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Think different: how we completely changed the visualization of Pseudo-Pilot

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Abstract

During their initial and on-the-job training, air traffic controllers communicate with human operators called pseudo-pilots who act as pilots for several simulated aircraft. With the expected increase in air traffic, a significantly higher number of aircraft will be handled during the simulations. The existing tools and working methods of the pseudo-pilots do not allow them to handle more traffic without increasing the number of operators. The increase in the number of pseudo-pilots induces problems of cost, logistics and collaboration (distribution of traffic and radio frequency congestion). This article describes the design process and improvement of a pseudo-pilot HMI which led us to a radical change of both the visualization and the interaction. This user-centered process aims to optimize visualization, effectiveness of interaction and the level of realism of the simulations. We also integrated in a seamless and robust way voice recognition in the visualization.

Keywords: human-centered design, multi-modal interaction, pseudo-pilot interface, air traffic control, voice recognition.

Index Terms: H.5.2 Information interfaces and presentation: User Interfaces - Graphical user interfaces.

1 Introduction

Initial and on-the-job training sessions of air traffic controllers are carried out using air traffic control simulators. During simulations controllers interact with pseudo-pilots who play the role of pilot for several aircraft at once. Depending on the density of air traffic, there can be several pseudo-pilots associated with only one controller position. The pseudo-pilot is a key element in the simulation. He receives orders transmitted by the controller using the Voice Over IP radio and interacts with the simulator via a graphical user interface. Moreover, pilots must initiate communication with the controller to perform tasks required by the pedagogic goals of the exercise. The smoothness and realism of the simulation depends on its effectiveness and efficiency. Forecasts of the development of air traffic show that it is likely to double in the next twenty years; and as a result, control systems and simulators will have to adapt to these changes. Simulation systems will also have to take into account an increase in data link exchanges between controllers and pilots with CPDLC system (Controller–pilot data link communications).

The tools and the current working methods of pseudo-pilots do not allow them to support a large number of aircraft; consequently simulations with many aircraft are performed using several pseudo-pilot working positions associated with one controller working position.

Today the number of pseudo-pilots required to perform an effective simulation is determined empirically by the instructors who create the exercises. In addition, the pseudo-pilot's workload induced by a simulation does not only depend on the number of aircraft but also on the situations created in the exercise and the sector geometry.

The use of more pseudo-pilots during simulations creates problems of cost, logistics and an extra workload brought on by the coordination between the pseudo-pilots because they have to share responsibility for traffic and radio frequency. Moreover, the pseudo-pilot positions available are not easily adaptable to the new working methods induced by the evolution of air traffic control.

The number of radio exchanges between controllers and pilots is very large. Verbal communication can represent up to 65% of the physical occupation of the frequency [6]. During workload peaks, radio transactions are uninterrupted, at the expense of interactions with the simulator. In a simulation context, as opposed to the operational one, the radio quality is perfect and a limited number of pseudo-pilots interact with the controller. In 40% of radio communication the pilot initiates the dialogue. The dialogue initiated by the pseudo-pilot are triggered either by his analysis of the traffic situation on the radar display, or by reading his paper log that records messages associated with the simulation time.

The research and development department of the French Civil Aviation Administration has launched a study on a new kind of pseudo-pilot working position addressing present and future challenges. This HMI has been designed for an ACC (Area Control Center - en-route traffic) simulator bearing in mind these existing design solutions with both their qualities and drawbacks while improving realism of the simulation and pseudo-pilot's efficiency. This paper presents a state-of-the-art on the pseudo-pilot positions available, and then details the methodology we have used to create and improve the pseudo-pilot working position. Finally, the results obtained during two experiment-tations are presented.

2 Study of existing pseudo-pilot interfaces and tools

There are two types of simulators, those for ACC and those for APP (Approach Control - terminal areas and airports traffic). ACC traffic involves aircraft at high altitudes and routes which consist of a list of characteristic points (waypoints). The orders issued by controllers are mostly composed of flight level (altitude change) and headings or direct to waypoints on to shorten aircraft's routes. Changes in direction (heading) or speed (mach number or indicated air speed) are used to manage conflict-prone situations between aircraft, i.e. getting too close with regards to safety standards and rules. APP traffic involves aircraft departing from or arriving at airports. The magnitude of flight levels from the ground to high altitudes and limited space availability leads to a very large number of orders in level, speed and direction and the monitoring of complex procedures related to the airport platform. Activities in both cases are significantly different, as the most common orders are not the same and the monitoring activity from a pseudo-pilot point of view is critical in APP simulations. A summary of existing solution is given in table 1.

2.1 Study of existing ACC and APP interfaces

The main tool of existing pseudo-pilot positions is a radar display (roughly the same as to the controller's display), the orders are made by selecting them from lists and inputting values on a dedicated HMI distinct from the radar image (Figures 1 & 2).

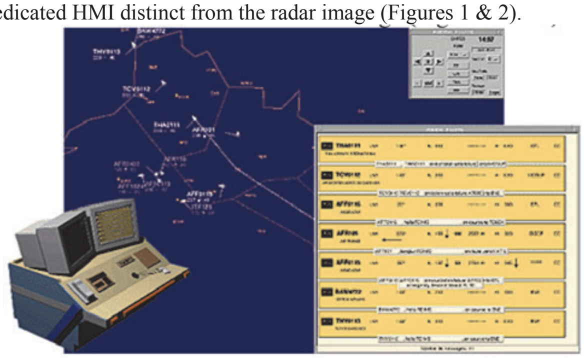

Figure 1: ACC HMI Electra

Figure 1 presents a pseudo-pilot HMI from a French ACC simulator: Electra. The operator uses two screens, one for the radar image, the second for the tool which contains an electronic version of the 'paper strips' used by the controller where orders are entered by using scrollable lists. Figure 2 presents Eurocontrol's pseudo-pilot HMI from the Escape ACC simulator, a radar image coupled with a flight list and an order box window on a single screen. CPDLC dialogs are only supported on Escape's pseudo-pilot HMI. Figure 3 shows an APP pseudo-pilot and a radar display; orders are issued using a dialog box opened on a dedicated screen with multiple scrollable lists.

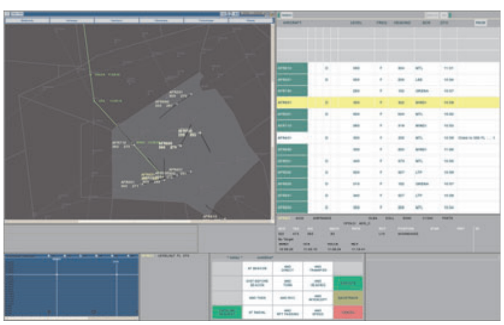

Figure 2: Escape

These two tools use a replication of the controller's working position.

The only exception to this metaphor is MACS [11] (Figure 4) developed by NASA to be used in a research simulator. It uses a cockpit metaphor with virtual instruments similar to those found in an aircraft.

The operator can control several planes by interacting with a mouse and a keyboard. MACS started with a single aircraft interface simulation – which explains the metaphor - and evolved thereafter to be used in multiple aircraft simulations.

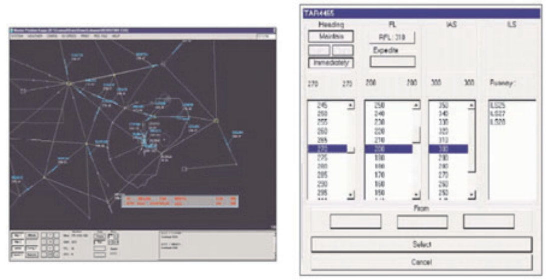

Figure 3: APP HMI Scansim

The perspective is completely different from the one with a radar display where the pseudo-pilot sees all traffic in a Cartesian coordinate system, a cockpit view is aircraft-centric, so the pilot sees the traffic from its position.

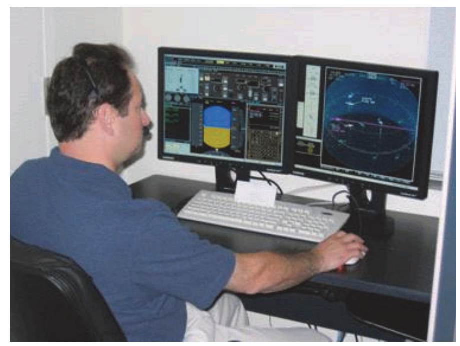

Figure 4: MACS pseudo-pilot HMI

2.2 Piloting with voice recognition

Major ATC (Air Traffic Control) systems companies offer pseudo-pilot positions associated with their simulators. Two of them, (UFA with ATVoice and ADACEL Maxsim) are characterized by the use of voice recognition and speech synthesis. They aim to replace the pseudo-pilot with a system able to recognize and execute the controller's orders: the virtual pilot's voice responses are carried out by a speech synthesis system. These systems work only in English and need to be adapted in order to properly recognize English pronounced by non-native speakers. They are not adaptable to our pseudo-pilots who use both French and English. While these systems may be attractive, they do not meet our requirements in terms of adaptability and realism: they do not provide the realistic interactions we need between humans because the controllers are limited to dialogues easily interpreted by the speech recognition system. Moreover, the controller's prosody and stress are not taken into account in the 'reaction' time of the pseudo-pilot, thus hindering the realism of the simulation. Controllers and pilots are required to use specific phraseology. Truillet and colleagues [15] in the 'Voice' project have used a speech recognition engine and set it up to take into account the context of air traffic and its limited phraseology to improve the speech recognition process. Prototypes of HMI using voice recognition to enter controller's orders to the system have been made with this system bearing in mind the need to keep the human operator in the loop.

	Controller view with Radar Image	CockpitView	Speech recognition (no view)
Existing pseudo-pilots	Electra [fig1] Scansim [fig3] Escape[fig2]	MACS [fig 4]	ATVoice (UFA) Maxsim (Adacel)

Table1: types of views in the existing simulators

2.3 Using the voice transformation

If voice recognition is commonly used in the industry, as far as we know, none of the products available on the market propose a dynamic voice modification of the pseudo-pilot as a function of the flight calling. This system has been developed for IIPP (Innovative Interaction for the Pseudo-Pilot) and Serrurier et al. [13] have shown that by modifying the voice of pseudo-pilots and mixing it with cabin sounds and noises, it was possible to considerably improve the 'sound' realism of the simulation for controllers. Indeed, a characteristic sound helps controllers to identify the aircraft faster. In addition, during the simulations, it has been shown impossible for the controllers to know how many pseudo-pilots were operating. This new sound environment, which is very close to the real situation, promotes greater immersion in the simulation.

2.4 Dealing with time

Interruption and context switching can be disruptive during day work, Hurter et al. [7] investigated these issues. The time and tasks management issues of a pseudo-pilot's activity are not addressed by existing interfaces. However a paper log helps the pseudo-pilot to execute scripted actions, and the radar image helps to monitor the aircraft's situation and trigger actions. The perception of task over time by anticipation helps to keep available cognitive resources [1] and activates the knowledge stored in long-term memory. Lini & al. [9] have addressed this topic in developing ASAP (Anticipation Support for Aeronautical Planning) for pilots.

3 IIPP: METHODOLOGY

This section details the tools and methods used to create this new pseudo-pilot position as well as its objectives. IIPP is being used on an existing ATC simulator dedicated to research for air traffic control. As such, it has undergone several changes depending on the experiments in which it has been used since its first functional version in 2004.

3.1 Design approach

IIPP design comes from an analysis of the activity of pseudo-pilots using simulators at ENAC (École Nationale de l'Aviation Civile) a university dedicated to teaching air traffic controllers, pilots and engineers specialized in air traffic management. Different releases of IIPP have been designed and built using the methodology of user-centered design (UCD ISO 9241-210:201 [8]). Participatory design sessions based on work scenarios consistent with the activity were carried out with pseudo-pilots and controllers. Paper prototypes were designed and evaluated using design walkthroughs [10]. Finally software versions were evaluated by testing users on realistic scenarios during many ATC experiments using our simulator.

By in-situ observations of users, task models and work scenario modelling the activity of pseudo-pilots were established. The studied simulators have a large number of functions, some of them - although only used exceptionally - dramatically increase the complexity of the interaction. The activity analysis has led us to select the most commonly used features to simplify the HMI as much as possible.

3.2 Objectives of the HMI

The activity analysis helped us to identify a set of usability criteria to design and evaluate our interfaces, grounding the ergonomic studies of Bastien and Scapin [1] in the pseudo-pilot context. Major criteria related to the task of pseudo-pilot are: confidence in the system, efficiency, ease of use, fast learning and perception of the task in time. The overall objective of this new working position is to focus on usability, efficiency and effectiveness. The two main design choices that we followed are, firstly, an interface optimized to minimize the actions to be taken while having the error rate as low as possible and secondly to synthesize information to increase awareness of context and thus reducing the cognitive workload of users.

4 ANALYSIS OF THE EXISTING: STEP 1

In this section, we describe and evaluate the first version of IIPP. This study was conducted on the basis of observations in a real context of use (5 experiments with observations and interviews with pseudo-pilots). The first version of IIPP, following the design cycle used a two-screen solution: a screen with a radar image (Figure 5, vertical screen) and a resistive touch screen (Figure 5 & 6, horizontal screen) used for entering orders and to display synthetic information.

Figure 5: IIPP V1

4.1 Study of visualizations

IIPP has five visualizations (Figure 6) always visible: the *flightlist*, the *agenda*, the scrolling selectors *box for orders*, the *flight display* and the *radar display*.

The *flightlist* displays the aircraft which are currently being managed by the pseudo-pilot and those which will enter the simulation in the next 20 minutes.

The *agenda* scripts the simulation. It allows the pseudo-pilot to anticipate operations to achieve in the next 4 minutes. It represents a time scale with labels (actions or orders to be done to realize the scenario) moving to the left over time until reaching the current time when the action has to be done. Instant objects can be created in the agenda when notifications from the TCAS system (anti-collision system) or CPDLC messages occur. It also allows him to see actions not taken on the second line with labels in red in Figure 6. The *agenda* materialized reification [4] of orders with an area which shows the last three orders entered (upper left corner of the *agenda*). Yellow labels are mandatory information given to the pseudo-pilot for the scenario and are displayed on the third line.

The *flightdisplay* is purely advisory; it provides current information on the selected flight (destination, flight plan, company, course, speed and flight level) and its design is based on instruments found in the cockpits.

The orders scrollbox allows controller's orders to be entered by using horizontal scroll selectors. Orders are sent by pressing the validation button.

The radar image (vertical screen) displays the current position of all aircraft in the simulation.

4.2 Study of interactions

All interactions are performed on the touch screen (Figure 6). The user must first select an aircraft (on the *flightlist* or with a label on the *agenda*), then inputs the controller's order (with the scrolling selectors box) in heading, altitude, speed and waypoint (geographic point referenced). The *scrollbox* displays multiple values for each parameter of the aircraft (Figure 7).

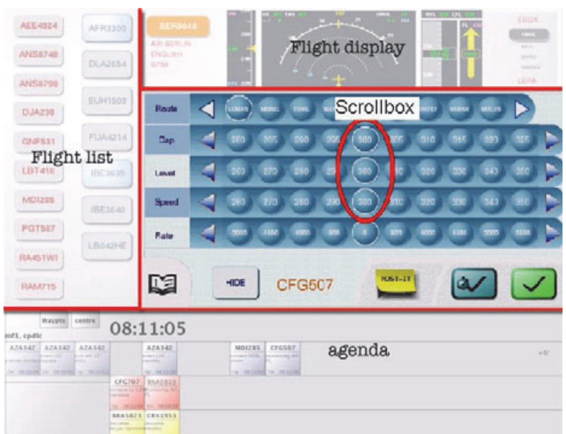

Figure 6: IIPP V1, horizontal screen

4.3 Conclusion on the use of IIPP

The use of IIPP during five experiments has allowed us to identify a set of drawbacks that hindered its effectiveness. These limitations have been grouped into three categories: interaction (INT), visualization (VIS), realism (REA).

The resistive touch screen is not sufficiently reliable, as users are sometimes forced to re-enter the command (false release, non-uniform calibration over the entire surface) (INT_P1). The touch screen does not allow the user to touch it outside the interaction which causes muscle fatigue (INT_P2). In case of heavy workload, input errors are caused when heading / level and / or speed have similar values in the scrolling selectors box (Figure 6 - all values set to 300) (INT_P3). The user must always validate input although he makes few errors - this reduces the efficiency of the interaction (INT_P4).

In case of high workload, it was observed that the visual scanning of the pseudo-pilot is reduced to the touch screen, so it seems to be possible to work without the radar image (VIS_P1), but the radar gives feedback control of the actions more clearly than on the current touchscreen HMI (VIS_P2). Information is redundant between visualizations (VIS_P3). For example: an aircraft entering the area may be on the radar but it is much more efficient to read it on the *agenda*. The user may waste time by not adopting the optimal strategy.

The radar image shows the context of aircraft that is useful to controllers and the instructor in charge of the exercise. By providing this tool to pseudo-pilots, they are given the opportunity to act as assistants to the instructors. This can be an obstacle to the realism of the simulation. In flight, the pilots don't have a radar image of the traffic but a relative view of it with the navigation display (REA_P1). Audio exchanges between the controller and all aircraft operated by a pseudo-pilot have the same voice and the radio quality is perfect which is unrealistic (REA_P2). Orders are sent immediately to the simulator, whereas the pilots in 'real life' execute the orders after a few seconds (REA_P3)

5 IIPP IMPROVEMENT: STEP 2

These limitations led us to start a new design iteration by taking into account the problems described above while evaluating the integration of change in voice and speech recognition in the HMI. Given the observations on the use of radar display during the experiments, it has been decided to remove it and rethink this version with a single interface screen containing all the necessary information (REA_P1, VIS_P1).

5.1 Technology change

Work scenarios were evaluated with several physical interactors to achieve controller's orders with an extended version for tactile and stylus interactions of the keystroke predictive model [5]. We compared the resistive tactile screen originally used with IIPP with a Wacom screen and a physical rotating button (powermate). The Wacom screen (21") using a stylus was chosen because predicted interaction time was twice smaller (i.e. for speed selection #2.2s vs 5.5s and 6.1s). Stylus is also more precise compare to finger and gives a low error rate compared to resistive touch screens false releases. Additional information can also be used from the pen (pressure / overview / tilt angle) (INT_P1). In addition, it uses a stylus, which means that you can touch the screen with the hand (INT_P2) without triggering interactions.

5.2 Improve the interaction

We performed two participatory design sessions with 13 people from R&D department at ENAC. Scenarii were inspired of pseudo-pilots activity, each group was asked to find relevant solutions to address these scenario using a wacom screen. This work led to a paper prototype and a HMI (figure 7).

The analysis of the use of IIPP v1 has shown that an interaction requiring the user to systematically validate the input takes time and is not necessary (INT_P4). To improve the interaction and discriminate interactors (INT_P3), all control commands are entered without final validation on an enlarged version of the flight display (Figures 7, 8) used in the previous iteration. To reduce errors (INT_P3), we tried to discriminate geographically the data to be entered; the speed is placed to the left, altitude to the right, heading to the center with an arc interactor. These three interactors can be used to scroll if the orders must be sent with values that are not displayed. A move in one direction causes the interactor to scroll values with inertial damping, if the gesture is faster, the values scroll faster. The fly-over information of the stylus was used to show selectable areas. The route of the aircraft is shown in the center (green line) of the *flightdisplay*, waypoints are materialized by a diamond icon, a click on a diamond trigger a 'direct to waypoint' order. Because *flightdisplay* interactions are done directly and without validation, it was necessary to propose a way to cancel the orders and data entry errors: the stack order has been added for this purpose (figure 8).

Figure 7: IIPP V2

The stack implements the principle of reification [4] of orders. Each order entered in the *flightdisplay* causes the fall of a label in the *order stack*. This label is the materialization of the order, it can be manipulated and removed from the stack during his fall in order to cancel it. The order is transmitted to the simulator only when it reaches the red line. The fall time of the label simulates the response time and performance of the real pilot (REA_P3). An order already executed can be cancelled by a drag and drop of the label present in the red line (historic threshold) to the outside of the stack. The color code represents the type of label information, yellow for a *flightdisplay* order, orange for an order recognized by voice recognition (detailed later), cyan for a reminder. Interaction and visualization details are provided in a video on http://iipp.recherche.enac.fr.

5.3 Improve visualization

A flight information panel (Figure 7) shows all current information concerning the flight and the orders previously entered. This synthesis was lacking in the previous version of IIPP (VIS_P2 and VIS_P3). It also allows to 'shoot' (i.e. transfer) a flight to the next sector when it leaves the pilot's field of interest, this action will remove it from the list of flights to manage. The information on this panel was previously present on the radar image, the *flightdisplay* and the scrolling selectors' box. *"Rappeler"* (i.e. call me back) was added to reduce the cognitive load of the pseudo-pilot; this button allows the pilot to be warned on the agenda when an aircraft passes a point on the road or a level when the controller requests it. This monitoring task was reported by pseudo-pilots to be very time consuming. With this functionality, they don't have to monitor aircraft's position or altitude anymore. *"Double"* is used to bind in time two controller's orders; it links like a macro two orders. The *agenda* has not been amended; however, the removal of the radar visualization means that additional information like aircraft first contact with the controller has to be inserted in the agenda (VIS_P2).

5.4 Improve the realism

During the simulations, controllers and pseudo-pilots interact with voice. In order to improve the realism of the simulation and make the controller believe that there are many pseudo-pilots, a voice modification application has been coupled with *flightlist* (REA_P2). Therefore, the pseudo-pilot must select the aircraft in the *flightlist* before talking. This is a significant change in the work method since previously they could speak freely without interacting on their HMI. *Voicemodifier* changes several characteristic of the voice and mixes it with the sounds of aircraft cabin noises. Serrurier and colleagues [13] have shown a real benefit of mixing voice and cockpit noise in terms of the perceived realism of the simulation for controller trainees.

5.5 Integration of voice recognition

From the brainstorming sessions, the use of speech recognition emerged as an additional modality to provide to the interface in order speed up the entry of orders.

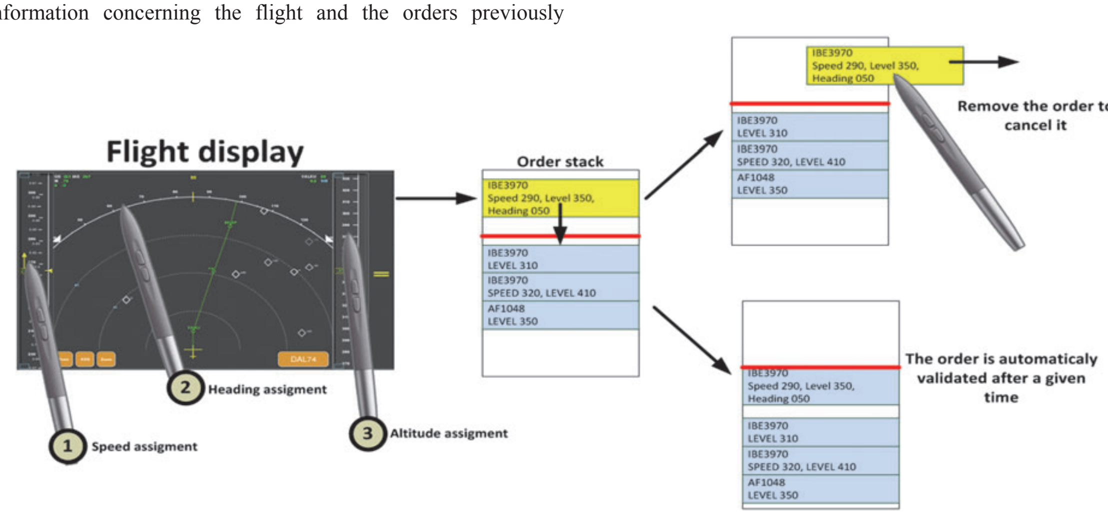

Figure 8: execution or cancellation of an order storyboard

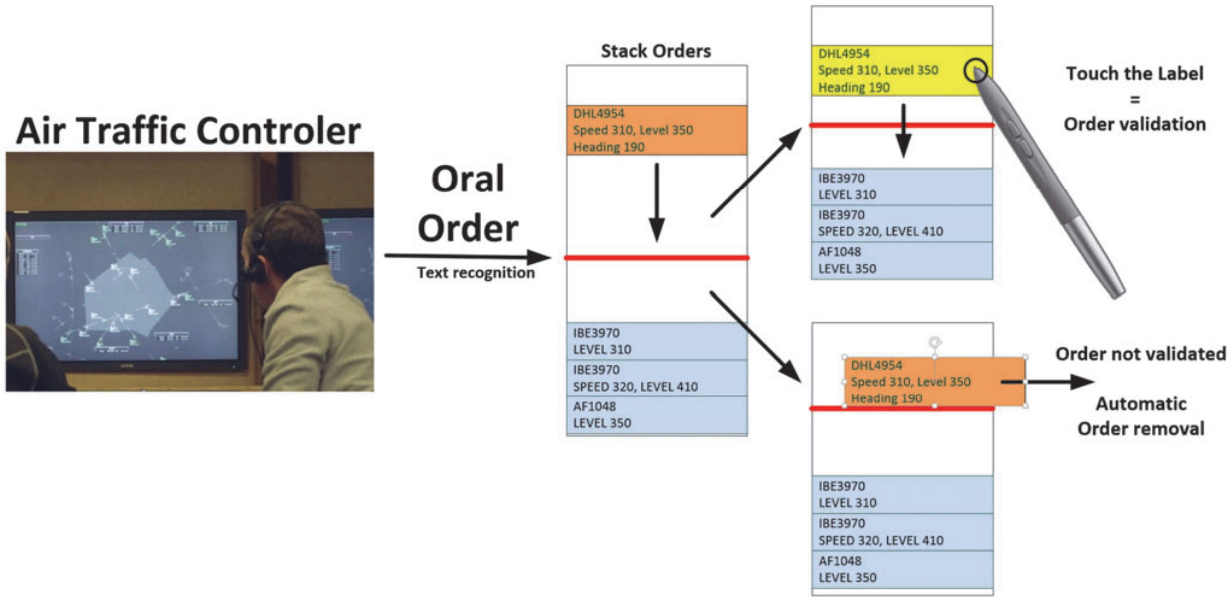

Figure 9: Validation or invalidation of voice order

The design choice was to offer a non-intrusive voice recognition service to the pseudo-pilot. Controllers in France speak on the radio in English and French using restricted aeronautical phraseology. To speed up the selection process of the flight and entry of orders on the *flightdisplay* a tool has been developed based on a grammar reduced to recognize both the callsign and simple commands (heading, level, speed, direct to a waypoint, shoot to next sector) in both languages. This tool uses the speech recognition engine provided in Windows7.

The context of the simulation and possible values for orders are taken into account to improve the voice recognition. The system recognizes orders only for aircraft currently in the pseudo-pilot area of interest. In order to improve the recognition rate, the choice in the engine's proposals is being made using the knowledge of the context. For example, flight levels can only be a multiple of 10 (i.e flight level 320, 330 etc), heading or speed a multiple of 5. Each sentence is analysed by two instances of the engine (English and French). The result with the best probability is chosen and sent to the *order stack*. The system was designed to operate without training so as to be easily usable with a diverse population of controllers. When an order is recognized, an orange label falls into the stack, if it is not touched by the operator, it is automatically destroyed when arriving at the red line, when touched it switches to yellow thus signifying a validated order (figure 9). Touching the recognized label causes the automatic selection of the flight and delivery of the order which improves the efficiency of the interaction.

The standard way for entering an order is to select an aircraft in the *flightlist* and select the order on the *flightdisplay*. This new interaction removes the process of visual scanning the *flightlist* for the aircraft and the search for the value on the *flightdisplay*. By touching the voice order on the *order stack*, the pseudo-pilot executes three operations at the same time. He selects the aircraft on the *flighlist*, executes the order and changes also the voice of the pseudo-pilot for the selected aircraft, allowing him to directly answer the controller with the correct voice.

6 Evaluation

This new interface was used in two validation sessions at the Bordeaux ACC for three weeks (2 weeks for the first one, one week for the last one). The main purpose of these experimentations was not to evaluate IIPP, but it was an opportunity to test the performance of IIPP in an operational context. Fifty simulations of a duration of 45 minutes each were made, behavioural data were recorded by IIPP. The exercise played in these simulations corresponds to a situation of high workload for the controller and therefore for the pseudo-pilot (53 aircraft in 45 minutes) with several conflict situations. A pseudo-pilot qualified on two types of simulators (en-route and approach) led the major part of the simulations. Three others pseudo-pilots did simulations, they all filled up a dedicated questionnaire about IIPP. Although the training time of pseudo-pilots on operational simulators usually takes a week, for these simulations, the training took place over two sessions of 45 minutes and they felt enough comfortable with the HMI. The CPDLC feature of IIPP was not used during these sessions because the controller working position did not support CPDLC.

6.1 Feedbacks

Four simulation experts from the ACC have reported, after observation of the simulation, that two pseudo-pilots would have been necessary to carry out the workload on operational simulators. This still remains to be validated by comparative tests between the different positions of pseudo-pilot on a calibrated exercise.

The pseudo-pilots reported during a debriefing session that they were initially unsettled by the lack of radar images. Even though they could perform the task in good conditions, they were able to use the IIPP HMI without the radar image after a short training phase. The radar image provides an overview of the traffic; with

IIPP, only the *flightlist* shows the aircraft managed by the pseudo-pilot. Following the remarks of pseudo-pilots, we added an additional information in *flightlist* to avoid changing the current flight to know in which ‘mode’ they are (following a heading, following the planned route or a direct route, climbing to a flight level…) in the APP version of IIPP. The requirement for the selection of an aircraft before speaking on the frequency changed the working method, a learning session of two exercises was not sufficient to fully take into account this change. The pseudo-pilots were positively surprised by the speed of handling of the interface and acknowledged that they had improved over time. The interaction with the stylus on a wacom device is proving to be very powerful since they succeeded in handling a high traffic workload. A large number of observations were made on the representation of information on the *flightdisplay* and feedback associated with actions and they led to the evolution of the prototype.

6.2 Impact of speech recognition

Two sessions were conducted. In the first one, 4,258 orders were sent to the simulator, 1,173 orders were made through voice recognition and 3,085 through the *flightdisplay*. The use of speech recognition on the overall activity of the pseudo-pilot was therefore about 27% which is rather low and related to the low recognition rate of the instructions. The simple orders heading / level / speed / direction are poorly recognized by the system (see Figure 10) and not systematically used by the operator. Only the ‘shoot’ action is done mainly through speech recognition (55%). No speed clearance has been properly recognized and after checking it was found to be a problem with the grammar used. A very detailed analysis of speech recognition results of requires listening to and transcribing all the simulations. Partial results show that the orders given in French were recognized in English with incorrect values and vice versa, so adjustment of the choice function was necessary. The French and English grammars’ and the choice function were modified between the two sessions. A voice recognized order is being sent by the engine when its probability is above a threshold; this threshold was raised on the second experiment to avoid incorrect orders. The decision to avoid the learning phase results in poor detection of spoken English with a French accent, otherwise in English, waypoints are usually pronounced like in French which raises an additional problem. During the second session, 1,390 orders were sent to the simulator, 819 were made through voice recognition and 571 through the *flightdisplay* which means that the voice interaction was used in 58% of cases (for both English and French orders) which is a great achievement. Despite the imperfections of the system mainly due to English spoken by non-native speakers, the positive impact of speech recognition is valuable. Fine tuning of the speech engine may improve the performance.

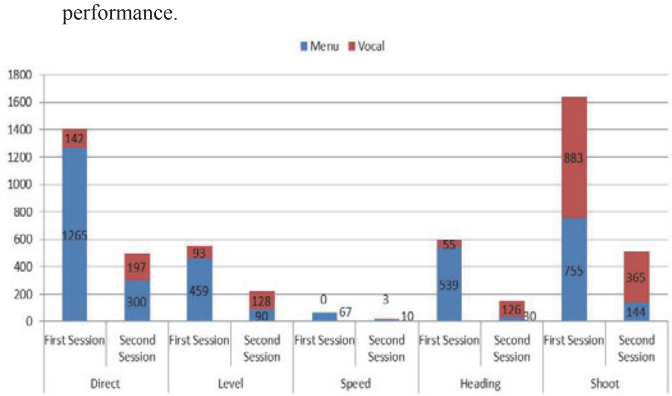

Figure 10 : Distribution of orders between voice and HMI order by category during the two sessions.

6.3 Impact of the voice change

As in the real situation, the 'radio' audio quality is not perfect; the controllers sometimes have to repeat messages to the pseudo-pilot. This has been criticized by some controllers who expected a perfect 'radio' in simulation. 16.5% reported it was a nuisance during their activity versus 67% found it did not represent a nuisance. 61% of controllers like the system as a significant contribution to the simulation environment, 7% think it does nothing and 32% have no opinion (over 50 controllers).

Changing dynamically the pseudo-pilot’s voice opens the way to the integration of cockpit simulators in ATC simulations. Without it, it would have been obvious to the controllers to identify aircraft piloted by a crew because of a unique voice for a single aircraft. If it is crucial for the objectives of the scenario that the controller cannot identify which aircraft is the cockpit simulator this system is mandatory (for example in TCAS Simulations). This is an innovative contribution for the domain of air traffic control simulation. This system has already been used in a platform where an Air Traffic Simulator was connected to an A320 aircraft simulator.

7 Discussion

Removing the radar view from IIPP was a considerable change in the working method for pseudo-pilots. Most of them think it is impossible to work without it, even after a demonstration of IIPP v2. Eradicating many years of activity and training with radar’s type HMI is a major challenge, but after only a few hours of usage, they can handle heavy traffic without it. User’s opinions can lead to conservative solutions that improve functionalities of an existing HMI without questioning past choices. The method we used for that purpose led us to dramatically different choices of conception. As far as we know, pseudo-pilot working positions in the industry systematically use the radar visualization; during this work we proved that it reduces the efficiency of the pseudo-pilot and impaired his ability to handle the same number of aircraft as controllers do.

IIPP has been designed bearing in mind Shneiderman’s [14] criteria : strive for consistency, enable frequent users to use shortcuts, offer informative feedback, design dialog to yield closure, offer simple error handling, permit easy reversal of actions, support internal locus of control, reduce short-term memory load.

Among them, offering simple error handling and easy reversal of actions provided by the *order stack* are a cornerstone of the pseudo-pilot efficiency. All orders are entered without modal interaction or validation process, this choice makes the interaction faster since it removes a validation phase without hindering error management because we provide a simple way to handle errors with the *order stack*. *Agenda* plays a great role in reducing the workload by giving an overview of the coming events. *Flightlist* and *flighdisplay* are our answer to consistency and informative feedback, they provide a homogenous and simple way of interacting with an aircraft, the sequence of actions lead to a label in the *order stack*. Shortcuts were enable for frequent users with the speech recognition engine and the *order stack*.

One of our objectives in creating this new design was also to improve realism; the voice modification process we integrated in the pseudo-pilot was done for this purpose. Even if we cannot prove that this new functionality improves the training process of the controllers, most of them think that it is an important contribution to immersion and realism. Nevertheless, this choice induces a cost for the pseudo-pilot because he has an obligation to select the aircraft before talking to have the correct voice modification applied. During the training process we observed many incorrect voice modifications due to fact that the pseudo-pilot did not select the aircraft on the HMI before talking.

The easy integration of voice recognition in the HMI has been possible because of the choice to create the order stack windows which materialize orders with labels. This specific voice recognition label is automatically destroyed without user validation. This neat design overcomes the weakness of the speech recognition engine giving the control to the user. Nevertheless, voice recognition in English for French speakers has yet to be more accurate to be considered a real improvement; otherwise it could be perceived as a nuisance.

8 Conclusion

In this paper, we detailed our work for the study and the improvement of a pseudo-pilot interface using a user centered approach. We also described how this approach led to radically change the pseudo-pilot HMI by removing the main display pseudo-pilot use in operational working positions and create a brand new HMI build to increase efficiency.

The proposed design tried to improve all Shneiderman's [14] criteria. The interface was perceived as easy and pleasant to use, the errors are rare and easily corrected and the learning curve was very short. Comparing the final design to the previous version of IIPP, several responses were offered to correct the defects. Direct interaction without validation improves the performance of the HMI, the discrimination of interactors has eliminated incorrect entries. Removing the radar screen and the flight panel introduced in v2 has shortened the visual circuit of the pseudo-pilot. The realism of the simulation is improved by the dynamic modification of the pilot's voice. The integration of speech recognition as a 'non-intrusive' mode in the interface appears to be a good choice. Despite the imperfections of the system, it has been used with a significant gain in terms of interaction time. The use of speech recognition is a promising start, no system currently operates simultaneously in multiple languages, and progress remains to be made to improve the performance in this area. Changing the pseudo-pilot's voice dynamically turns out to be an improvement for realism to the controllers and could open the way for a new type of simulation that will include cockpits without the radio bias in air traffic.

The new interface design allows the task of the pseudo-pilot in the ACC context to be done in good conditions while reducing the number of pseudo-pilots and improving the realism perceived from the controller's point of view. It has been used with success in several projects as an operational pseudo-pilot working position. Even with high traffic load, we never had to use more than one pseudo-pilot during the simulations; this will reduce operating costs in the future.

From a more general perspective, lessons learned during IIPP development could be applied to other supervisory and time critical HMI. Bearing in mind efficiency and realism, our approach led us to think differently and build a new visualisation paradigm. Iterative conception and evaluation cycles helped us to even improve the first version of IIPP and realize an efficient pseudo-pilot working position. 'Think different' when it comes to performance and realism could be generalized to other supervisory and time critical HMIs.

9 Greetings

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10 Future works

IIPP has been presented during World ATM Congress 2013 and is in the process of being connected to an operational simulator. A prototype of an APP oriented HMI is also being developed and connected to operational simulators.

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