adapted sticks on controller. Adapt to force and precision of motor movement.
Technical Support drone stabilization and difficult flight phases such as take-off and landing.

Sidebar 2: User needs summary

INTRODUCTION

Piloting drones (Unmanned Aerial Vehicles, UAV) as a leisure activity is becoming more and more widespread thanks to numerous mass-market models that were recently introduced. In Human-Computer Interaction, interaction with drones is relatively recent but is gaining more and more attention [5]. Various applications emerged such as navigation support [1], social companions or art and with diverse interaction techniques [3].

To operate a drone, the pilot must take off, stabilize the drone by adjusting the power and make trajectories with translations and rotations before landing the aircraft. While performing these tasks, the pilot must constantly check the location of the drone in the environment, its speed and its battery life to avoid damages and crashes. This requires perceptual skills (distance, altitude, orientation) and motor skills (precision, movement) which makes the activity fun but can be too difficult for people with motor and cognitive impairments.

Our goal is to support people with disabilities to fly drones as a leisure activity. We worked with ELHEVA, an association for people with disabilities, and the Artilect FabLab which were already organizing drone piloting activities for disabled people and needed support for designing interactions.

This paper presents our work towards designing interactions for drone pilots with sensory, motor or cognitive impairments. We conducted a first workshop with four participants and two therapists to understand their needs and derive an adaptation design space. We then designed HandiFly, a prototype application that can adapt the degree of control to users' abilities by taking advantage of the Paparazzi autopilot [6]. In a second workshop with the same participants, HandiFly allowed them to fly drones with greater success and satisfaction. We conclude with directions for future research.

OBSERVATIONAL STUDY

We observed a drone piloting workshop at the Artilect FabLab with four special needs participants (P1-P2-P3-P4, see sidebar 1), two therapists (T1-T2), and four companions from Elheva and Artilect. The workshop lasted approximately four hours. We took pictures and conducted interviews with the participants and their families when possible. The drones were small JJRC H36 drones modified to be controlled with a professional remote control. Sidebar 2 summarizes the identified user needs.

The drone piloting workshops had been held for eight months. The companions and the therapists had already implemented contextual and material adaptations. We observed, that the companions and the therapists spent a considerable effort setting up the configuration for each person (e.g. use of a table or tablet, type of remote control). Moreover, they had to memorize the configuration for each
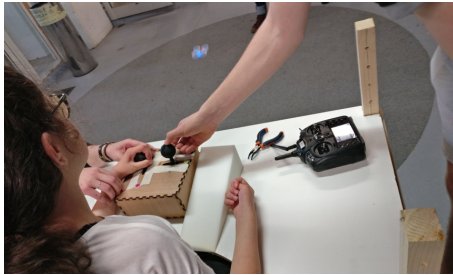
Figure 3: P1 with the dedicated table and the remote control in a wooden box

Figure 4: P3 with the remote control on the tablet fixed on his shoulders

Figure 5: P4 with the remote on an inclined support and foam to support the forearms

participant. All participants, except P3, struggled with managing to pilot the drone for more than several seconds and regularly crashed it against the walls. This is mostly due to difficulties stabilizing the drone vertically as well as the high demand on cognitive and motor skills.

Cognition and perception. We chose a calm space to avoid distractions and to facilitate attention. For P1 all participants had to hide out of sight. Understanding directions was challenging and supported by placing one participant inside the flight space while wearing colored stickers on his body which corresponded to colored stickers on the remote. P2 wore virtual reality glasses with first person view while a companion was piloting. He has a limited 2D perception (no depth). He also needed explanations at the beginning of each session to remember how the system worked. P1 and P4 used a wooden box (Figure 3) hiding the remote's complexity and limiting the ranges of the joysticks vertical and horizontal displacement with a cross-shaped opening. Another challenge faced by participants concerns driving a drone in 3D with a yaw (rotation around its own vertical axis) that forces to adopt an egocentric and inverted orientation on the drone.
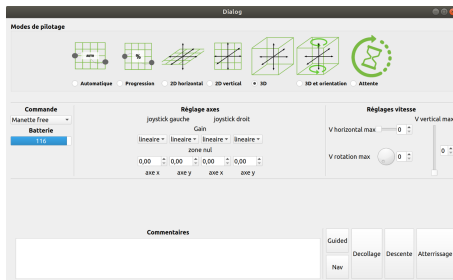
Motor skills. A table has been manufactured for P1 and P4 that can be adjusted to the height of their wheel chair to support a comfortable position of their arms with pieces of foams (see Figure 3 and Figure 5). A support helps keeping the remote in a pleasant position. P3 used a custom made tablet hanging on his shoulders to put the remote and prevent wrist fatigue (Figure 4). All participants used longer sticks and/or with larger tips that have been printed in 3D for a better grip. We observed that some participants make small but precise motor movements where others make large, strong and imprecise movements.

ADAPTATION SPACE: THREE AXES FOR ADAPTED AND ADAPTABLE INTERACTIONS

Hardware: We argue for flexibility in terms of physical controllers to match the users' motor skills. Indeed, existing remote controls can be complex and not adapted to postures and movements available to the users. We propose to use a variety of controllers including game controllers, software keyboards or makey makeys [4] that make it possible to create innovative interfaces that can be easily reconfigured, for example changing the position or shape of controls. Microsoft adaptive video game controllers [7] are good instances of such dedicated hardware.

Software: we propose to allow the adaptation at the software level in order to fine-tune the controls while maintaining the maximum physical amplitude of the controllers used. For example, the software can set the zero position of a joystick to the rest position of a user or increase the gain to accommodate very precise movements with low amplitudes. Other adaptations include the use of a filtering function to minimize undesirable jitter in the input such as tremors of the hand.

Automation: we propose to automate some parts of the piloting so as to meet sensory and cognitive abilities of the pilot. Progressive and disengagable automatism that restrict the possible motions, such as limitation to vertical 2D flight or 3D flight but with fixed orientation, could help with specific impairments such as depth perception issues. For people with important cognitive impairments, using a predefined flight plan can help the user to gradually understand the motion of the drone and locate it in space. In this case, entering any command on a controller will advance the drone on the flight plan, so that the user does not have to decide about directions and orientations.

By combining these three facets we aim to increase the pleasure of piloting since users would be able to interact in a way that is more adapted to their abilities and needs. These features should be accessible and adjustable by the users and their companions.

HANDIFLY: AN ADAPTED AND ADAPTABLE APPLICATION

HandiFly is an application that takes into account the three dimensions of the adaptation space to support flying drones. It is implemented in Python using the Qt5 framework and relies on Paparazzi UAV, an open-source hardware and software project for drones [6]. HandiFly integrates with the existing paparazzi ecosystem by exchanging messages on the Ivy bus [2] as illustrated in Figure 2. This allows to retrieve the current drone's position and data such as the battery level and to send control instructions to operate the drone. We used Parrot ARDrone 2 modified to use Paparazzi's autopilot (Figure 1) in a flight arena equipped with an Optitrack external positioning system.
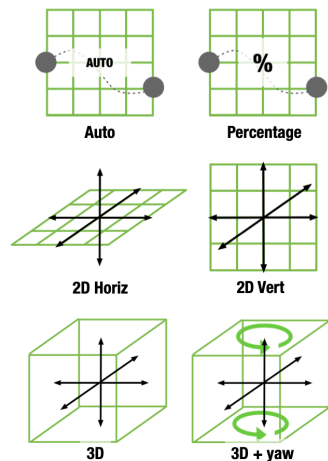
Adapting interactions to match users' abilities

A Graphical User Interface (GUI, Figure 6) allows the pilots or their companions to change dynamically the settings described below to best adapt the system to the users needs.

Hardware: selecting input devices. HandiFly supports different types of remote controls (e. g. classic remote control, video game console controller, keyboard) to match the physical abilities of the users. The software allows the user to choose the remote from an existing list of devices including the possibility of using a makey makey that can simulate the keyboard keys (Figure 8).

Software: fine tuning of the mapping. The sensitivity of the input device can be adapted by changing the gain of each joystick axis. Indeed, we observed that some participants have very precise motor skills for small movements, while others make large but not very precise movements. The maximum speed of motion and rotation for the drone can be adjusted with sliders and number boxes.

Automation: Piloting modes. HandiFly offers several piloting modes with different levels of assistance that constitute a continuum from fully automatic to manual control (See Fig. 7 and Sidebar 3). We designed them to adapt to specific abilities and create a continuum that supports progressive disclosure of the piloting tasks. For instance, the goal of the fully automatic mode is to help apprehend

Figure 6: Handifly Graphical User Interface. Pilots or their companions can choose the input device, the flying modes, the gains for sticks and the control speed.

Figure 7: HandiFly piloting modes

Auto: by moving a joystick or pressing the keyboard (depending on the remote control selected) the UAV follows a pre-defined flight plan (e. g. a 2D rectangular shape).
Percentage: the user advances the drone on a flight plan regardless of the command he or she uses and the drone stops when released;
2D Horizontal: the user controls the drone in a horizontal plane. He or she can move it forward & backward (z-axis), right & left (x axis), but not up & down (y axis).
2D Vertical: the user controls the drone in a vertical plane. He or she can move it up & down (y-axis), right & left (x-axis), but not forward & backward (z-axis).
3D: the user controls the drone in 3D. He or she controls the x, y and z axes.
3D + Yaw: the user controls the drone in 3D (x, y and z axes), as well as the yaw of the drone.

Sidebar 3: Description of modes

a trajectory and to practice locating it in space. The user can scroll thought the modes on the GUI or with buttons on the hardware controllers.

Facilitating interactions

As we had observed concerns related to the start and landing of the drone, we implemented the possibility of starting and stopping the propellers, as well as lowering the drone to standby mode with buttons. Since autonomy is a major limitation for operating drones, the GUI displays the battery state. Finally, it is possible to take notes in the GUI so that the users or the companion can keep track of any relevant details such as "using big sticks for 3D mode with low velocity".

PILOT STUDY

We met the same users as during the observation session (except P2). This session took place in a flight arena equipped with the necessary equipment. We proposed individual adaptations for each participant and validated them with the two therapists.

All participants were able to fly drones the whole time (increased flight time and less crashes), and enjoyed the session. They all wanted to be able to reuse the new control modes in subsequent sessions. The participants and the therapists appreciated the ability to quickly change the input device or to modify the settings to fine-tune the control. They explained that saving all settings along with the comments on the GUI would be a very valuable addition to encourage reuse.

P1 tested the drone control with the makey makey interface (Figure 8). We hid the control board to simplify the interface as much as possible. P1 was able to fly the drone longer than in the previous study, and expressed joy about this success. However, it was difficult for P1 to look at the drone and the control at the same time. Unlike a remote control, our makey makey installation lacks touch feedback that would allow non-visual piloting. This problem was partially solved by tilting the table to improve the overview. P3 used a video game controller and did not need the support tablet (Figure 9). He quickly advanced from piloting in 2D vertical mode, to 3D mode with yaw. P4 used the remote control with adapted joysticks. He faced challenges with the independent use of the two joysticks since he often used both hands in parallel. By increasing the motion gain, we were able to adapt to his small yet precise movements. With this setting, P4 achieved a better level of control and could even fly the drone in 3D mode (without yaw). As he was able to link his actions and their results, the therapists asked us to limit the use of automation so that he could improve his motor-skills.

Overall, HandiFly proved successful in designing interactions tailored to the participants abilities. We took advantage of different input devices (makey-makey, game control, standard remote) for each participant and tuned them with software ranges and gains to maximize the control. The automation embedded in piloting modes allowed the participants to avoid incessant crashes while maintaining enough challenge so that they could enjoy the activity.
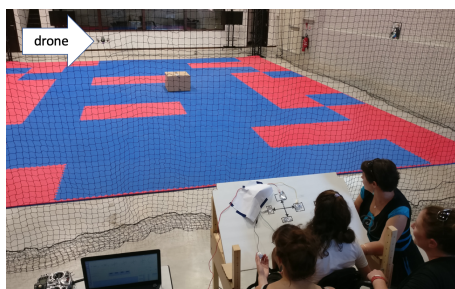
Figure 8: P1 using makey makey and conductive zones on the table as directional arrows

Figure 9: P3 using a game controller with a single hand

Figure 10: P4 trying to land the drone on the box

CONCLUSION AND PERSPECTIVES

This work is a first step towards more accessible interfaces for drone piloting. We collaborated with a FabLab and an association for people with impairments to explore how adapted and adaptable technologies can support people with disabilities to fly drones. We conducted two studies with participants with disabilities and their companions. We designed and tested HandiFly, an interactive application that supports the design of ad-hoc interactions by leveraging hardware, software and automation adaptations.

We operated HandiFly based on the suggestions made by the participants, their companions and the therapists. To make it more usable and effective, we are planning to ease the settings by designing simple tasks such as "move your stick to the greatest amplitude" or "say when you cannot see the drone" to calibrate the system.

Further user-driven studies with more participants are needed to collect more quantitative information and to refine our adaptation space. We believe this work can have implications for Assistive Technologies but also for interaction with automated systems during degraded conditions such as cognitive overload or perception problems.

ACKNOWLEDGMENTS

REFERENCES

[1] 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 *Proc. of the 7th ACM International Symposium on Pervasive Displays*. ACM, 13.

[2] 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 *Proc. 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

[3] Jessica R Cauchard, Kevin Y Zhai, James A Landay, et al. 2015. Drone & me: an exploration into natural human-drone interaction. In *Proc. of the 2015 ACM international joint conference on pervasive and ubiquitous computing*. ACM, 361–365.

[4] Beginner's Mind Collective and David Shaw. 2012. Makey Makey: Improvising Tangible and Nature-based User Interfaces. In *Proc. 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

[5] 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

[6] 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.

[7] Microsoft. 2019. https://www.xbox.com/adaptive-controller. webpage. Retrieved January 4, 2019.