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Design and evaluation of braced touch for touchscreen input stabilisation

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ABSTRACT

Incorporating touchscreen interaction into cockpit flight systems offers several potential advantages to aircraft manufacturers, airlines, and pilots. However, vibration and turbulence are challenges to reliable interaction. We examine the design space for *braced touch* interaction, which allows users to mechanically stabilise selections by bracing multiple fingers on the touchscreen before completing selection. Our goal is to enable fast and accurate target selection during high levels of vibration, without impeding interaction performance when vibration is absent. Three variant methods of braced touch are evaluated, using doubletap, dwell, or a force threshold in combination with heuristic selection criteria to discriminate intentional selection from concurrent braced contacts. We carried out an experiment to test the performance of these methods in both abstract selection tasks and more realistic flight tasks. The study results confirm that bracing improves performance during vibration, and show that doubletap was the best of the tested methods.

1. Introduction

Commercial aircraft cockpits currently make extensive use of computer displays for system output to the pilot, and input is separately provided through a wide array of devices, including joysticks, trackballs, dials, switches, levers, and buttons. In contrast, through the use of touchscreens, input and output could be co-located, offering several potential advantages for aircraft manufactures and operators. In particular, cockpit flight systems could be updated by modifying the touchscreen user interface, without the prohibitive expense of reconfiguring and rewiring hardware cockpit panels. Other touchscreen advantages include reduced space and weight, as well as potential for eased operation. Consequently, many commercial and military aircraft manufacturers are investigating touchscreen interaction in the cockpit (ARINC661, 2016; Komer et al., 2013; Mark Fletcher, 2010; Zammit-Mangion et al., 2011).

Air turbulence and other causes of aircraft vibration, such as taxiway roughness, are a challenge for the potential use of cockpit touchscreens. When using physical controls, the pilots' hands are stabilised through contact or grip, but touchscreens do not offer equivalent means for mechanical stabilisation, causing errors. A previous study of touchscreen interaction during simulated turbulence showed that users relied on the bezel edge surrounding the touchscreen for hand stabilisation during vibration (Cockburn et al., 2017), as shown in Fig. 1. Users spanned their fingers to targets from the bezel, keeping some fingers on the bezel while one digit reached to the displayed content (typically the index finger or thumb). A firm grasp on the bezel improved accuracy, although this sometimes required awkward hand postures (e.g., Fig. 1d).

Although spanning the hand from the bezel edge can improve stabilisation, it has several important limitations. First, on large displays many areas of the touchscreen will be inaccessible via spanning. For example, if the fingers are placed on the top bezel edge as shown in Fig. 1b, then the thumb will be unable to reach targets that are further than ≈ 13 cm from the top of the display. Yet large displays are desirable in the cockpit to accommodate concurrent subsystem display (e.g., the F-35 Lightening II includes a 50 × 20 cm touchscreen, and larger sizes would be desirable in passenger aircraft). Second, stable bezel edge bracing often requires moving the hand into awkward postures (e.g., Fig. 1d). Third, users may be forced into completing selections with non-preferred and sub-optimal digits because their fingers/thumb are dedicated to stabilisation (e.g., Fig. 1b). Fourth, certain

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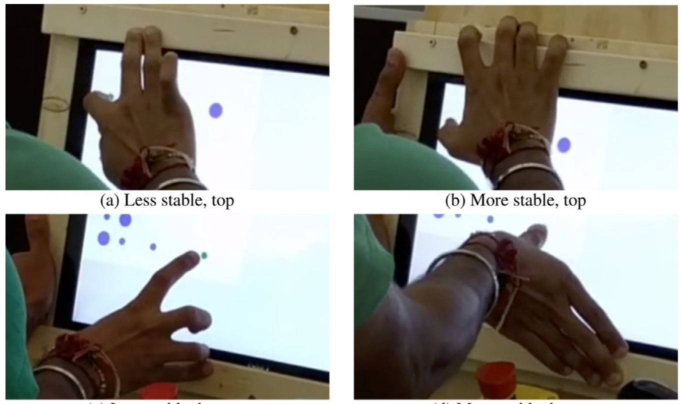

(a) Less stable, top (b) More stable, top
(c) Less stable, bottom (d) More stable, bottom

Fig. 1. Bezel edge bracing at top and bottom of the display. Left, less stable grasps; right, more stable grasps.

forms of interaction are largely incompatible with bezel edge stabilisation – for example, pinch-to-zoom may be impractical when multiple fingers are grasping the display edge.

One obvious reason that users rely on the bezel for stabilisation is that it is not part of the touch-sensitive surface – users currently have no option for stabilisation other than to use areas off the touchscreen, because placing their fingers on the touchscreen would lead to unintended selections or interface actions. However, the multi-touch sensing capabilities of touchscreens could enable new forms of interaction that allow stabilisation through hand-bracing on the touch surface itself, as suggested in Fig. 2.

This paper describes the design and evaluation of new touchscreen interaction methods that allow the user to achieve mechanical stabilisation by bracing multiple fingers on the touchscreen before completing selection with further contact information. By allowing users to place stabilising fingers onto the display surface, we intend to overcome the four limitations described above – the full area of the touchscreen is available for interaction; the need for awkward postures is substantially reduced; the user is free to complete selections with whichever digit they prefer; and the full range of touch interactions are possible. Furthermore, the braced interaction methods that we describe are designed to be compatible with non-braced counterpart methods, allowing users to make selections that are mechanically stabilised during turbulence, while also allowing for unstabilised normal interaction during level flight.

After reviewing prior research on touchscreen selection methods, cockpit touchscreen systems, and vibration tolerance, we present a design framework analysing design considerations for braced touch, leading to a description of three candidate methods that differ in the criteria used to determine completion of a selection gesture – doubletap, dwell, and force threshold. We then describe our three experimental tasks, which were used to compare performance and preference with braced and unbraced selections with the three methods. All three tasks were conducted in conditions of no vibration and high vibration using a motion platform. The first task examined braced and unbraced performance during a batched sequence of target selection activities using a method similar to the ISO 9241-9 Fitts' Law standard Soukoreff and MacKenzie (2004). The second task examined performance during simulated in-flight tasks that involved responding to warnings concerning the auxiliary power unit (these tasks were adapted from the training manual of the Airbus A350). The third task again used abstract target selections, but with the selection hand returning to the flight stick between selections, and with subjects free to choose whether and how to brace their hand during selection.

Results showed that during vibration, bracing significantly reduced selection times in comparison to unbraced selections. The doubletap selection method was much faster, more accurate, and preferred to the dwell and force-threshold selection methods, and when using a bracing

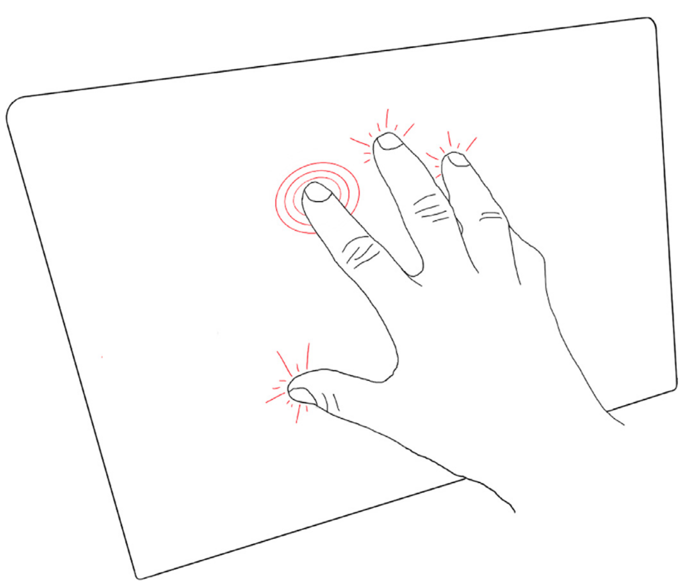

Fig. 2. Finger bracing. The hand is stabilised by placing multiple digits onto the touchscreen. Selection criteria such as doubletap or force threshold then determine the action required to select an object.