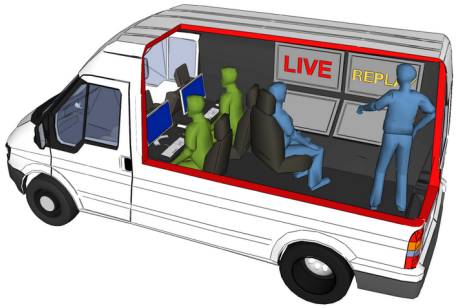

Figure 1: Van from 3i UAS

Tactile Human Drone Interface for End-Users and Qualified Pilots Collaboration

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ABSTRACT

During the 3i European project for maritime surveillance, a solution has been designed to support crew collaboration in Unmanned Aircraft System. This study focuses on Human Drone Interface usability and raises issues about how it could help end-users to collaborate with pilots. Software architecture and interaction tricks are explained. As we particularly paid attention to give to the end-users the capabilities to easily submit maneuvers to the pilots, we assessed the usability of this new solution. We found limits and perspectives, and also opened discussion about end-users / pilots collaboration issues.

CCS CONCEPTS

• **User studies**; • **Empirical studies in interaction design**;

iHDI '19 - International workshop on Human-Drone Interaction, CHI '19 Extended Abstracts, May 5, 2019, Glasgow, Scotland, UK, http://hdi.famnit.upr.si

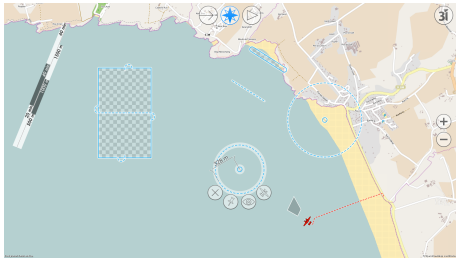

Figure 2: 3i tactile HMI display overview

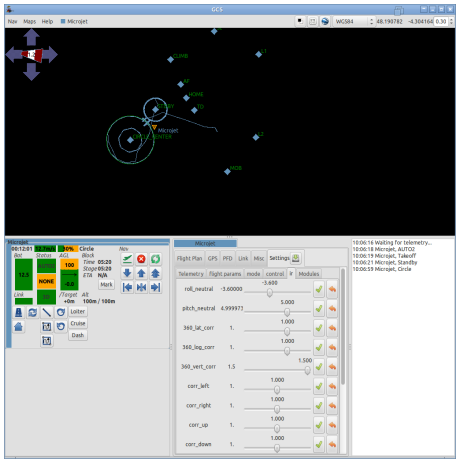

Figure 3: The paparazzi GCS display

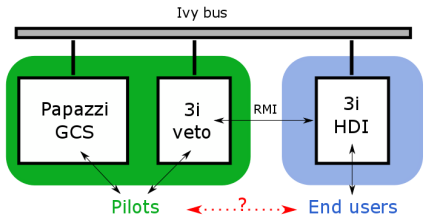

Figure 4: Architecture of the 3i UAS HDI

KEYWORDS

Human Drone Interaction, collaboration, end-users, pilots, usability

ACM Reference Format:

Mathieu Simonnet, Philippe Tanguy, Francois Legras, and Gilles Coppin. 2019. Tactile Human Drone Interface for End-Users and Qualified Pilots Collaboration. In . ACM, New York, NY, USA, 6 pages.

INTRODUCTION

Recently some studies focused on new ways to interact with drones [6], on how an operator could manage multiple Unmanned Aircraft Vehicules (UAV) at the same time [3] and on how multiple operators could collaborate to manage one drone to properly complete a common mission [7]. The 3i project focused on this third case where a team manage a unique UAV. It was an INTERREG project from 2012 to 2014 which aimed to set up a Unmanned Aircraft System (UAS) for maritime surveillance. The system is composed from a van (figure 1) included a tactile HDI (Human Drone Interaction) (figure 2), a Ground Control Station (GCS) (figure 3), a video display and a long range UAV. Although the project has already ended, interactions issues between humans, interfaces and the drone are still current.

The 3i tactile HDI runs computer using a touch screen for user interaction. It is a software designed to allow laymen operators, so-called the **end-users**, to manage UAV missions. More precisely, these end-users need to easily move a video camera in the air to complete observation missions. By this respect, it has to be done under the control of qualified experts, so-called the **pilots**, to deal with aviation regulation, weather constraints and technical capabilities of the UAV on flight. Thus 3i tactile HDI has been designed to provide the end-users with the option to easily draw flight primitives and then submit them to the pilots. These pilots actually used the paparazzi ground station (GCS) running on another computer to set up the flight plans and manage UAV behavior during missions [4]. The paparazzi GCS is where the pilot interact with the UAV. It provides feedback about UAV activity, allows command and control of the aircraft and has a method of override control for the system (https://wiki.paparazziuav.org/). In the 3i project, pilots accept or reject submitted maneuvers thanks to another component: the 3i Veto HDI. This organization raises at least 3 questions:

(1) Which UAS architecture can afford flexibility and safety for end-users / pilots interactions?
(2) Is the 3i HDI really more usable than the paparazzi GCS for the end-users?
(3) How communication between end-users and pilots could be enhanced?

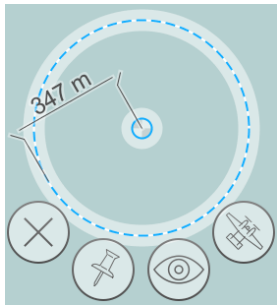

Figure 5: The circle maneuver

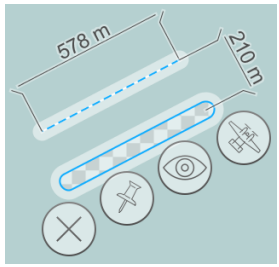

Figure 6: The line maneuver

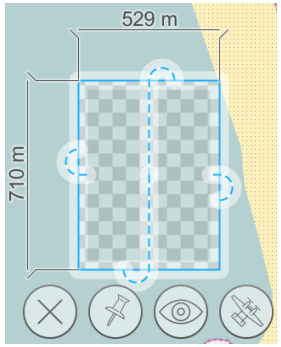

Figure 7: The box maneuver

THE UNMANNED AIRCRAFT SYSTEM

Interface

As mentioned above, two computers are involved in the communication between the 3i HDI and the Paparazzi GCS (figure 4).

- The computer 1 (in blue on the right in figure 4) is dedicated to the end-users. Here, they use the 32" touch screen and the 3i HDI to manipulate maps and submitted maneuvers.
- The computer 2 (in green on the left in figure 4) is dedicated to the pilots. Here they control the UAV with the paparazzi GCS and also receive new maneuvers the end-users submitted via the local network. These maneuvers are displayed on the Veto HDI and can be transmitted to paparazzi GCS id accepted.

An Ivy communication protocol put the 3i tactile Interface, the paparazzi GCS and the UAV in relation.

The main goal of the 3i HDI is the simplicity. Here, a non-specialist could plan and manage a flight mission by using this interface. When launched, the interface displayed a map in full screen (figure 2). On this map, user can switch between the 3 following modes within buttons.

(1) The **Map mode**. This is the default mode where it is possible to interact with the map: pan and zoom using the "plus" and "minus" buttons.
(2) The **Maneuver mode**. Here, the end-users can define maneuvers to be sent to Paparazzi. To differ from the previous display, a grid is shown on the map.
(3) The **Replay mode**. This mode is designed to control the video replay. When this mode is on, a time line appears at the bottom of the screen (https://videopress.com/v/TGtY9IfQ).

End-users maneuvers and interactions

To define a maneuver, end-users have to use the maneuver mode and draw on the map the point, the line or the area that they want to see with the camera. The system was designed to be "camera-centered" and not "drone-centered".

3 simple maneuvers can be used in the 3i HDI in the maneuver mode.

(1) The **circle maneuver**: The drone turned around the center. (figure 5)
(2) The **line maneuver**: The drone performs round trips on the defined line. (figure 6)
(3) The **box maneuver**: The drone performs round trips inside the defined area. The round trips can be defined as North-South or West-East (figure 7).

Each new maneuvers offers 4 buttons (figures 5,6,7).

(1) The **cross button** deletes the maneuver.
(2) The **pin button** stores a maneuver between two or mode sessions.

Figure 8: The veto HDI for pilots

(3) The **eye button** shares the maneuver with the pilots. The maneuver appears on its own interface and a discussion can be performed with him: feasibility, modifications needed, etc.
(4) The **aircraft button** is nearly the same than the eye button - the maneuver is shared with the pilots - and an execution of the maneuver is asked. The maneuver can be accepted (the color becomes green) or rejected (red).

Veto HDI

The 3i Veto HDI is a very simple interface (even more than the main interface) dedicated to the pilots. Its main goal is to supervise maneuvers defined by the end-users on the main interface. The 3i Veto HDI display a map. At least, the following two use-cases do exist :

- In the first one, the end-users need the technical opinion from the pilot: feasibility, modifications needed, etc. This use-case is linked to the eye button in the main interface. The defined maneuver is sent and displayed on the 3i Veto with information about size (radius, length) and localization on the map. When a maneuver is shared, the screen is automatically centered on the maneuver. No action is needed, it is just information, both of them can discuss about this maneuver.
- In the second use case, the end-users want to execute a specific maneuver. As in the first use-case, the maneuver is sent to the 3i Veto HDI and displayed on it. In this case an action is expected from the pilots: acceptance or rejection of the maneuver. If the maneuver is accepted, it becomes green on the end-users HDI and red if it is rejected (figure 8).

If the maneuver is accepted, it is transmitted to the GCS running paparazzi (figure 3)

USABILITY STUDY

In the usability study, we focused on 10 end-users. They performed a simple activity in simulation condition. They actually managed 3 maneuvers directly with the paparazzi system on the one hand, and with the 3i HDI on the other hand. We collected System Usability Scale (SUS) Scores [2]. The global overview showed that the 3i tactile HDI obtained an average of SUS scores about 86. This suggests a good user experience [1]. Here, Paparazzi only obtained 58. Analysis also revealed a statistically significant difference (Wilcoxon test, $V=55$ $p<.01$). More precisely, 9 users had a higher score than the SUS average (*i.e.* 68) using the new tactile 3i HDI whereas only 4 of them crossed this boundary using existing paparazzi GCS. This result is not surprising since Paparazzi GCS is designed for pilots, flight plans and technical aspects whereas HDI specifically targets end users. However, focusing on details, this experience is such an opportunity to better understand the features which still could be increased in HDI and paparazzi GCS. In order to better explain why 3i HDI was more usable, we tried to correlate SUS results with the remarks some users made during the tests.

Managing maps

Almost every user complained when they experienced zoom and pan actions in Paparazzi GCS. About zooming in paparazzi, map tiles were in a low resolution and force the users to zoom in and out often to understand the environment. About panning, map tiles did not refresh automatically in paparazzi. In comparison, the 3i map tiles were clearer and refreshed automatically very fast. This map management advantages in 3i HDI seemed to explain why the users found paparazzi more cumbersome than 3i. It appeared obvious that the experts would appreciate to get rid of these multiple actions to explore the environment features. Moreover, this would widely participate to improve the "situation awareness" which we recall "is the perception of environmental elements with respect to time and/or space" [5].

Creating maneuvers

Another critical function of this UAS was the maneuvers creation. Some users told they found tedious the Paparazzi procedure to do so. Indeed, using Paparazzi GCS, end-users had to first move the waypoints of the attempted maneuver. Each waypoint displacement required a confirmation in dialog box displaying coordinates. Then, even if the maneuver was not directly drawn on the map, they had to find the right block in the flight plan to launch the maneuver. To perform the same action in 3i HDI, users had to activate the maneuvers mode, draw the primitives (circle, line or box) which will be clearly drawn on the map and click on the button representing the UAV. This difference could explain why users answered that 3i HDI functions were better integrated than the paparazzi GCS ones. It is also possible that this procedure led end-users to answer that 3i HDI was less complex and required less things to learn. Thus, the two main functions: "managing maps" and "creating maneuvers" were perceived as more simple in 3i HDI and could explain why this new application provides the end-users with an HDI which seems more adapted to their needs.

Usability Limits

To conclude about HDI usability, it is important to recall that the task the users were asked to do was very simple and did not aim at using advanced features of paparazzi GCS or 3i HDI. Taking this into account, we mean that 3i HDI is more adapted to the end-users to complete simple tasks without any knowledge in UAV, but this does not mean that Paparazzi GCS does not work properly. The latest offers much more possibilities and is particularly suitable for UAV specialists (*i.e.* the pilots). Eventually, this study allowed end-users to suggest some perspectives to improve 3i HDI. The first remark was the automatic switch between the map mode and the control mode. To date, to create a maneuver, the user has to click the maneuvers button. As soon as the maneuver is drawn the HDI automatically switches back to the map mode. Certain users tried to draw a second maneuver without

re-click on the maneuver button because they did not notice that the HMI state went back to the map mode. Although there is already a grid on the map to show that we are in the map mode, one suggestion was to make a bigger difference between the display in map and maneuver modes. Users suggested graphical animations and/or sounds to help to notice the automatic switch. They also suggested a sort of negative color when in maneuver mode.

END-USERS / PILOTS COLLABORATION PERSPECTIVES

To the question "Which UAS architecture can afford flexibility and safety for the end-users / pilots interactions?", it seems that the UAS composed of paparazzi GCS and the 3i HDI with the Veto is a suitable solution. It is at least technically robust and the link provided by the Veto ensures the end users to submit maneuvers under control. The remaining question is "How communication between end-users and pilots could be enhanced?" Indeed, although the end-users are able to submit different maneuvers to the pilots, some circumstances could imply temporal pressure or need higher precision's feed backs. In such cases, one could ask whether simple veto (*i.e.* "validating system") is enough to support efficient collective decision. In other words, should we encourage free "end-users/pilots" verbal discussions during missions? Or could crew take greater advantages from other interaction tricks? An interesting debate could be opened to try to position the cursor on the most legitimate level on a continuum between constraints and freedom for collaboration.

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