Tacsel: Shape-Changing Tactile Screen
applied for Eyes-Free Interaction in Cockpit

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Figure 1: The Tacsel concept providing shape-changing tactile screen. First image: a touch screen displaying a tree. Second image: a group of Tacsels emerging from each apple of the tree to provide eyes-free touch interaction. Third image: user interacting with one Tacsel. Fourth image: apple falling from the tree as a result from the touch interaction, the Tacsel disappears providing an eyes-free interaction as a robust feedback.

ABSTRACT

Touch screens have become widely used in recent years. Nowadays they have been integrated on numerous electronic devices for common use since they allow the user to interact with what is displayed on the screen. However, these technologies cannot be used in complex systems in which the visual attention is very limited (cockpit manipulation, driving tasks, etc.). This paper introduces the concept of Tacsel, the smaller dynamic element of a tactile screen. Tacsels allow shape-changing and flexible properties to touch screen devices providing eyes-free interaction. We developed a high-resolution prototype of Tacsel to demonstrate its technical feasibility and its potential within a cockpit context. Three interaction scenarios are described and a workshop with brainstorming and video-prototyping is conducted to evaluate the use of the proposed Tacsel in several cockpit tasks. Results showed that interactive Tacsels have a real potential for future cockpits. Several other possible applications are also described, and several advantages and limitations are discussed.

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Keywords

Tangibility, eyes-free touch interaction, shape-changing, cockpit control, complex system

INTRODUCTION

Touch screens have become ubiquitous in the last years. By and large, we are witnessing a paradigm shift where typical physical controls are being replaced by touch enabled surfaces on numerous devices of common use. These technologies enable the user to interact directly with what is showed on a screen by touching it through simple or multi-touch gestures. They have been adapted to different electronic devices due to their natural and direct interaction, comfortability, flexibility, low cost, etc. We find touch screens in a daily basis in cash machines and ticket-selling points at streets, in mobile phones, or in-home appliances such as washing machines or microwaves, to cite some. However, touch screens are not well suited to eyes-free interaction and cannot be used in dynamic environments subjected to vibrations and acceleration [24]. In addition, touch interaction provides poor sensory feedback and they cannot be applied to some activities involving simultaneous tasks since these technologies require complete visual attention and stable manipulation especially within complex systems. Indeed, the design of interactions within a complex system is challenging. A complex system involves many components which may interact with each other. It is common to say that a system is complex when Human is in the loop, otherwise, as much as sophisticated the system is, we can qualify it of "merely complicated ». The system we are studying is therefore of great interest in the context of a complex system. As said in [3], human system integration within complex systems requires more flexibility and new approaches including creativity as an integral part and where the functions of people and technology are appropriately allocated. For example, in a cockpit context a touch screen is difficult to manipulate in flight when severe turbulence occurs [24], in addition pilots require to manipulate several tasks in critical situations in which the visual attention time is very limited. Another example of complex system is in the case of driving task, where we observe a poor use of physical space related skill [9]. Using touch screen, the driver visual attention can be drawn away from the road and towards the screen easily. In recent years, advancements in robotics have brought the development of touch screen devices for use in medical surgery [14]. However, the requirement of visual attention can make the medical surgery task very complicated [14]. Finally, touch screen technologies are also difficult to be operated for the visually impaired. It is necessary to let these people know where they need to touch. A key point, therefore, is to provide eyes-free interaction in system. Despite numerous advantages supported by touch screen technology, a full touch screen system is not optimal and hence a process of tangibilisation must be undertaken.

In this article we introduce and explore the feasibility of introducing adaptable, shape-changing technologies in touch screen devices in the coming years. With this purpose, we have adopted a metaphor. In the same way "pixel" stands for the smallest element of a picture (picture element, for short pi(ct)el = pixel), we propose similarly "Tacsel", the smallest tangible element of a tactile device (tactile screen element, for short *tac* + *s* + *el* = Tacsel) that allows for a shape-changing tactile device, that means tangible touch screen. In our proposed approach, multiple Tacsels will be integrated into touch screens and will emerge according to the use context. In this way deformable and adaptable properties will provide eyes-free interaction to tactile devices. Several functionalities are envisaged such as providing relief to tactile surfaces, pressing a tactile button without looking at it, improve perception in tactile alarms, transform a tactile surface into a joystick, combining several buttons into a larger button that can be manipulated on the sides, etc.

The article is organized as follows: we begin by revisiting the related work. Then, the implementation of a prototype of the Tacsel concept is described. After, the potential of the proposed prototype is validated within a complex system (a cockpit). We explore and validate the possibilities of our proposal by describing three interaction scenarios and conducting a workshop involving different cockpit tasks. Finally, we draw several conclusions and point out future trends.

RELATED WORK

Several authors have proposed touch screen technologies with shape-changing and flexible properties. These technologies could be used to provide eyes-free interaction in complex tasks. Robinson et al. [21], showed that deformable displays, called emergeables, have a strong potential for on-demand, eyes-free control of continuous parameters. They showed the value and benefits of tangible controls -which "morph" out of a flat screen- in terms of accuracy, visual attention and user preference. Based on the previous work, Rosso et al. [22] proposed an extendable tangible slider to provide eyes-free and one-handed interaction on mobile devices. The tangible slider's knob extends to maintain the thumb's movement within its comfortable area. Pauchet et al. [17] introduce GazeForm, an adaptive touch interface with shape-changing capacity that offers an eyes-free interaction according to gaze direction. When the user's eyes are focused on interaction, the surface is flat and the system acts as a touch screen. When eyes are directed towards another area, a salient tangible control emerges from the surface. The proposed interface was implemented in a cockpit context where simple pilot tasks were simulated in an experimental study. An input technology that can be merged with a screen is FlexSense [19], a thin-film, self-sensing deformable surface that, based on printed piezoelectric sensors, can reconstruct complex deformations in a computer. However, there is major limitation due to its bulkiness. PAPILLON [4] is a technology for designing curved interfaces that can both display information and sense two dimensions of human touch. Some of the constraints of this technology is that images are in grayscale with low resolution. Rudeck et al. [23] proposed rock-paper-fibers which is a device functionally equivalent to a touchpad. However, each sensor element is composed of an optical fiber. By using a bundle of fibers, a user can reshape and deform it to enable different applications.

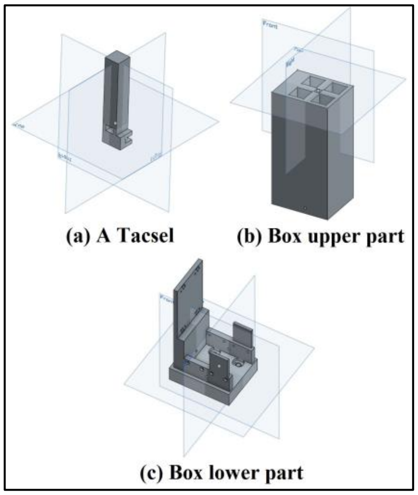
Deformable User Interfaces (DUIs) is a promising domain proposing new tangible and organic interaction metaphors and techniques. Researchers at the Nokia Research Center have developed a prototype of a mobile phone with bendable display and deformable back cover [1]. Yao et al. [27] proposed PneUI, which is a pneumatic system made by soft composite material that integrates both sensing and actuation mechanisms. Close to pneumatic systems are the hydraulic systems [26] since liquids are incompressible, the pressure and force obtained are quite high. Drawbacks on these systems are similar to those from pneumatic systems regarding uniform liquid distribution and fault tolerance. Dielectric-based devices are another type of systems with a good response time that can create Braille pins and vibratory devices. An interesting system is Teslatouch, by Bau et al. [2]. They developed a technology that, based on the electro vibration principle, provides tactile feedback in touch screens. However, its size is too large and the modulated electrostatic field, 10 kvolt, is quite strong for a comfortable use. DeFORM [7] is a digital tangible interface that allows users to imprint 2.5D shapes from physical objects into their digital models by deforming a malleable gel input device.~~,~~ Since it can recognize physical shape as well as pressure depth, authors advocate their use as a means to provide tangible controls. LineFORM [15] is a shape-changing interface to explore new possibilities for display, interaction and body constraint. This actuated curve interface is able to convey information and provide dynamic affordances according to its current shape. Leithinger et al. created inFORM [8], a shape display implemented as a surface with multiple actuators (pins) and sensors. The surface is able to render different shapes and provide dynamic feedback when the user touches it, such as vibration or elasticity. This provides great versatility, allowing for the creation of dynamic UIs such as handles, buttons, slides, etc., which react to touch or deformation. It has been used as well to provide physical telepresence by creating shapes that respond to a remote human controller. An evolution of the inFORM display was the TRANSFORM project [10]. This project challenged the conventional notion of static furniture design by providing three inform displays that could reshape a surface on demand.

Despite numerous touch screen technologies allowing shape-changing and deformable properties, most of these existing technologies have several limitations (bulkiness, complex materials, not enough flexibility, etc.) to be used in different contexts involving complex tasks. Inspiring by the state of the art and especially by inFORM our objective has been therefore to create a system small and lightweight, that could be adopted in different contexts.

DESIGN AND IMPLEMENTATION OF TACSEL

Based on this deep study of related work, we imagine a matrix of Tacsels as a flexible and shape-changing tactile screen. The biggest challenge of the high-resolution prototype is to design the technical functionalities, including shape-changing interfaces, combining actuators and sensors in a small form factor. Concerning the specification of the Tacsel, it should travel at a vertical distance large enough to be noticeable by the user, define to be 6cm. The Tacsel also be stable in a medium position, despite a pressure made by a user. It should also move at variable speed to demonstrate different scenarios, which is chosen to be between 1mm/s and 5mm/s. A prototype with one Tacsel has been designed in order to demonstrate the concept, its technical feasibility, its operationality and to test its potential. The vertical movement of the object is made with a micro gear-motor coupled with a threaded rod. A nut is incorporated inside the Tacsel which allows to move the object vertically when the motor shaft is rotating. The Tacsel is a parallelepiped rectangle (Figure 2(a)), integrated in a box of 16 cm high designed to incorporate 4 objects. This box has been designed in 2 parts: the upper part (Figure 2(b)), which covers the motors and guides the moving Tacsel; and the lower part (Figure 2(c)), hosting the motors and electronic devices. All these objects have been designed with the Onshape CAD tool and built with a 3D printer. A picture of the built prototype is shown in Figure 3.

In order to interact with the Tacsel, two sensors have been incorporated to the prototype. The first one is a position sensor, made with a linear potentiometer slider, measuring the exact position of the movable object. The second one is a motor current sensor, which allows to measure the electric consumption of the motor, thus to know if a pressure is made to the movable object. An electronic board has been designed to control the motors, collect information (thanks to the sensors), and communicate with other devices of the cockpit. The microprocessor used is an Arduino Micro.


(a) A Tacsel
(b) Box upper part
(c) Box lower part

Figue 2: The design of the Tacsel system

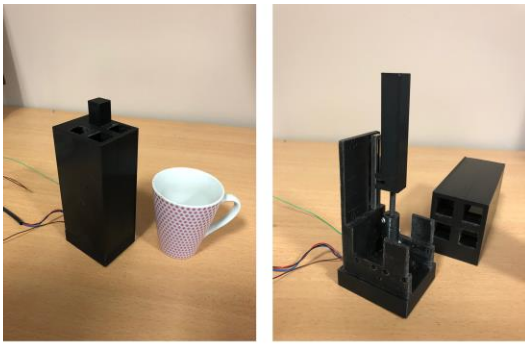

(a) With cover
(b) Without cover

Figure 3: High-resolution prototype: the Tacsel system

SOFTWARE ARCHITECTURE FOR CONTEXT AWARE INTERACTIVITY

We are interested in providing a more advanced, richer and eyes-free interaction to the user through context-based dynamic adaptation of tangible controls. In the proposed interaction, the touch screen management system must be able to emerge the necessary tangible controls according to the context of use and the respective situation. Tangible controls can be emerged from two situations: when the user performs a hand gesture event (e.g. open palm) on the touch screen; when the touch screen management system requires a specific intervention from the user. In both situations, the tangible element will provide the necessary tangible controls to the user when needed. Hand gesture events can be detected accurately by embedding to the touch screen small gesture recognition devices such as Leap Motion Controllers. These hand gesture events can then be sent to a particular tangible control designated by the context. Figure 4 presents the software architecture diagram of the proposed interaction. As shown in this diagram, a server module continuously receives the events generated by the touch screen management system and the hand gesture detection module. The server then emerges a tangible control, a Tacsel, that corresponds to the event received and the current context.

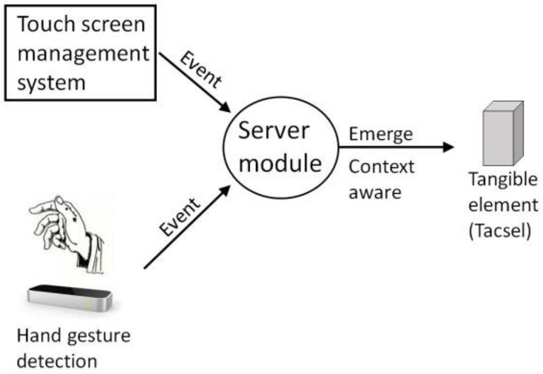


Figure 4: Software architecture diagram.

APPLICATION FOR AERONAUTICS

Future dematerialization of aircraft panels will allow us to foresee a more interactive, full-tactile cockpit in the dawn of 2035. The trend is towards the replacement of instrument panels by touch screens that combine both the input and output role [12,24]. However, touch-based interaction requires high demands on the visual attention in several cockpit tasks [25]. Tangible interaction technologies could improve the safety needed by cockpit tasks allowing eyes-free interaction and adaptability to dynamic flat cockpit environments [24]. The potential of tangible interactions embodied in flat cockpits have been explorer recently by [17]. These authors also address the importance of multimodal interaction to support the significant level of multitasking involved in pilot activities. Letondal et al. [11] explored how advanced interaction techniques (tangible, haptic, organic, etc.) could better support pilot flying and navigation activity. In 2016, Vinot et al. [24], studied how tangibility improves the safety of touch-based Interaction in the context of pilot system interfaces. They identified a set of design principles for touch based and tangible embodied interaction in the cockpit. A point of convergence of the previous work with Lorenzo and Couture [12], both in 2016. They both acknowledge the existence of similar cognitive requirements in current cockpits (performance in a degraded context, situation awareness, etc.). However, Lorenzo and Couture work's [13] starting point is the actual existence of a tactile cockpit and how to deal with the potential problems that might prevent its adoption. They proposed a set of 6 properties, from a usability point of view, that should be found in a tangible cockpit: free-form, interactive, morphable, reconfigurable, context-aware and eyes-free. Thereby, they envision a cockpit that, based on both existing and novel technologies, can convey information to the pilots by modifying their shape according to the context. Our proposition of Tacsel responds to all of the properties they defined. The aeronautical industry is not oblivious to this tendency, and so avionics manufacturers have been experimenting with prototypes of touch screen-based cockpits. Two main foreseeable benefits arise from the adoption of these tactile technologies. Firstly, manufacturers are addressing pilots that are still 5-year-old children. This means that they will grow up accustomed to the use of touch screens and many other types of tactile devices, and hence this type of interaction will be intuitive and efficient for them. Secondly, the multi-purpose nature and flexibility of a full software-based system will reduce both capital and operational expenditures, allowing for shorter development and-and-testing periods of newer cockpit generations. Of course, an interactive cockpit based on a continuous tactile surface presents several potential usability problems that must be addressed. Examples are the need for a good visual perception of the on-screen objects, a proper response to fine-motor skills, or hand comfort and palm detection on the touch screen [17]. There also exist important issues regarding the situational awareness and performance under degraded conditions that are caused by instability in a plane such as turbulences. These drawbacks have limited the adoption of tactile surfaces in the cockpit and, hence, have led to an understandable resistance from the aircrew to remove critical controls from their physical form. However, studies, in cockpits, indicate a clear performance advantage of touch systems accompanied by less workload when compared to, for example, trackball interaction [6]. So, while it is accepted that some issues exist, the idea of a tactile cockpit is to be kept at the expense of addressing their limitations. This is the reason why newer ways of interaction must be envisioned, and the idea of mixing the digital and the physical world leads us to the concept of a "tangible cockpit" with shape changing and flexible elements. Looking at the current evolution of the cockpit in the last sixty years, we observe how manufacturers have gravitated towards grouping the maximum number of related functions into a common display, as well as increased the number of functions and information available to pilots. To go further it is now important to design a cockpit where the pilot will be provided with an environment in which she does not have to distract her visual attention (i.e. looking at her hands) while she is performing any manual action. In this context, the cockpit must convey accurate learning and representation of information, perhaps not necessarily the same way as a visual display does but provided through physical contact.

User interaction scenarios

We have implemented three different interaction scenarios to demonstrate the potential of the proposed context-based interaction. Each scenario describes a different context or situation showing the eyes-free interaction provided by the emergeable tangible cockpit controls. For this demonstration, we have integrated in a simulated cockpit the Tacsel prototype described previously and a Leap motion controller. For each scenario, we have added to the Tacsel a different interaction device that will be emerged depending on the context of use. Each scenario is described in the following subsections:

First scenario: tactile display (applied to flight instruments)

Consider the scenario in which a pilot must read carefully the airspeed variation values showed in a screen during extreme turbulence conditions. While focused on the screen, the pilot must be able to maneuver correctly the aircraft speed in order to prevent the aircraft from being damaged. At the timing when the airspeed variation value changes abruptly, the pilot performs immediately a hand gesture in front of the cockpit (figure 6). Then, a Tacsel containing a small tactile display (smartwatch attached for testing) emerges from the cockpit directly to the position where the hand of the pilot is located (figure 6a). Using the context information (flight context), the Tacsel propose a tactile interface that allows reducing the aircraft speed. The pilot then touches the small tactile device to reduce the aircraft speed and preventing a possible damage in the aircraft (figure 6b). Finally, the Tacsel returns to its original position inside the cockpit.

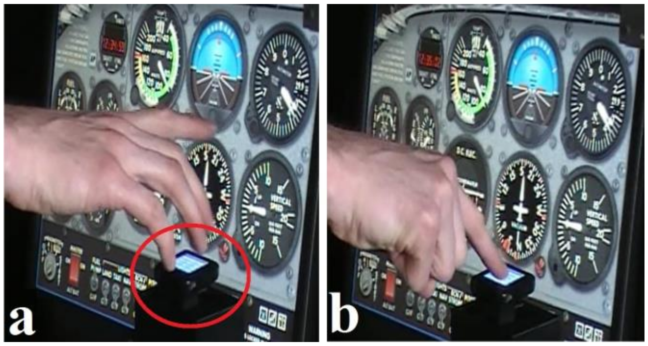


Figure 6: Flight context scenario. A Tacsel containing a tactile display (highlighted with a red circle) emerges when the pilot performs a hand gesture (a). The pilot uses the tactile device (b).

Second scenario: joystick interaction (applied to navigation instruments)

In this scenario, the pilot is guiding the aircraft toward a landing field. In this task, the pilot must use a yoke to control the plane's attitude. In order to ensure a successful landing, the pilot has limited time to adjust the airframe parameters using a specific joystick. While focused on the guiding, the pilot approaches his hand to any part of the cockpit (figure 7a). Then, using the context information (navigation), a Tacsel containing the specific joystick emerges near the location of the pilot's hand (figure 7b). The pilot then manipulates the joystick to adjust the airframe parameters. Finally, the joystick returns to its original position inside the cockpit.

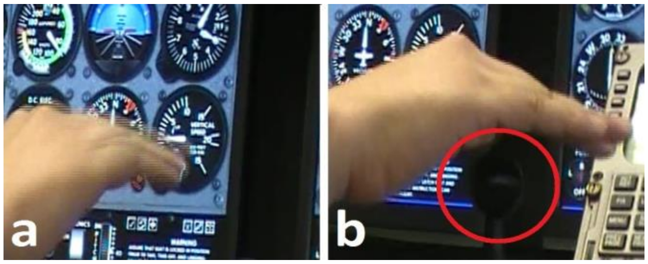


Figure 7: Navigation context scenario. A Tacsel containing a joystick control (highlighted with a red circle in image b) emerges near the pilot's hand (b). The pilot then manipulates the joystick (c).

Third scenario: battery contact activation (applied to systems management)

In this scenario, the pilot is focusing all his attention in landing the aircraft. At the same time, he must perform four necessary tasks to shut down correctly the engine system (figure 8). At the moment when each task must be performed, a Tacsel containing a switch button emerges from the cockpit near the pilot is located (figure 8a). The pilot then notices the Tacsel and proceeds to press the switch button that activates the specific task (figure 8b). Finally, the Tacsel containing the switch button returns to its original position inside the cockpit.

Figure 8: System management context. The system knows that the pilot must activate the battery contact.Therefore, a Tacsel containing a switch button (highlighted with a red circle) emerges near the pilot (a). The pilot notice the Tacsel and immediately press the switch button (b).

VALIDATION OF THE CONCEPT

In order to validate the potential of the Tacsel concept, and of its technology within a cockpit, we conducted a workshop. The aim of the workshop was to verify if the concept is, indeed, a good candidate for the design of a shape changing and flexible cockpit, or, in other words, if the Tacsel is able to inspire new metaphors of interaction for cockpit's usages.

Procedure

We invited 18 participants (4F, 12M, age around 23 years old), to take part in 2 half-day sessions. All of them were knowledgeable about aeronautics and human-computer interaction in cockpits. Two of them are pilots. In order to stimulate idea generations, we used the method of creating video-prototypes. The video-prototypes were introduced by Mackay [13] to illustrate by video how users will interact with a new system. The goal is to refine a single system concept, making design choices that highlight and explore a particular design path. The technique appears similar to video-brainstorming. Both involve small design groups who work together to create and interact with rapid prototypes in front of a video camera. Both result in video illustrations that render abstract ideas concrete and help team members communicate with each other. Both use paper and pencil prototypes or cardboard mockups to simulate the technology. The critical difference is that video-brainstorming expands the design space, by creating a number of unconnected collections of individual ideas, whereas video-prototyping contracts the design space, by showing how a specific collection of design choices work together in a single design proposal.

During the workshop, the video-prototypes was built upon a number of design resources created in two earlier design exercises (also included in the workshop process): brainstorming at first and then cyber physical system design. Therefore, the workshop took place in 3 stages.

Results

Stage 1: 64 concepts generated

After the brainstorming, 37 concepts in first group and 27 in the second group, 64 in all, were generated and written on paper board. All of them illustrate a usage in a cockpit of the interactive Tacsels.

Stage 2: 3 Concept-Designs (CD) generated

During the cyber physical (or mecatronic) design session, 3 concepts (among the 64) were explored by 3 groups of 6. **[CD1] Fly-Pilot** is both an actuator and an instrument that indicate the attitude of the plane for the control. It is designed using Tacsels, with those characteristics: 6 cm. of amplitude maximum, speed of movement (vertical): 2cm/s, rounded Tacsels (without edges). The system consisting of 5x8 pimples, which are organized in a rounded shape (like the top of a mouse to correspond to the hand, Figure 10). The system must bear a force exerted by the hand posed without pressing. The system embeds pressure sensors to know when user pushes on the Tacsels in order to modify the position of the plane and position sensors to visualize and give the information in real time). **[CD2] breakdown of the artificial horizon** is for the pilot to obtain quickly and easily an alert in case of road converging with a relief, according to its route and its position. This system is tangible, this means that it will be able to interact physically with the pilot. In the case of a collision route, the Tacsel associated with the ground will rise to signify the alert. The pilot will then be able to press this Tacsel and receive the information on the obstacle on a related screen. Mechanical technical considerations: given an anticipation of 5 mm between the display and the actual terrain, it is not necessary to have a quick lifting movement of the Tacsels in case of alert. Thus, we consider a movement of an amplitude of 5 cm in 10 s, 5mm/s i.e. 5 revolutions/s with a screw thread of 1mm. A power sensor will allow to perceive the push on the Tacsel that have triggered the alert. The information relating to the obstacle will then be displayed on a screen. **[CD3] Tangible Interactive Radar** is to indicate to the pilot the location of other aircraft within a radius of 80 kilometers. The pilot's plane is at the center of the radar and is marked with a blue color. The other planes are red or green if communication between the two devices is established. To establish a communication with a device visible on the radar, it is enough for the pilot to touch the top of the representation. The radar shows the altitude of the other planes relative to the ground and proportionally to that of the radar of the aircraft. The maximum height is 15cm (representing 10 kilometers in reality) A refresh of the positions is carried out all in real time. Technical considerations: the radar has a diameter of 20 cm. and a maximum height of 15 cm. Touch surfaces (tactile sensors or pressure sensors) are present on the top of the Tacsels allowing the selection of aircraft for communication. Inside the Tacsels there are two leds (one red for the position of the other devices and one green to know with which one communicates). The maximum lifting speed of the Tacsels is 1 cm/s.

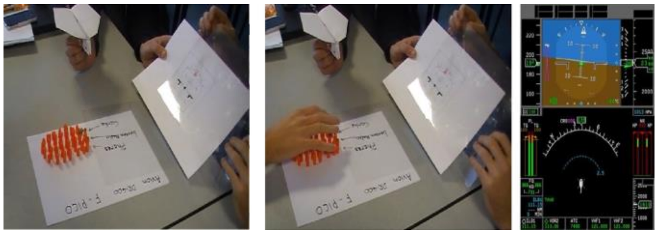


Figure 10: Video-prototype F-PICO. First image: beginning. Second image: using by moving hand with Synthetic Vision System (SVS) feedback. Third image: real SVS.

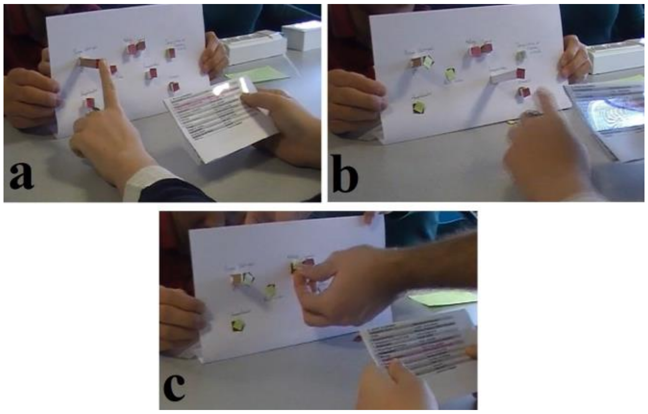


Figure 11: Video-prototype CHECKLIST: (a) beginning with all buttons on red and the first button of the checklist emerges, (b) the checklist takes place some buttons turn to green, (c) change sticker from red to green.

Stage 3: 2 video-prototypes generated

Then, in two groups of 9, participants constructed low fidelity prototypes and then used them to realize the two video-prototypes. They begin with a title card that includes the name of the system, the date and the list of each team's name. Their use narrator voices to explain, at first, and after, to play the situations as it happens in cockpit. Team members can play with low fidelity special effects. For example, record a user pressing a button; change round sticker from red to green (Figure 11c). The two simulations are very convincing. First one was called **[VP1] F-PICO** (1'27"), it goes further in order to simulate the first concept above (Fly-Pilot). Second was called **[VP2] CHECKLIST** (1'32"), it simulates the checklist before take-off (Figure 11).

The results of the workshop, their number and their richness, show that interactive Tacsels have a real potential in terms of use in cockpit.

DISCUSSION AND CONCLUSION

We proposed a concept of system, called Tacsel, that provides eyes-free interaction with touch screens. To the best of our knowledge, this is the first concept that combine tactile screen and tangible interfaces for eyes-free interaction by shape-changing of the display. Since no fully general theory of complex systems has emerged, we must design complex systems in domain-specific contexts. This is what we have done this study within the aeronautical domain.

We tackle the problem by considering the main task to be capturing, rather than reducing the complexity of the interaction system following the advice "do not substituting complexity with simplicity" of D. Norman [16]. We started this paper by justifying the need for a tangibilisation of the touch screens due to the adoption of tactile technologies for different tasks. Then, we review existing technologies that could provide shape changing and eyes-free interaction to tactile technologies. We propose a hardware design in small form factor that proof the technical feasibility of deformable display. We implemented the functional prototype in interaction with gestures of the hand (connect with a leap-motion). Two different interactions are proposed using this prototype: 1) tangible controls can be emerged with hand gestures (open palm) or context-aware. 2) user can interact directly with a Tacsel by touch or joystick manipulation. According to Rasmussen et al. [18], the level of control offered to the user over a shape changing interface can be performed in four different types: 1) directly controlled by the user's explicit interactions; 2) negotiated with the user; 3) indirectly controlled by the users actions; 4) fully controlled by the system. In our prototype the first and the fourth type of interaction is proposed by implementing three interaction scenarios in a cockpit manipulation context. The proposed interactions allow three different types of feedback behavior: 1) if the Tacsel emerges, the Tacsel tells the user to perform an action by touching it. 2) if the action was validated, then the Tacsel disappears and the user knows that the action was correctly done without necessity to look at it. 3) if the action was not validated the Tacsel remains and the user knows that there was a problem with the action by looking the behavior of the Tacsel. These interactions allow to develop adaptive and responsive tactile interfaces.

We also conducted studies that show the generative power of this concept and the adhesion of future designers. These studies proved the potential of a Tacsel based system for shape changing cockpit and validate the generative power of Tacsel in term of usage.

Our system could be improved by using the direction of the gaze. For example, if the user is looking at the touch screen then the touch screen would remain flat, otherwise shape-changing deformation would be created on the touch screen, this has been explored for aeronautics in [17]. In addition, if the surfaces on the 4 sides of the Tacsel become tactile then new way of interactions would be possible. For example, a Tacsel would behave as a kind of miniature Cubtile [20], an interaction device allowing the manipulation of 3D models. Another key element to consider in the Tacsel is the shape transition. In this case, the shape changing properties of the tangible interface during the actuation could be studied according to the context of usage. For instance, the speed of actuation was studied by [5]. We plan, specifically, to study the changing phase. Is an instant transition better than a gradual transition? Our next step is to multiply the Tacsels in a Tacsel matrix system and then to focus on experimentation of the Tacsel system embedded in a cockpit simulator such as ODICIS [28] for several scenarios. Finally, we can inspire from new technologies to evolve the Tacsel toward a more flexible tangible element. This would allow to adapt the Tacsel more easily to different tasks such as driving and medical surgery.

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