# Tactile Arrays for Virtual Textures

Submitted by Alan Christopher Brady, to the University of Exeter as a thesis for the degree of Doctor of Philosophy in Physics, September 2010.



I certify that all material contained in this thesis which is not my own work has been identified and that no material has been previously submitted and approved for the award of a degree at this or any other university.

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# Abstract

This thesis describes the development of three new tactile stimulators for active touch, i.e. devices to deliver virtual touch stimuli to the fingertip in response to exploratory movements by the user. All three stimulators are designed to provide spatiotemporal patterns of mechanical input to the skin via an array of contactors, each under individual computer control. Drive mechanisms are based on piezoelectric bimorphs in a cantilever geometry.

The first of these is a 25-contactor array (5 $\times$ 5 contactors at 2 mm spacing). It is a rugged design with a compact drive system and is capable of producing strong stimuli when running from low voltage supplies. Combined with a PC mouse, it can be used for active exploration tasks. Pilot studies were performed which demonstrated that subjects could successfully use the device for discrimination of line orientation, simple shape identification and line following tasks.

A 24-contactor stimulator (6 $\times$ 4 contactors at 2 mm spacing) with improved bandwidth was then developed. This features control electronics designed to transmit arbitrary waveforms to each channel (generated on-the-fly, in real time) and software for rapid development of experiments. It is built around a graphics tablet, giving high precision position capability over a large 2D workspace. Experiments using two-component stimuli (components at 40 Hz and 320 Hz) indicate that spectral balance within active stimuli is discriminable independent of overall intensity, and that the spatial variation (texture) within the target is easier to detect at 320 Hz that at 40 Hz.

The third system developed (again 6 $\times$ 4 contactors at 2 mm spacing) was a

lightweight modular stimulator developed for fingertip and thumb grasping tasks; furthermore it was integrated with force-feedback on each digit and a complex graphical display, forming a multi-modal Virtual Reality device for the display of virtual textiles. It is capable of broadband stimulation with real-time generated outputs derived from a physical model of the fabric surface. In an evaluation study, virtual textiles generated from physical measurements of real textiles were ranked in categories reflecting key mechanical and textural properties. The results were compared with a similar study performed on the real fabrics from which the virtual textiles had been derived. There was good agreement between the ratings of the virtual textiles and the real textiles, indicating that the virtual textiles are a good representation of the real textiles and that the system is delivering appropriate cues to the user.

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