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Using image processing based on neural networks in reverse engineering

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Abstract

Various techniques have been employed to recover three-dimensional (3D) surfaces in the redesign of products, customized designs, and the building of virtual environments. Reverse engineering methodology provides an efficient tool for the manufacturing of free-form and sculptured shapes. This paper describes an image processing approach to the 3D shape recovery based on neural networks that tackles the major bottleneck in the current reverse engineering process, namely the lack of a rapid link between the physical object and its design representation. A range of applications has shown this method to be feasible and efficient.

Keywords: CAD/CAM; Reverse engineering; Image processing; Neural networks

1. Introduction

There is always pressure on the designer and manufacturer to be able to respond to the consumers' needs and provide products as quickly as possible. In many cases, constructing a product from an existing object can be quicker than creating a new product model. Also, creating the built component from the machined output of an NC (numerical control) machine provides a fast method for realizing the design that can then be compared with the original product model.

Reverse engineering, unlike the traditional design process which transforms design concepts and models into products, builds products based on existing parts. This is a rapidly developing discipline in which measurement, analysis, and modification of existing artifacts are taken through

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to the design and manufacturing of a new product. Application areas of a reverse engineering process include:

- The reverse design: either creating a new product from an initial model or feeding a recovered result back to an existing product model to compare and update. This is a widely used technique in the tool, die, and mould-making industries.
- The customized design: customized products are worn on our bodies, or have prolonged functional contact with the human body. There can be considerable variation in performance and function required for this kind of products and it is, therefore, essential to involve the customer in the design process.
- The virtual environment: to build the virtual reality (VR) environment in which the overall design of a product can be evaluated quickly and effectively.

Data acquisition is the most important requirement in reverse engineering. The data can be processed to create computer-aided design (CAD) representations of a product, to extract dimensional measurements, or to redesign the product. According to Varady et al. [1], who discussed the different methods for acquiring shape data, an ideal data acquisition system would be able to deal with data from a wide range of source objects automatically, and produce a complete data set which is easy to model.

The most popular devices for data acquisition are coordinate measuring machines (CMMs) and laser scanners. Both can obtain very accurate data by following programmed tool paths along the surface of the measured object, with the CMMs in contact and the laser at a predetermined distance. However, the high cost of these measuring systems and the time taken to recover surface details by the measurement process limit their application in some areas.

This paper, following the authors' previous work [2], describes a neural network-based approach to the 3D surface recovery from 2D image information, which involves the evaluation and simulation of data prior to translating the information to other models for modifying or machining. The proposed process provides a non-contact 3D object recovery approach. The method has the capability to rapidly and non-destructively produce the new parts from the original components. It can obtain thousands of measurements simultaneously, without special preprogramming, hardware training and special fixtures to position the parts.

The following section introduces the image-based method and its background. The illumination model and parameter determination are described in Section 3. The 3D shape recovery algorithm based on neural networks is proposed in Section 4. Applications to verify the approach are presented in Section 5, and followed in Section 6 by conclusions on the overall research.

2. The image-based method and its background

The image-based reverse engineering process, as shown in Fig. 1, uses a digital camera and an image processing technique to capture data from the existing object. Products, based on such data, can be redesigned and improved according to custom requirements prior to the manufacturing stages.

The image-to-CAD process involves two major steps: first, the definition of the illumination