Surface Deformation on Composite Patches by Constrained Morphing

by

Lo Kin Man

M-A3-6524-3

Master of Science in Electromechanical Engineering

2010

Faculty of Science and Technology
University of Macau

UNIVERSIDADE DE MACAU
仁義禮知信
澳門大學

Surface Deformation on Composite Patches by Constrained Morphing

by

Lo Kin Man

A thesis submitted in partial fulfillment of the
requirements for the degree of

Master of Science
in
Electromechanical Engineering

Faculty of Science and Technology
University of Macau

2010

Approved by _____

Supervisor

_____

_____

_____

Date _____

UNIVERSIDADE DE MACAU
仁義禮知信
澳門大學

In presenting this thesis in partial fulfillment of the requirements for a Master's degree at the University of Macau, I agree that the Library and the Faculty of Science and Technology shall make its copies freely available for inspection. However, reproduction of this thesis for any purposes or by any means shall not be allowed without my written permission. Authorization is sought by contacting the author at

Address:

Telephone: +853 66810817
Fax:
E-mail: lo_kin_man@hotmail.com

Signature _____

Date _____

UNIVERSIDADE DE MACAU
仁義禮知信
澳門大學

University of Macau

Abstract

SURFACE DEFORMATION ON COMPOSITE PATCHES BY CONSTRAINED MORPHING

by Lo Kin Man

Thesis Supervisor: Assistant Professor Yang Zhixin
Electromechanical Engineering

This thesis proposes a novel freeform surface deformation method for all freeform surfaces regardless of their mathematical representation. This method is particularly designed for automatic matching of freeform surface.

Shorter development time of a new product allows manufactures to response quickly to various demands from market and saving time costs. A product platform employing reverse engineering and feature-based product family database can support mass customization, which aims at developing, producing, marketing, and delivering affordable goods and services with sufficient variety and customization that nearly everyone finds exactly what he/she wants by employing mass production processes.

Customization can be supported by “re-usage of features” from product family database. Re-usage not only can save the development time of a new product model, but also reuse the “design intention”, like shapes and functions. However, features must be well defined so that features of the same kind are compatible to each other.

Reverse engineering is a design approach that transforms a physical model into a digital model through a series of procedures. The physical object often consists of freeform surfaces that is difficult to be described exactly on draft paper. However, reverse engineering can transform a physical model prepared by a stylist into digital

one. Designer can define features in the procedures of reverse engineering in order to facilitate feature re-usage.

When features are reused to construct a new product model, they must be classified as either base feature, where deformation is not necessary and working feature, where deformation is to be imposed on. This thesis aims at deforming freeform surface globally and uniformly.

Repositioning of control points of a freeform surface has an obvious geometric meaning in shape design. Designers often modify surface by control points. Hence, a control-point based deformation method is proposed, regardless of type of freeform surfaces. Designers can avoid handling mathematics related to freeform surfaces. The proposed method triangulates control net and treats the triangulated control net as a spatial spring network.

Control point constraints of a freeform surface can be imposed on the spring network to achieve a global and uniform deformation for preservation of smoothness and similarity. The deformation adopts the technique used for finite element analysis of space truss. Solution is determined by minimum total potential energy of the spring network.

The proposed method is tested by seven examples, from simple one to industry application of shoelast design. However, it can be foreseen that this method can be extended any application where freeform surface deformation is required.

KEYWORDS

Product platform

Product family

Mass customization

Surface feature re-usage

Reverse engineering

Segmentation

Freeform surface deformation

Geometric constraint

UNIVERSIDADE DE MACAU
仁義禮知信
澳門大學

Table of Contents

UNIVERSIDADE DE MACAU
仁義禮知信
澳門大學

LIST OF FIGURES

LIST OF TABLES

PREFACE

This thesis is the product of my MSc study at the Department of Electromechanical Engineering, Faculty of Science and Technology, University of Macau. It serves as documentation of my work during the study, which has been made from autumn 2004 until April 2010. The study is supervised by Dr. Yang Zhixin.

China is a major exporter of footwear. To maintain its leadership position in this industry where entry barriers are relatively low, it is important that product design and development be promptly responsive to customers' requirements. The ability to respond to customers' needs at all levels has tremendous impact on the market acceptance and increase in sales of footwear. Surface feature re-usage from existing product model in a product family database can be an effective way to achieve this goal if features can be deformed properly. This study is about freeform surface deformation and was initiated by the need of deforming & joining reused surface features when creating a new product model.

Two papers related to this research have accepted by international conference proceedings. This thesis consists of seven chapters. This thesis covers various aspects of a product platform employing Reverse Engineering for the creation of product models that contain reusable surface features.

Through many years of study in the University of Macau, I've learnt a lot. I am sure that this thesis contains broad perspectives and allows readers to understand the concept of feature re-usage for product model creation.

UNIVERSIDADE DE MACAU
仁義禮知信
澳門大學

ACKNOWLEDGEMENTS

I am grateful to many people who have been supporting me during this MSc course: teaching staff, friends, and family. First, I would like to express my great thanks to the University of Macau for granting me the Master Studentship. I would also like to appreciate Dr. Yang Zhixin, my supervisor, for his patience and helpful guidance for this research project.

I have spent almost 7 years on this MSc degree. I stayed in the Automotive Laboratory during the studentship period (September 2003 until August 2006). I would like to express my sincere thanks to Prof. Wong Pak Kin who taught me plenty of interesting knowledge of Automotive Engineering.

Another Professor I would like to appreciate is Prof. Tam Lap Mou for his great assistance for my further education without any hesitation.

Many bachelor students contributed their efforts on building "University of Macau Database of Shoes Shapes (UMDS)". Their contributions are crucial to this research.

I would also like to give my sincere thanks to Ms. Quan Lulin & Mr. Fabio Ferreira Novo, master students of Dr. Yang for their valuable suggestion and experience for this research projects.

Finally, I would like to appreciate to my family for supporting my study for so many years.

UNIVERSIDADE DE MACAU
仁義禮知信
澳門大學