

**Surface Deformation on Composite Patches by  
Constrained Morphing**

by

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Morphing**

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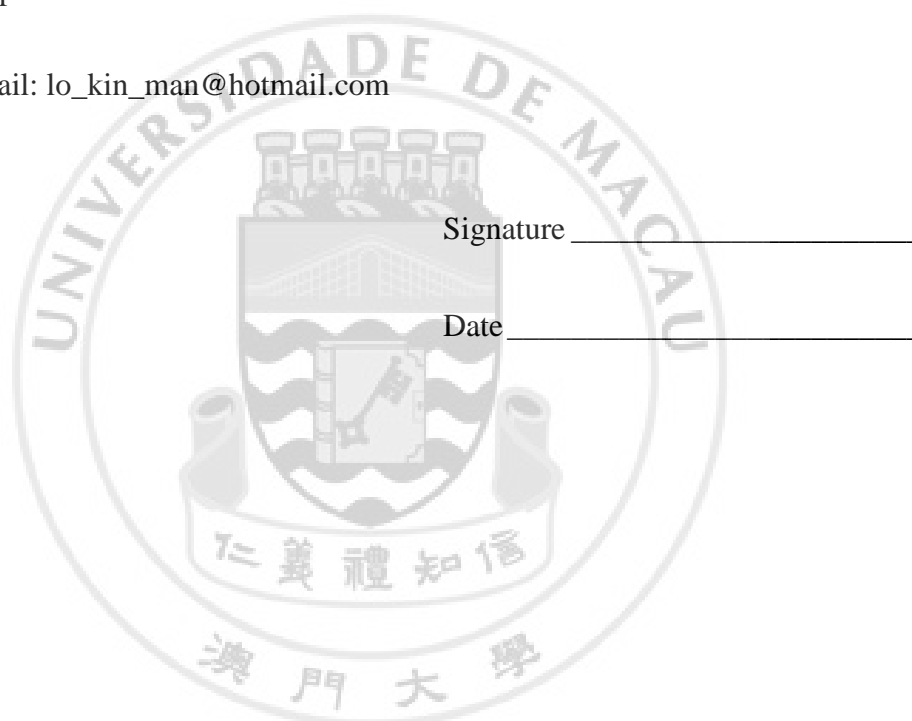
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Abstract

SURFACE DEFORMATION ON COMPOSITE PATCHES  
BY CONSTRAINED MORPHING

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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





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# 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.



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