A Deported View Concept for Touch Interaction

Alexandre Alapetite,
Henning Boje Andersen
Department of Management Engineering,
Technical University of Denmark
Produktionstorvet 424,
DK-2800 Kongens Lyngby, Denmark
{alal, hebq}@dtu.dk

Rune Fogh
Centre for Playware,
Department of Electrical Engineering,
Technical University of Denmark
Elektrovej 325,
DK-2800 Kongens Lyngby, Denmark
{rufo}@dtu.dk

Ali Gürcan Özkil
Department of Mechanical Engineering,
Technical University of Denmark
Produktionstorvet 426,
DK-2800 Kongens Lyngby, Denmark
{alio}@dtu.dk

***Abstract*—Following the paradigm shift where physical controls are replaced by touch-enabled surfaces, we report on an experimental evaluation of a user interface concept that allows touchscreen-based panels to be manipulated partially blindly (aircrafts, cars). The proposed multi-touch interaction strategy – involving visual front-view feedback to the user from a copy of the peripheral panel being manipulated – compares favourably against trackballs or head-down interactions.**

Keywords-HCI; Tactile interaction; Touch; Blind; Visual attention; Cockpit; In-vehicle systems

I. INTRODUCTION

There is a trend to replace physical controls (buttons, dials, switches, etc.) by touch-enabled surfaces with adaptive layout. Doing so provides some advantages but also some drawbacks such as the loss of convenient blind activation, where users "feel" controls with their fingers. To explore this problem, we have made a study of a "deported view" mode of interaction with touchscreens and we report the results of an experimental evaluation of the concept. This mode of touchscreen interaction can be particularly useful in aviation and automotive applications in which pilots and drivers may be required to maintain a head-up position for safety reasons.

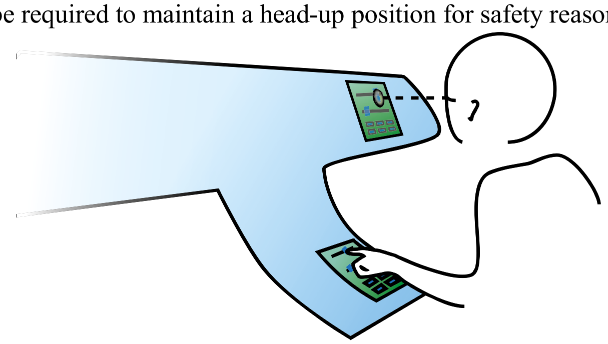

Figure 1. The "deported view" concept in a cockpit.

Figure 1 illustrates the proposed concept: When a user must operate (blindly) a control panel that lies outside his or her natural line of sight, the display area (being touched) will be temporally duplicated on a control screen area in front of the user. Simultaneously, a pointer is shown on the front display indicating the position of the user's finger. By doing so, the lower touch-display panel becomes an indirect pointing device somewhat similar to that of a track-pad.

II. STATE OF THE ART

The idea of implementing touch-based interaction in cockpits dates back to the "Super Cockpit" (US Air Force 1986) which contained a touch-enabled display system to provide *spatial awareness to the pilot in all directions and in three dimensions*. Furness investigated the system and the challenges it poses to the human factors community [1], focusing on *how should information be rendered in the "focal" versus "ambient" visual areas of the display*? NASA also investigated touchscreen input concepts for interaction with a large screen cockpit display as early as 1990 [2], comparing three input methods: thumball, thumb switch and touchscreen, to interact with a large, multi-window, "whole-flight-deck" display. While the thumball concept outperformed the others in simulator tests, it is acknowledged that *touch entry would be useful in transport environment, dependent on error-free operation*. Pilots emphasized the importance of positioning the touchscreen, suggesting that it should be placed so close to the throttle controls that the operator need not reach forward.

Touchscreens were then put into operations, first in military aircrafts such as the Dassault Rafale in 1991 [3]. Since 2009, Garmin [4] and others offer similar touch-based panels for commercial aviation. Kaminani [5] identified two unique interaction issues with touchscreen in cockpits, namely *touch activation and accidental touches,* and *fatigue due to extending arms to touch and reach.*

Similar work has also been done for automotive applications. Young et al. [6] research experiments on using touch interfaces for music selection in cars show how the participants' driving performance decreases and the amount of time drivers have their eyes off the road increases. A multi-touch interface implemented in a car's steering wheel was presented by Döring et al. [7], showing that gestural interactions can significantly reduce visual demand for non-critical interactions. Bach et al. [8] compared three different means of interaction (tactile, touch, and gestures) for in-vehicle systems in terms of efficiency and visual demand, finding that gestures reduce visual demands while touch interaction is most efficient. Although gesture interactions demand less visual attention [8], they are less useful for more complex environments with dozens of precise controls such as found in a cockpit.

 ISBN: 978-1-61208-250-9

The differences in performance between touchscreens and physical interfaces, such as a joystick or a stencil, have also been studied by Kadytė and Tétard [9], showing how applications such as navigating through menus were more efficient with touch devices than the joystick.

Using a touch display for remote control has been investigated for the television market. Han et al. [10] developed a remote control using absolute position on a touch display: the user's finger is detected by infrared when hovering over the remote, which is shown on the TV with a shadow of the finger (pointer). But the hovering concept was found more difficult and stressful than current remotes.

Turning to research into cognitive demands and input modalities, other studies have demonstrated the importance of spatial memory [11] and kinaesthetic cues for user interfaces. For instance, Tan et al. [12] have shown a 19% increase in spatial memory for information controlled with a touch-screen compared to a mouse interface. Similarly, Jetter et al. [13] found that multi-touch instead of mouse input improves users' spatial memory and navigation performance for user interfaces involving panning.

We would like to explore a variation of the concepts above in order to preserve some of the assets traditionally offered by physical interfaces, such as spatial memory, while migrating to touch-screen interfaces.

III. FUTURE AIRCRAFT COCKPITS

The main use-case for the concept presented in this paper is for future aircraft cockpits, as envisioned by the EU project ODICIS [14] on "One Display for a Cockpit Interactive Solution" (2009-2012, see Figure 2).

Figure 2. The ODICIS single-screen tactile cockpit.

It is the view of the ODICIS consortium [14], [15] that the next evolutionary step in cockpit design is to provide the crew with a large continuous, adaptive, multi-touch display that no longer is limited by the physical boundaries of adjacent displays. A single screen offers a more flexible design of the human-machine interface and therefore improved opportunities for providing the right information at the right place at the right phase of flight. Moreover, it offers optimised usage of the main instrument panel in terms of display space. Finally, prompted by novel design concepts in the consumer industry, new tactile technologies are introduced into the cockpit, offering more natural ways of interacting with controls, e.g., by allowing the locus of interaction to coincide with the locus of feedback [16].

The ODICIS concept aims to integrate the emerging tactile technologies into its single display concept. While offering new possibilities, it also raises many questions and potential pitfalls and, therefore, challenges in creating a design to make the most out of this new tool. One of the most salient drawbacks of the approach is the loss of tactile feedback of physical buttons and knobs [16]; hence, pilots will have to rely on other means of ensuring that they operate the intended control and in the intended way. This is especially true for those control-panels, which are located at the periphery of the pilot's centre of vision.

IV. THE "DEPORTED VIEW" CONCEPT

To compensate for the loss of tactile feedback, which can increase the amount of time spent on looking at the interface [6], the "deported view" concept makes use of the flexibility of having a large display (as ODICIS) and instantly duplicates the lower-positioned (or overhead) panel being operated, onto the front display and thus directly in front of the pilot. The feature is optional since pilots can choose to use it or not at any time.

In an aircraft cockpit, the surfaces available in the periphery of a pilot's vision (sides, above) provide important locations for controls and lamps, because many functions require direct access, and not everything can fit in front of the pilot.

The user's initial touch will activate the duplicate screen (the "deported view" panel) and show the area now initialized by the user's finger – like a mouse cursor. The "deported view" control panel will thus function both as a display and pointing device.

The proposed pointing device uses absolute positioning, differing from the relative positioning of a track-pad or mouse. This will allow a user to operate the panel looking either directly on the lower display or using the duplicate on the front display.

Using absolute positioning also means that users can use their spatial skills in order to increase efficiency. While the first finger controls the location of the cursor, clicking is performed with a tap of a secondary finger (Figure 3). In order to avoid inadvertent actions, the lower positioned control panels should not trigger any action when the first finger is just landing. This multi-touch approach creates a mouse-like interaction that should be efficient and robust to operate.

V. EXPERIMENTAL SETTINGS

We report an experimental assessment of a prototype that implements the "deported view" concept, compared with three other modes of interaction: a traditional touch interaction (in two different positions) and a trackball, all programmed with the Microsoft technology WPF (Windows Presentation Foundation). Ten participants were recruited (2 females, 8 males, all but one right-handed; mean age 24 years, range 20-27). The participants executed two tasks simultaneously (Figure 3).

Figure 3. The “deported view” experimental setup, with the operator using a second finger to perform a click.

The first task required participants to move sliders on a screen. The second task was a control task, which required them to respond as fast as possible and within three seconds to a randomly appearing visual cue, and which was introduced to prompt participants to maintain a head-up position as much as possible. Participants would receive points depending on the speed with which they completed each of the tasks, thereby using a game concept as motivation for being as fast as possible. A penalty was implemented for the control task to prevent users from clicking if no cue was presented, discouraging them from gambling when they were looking head-down at the control panel at their side.

Prior to the experiments, participants were trained for each setup until they reached a certain skill level (criterion level). The order of tasks and task training was randomly distributed among participants in order to balance out any effect of order of training, task familiarity, or fatigue. Each setup trial was performed for two minutes.

A. Detailed Description of the Tasks

(Cf. appendix for an explanatory video.)

1) Control Task (left hand)

The *control task* required the participants to respond to a visual alert, in the form of a red box on the left side of the upper monitor (see Figure 3). The alert appeared randomly at intervals ranging between 0.1 to 3 seconds, and was turned off by pressing any of the joystick’s buttons.

2) The Slider Task (right hand)

The program would randomly display one of two sliders on either the desktop screen, lower screen or both, depending on the setup. Participants had to pull the slider down as fast as possible to reach a highlighted area and then release it. When completed, the slider disappeared and a new one would be randomly generated. When the participants had completed three sliders, the program would wait three seconds before generating three more sliders.

B. Description of the Four Setups

1) The “Deported View” Setup

As described in the concept description, the lower multi-touch screen was used as remote input for operating the sliders. Users could look down but were instructed that it was more efficient to stay heads-up.

2) The “Direct Touch Desktop” Setup

In this setup the sliders were operated by the touchscreen on the desktop in a traditional touch manner. However, before the sliders were available on the desktop screen, the correct area must be selected on the lower screen by a single tap. This was done to simulate that a secondary control-panel was selected in a lower position, but operated in front of the participant.

3) The “Direct Touch Low” Setup

Participants operate the two sliders directly on the lower touchscreen and must thus look down to be sure to touch the correct areas.

4) The “Trackball” Setup

Similar to the “direct touch desktop” setup, the proper panel must first be clicked on the lower screen, (again to simulate that a secondary control-panel is selected) after which the slider must be operated by trackball. The trackball is located near the lower touchscreen (Figure 4), in a setup similar to what is found in some plane cockpits.

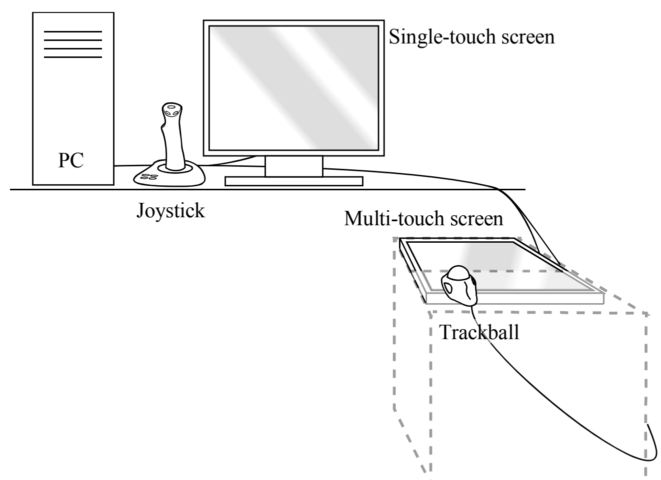

Figure 4. Illustration of experimental setup.

C. Data Collection

The participants’ performances were logged in a text file by the program during the experiments. The main performance indicator was the amount of time before the participants responded to the alert (“reaction time”), and how fast they completed the slider tasks (“completion time”).

VI. QUANTITATIVE RESULTS

The software R version 2.15 was used for the statistical analyses. First, an analysis of variance (ANOVA, within-subjects) showed that there was a strongly significant effect of the type of setup with regard to the “completion time” ($p<0.0001$), and “reaction time” ($p<0.0001$).

TABLE I. POST-HOC BONFERRONI-ADJUSTED PAIRWISE COMPARISON WITH P-VALUES FOR SIGNIFICANT DIFFERENCES.

α<0.05	**Deported view**	**Direct touch desktop**	**Direct touch low**
Direct touch desktop	Completion Time (p<0.004)	-	-
Direct touch low	Completion Time (p<0.0004) Reaction Time (p<0.0005)	Reaction Time (p<0.004)	-
Track ball	Completion Time (p<0.002)	Completion Time (p<0.0001)	Completion Time (p<0.0001)

A post-hoc Bonferroni-adjusted pairwise comparison was then conducted on the two dependent variables with a significant effect ($\alpha \leq 0.05$), as reported in TABLE I.

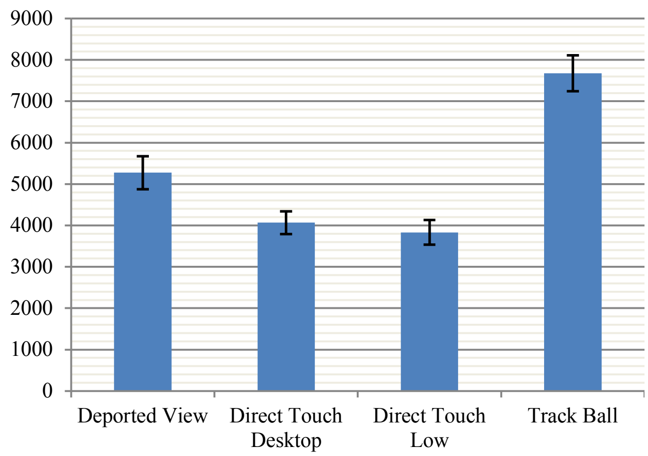

Figure 5. Average time (ms) for participants to complete the task of pulling the 3 sliders for the four different setups. Error bars indicate the standard deviation.

Figure 5 summarizes the results of the participants' average time of completion for pulling down three coherent sliders across the four setups. The average amounts of completed tasks (i.e., three sliders in a row) were: 14.5 for "deported view", 17 for "direct touch desktop", 17.7 for "direct touch low" and 10.9 for the trackball.

The "trackball" is by far the least efficient mode of operation (p<0.004, cf. TABLE I). The "deported view" concept ranks third, being considerably faster than the "trackball" (p<0.0004), while not quite as fast as the two direct touch setups (p<0.004).

Figure 6 summarizes the results of the participants' average reaction time to turning off the alert (the measure of head-up attention). The "deported view" and the "direct touch desktop" setups perform the best, and there is a significant difference (p<0.0005) between "deported view" and "direct touch low". However, there is no significant difference between "deported view" and the two other setups ("direct touch desktop" and "trackball").

Regarding the number of errors during the control task (pressing buttons at a wrong time, or no reaction within 3 seconds), no significant difference between the four setups was found.

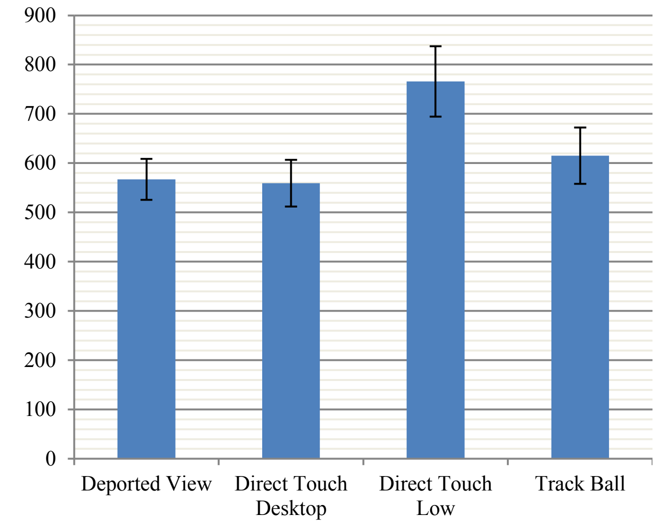

Figure 6. Average time (ms) for participants to react to the control task for the four different setups. Error bars indicate the standard deviation.

VII. RESULTS FROM QUESTIONNAIRES

The participants ranked the four setups according to their general preference and also according to the perceived stress experienced. The results are summarised in Figure 7, where the different setups received 0 points for being ranked last, 1 point for second last and so on up to 3 points.

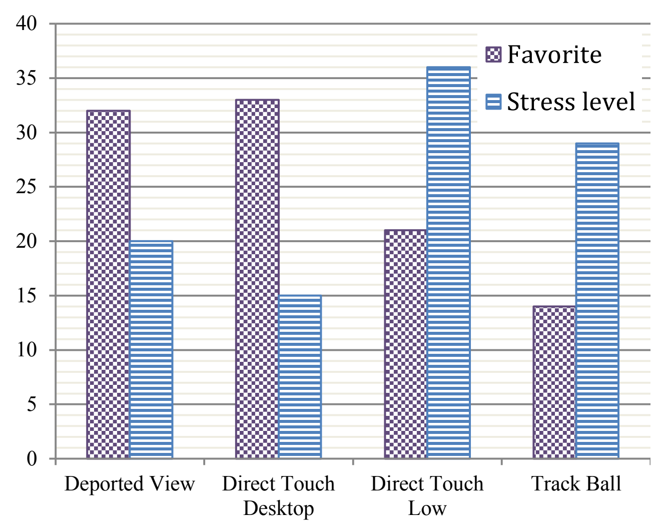

Figure 7. Ranking results from the questionnaire.

The "direct touch low" has the highest reported stress level, while the "deported view" and the "direct touch desktop" were globally preferred by the participants.

 ISBN: 978-1-61208-250-9

VIII. INTERPRETATION

The lower performances of the trackball (Figure 5, TABLE I, $p<0.002$) may be explained by the fact that a three-step manoeuvre is needed to start the task: first grabbing the trackball (which is smaller than the tactile areas), then move the ball to locate the cursor (not obligatory since the cursor is always visible and placed in the middle of the screen, but a natural behaviour), and finally operate the ball to move the cursor to the appropriate area. This manoeuvre is relatively more complex than with direct touch interaction, which allows these three steps to be performed at once. Although the participants were not familiar with trackballs, they had a chance to train before the experiments just like for the "deported view" and the other setups.

The lower operating speed of the "deported view" compared to the two "direct touch" conditions ($p<0.004$) can be explained by the fact that the "deported view" uses an artificial feedback (cursor), which both introduces some technical latency, and is more demanding for the user. The physical movements involved in the "deported view", while somewhat similar to a mouse, are not as natural as the "direct touch" ones. Furthermore it was clear that the participants were very accustomed to a relative positioned pointing device (such as a mouse or track-pad) compared to the "deported view" absolute positioning. Using this inappropriate mental model, the participants sometimes tried to move the cursor by moving the finger a bit forward, lifting the finger back to the original position and moving a bit forward again (see Figure 8), like with mouse when reaching the end of the mouse pad. With absolute positioning, this approach will not move the cursor onward but instead keep bringing it back to the start position. Further studies on the effect of using absolute position for an indirect pointing device should be investigated.

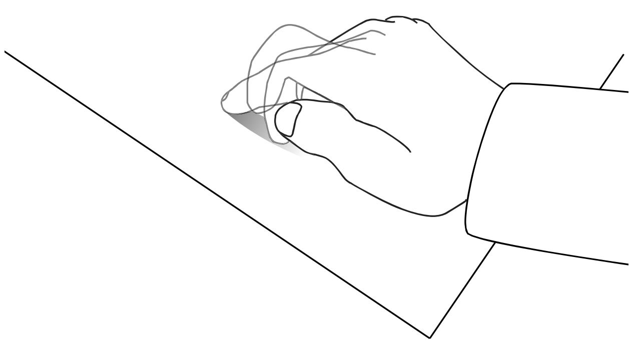

Figure 8. Typical beginner mistake of trying to move the cursor by repeatedly pushing, and lifting the finger back to the original location.

Regarding the reaction time (Figure 6), the fact that the "deported view" performed better than the "direct-touch low" ($p<0.0005$) setup is because participants could stay heads-up and therefore immediately notice the visual alert appearing on the upper screen.

IX. CONCLUSION AND FUTURE WORK

The results suggest that the "deported view" concept could provide an efficient and secure means for interacting with out-of-sight displays in e.g., automotive and aviation applications.

While the "deported view" design is slower to operate than a touchscreen directly on a front panel, it offers better ergonomics than the latter, as it does not require the user to have an arm in the air with ensuing fatigue [5]. In any case, it is not always possible to place all instruments directly in front of the user at all times due to space and ergonomic considerations. In this regard the proposed concept – temporally showing a secondary touch display in front of the user – may be helpful and safer. Finally, the proposed method proved to be intuitive, attracted greater preference rating and was more efficient than the traditional trackball (which is used in current aircraft cockpits), and resulted in better reaction times than head-down interactions. Anyhow, the concept is mainly meant to supplement and enrich future touchscreen-based solutions, not to replace or compete with other technologies such as haptic feedback, and in combination these solutions may very well benefit from each other to produce increased usability.

This interaction concept might also, we may speculate, be convenient in the tablet and gaming industry. With an increase in integration between TV screens and tablets, the "deported view" concept could provide a means for interacting with the TV screen on the tablet without looking down. In gaming, this could provide some of the many controls needed to play real-time strategy games – which normal gamepads cannot handle – or accessible menus when playing fast paced shooter games. These hypotheses are left for future studies.

While the results are promising, further investigation is required to assess human factors aspects of operational use in a cockpit environment, as well as the effect of different types of feedback such as haptic and auditory.

X. ACKNOWLEDGMENTS

The work presented in this paper has been carried out as part of the EU project ODICIS [14] on "One Display for a Cockpit Interactive Solution" (2009-2012), led by Thales Avionics (France) and partly funded by the European Commission's Framework Programme 7 under grant number ACP8-GA-2009-233605.

XI. APPENDIX

A video of the different setups presented in this article is available at:
http://alexandre.alapetite.fr/research/odicis/#DeportedView

XII. REFERENCES

[1] T. A. Furness, "The Super Cockpit and its Human Factors Challenges," Human Factors and Ergonomics Society Annual Meeting, pp. 48 -52, 1986. doi:10.1177/154193128603000112

[2] D. R. Jones, and R. V. Parrish, "Simulator comparison of thumball, thumb switch and touch screen input concepts for interaction with large screen cockpit display format," NASA Technical Memorandum; no 1025, 1990.

[3] P. Coni, L. Laluque, J. N. Perbet and J. Blanc, “Capacitive Touchscreen Under Electromagnetic Environment,” EuroDisplay’2011 conference, 2011.

[4] S. Pope, “Garmin G3000 brings touch screen tech to flight deck,” Avionics Magazine, 2009.

[5] S. Kaminani, “Human computer interaction issues with touch screen interfaces in the flight deck,” In Digital Avionics Systems Conference (DASC), 2011 IEEE/AIAA, 6B4–1, 2011. doi: 10.1109/DASC.2011.6096098

[6] K. L. Young, E. Mitsopoulos-Rubens, C. M. Rudin-Brown and M. G. Lenné, “The effects of using a portable music player on simulated driving performance and task-sharing strategies,” Applied Ergonomics, 43(4) 738-746, 2012. doi:10.1016/j.apergo.2011.11.007

[7] T. Döring, V. Gruhn, D. Kern, P. Marshall, M. Pfeiffer, A. Schmidt and J. Schöning, “Gestural Interaction on the Steering Wheel – Reducing the Visual Demand,” Proc. of the 2011 annual conference on Human factors in computing systems (CHI'2011), ACM, pp. 3033-3042, 2011. doi:10.1145/1978942.1979010

[8] K. M. Bach, M. G. Jæger, M. B. Skov and N. G. Thomassen, “You Can Touch, but You Can’t Look: Interacting with In-Vehicle Systems,” CHI’2008, pp. 1039-1048, 2008. doi: 10.1145/1357054.1357233

[9] V. Kadytė and F. Tétard, “The role of usability evaluation and usability testing techniques in the development of a mobile system,” NordiCHI’2004, 2004.

[10] J. Han, G. Lee N. Lee, S. Choi and W. Lee, “Remote Touch - Touch-Screen-like Interaction in the TV viewing Environment,” CHI’2011, pp. 292-402, 2011. doi:10.1145/1978942.1978999

[11] A. Cockburn and B. McKenzie, “Evaluating the effectiveness of spatial memory in 2D and 3D physical and virtual environments,” Proceedings of CHI'2002, the SIGCHI conference on Human factors in computing systems, 2002 doi:10.1145/503376.503413.

[12] D. S. Tan, J. K. Stefanucci, D. R. Proffitt and R. Pausch, “Kinesthetic cues aid spatial memory,” Extended abstracts of CHI'2002, conference on Human factors in computing systems. ACM, New York, NY, USA, 806-807, 2002, doi:10.1145/506443.506607.

[13] H. Jetter, S. Leifert, J. Gerken, S. Schubert, and H. Reiterer, “Does (multi-)touch aid users' spatial memory and navigation in 'panning' and in 'zooming & panning' UIs?,” Proceedings of AVI’2012, the International Working Conference on Advanced Visual Interfaces, Genny Tortora, Stefano Levialdi, and Maurizio Tucci (Eds.). ACM, New York, NY, USA, 83-90, 2012, doi:10.1145/2254556.2254575.

[14] ODICIS Web site https://odicis.org

[15] D. Z. Mangion, L. Bécouarn, M. Fabbri and J. Bader, “A Single Interactive Display Concept for Commercial and Business Jet Cockpits,” ATIO’2011, Conf. of the AIAA (American Institute of Aeronautics and Astronautics) on Aviation Technology, Integration, and Operations, 2011.

[16] A. Alapetite, R. Fogh, D. Zammit-Mangion, C. Zammit, I. Agius, M. Fabbri, M. Pregnolato and L. Becouarn, “Direct tactile manipulation of the flight plan in a modern aircraft cockpit,” Proceedings of HCI Aero’2012, International Conference on Human-Computer Interaction in Aerospace, Brussels, Belgium, 13 September 2012.