Tactile Information Presentation in the Cockpit

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Abstract. This paper describes two aspects of the application of tactile information presentation in the cockpit. The first half of the paper discusses why the tactile channel might be used instead of, or in addition to, the more common visual and auditory channels. It lists several categories of information used in cockpits and explores their appropriateness for tactile stimulation. The second half of the paper briefly describes an experiment on the perception of vibro-tactile stimuli under high G-load conditions (in a centrifuge). It is concluded that the perception of vibro-tactile stimulation on the torso is not substantially impaired during high G-load conditions, at least up to 6G.

1 Why We Should Use Tactile Information Presentation in Cockpits

The tactile channel is a relatively neglected information channel in display research, also in cockpit displays. Worldwide only a few groups have current research programmes in this area (e.g., see [2], [3], [4]). Visual displays dominate the design of cockpits, and auditory displays are increasingly being used as well. Tactile displays, however, are virtually absent in cockpits. Nevertheless, there are many situations in which the tactile channel can become an important or even vital alternative, because the visual (and/or auditory) channel is not available, not adequate, or overloaded (e.g., see [2]). Some relevant considerations (some more speculative than others) are:

∀The enormous amount of information that is available to the pilot is offered primarily in a visual format. The limits of the visual processing capabilities of pilots constitute a real design constraint in the development of new cockpits.
∀The view on the outside world in a cockpit (field-of-regard) is generally and obviously limited, because only a part of the cockpit is transparent. Systems that use forms of indirect sight (such as camera-monitor systems) can be used to overcome this limitation, but always have a restricted instantaneous field-of-regard.
∀High G-loads, such as experienced in fighter jets, can severely degrade visual perception. Maybe tactile perception does not suffer from this problem.
Visual information can be hard to interpret, e.g., when representing 3D spatial information on 2D visual displays. Presenting such information to the skin might reduce those interpretation problems. The surface of the skin is a 2D surface like a visual display, but unlike such a display it is also a closed manifold embedded in a 3D space (sphere topology), and can therefore be used to represent part of the 3D spatial relations directly, namely, directions in 3D space.

Pilots commonly experience visual and visual-vestibular illusions, some of them resulting in disorientation. It is conceivable that tactile stimulation could support the pilot in recognising the occurrence of such illusions and in avoiding their negative effects on performance.

Visual attention is usually restricted to a single entity (with the exception of moving objects). Thus, tracking multiple visual information sources in parallel is probably limited. How this translates to the tactile modality (and multi-modality) is not exactly known, but there are some indications that tactile attention may be directed to more than one location concurrently.

The above considerations are really examples of the earlier mentioned arguments for using tactile instead of, or in addition to, visual/auditory stimulation: non-availability, inadequacy, and processing overload. Another dimension along which this problem needs to be studied is the type of information that is suitable for presentation via the tactile channel. At least four relevant categories of information present in cockpits can be identified:

1. Geometric information: the projection of spatially organised information on a spatially organised medium. Major examples are:
   - Directions in 3D space. Waypoints, other aircraft, targets, etc., can all be characterised by a direction in 3D space. These directions change rapidly when the pilot moves through the environment. Information of this type could be presented continuously, when the pilot asks for it, or could be used as a cueing/warning system (e.g., see [1]). See figure 1.
   - Reference frames. An artificial horizon can be represented in the tactile modality by stimulating those parts of the torso that form the intersection of the torso with the actual horizon. See figure 2.
   - Borders in the sky. Borders in the sky can originate from airspace rules (restricted areas, minimum height, etc.), from course restrictions (tunnel-in-the-sky) or course planning, from missions (e.g., dropzones), and probably from many other causes. When such borders are interpreted as surfaces in 3D space, pilots can be made aware of them by appropriate tactile stimulation during approach (e.g., tactile stimulation of the relevant side of the body with increasing intensity or frequency upon approach) and passing (e.g., similar to the type of stimulation suggested for indicating reference frames) of such surfaces.