

Contents

1	Introduction	1
	References	4
2	Human Perception	5
2.1	Introduction to Psychophysics	5
2.1.1	Just Noticeable Differences and Weber's Law	6
2.1.2	Weber-Fechner Law and Stevens' Power Law	7
2.1.3	Measuring Psychometric Distances	8
2.1.4	Statistical Analysis	9
2.1.5	Signal Detection Theory	10
2.1.6	Multidimensional Scaling	12
2.2	The Human Nervous System	15
2.2.1	Neurons	15
2.2.2	Neural Integration	17
2.2.3	Sensory Reception	17
2.3	Human Tactile Perception	18
2.3.1	Mechanoreceptive Afferents	18
2.3.2	Perception of Form and Texture	19
2.3.3	Perception of Fine Textures	20
2.3.4	Perceptual Model of Tactile Simulation	20
2.4	Conclusion	22
	References	22
3	Devices for Tactile Simulation	25
3.1	Survey of Existing Devices	25
3.1.1	Electromagnetic Displays	26
3.1.2	Pneumatic Displays	27
3.1.3	Displays with Shape Memory Alloys	27
3.1.4	Piezoelectric Displays	27

3.1.5	Other Actuator Mechanisms	28
3.2	The Tactile Displays Used	28
3.2.1	The Piezoelectric Effect	29
3.2.2	Mechanical Behaviour	30
3.2.3	Geometrical Configurations	31
3.3	Drive Electronics	33
3.3.1	USB Controller	34
3.3.2	Data Bus	37
3.3.3	Variable Voltage Supply	39
3.3.4	Digital–Analogue Conversion	39
3.3.5	Amplification	41
3.4	Force-Feedback Devices	42
3.4.1	The Haptic Loop	43
3.4.2	Modeling the Contact Forces	43
3.4.3	Different Degrees of Freedom	44
3.5	Conclusion	44
	References	45
4	Generation of Virtual Surfaces	49
4.1	Sample Fabrics	49
4.1.1	Fibres, Yarn and Fabrics	50
4.1.2	Selection of Sample Fabrics	52
4.2	Kawabata Evaluation System for Fabrics	53
4.2.1	KES-F Roughness Test	54
4.2.2	KES-F Friction Test	55
4.3	Spatial Frequency Analysis	56
4.3.1	Selection of Appropriate Sections	57
4.3.2	Discrete Fourier Transform	58
4.3.3	Two-Dimensional Composition	60
4.4	The Correlation–Restoration Algorithm	61
4.4.1	Data Reduction	62
4.4.2	Two-Dimensional Composition	63
4.5	Surface Reconstruction from an Optical Surface Scan	64
4.5.1	Symmetry Detection	65
4.5.2	Shape from Shading	67
4.6	Artificial Surfaces	68
4.6.1	Brownian Surfaces	69
4.7	Conclusion	72
	References	73
5	Tactile Rendering	75
5.1	Rendering Framework	76
5.1.1	Position Tracking	77
5.2	Experiment with a Force-Feedback Device	80
5.2.1	Method	80

5.2.2	Results.....	81
5.3	Vibrotactile Rendering	85
5.3.1	Computation of Resulting Vibrations	85
5.3.2	Decomposition of Vibrations into Base Frequencies	86
5.3.3	First Results with Brownian Surfaces	88
5.3.4	Further Evaluation	89
5.4	Integration with a Force-Feedback Device.....	91
5.4.1	Physical Simulation and Haptic Rendering.....	93
5.4.2	Integrated Interface Hardware	94
5.4.3	Software Integration	95
5.4.4	Evaluation of the Integrated System	96
5.5	Conclusion	98
	References	99
6	Summary and Outlook	101
	References	103
A	Fabrics	105
	References	117
	Index	119