

# University of Wollongong - Research Online

## Thesis Collection

Title: 3D geometric and haptic modeling of hand-woven textile artifacts

Author: Hooman Shidanshidi

Year: 2009

Repository DOI:

### Copyright Warning

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site.

You are reminded of the following: This work is copyright. Apart from any use permitted under the Copyright Act 1968, no part of this work may be reproduced by any process, nor may any other exclusive right be exercised, without the permission of the author. Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material.

Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

**Unless otherwise indicated, the views expressed in this thesis are those of the author and do not necessarily represent the views of the University of Wollongong.**

Research Online is the open access repository for the University of Wollongong. For further information contact the UOW Library: [research-pubs@uow.edu.au](mailto:research-pubs@uow.edu.au)

2009

## 3D geometric and haptic modeling of hand-woven textile artifacts

Hooman Shidanshidi  
*University of Wollongong*

Follow this and additional works at: <https://ro.uow.edu.au/theses>

### University of Wollongong

#### Copyright Warning

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site.

You are reminded of the following: This work is copyright. Apart from any use permitted under the Copyright Act 1968, no part of this work may be reproduced by any process, nor may any other exclusive right be exercised, without the permission of the author. Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material.

Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

Unless otherwise indicated, the views expressed in this thesis are those of the author and do not necessarily represent the views of the University of Wollongong.

---

### Recommended Citation

Shidanshidi, Hooman, 3D geometric and haptic modeling of hand-woven textile artifacts, Master of Engineering thesis, Faculty of Informatics, University of Wollongong, 2009. <https://ro.uow.edu.au/theses/3095>

Research Online is the open access institutional repository for the University of Wollongong. For further information contact the UOW Library: [research-pubs@uow.edu.au](mailto:research-pubs@uow.edu.au)

## **NOTE**

This online version of the thesis may have different page formatting and pagination from the paper copy held in the University of Wollongong Library.

## **UNIVERSITY OF WOLLONGONG**

### **COPYRIGHT WARNING**

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site. You are reminded of the following:

Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material. Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

# 3D Geometric and Haptic Modeling of Hand-Woven Textile Artifacts

---

by

**Hooman Shidanshidi**

***B.Sc. Computer Science (Hons.)***

**This thesis is submitted in fulfillment of the requirements for the award of the Degree of  
Master of Engineering by Research of the University of Wollongong, Australia**

**School of Electrical, Computer and Telecommunications Engineering**

**Faculty of Informatics**

**March, 2009**



*" Man is the supreme Talisman. Lack of a proper education hath, however, deprived him of that which he doth inherently possess. Through a word proceeding out of the mouth of God he was called into being; by one word more he was guided to recognize the Source of his education; by yet another word his station and destiny were safeguarded. The Great Being saith: Regard man as a mine rich in gems of inestimable value. Education can, alone, cause it to reveal its treasures, and enable mankind to benefit therefrom. "*

Baha'u'llah

*To my Mum*



## **CERTIFICATION**

I, Hooman Shidanshidi, declare that this thesis, submitted in fulfillment of the requirements for the award of Master of Engineering by Research, in the School of Electrical, Computer and Telecommunications Engineering, Faculty of Informatics, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Hooman Shidanshidi

March 2009





## Acknowledgments

This thesis could not have been pursued without the undeviating support from Bahá'í Institute for Higher Education (BIHE) University, the National Spiritual Assembly of Bahá'ís of Australia and the sacrifices made by my family and friends. The facilities provided by the University of Wollongong have enabled me to achieve project outcomes using optimal resources.

First and foremost, I would like to thank my supervisor, Professor Fazel Naghdy and my Co-Supervisors, Associate Professor Golshah Naghdy and Professor D. Wood Conroy for their continued support and guidance from the very early stages of this research. They gave me the opportunity to grow and mature as an experienced researcher. I am indebted to my supervisors more they are aware. Fazel's high level of professionalism, Golshah's truly scientist intuition and Diana's unflinching encouragement made this research possible.

I would like to thank Kamran Mortezaei Farid, BIHE University's Vice-chancellor to whom I owe my success in life and to all of my professors during my study as well as my colleagues in BIHE Computer Engineering Department who have sacrificed their lives for education of Bahá'í youth in Iran. The Bahá'í Institute for Higher Education (BIHE) was founded in 1987 in response to the Iranian government's continuing campaign to deny Iranian Bahá'ís access to higher education. As such, the origin of BIHE is rooted in a spirit of purposefulness, dedication, and a belief in the power of true education. The unique circumstances surrounding BIHE, whereby professors taught without compensation, and all staff and students participated in the university at great personal risk, have unwittingly forced university to become a leader in combining on-line learning, traditional classroom instruction and preparation for a successful career.

I would like to thank Bahá'í International community and in particular the Iranian Bahá'í community. This degree would enable me to serve more efficiently my fellow Bahá'í brothers and sisters in Iran who face unrelenting religious persecution involving a wide range of human rights violations, including systematic denial of access to higher education.

I would like to thank my beloved mum for her moral support during my study and her sacrifices in bringing me up, especially after passing of my father. She has sacrificed her life for my education. Also I would like to thank my sister and other family members and friends in Iran and Australia

who have always encouraged and supported me. I would also like to acknowledge my appreciation of academic, administrative and general staff in the School of Electrical, Computer and Telecommunication Engineering at the University of Wollongong.

I am truly grateful to be given the opportunity to become involved in this interesting area of research and am ever thankful to those who have helped me achieve it.

Hooman Shidanshidi

August 2009

Wollongong, Australia

## Abstract

Haptic Modeling of textile has attracted significant interest over the last decade. In spite of extensive research, no generic system has yet been proposed. The majority of the haptic models developed in the previous work assume a 2D mesh model for the textile which does not represent the real geometric configuration of the textile. In addition, they are based on empirical parameters obtained from textile samples using specialized instruments. The process is often time consuming and elaborate, consisting of manual measurement of physical and mechanical properties of the artifacts. The development of a generic approach for 3D haptic modeling of hand-woven textile artifacts is pursued in this work.

In the proposed approach, the textile pattern and structure are recognized by digital processing of the artifact still image. A fuzzy-rule based expert system is developed to perform the recognition process. The data obtained in this process is employed to automatically generate the 3D geometric model of the artifact in VRML. The mechanical properties of the artifact are estimated by processing the textile geometric characteristics and yarn properties in a neural network system. These mechanical properties are then deployed in the construction of the textile mechanical model. The mechanical model is superimposed over the 3D geometric model to construct the haptic model. The proposed system is validated through both subjective and objective methods using a number of artifact samples.

An extensive review of the published literature on the haptic modeling of textile is provided in the thesis. The benefits of textile haptic modeling are identified. Applications of existing models are reviewed and the significance and unique contribution of the work is presented.

The image processing method and the fuzzy rule based expert system deployed in the construction of the geometric model are described in detail. The outcome is a 3D geometric model of the artifact in VRML which could be explored in a virtual reality world viewer. Similarly, the neural network model designed to estimate the mechanical characteristics of an artifact is presented the results of the training and validation of the model are provided.

Finally, two methods developed for the haptic model based on geometric and mechanical models in the Reachin are explained. The accuracy and effectiveness of the overall approach are validated through a series of experiments.

Overall, the work conducted in this study offers a novel 3D generic haptic modeling for textile artifacts. It can be deployed in museums providing an opportunity for the visitors to touch unique samples of hand-woven textile artifacts. The approach is cost-effective, reliable and reproducible as the haptic modeling of these samples does not need time-consuming and costly laboratory conditions.

## Table of Contents

CERTIFICATION .....	
Acknowledgments .....	i
Abstract .....	iii
Figures list .....	ix
Tables list.....	xi
<a href="#">Chapter 1</a> Introduction .....	1
1.1 Overview and problem statement.....	1
1.2 Research questions.....	5
1.3 Proposed haptic system architecture .....	6
1.3.1 Image Processing & Features Extractor Engine .....	9
1.3.2 Knowledge-base & AI Engine.....	10
1.3.3 3D Geometric Model Generator .....	10
1.3.4 Mechanical Model Generator.....	10
1.3.5 Haptic Model Integrator.....	11
1.3.6 Physical Simulator & Haptic Renderer .....	11
1.3.7 Virtual Reality World Manager .....	12
1.4 Thesis scope .....	12
<a href="#">Chapter 2</a> Background.....	15
2.1 Introduction.....	15
2.2 Haptic simulation of fabric hand .....	16
2.3 Haptic sensing of virtual textiles.....	18
2.4 Sensing the fabric: to simulate sensation through sensory evaluation.....	19
2.5 Subjective assessment of fabrics in haptic modeling .....	20
2.6 Fabric hand modeling in haptic systems.....	21
2.7 Textile physical simulation in haptic systems.....	21
2.8 Haptic model through image processing .....	22
2.9 Psychological and tactile perception .....	23
2.10 Conclusion .....	25
<a href="#">Chapter 3</a> Textile Geometric Modeling.....	27

3.1	Introduction .....	27
3.2	Textile structure .....	28
3.2.1	Weave patterns .....	28
3.2.2	Plain weave .....	28
3.2.3	Twill.....	29
3.2.4	Satin .....	29
3.2.5	Yarn structure.....	30
3.2.6	Considerations in hand-woven artifacts geometric modeling .....	30
3.3	Textile pattern recognition .....	31
3.4	Background and literature review.....	33
3.5	Proposed method for textile pattern recognition.....	38
3.5.1	Image enhancement.....	38
3.5.2	Crossed-points detection .....	41
3.5.3	Crossed-states detection .....	55
3.6	Textile 3D geometric model generation.....	60
3.6.1	Background .....	60
3.6.2	Yarn flow formulation .....	62
3.6.3	Weft/Warp yarn set modeling .....	64
3.6.4	Applying yarn cross-section to yarn curve .....	66
3.7	3D geometric model generation .....	68
<a href="#">Chapter 4</a>	Textile Mechanical/Physical Modeling .....	73
4.1	Introduction .....	73
4.2	Fabric hand .....	73
4.3	Subjective methods for fabric hand evaluation .....	74
4.4	Objective assessment for fabric hand evaluation .....	75
4.5	Factors affecting fabric hand .....	80
4.6	Textile mechanical properties.....	83
4.7	Mechanical/Physical modeling of textile literature review .....	85
4.8	Textile mechanical model generation .....	87
4.8.1	Neural Network input parameters .....	89
4.8.2	Neural Network output parameters.....	91
4.8.3	Neural Network architecture .....	92

4.8.4	Neural Network training and validation.....	93
4.8.5	Mechanical/ physical model generation with neural network.....	94
<a href="#">Chapter 5</a>	Textile Haptic Modelling.....	95
5.1	Introduction.....	95
5.2	Haptic devices and controlling .....	95
5.3	Haptic implementation platforms .....	100
5.4	Reachin environment for haptic modeling and programming.....	102
5.4.1	SimpleSurface .....	104
5.4.2	FrictionalSurface .....	105
5.4.3	RoughSurface.....	106
5.4.4	BumpmapSurface.....	107
5.4.5	FrictionImageSurface .....	107
5.4.6	Button Surfaces.....	108
5.4.7	Dynamic objects.....	108
5.4.8	PythonScript and C++ .....	109
5.5	Haptic model implementation in Reachin .....	109
5.6	Alternative methods for textile haptic modelling with Reachin built-in facilities.....	113
5.7	Model validation.....	113
<a href="#">Chapter 6</a>	Conclusions and further work.....	117
6.1	Overview .....	117
6.2	Setting the scene .....	118
6.3	Evolution in textile haptic modeling .....	118
6.4	Textile geometric modeling.....	119
6.5	Mechanical/ physical modeling of textile artifacts.....	119
6.6	Haptic modeling of textile .....	120
6.7	Current constraints and further work.....	120
6.7.1	Improvement of image processing techniques and the fuzzy rule based system.....	120
6.7.2	Improvement of 3D geometric model generation.....	120
6.7.3	Improvement of the neural network .....	121
6.7.4	Improvement of the haptic model.....	121
6.7.5	Improvement of the haptic device.....	121
Appendix I	The image processing Matlab code.....	123



Appendix II	International Journals and Conferences on Haptics .....	135
Appendix III	International Haptic Research Laboratories .....	141
Bibliography	.....	143

## Figures list

Figure 1. Virtual Reality World with Haptic Capability.....	1
Figure 2. 2D mesh structure for modeling the textile artifact widely used by almost all of the textile representation and haptic systems [5] .....	2
Figure 3. Typical graphic representation of a textile artifact with 2D mesh with physical simulation of draping [5] .....	3
Figure 4. Kawabata Machine- Tensile and Shear tester [5].....	3
Figure 5. Kawabata Machine- Compression tester [5].....	4
Figure 6. Kawabata Machine-Surface tester [5] .....	4
Figure 7. The haptic system architecture .....	8
Figure 8. Skin mechanoreceptors, (from NEUROSCIENCE [Purves et al., 2001]).....	24
Figure 9. Plain Weave.....	28
Figure 10. Twill.....	29
Figure 11. Satin .....	29
Figure 12. Traditional deterministic methods for Crossed-points detection with fixed and straight shape assumption for warp and weft yarns .....	33
Figure 13. Image histogram a) before and b) after equalization.....	39
Figure 14. a) Original gray-scale image b) Image enhancement output.....	40
Figure 15. a) A textile sample with almost straight and fixed-shape yarns b) Result of yarn edge detection by finding the peaks of autocorrelation function which is successful in this case .....	41
Figure 16. Inefficiency and rigidness of finding the peaks of autocorrelation function in a complicated hand-woven artifact.....	42
Figure 17. The horizontal and vertical slicing and the corresponding horizontal autocorrelation curve .....	43
Figure 18. Intelligent filtering mechanism for removing the false peaks and picking the real peaks .....	43
Figure 19. Global combination mechanism.....	44
Figure 20. Edge detection mechanism.....	45
Figure 21. Gradient pattern for yarn boarder .....	48
Figure 22. The distance fuzzy variable membership function using for fuzzification.....	48
Figure 23. Crossed-points detection for two samples a and b .....	52
Figure 24. Vertical and horizontal feature points.....	53
Figure 25. First iteration of fuzzy rules implication for yarn edge detection .....	54
Figure 26. a) Warp yarn floating over weft yarn, b) Weft yarn floating over warp yarn .....	55
Figure 27. A detected cell and rectangular inside the boundary .....	56
Figure 28. Rectangular of a) Warp yarn floating over weft yarn, b) Weft yarn floating over warp yarn .....	56
Figure 29. Black and white image of the rectangular cells.....	57
Figure 30. Discrete Fourier Transform of rectangular cells.....	58

Figure 31. a) A horizontal pattern b) A vertical pattern .....	58
Figure 32. Discrete Fourier Transform of a) Horizontal pattern, b) Vertical pattern .....	59
Figure 33. Weave pattern diagram produced in crossed state detection .....	60
Figure 34. Weft/Warp yarn flow in textile 3D geometric model .....	63
Figure 35. 3 warp yarn curves in a plain weave sample .....	65
Figure 36. Yarn curve produced from a weave pattern diagram .....	66
Figure 37. Yarn ellipsoid cross-section .....	67
Figure 38. Partial 3D geometric model for: a) A plain artifact sample b) A twill artifact sample .....	71
Figure 39. An artifact VRML 3D geometric model in Virtual Reality Viewer.....	72
Figure 40. Kawabata Tensile and shear tester .....	77
Figure 41. Kawabata Bending tester.....	77
Figure 42. Kawabata Compression tester .....	78
Figure 43. Kawabata Surface tester.....	78
Figure 44. Factors affecting the fabric hand [39] .....	81
Figure 45. Neural Network system for textile mechanical & physical properties prediction .....	89
Figure 46. Number of neurons in hidden layer and the error in back-propagation.....	92
Figure 47. Number of neurons in hidden layer and the execution time .....	93
Figure 48. The PHANTOM 6DOF haptic device .....	96
Figure 49. The HAPTEx haptic device .....	97
Figure 50. A haptic device for home user .....	98
Figure 51. Haptic interface on new mobile phones .....	98
Figure 52. An advanced glove haptic device .....	99

## Tables list

Table I - Organizations forming HAPTEX .....	18
Table II - Usage Frequencies of Descriptors in Bishop Research .....	75
Table III - Mechanical properties of textile in objective assessment of the Fabric Hand .....	79
Table IV - Neural Network validation result .....	94
Table V - Some of the Reachin API geometry nodes.....	102
Table VI - Some of the Reachin API surface nodes .....	103
Table VII - The subjective experiment result for 13 samples and 3 different methods.....	114
Table VIII - Number of True identification in 25 tests for each haptic group.....	115

