Evaluation and Optimization of a Multi-Point Tactile Renderer for Virtual Textures

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

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Matthew Philpott

October 21, 2013

Abstract

The EU funded HAPTEX project aimed to create a virtual reality system that allowed a user to explore and manipulate a suspended virtual textile with the thumb and index finger. This was achieved through a combination of a tactile renderer on the fingertips for surface textures and a force feedback system for deformation of the virtual material.

This project focuses on the tactile rendering component of this system, which uses a tactile display developed at the University of Exeter. The 24 pin display is driven by piezoelectric bimorphs. Each of the pins can be driven independently, allowing for a variety of different sensations to be transmitted to the fingertip.

The display is driven by rendering software that uses a spatial spectrum of the intended surface, in combination with the frequency response of touch receptors in the skin, position on the surface, and exploration velocity to produce a signal that is intended to recreate the sensation of exploring the surface texture. The output signal on each of the 24 contactors is a combination of high (320 Hz) and low (40 Hz) frequency sine waves.

In this project, the tactile renderer is initially evaluated based on its ability to recreate the sensations of exploring particular textured surfaces. The users were asked to rank virtual textures in order of similarity to a real target texture. The results of the initial test were disappointingly low, with a 38.1±3.1% correct identification rate. However, feedback from this initial test was used to make improvements to the rendering strategy. These improvements did not give a significant improvement in identification (41.3±1.6%).

Finally, the tests were repeated with a target virtual texture instead of the real one used in previous tests. This test yielded a higher identification rate (64.1±5.5%). This increase in identification suggests that the virtual textures are distinguishable but that they not always accurate recreations of the real textures they are mimicking.

Acknowledgements

When I started this project in 2009, having completed my MPhys in Astrophysics, I had minimal knowledge of haptics as an area of study. For me, the subject had mostly been an interesting curiosity but not something I had ever seriously looked into. However, when my PhD supervisor, Doctor Ian Summers, offered me the opportunity to work in this field, I found it hard to resist. The chance to dive into something almost completely new, connected to such a wide variety of subject areas such as Biology and Psychology, yet still not be completely out of my depth, thanks to my previous programming and scientific knowledge, was something I could not pass up.

Over the course of this project, Ian has been a great help to me. His ability to find solutions and new approaches to problems never ceases to impress me. I am grateful to him for the initial offer of this project and the support he is given me throughout.

Several other people also helped to make this project what it is today. My thanks go to Doctor Dennis Allerkamp, whose PhD work with the HAPTEX project created the original rendering software that was the starting point for this project. His help and documentation when I was first starting was a great help in my understanding of the renderer's code. I also want to thank Alasdair Allan for helping me while I was struggling with compiling the renderer's firmware. Without him, I would probably still be working on that now.

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> "When you are studying any matter, or considering any philosophy, ask yourself only: What are the facts, and what is the truth that the facts bear out. Never let yourself be diverted, either by what you wish to believe, or what you think could have beneficent social effects if it were believed; but look only and solely at what are the facts."
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> *(Bertrand Russell, BBC Interview on "Face to Face", 1959)*

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List of Acronyms

AHRC	Arts & Humanities Research Council
CNS	central nervous system
CoV	coefficient of variation
DAC	digital-analogue converter
EP	exploratory procedure
EPSRC	Engineering and Physical Sciences Research Council
FA	fast adapting
FAST	Fabric Assurance by Simple Testing
FFT	Fast Fourier Transform
HAPTEX	HAPtic sensing of virtual TEXtiles
IC	integrated circuit
IDT	interdigital transducer
jnd	just-noticeable difference
KES-F	Kawabata Evaluation System for Fabrics
MDS	Multi-Dimensional Scaling
MLE	maximum-likelihood estimate
NP	non-Pacinian
P	Pacinian
PNS	peripheral nervous system
PZT	Lead Zirconate Titanate
RAM	random access memory
root-sum-square	root of the sum of the squares
SA	slowly adapting

SAW	surface acoustic wave
SMA	shape memory alloy
USB	Universal Serial Bus
VR	virtual reality
warp	vertical
weft	horizontal