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

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

Submitted by Matthew Philpott, to the University of Exeter as a thesis for the degree of Doctor of Philosophy in Physics, October 2013.

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(Signature)..

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."
>
> *(Bertrand Russell, BBC Interview on "Face to Face", 1959)*

Contents

1 Introduction 18

2 The Sense of Touch 21

2.1 Psychophysics . . . 21

2.1.1 Just-Noticeable Difference and Weber's Law . . . 22

2.1.2 Psychometric Measures . . . 22

2.1.3 Multi-Dimensional Scaling . . . 23

2.1.4 Perception of Objects . . . 23

2.2 Biology of Touch . . . 25

2.2.1 Human Nervous System . . . 26

2.2.2 Mechanoreceptive Afferents . . . 29

2.2.3 Perception of Fine Textures . . . 31

2.2.4 Frequency Response . . . 31

2.3 Haptic Perceptual Spaces . . . 32

2.4 Summary . . . 38

3 Tactile Rendering Device 40

3.1 Existing Devices . . . 40

3.1.1 Electrostatic Display . . . 41

3.1.2 Piezoelectric Devices . . . 42

3.1.3 Rheological Fluid Display . . . 43

3.1.4 Electroactive Polymer Displays . . . 43

3.1.5 Ultrasound Display . . . 44

3.1.6 Surface Acoustic Waves . . . 44

3.1.7 Shape Memory Alloy Displays . . . 45

3.1.8 Electrocutaneous Display 45
3.1.9 Pneumatic Display 47
3.1.10 Electrovibration Display 47
3.1.11 Shear Force Display 48
3.2 The Tactile Rendering Setup 49
3.2.1 Principles of Operation 49
3.2.2 Tactile Display 53
3.2.3 Driving Electronics 56
3.2.4 Rendering Software 61
3.2.5 Texture File Creation 70
3.3 The HAPTEX Project 78
3.3.1 Overview of System Development 80
3.3.2 Physical Simulation 82
3.3.3 Force Feedback 83
3.3.4 Tactile Renderer 83
3.3.5 Evaluation 85
3.4 Improvements to Renderer 89
3.4.1 Direction of Motion 89
3.4.2 Textile Frequency Range 90
3.4.3 Modifications to Amplitude Calculation 90
3.4.4 Filter Modifications 91
3.4.5 Amplitude Scaling Factors 92
3.4.6 Buffering Calculated Amplitudes 94
3.4.7 Contactor Surface Area 95
3.4.8 Dynamic Range and Spectral Balance 95
3.4.9 Summary of Modifications 97
3.5 Summary 98

4 Characterisation of Renderer 99
4.1 Characterisation Strategy 100
4.2 Characterisation of Experimental Renderer 101
4.3 Comparison with HAPTEX Renderer 110

4.4 Characterisation of Scaled Texture Files . . . 111
4.5 Summary . . . 115

5 Public Demonstration **116**

5.1 Demonstration Environment . . . 117
5.2 Demonstration Setup . . . 118
5.3 Feedback . . . 121
5.4 Summary . . . 127

6 Virtual Texture Evaluation **128**

6.1 Experimental Design . . . 129
6.2 Experiment 1 . . . 131
6.3 Experiment 2 . . . 141
6.4 Experiment 3 . . . 148
6.5 Perceptual Dimensions . . . 153
6.6 Experienced Users . . . 157
6.7 Summary . . . 157

7 Conclusions **161**

7.1 Summary of Thesis . . . 161
7.2 Overview of Project Conclusions . . . 163
7.3 Discussion and Future Work . . . 164
7.4 Potential Applications . . . 166

Appendices **168**

References **168**

A Texture Database **177**

B Spectra of Texture Files **189**

C Chance Result Derivation **190**

D Ethics Application **193**

E Additional Discriminability Plots **196**

List of Tables

2.1 Comparison of different mechanoreceptor types based on their receptive field sizes and adaptation rates 30

2.2 The four mechanoreceptor populations, their sensitivity ranges, and their associated functions 33

2.3 List of the car seat material samples and their main characteristics 34

2.4 Co-occurrence matrix showing the number of participants who grouped specific pairs of stimuli together 35

2.5 Correlation coefficients between each adjective scale and each dimension of the MDS texture space 37

2.6 A comparison of the sensory perceptual spaces suggested in the literature . 38

3.1 The characteristic values that are output by the KES-F 73

5.1 Results of the survey conducted to gather feedback about the tactile renderer installation 125

5.2 Results of the survey conducted to gather feedback about the presented facsimiles 126

6.1 The recorded details of the eight subjects who participated in experiment 1 132

6.2 The sample set used in experiment 1 132

6.3 Cumulative scores for matching real and virtual textiles in experiment 1 . . 135

6.4 The number of subjects that chose the virtual textiles as their first choice match to the target textile 139

6.5 The sample set used in experiment 2 141

6.6 The recorded details of the eight subjects who participated in experiment 2 141

6.7 Cumulative scores from experiment 2 for matching real and virtual textiles 143

6.8 Dissimilarity matrix generated from the results of the second experiment, measuring dissimilarity between each real textile and the 16 virtual textile . 145

6.9 The recorded details of the eight subjects who participated in experiment 3 149

6.10 Cumulative scores from experiment 3 for matching virtual textiles 149

6.11 Dissimilarity matrix generated from the results of the third experiment . . . 151

6.12 The one- and two-dimensional solutions to the Multi-Dimensional Scaling . 154

6.13 Comparison of the correct identifications between the subjects in the experiments and more experienced users 157

A.1 Abbreviations of the fibre contents of the textiles 177

A.2 Database of the available textures 178

B.1 The spectral lines of the texture files 189

C.1 The number of microstates available for each number of subjects that selected the most popular choice, and the total number of microstates 192

List of Figures

2.1 Movement patterns associated with each of the exploratory procedures . . . 24

2.2 The maximum-likelihood estimate integration of two hypothetical situations 25

2.3 Signal propagation in neurons 27

2.4 A schematic of a triggered action potential 28

2.5 The mechanorecptors in the glabrous skin 29

2.6 Micrograph of a Pacinian corpuscle 30

2.7 Locations of Pacinian corpuscles within the right index distal phalange . . . 31

2.8 Threshold measurements for different populations of mechanoreceptors in the thenar eminence of the hand 32

2.9 Four dimensional MDS space presented as two two-dimensional planes . . . 36

3.1 An example of an electrostatic actuator, including structure and function . 41

3.2 Schematic diagrams of the piezoelectric display mechanism showing a cross-section side view and a top view 42

3.3 An example of an electrorheological actuator 43

3.4 A schematic of an electroactive polymer actuator 44

3.5 An example of an ultrasound display, consisting of an annular array of 91 ultrasound transducers packed in an hexagonal arrangement 44

3.6 A schematic of a surface acoustic wave tactile display 45

3.7 A side view of an example shape memory alloy actuator 46

3.8 A schematic of an electrocutaneous contactor 46

3.9 Schematic of the pneumatic circuit associated with an pneumatic actuator . 47

3.10 Schematic illustration of the electrode-skin interface 48

3.11 The ShiverPad generating a net rightward force 49

3.12 As the exploratory points move across the surface, they are displaced in a direction normal to the surface 49

3.13 A representation of the tactile workspace and how the spatial spectrum is mapped onto temporal frequency according to velocity of exploration 50

3.14 The spectrum of temporal frequencies is reduced to components at 40 Hz and 320 Hz, and the output is specified by their amplitudes, A_{40} and A_{320}. . 52

3.15 Schematic drawing of the Piezoelectric effect 54

3.16 Schematic of a parallel configuration Piezoelectric bimorph 54

3.17 Measured frequency response of a piezoelectric drive element with and without the mechanical load presented by the skin 55

3.18 The tactile display used in this project and the arrangement of the static and dynamic contactors 56

3.19 The driving electronics for the tactile display 57

3.20 A schematic of the operation of the drive electronics 58

3.21 The board that hosts the USB controller, data bus and variable voltage supply 58

3.22 The circuit galvanically isolating the USB controller from the rest of the system 59

3.23 Amplification stages of the variable voltage supply 60

3.24 The board hosting the DAC, address logic, and the amplifiers 60

3.25 Passive, first order low-pass RC filter 61

3.26 The two amplitude stages of each channel 62

3.27 An example of an output signal, as generated by the driving electronics . . 62

3.28 The tactile rendering framework, showing the four threads within the software 63

3.29 The Kalman filter uses a predictor-corrector feedback loop 64

3.30 An example of the graphical display presented to the user 66

3.31 The schematic operation of the software's tactile rendering thread 66

3.32 Average detection thresholds as a function of frequency of the tactile receptors in the skin for Pacinian and non-Pacinian channels used in this project 68

3.33 The filter functions H_{40} and H_{320} 69

3.34 The HAPTEX selection process 71

3.35 The KES-F surface tester 74

3.36 Schematic of the KES-F roughness tester contactor 75

3.37 An example of a Hamming window 76

3.38 Derivation of a set of spatial spectra from a Kawabata line profile 76

3.39 The surface profiles recorded by the KES-F roughness tester while travelling across the right-side surface of textile 03, as well as the first 20 lines of the mean of the spectra 77

3.40 The surface profiles recorded by the KES-F roughness tester while travelling across the right-side surface of textile 20, as well as the first 20 lines of the mean of the spectra 79

3.41 The target virtual scenario for the HAPTEX project 80

3.42 Schematic of the concept of the proposed HAPTEX device 81

3.43 The different threads within the HAPTEX system 81

3.44 The development levels of the HAPTEX system 82

3.45 The GRAB system from PERCRO 83

3.46 A CAD model of the layout of the HandExos device 84

3.47 The tactile array used in the HAPTEX system 85

3.48 Finger positions and manipulations used to test the properties 86

3.49 Comparisons between mean ratings from subject 1 and subject 2 for the properties of tensile stiffness, surface roughness, surface friction, and bending stiffness 87

3.50 The relation between the average subjective ratings of the virtual textiles for both subjects and the corresponding physical values for tensile stiffness, surface roughness, surface friction, and bending stiffness 87

3.51 The relation between the average subjective ratings of the real textiles for both subjects and the corresponding physical values for tensile stiffness, surface roughness, surface friction, and bending stiffness 88

3.52 The relation between the average subjective ratings of the virtual textiles for both subjects and the corresponding average subjective ratings of the real textiles for both subjects for tensile stiffness, surface roughness, surface friction, and bending stiffness 88

3.53 The original band-pass filters that were used to highlight the fundamental frequency components for tactile rendering, compared to the new filter functions 91

3.54 The sum in both channels of the maximum amplitudes that were calculated for a $10\,\mathrm{cm\,s^{-1}}$ exploration of the various surface textures 93

3.55 Without the buffer for the amplitudes, the output wave is updated when the new amplitudes are received by the firmware from the rendering software 94

3.56 The Exeter tactile display before and after the addition of caps to the contactors 95

3.57 Comparison between the sum of mean characteristic amplitudes of sample set 1, and the subjective best match to the real textiles, as established by the author, and the fitted scaling power law 96

4.1 The characterisation plots for the tactile renderer, based on the texture data used in the first experiment, showing the mean and CoV values of A_{40} and A_{320} during exploration of texture surfaces at $10\,\mathrm{cm\,s^{-1}}$ 102

4.2 Comparison between the root-sum-square of warp and weft geometrical roughness from the KES-F and the sum of the mean 40 Hz and 320 Hz amplitudes calculated for the characterisation plots 103

4.3 The characterisation plots for the tactile renderer, based on the texture data used in the first experiment, showing the mean and CoV values of A_{40} and A_{320} during exploration of texture surfaces at $3\,\mathrm{cm\,s^{-1}}$ 104

4.4 The characterisation plots for the tactile renderer, based on the texture data used in the first experiment, showing the mean and CoV values of A_{40} and A_{320} during exploration of texture surfaces at $30\,\mathrm{cm\,s^{-1}}$ 105

4.5 The mean amplitude values for the two channels as a function of exploration speed for $1\,\mathrm{cm\,s^{-1}}$ to $30\,\mathrm{cm\,s^{-1}}$ 106

4.6 The CoV of the amplitude values for the two channels as a function of exploration speed for $1\,\mathrm{cm\,s^{-1}}$ to $30\,\mathrm{cm\,s^{-1}}$ 107

4.7 A comparison of the anisotropy of the mean intensity experienced by a user travelling in each of the four directions of motion across a surface, between textures 37_R, 39_R, 03_R, and 54_R 109

4.8 Characterisation plots based on the tactile renderer and texture data that existed at the beginning of the project, showing the mean and CoV values of A_{40} and A_{320} during exploration of texture surfaces at $10\,\mathrm{cm\,s^{-1}}$ 112

4.9 A comparison of the mean intensity experienced by a user travelling in each of the four directions of motion, for texture 54_R, between the experiments renderer and the original HAPTEX renderer 113

4.10 A comparison of the sum of the mean amplitudes between the scaled and unscaled texture files, as well as the scaling that was used 113

4.11 The characterisation plots for the tactile renderer, based on the texture data used in the second and third experiments, showing the mean and CoV values of A_{40} and A_{320} during exploration of texture surfaces at $10\,\mathrm{cm\,s^{-1}}$. 114

5.1 The setup being used as part of “The Big Bang South West Fair” 116

5.2 Two other strategies presented at “Touching the Untouchable”, allowing for physical and virtual explorations of a “Lewis Chessmen” piece 118

5.3 A replica of the queen “Lewis Chessmen” piece 119

5.4 Diagram of the ghost touch setup 119

5.5 Use of the ghost touch setup to explore the surface of the "Lewis Chessmen" piece 120

5.6 Diagram of the haptic pen setup 120

5.7 Use of the haptic pen setup to explore the surface of the "Lewis Chessmen" piece 121

5.8 The textile that was the subject of the recreation for "Touching the Untouchable" project: the original, archaeological, textile along with a modern recreation 122

5.9 Schematic of the installation used at the museum 122

5.10 The installed tactile renderer, featuring the Exeter tactile display and a visual overlay to navigating the virtual environment 123

5.11 Two facsimiles of the Falkirk tartan 124

5.12 A group of the facsimiles presented at the "Touching the Untouchable" event 125

6.1 The tactile rendering setup used for the experiments 130

6.2 How the tactile display is held during use 131

6.3 Characterisation plots for the tactile renderer for the sample set of 16 textures used in the first experiment, showing the mean and CoV values of A_{40} and A_{320} during exploration of texture surfaces at $10\,\mathrm{cm\,s^{-1}}$ 133

6.4 An example of one of the virtual workspaces presented during experiment 1, showing four virtual textiles that are to be ranked against the target textile 134

6.5 An example of the presentation of a real textile as a target 134

6.6 A breakdown of the results of experiment 1, showing the percentage of times each of the 8 subjects assigned the correct textile with a particular rank of similarity to the target 135

6.7 A breakdown of the results of experiment 1, showing the percentage of times each of the 16 correct virtual textiles was assigned a particular rank of similarity to the target 136

6.8 Mean scores from 5 subjects for matching real and virtual textiles, as a function of the number of textiles in the stimulus set 137

6.9 From experiment 1, breakdown of the percentages of how the "most popular" choice scored across all the test items, compared to what would be expected from chance 138

6.10 A comparison of the distribution of mode choices between cases where the mode is the correct choice and cases were it is not the correct choice 139

6.11 The error patterns obtained from the first choices of the subjects made during experiment 1 140

6.12 Characterisation plots for the tactile renderer for the sample set of 16 textures used in the second experiment, showing the mean and CoV values of A_{40} and A_{320} during exploration of texture surfaces at $10\,\mathrm{cm\,s^{-1}}$ 142

6.13 A breakdown of the results of experiment 2, showing the percentage of times each of the 8 subjects assigned the correct textile with a particular rank of similarity to the target 143

6.14 A breakdown of the results of experiment 2, showing the percentage of times each of the 16 correct virtual textiles was assigned a particular rank of similarity to the target 144

6.15 From experiment 2, breakdown of the percentages of how the "most popular" choice scored across all the test items, compared to what would be expected from chance 146

6.16 Graph showing the relationship between the correlation coefficient between virtual textures and the Euclidean distance in the mean characterisation space 147

6.17 Graph showing the relationship between the correlation coefficient between virtual textures and the Euclidean distance in the CoV characterisation space 147

6.18 An example of one of the virtual workspaces presented during experiment 3, showing four virtual textiles that are to be ranked against the target textile 148

6.19 Comparison of the results from the 3 experiments 149

6.20 Graph showing the relationship between the correlation coefficient between virtual textures from experiment 3 and the Euclidean distance in the mean characterisation space 150

6.21 Graph showing the relationship between the correlation coefficient between virtual textures from experiment 3 and the Euclidean distance in the CoV characterisation space 152

6.22 A plot comparing the dissimilarity scores for identifying target textiles, experiment 2 against experiment 3, along with a line of equality 152

6.23 Scree plots comparing the stresses of various multi-dimensional solutions . . 153

6.24 The two-dimensional MDS solution 154

6.25 Schematic of the mean characterisation space being compared to the calculated MDS space 155

6.26 Comparison of the mean characterisation space and the two-dimensional MDS solution, rotated through 193.1° 158

D.1 The first information sheet given to potential subjects 194

D.2 The second information sheet given to potential subjects 195

D.3 The consent form to be signed by individuals who agree to participate in the study 195

E.1 Graph showing the relationship between the correlation coefficient between virtual textures and the Euclidean distance between mean 40 Hz amplitudes 196

E.2 Graph showing the relationship between the correlation coefficient between virtual textures and the Euclidean distance between mean 320 Hz amplitudes 197

E.3 Graph showing the relationship between the correlation coefficient between virtual textures and the Euclidean distance between CoV 40 Hz amplitudes 197

E.4 Graph showing the relationship between the correlation coefficient between virtual textures and the Euclidean distance between CoV 320 Hz amplitudes 198

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