Discrimination of tactile rendering on virtual surfaces

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Introduction

An array of vibrating contactors on the fingertip can provide information about virtual objects during active exploration of a virtual environment – for example, information about contact area, edges, corners and surface texture. For the operation of such a device, it is necessary to generate in real time an individually specified drive waveform for each contactor of the stimulator array. To reduce the complexity of the problem, a system has been developed at Exeter in which each drive signal is specified as a mixture of a small number of sinewaves.

The aim of this study is to investigate the discrimination of the virtual textures which can be produced in this way, with the aim of developing a library of textures for use in virtual reality applications. Textures produced by mixtures of sinewaves are differentiated in terms of the mean amplitude and the spatial distribution at each sinewave frequency. Experimental questions include the number of categories (i.e., frequency/amplitude/spatial combinations) that can be distinguished and the possible correspondence between virtual and real textures.

Apparatus

The tactile stimulator used for this study (Figure 1) is a device developed for the HAPTEX project on virtual textiles (Allerkamp *et al*., 2006), and is an evolution of an earlier system described by Summers and Chanter (2002) and Summers *et al*. (2001). Vibrotactile stimulation is provided by a 6 × 4 array of contactors with 2 mm pitch. Each contactor is driven by a piezoelectric bimorph. Each bimorph is under independent computer control, with a drive waveform specified as a superposition of up to eight sinewaves. (Only two sinewave components are used in the present study: 40 Hz and 320 Hz.) The amplitudes of these sinewaves are obtained from a software map – a virtual tactile "landscape" – written at a resolution of 1 mm. Data on absolute position within the 2D workspace are provided by an A4 graphics tablet (Wacom Intuos 3) and passed to the stimulus generation software at an update rate of 40 Hz. The A4 workspace is mapped to a window on a monitor, as shown in the inset to Figure 1. The visual representation is at 1:1 scale with the tactile workspace.

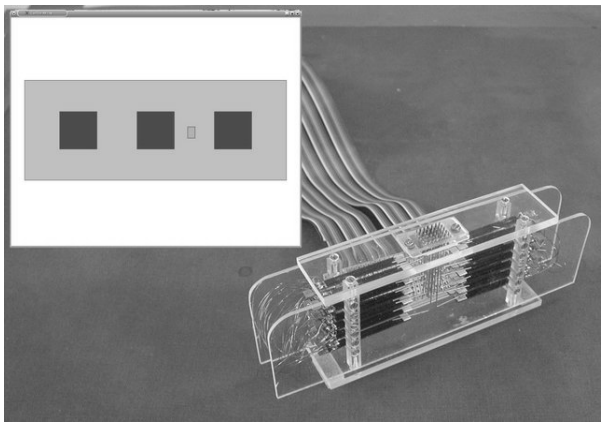

Figure 1. The tactile stimulator. The 24 contactors are central on the upper surface. In the inset screen shot, the tactile cursor which represents the stimulated area is visible between two of the square targets.

Experimental protocol

The 2D workspace is available for free, active exploration by the test subject. It contains three square targets, each 40 mm × 40 mm. When the tactile cursor lies outside the target areas, no vibratory stimulation is delivered to the fingertip. When the cursor lies within a target, the fingertip

is presented with a texture, specified by an amplitude map for 40 Hz stimulation and an amplitude map for 320 Hz stimulation. Two of the targets have the same texture and the remaining target has a different texture. The experimental protocol is an "odd-one-out-from three" task, intended to measure the subject's ability to discriminate the two textures.

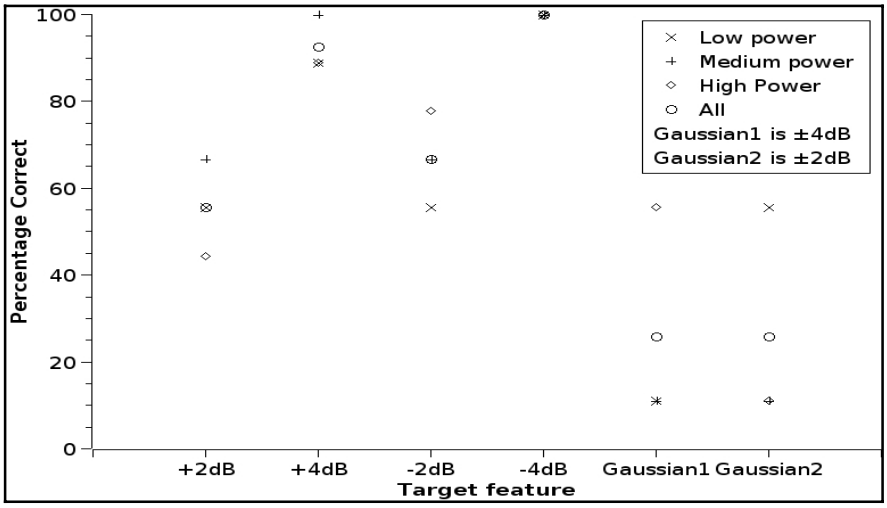

Figure 2. Scores (% correct) for discrimination of the textures within the three square targets. For each of the three settings of overall stimulus intensity, data are shown for the four amplitude contrasts and the two spatial contrasts.

At the time of writing, experimental work is under way for the main part of this study. Limited data are presently available from a pilot study. In the pilot study, stimulation was at 40 Hz only, and the target specifications were:

(a) uniform amplitude distribution within each target, contrast in overall amplitude of 2 dB or 4 dB; odd-one-out at – 4 dB, – 2 dB, + 2 dB or + 4 dB;

(b) same mean stimulation level within each target, contrast between uniform amplitude distribution and non-uniform distribution (Gaussian, range ± 2 dB or ± 4 dB).

Nine subjects (five female, four male) attempted the discrimination task, which was repeated at three different settings of overall stimulus intensity, differing by 4 dB steps.

Results and Discussion

Mean scores (percent correct identification) over the nine subjects are shown in Figure 2. Data for the amplitude contrasts show scores close to 100% for the 4 dB contrast and scores well above chance (33%) for the 2 dB contrast. For the spatial contrasts, inexperienced subjects mostly scored at chance but high scores were obtained by more experienced subjects (i.e., those with significant previous experience of tactile-perception experiments). The experienced subjects made more use of exploratory motion, and reported that the odd-one-out (always non-uniform) felt "rougher" than the others. In the absence of exploratory motion, a target with small amplitude variations over its surface appears to be indistinguishable from a target at the same mean level with uniform amplitude.

References

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