Reconstruction of free form Surfaces in Reverse Engineering Technology Applications

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Abstract

This paper presents a new experimental approach in reverse engineering for rapid reconstruction, modeling and manufacturing of products with complex free form surfaces. The proposed approach eliminates the requirement for camera calibration and poses estimation. Using planar sectioning, we generate a set of horizontal parallel planes slicing the object to a set of parallel cross-sections. For each object slice, we captured an image using single digital camera. In this paper an image-based slicing technique and system for 3D free form surface reconstruction of a real object is proposed and implemented, the system is relatively low cost and easy to implement. The test object is placed in a cubic container filled with a dark liquid and the intersections between the liquid level and the real object are generated by raising the movable base in step by step manner, and for each step an image has been captured. The depth of each cross section can be directly obtained for each of the captured image. After obtaining all the depth information of the real object, the data have been integrated to reconstruct the 3D free form surface

Keywords
Free form surfaces, Reverse engineering technology, Image processing and slicing techniques

Introduction

Nowadays, globalization has begun to drive industries to operate in a highly competitive environment. Besides delivering more competitive products with higher quality, lower prices, customized, and innovative products, the time-to-market of products has become a crucial issue. In order to deal with this challenge, rapid production methods have been developed and incorporated into many phases of the product life cycle. Many companies are becoming increasingly multi-sited, operating with partners around the world, and are more reliant on Reverse Engineering (RE) technology, which significantly enables fast design based on an existing physical object, typically, for parts comprising of free form surfaces [1, 2, 3].
Reverse engineering is a product development methodology and a kind of process of engineering backward for constructing CAD models of an existing physical object whose CAD models are unavailable, unusable, or insufficient, by digitizing the existing product to acquire the explicit 3D points position, processing the digitized 3D data, and then reconstructing it as a 3D CAD model, which are used for analysis, manufacturing or other applications [4, 5].
Three-dimensional (3D) reconstruction of the object shape from multiple images has an important role in many applications including: tracking, action recognition, virtual reality applications and reverse engineering.
Several approaches achieve 3D shape recovery by finding 3D locations of matching points in different view images using camera calibration and pose

In this paper, we propose new technique and implement a new simple system that eliminates the requirements for camera calibration and pose to reconstruct 3D object using image base slicing techniques. The proposed technique inspired by the layer capturing methods for performing 3D model based on capturing several cross-sections of the 3D object. The idea is to use multiple 2D cross sections to recover the object. The 3D object is then obtained by combining multiple 2D contours. The 3D model reconstruction system is mainly constituted by a liquid container of cube mounted on a table, a personal computer, and a camera placed in top of the liquid container. The test object is placed on a movable base containing several through holes moved inside the container up and down.

Shape recovery by intersection with the liquid level

A picture of the 3D shape recovery system is shown in Fig. (1). We specifically design the plastic cube as a liquid container with moveable base containing several through holes used to place the 3D object on it, so that the liquid level can cover the object, then the base with the 3D object rises upward gradually with predefined value in step by step by the rotation of the screw stably. We propose a method to obtain the depth of each cross-section by recording the movement of the movable base as it rises upward for each step using elevation scale and recording the depth of each cross section directly from the elevation scale, this procedure are greatly simplify the computing of the depth information.

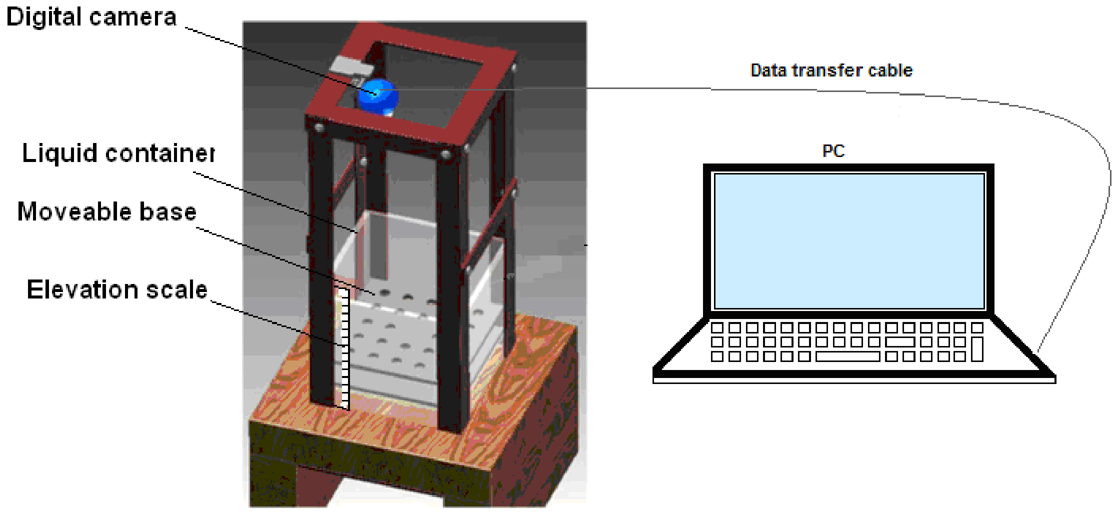
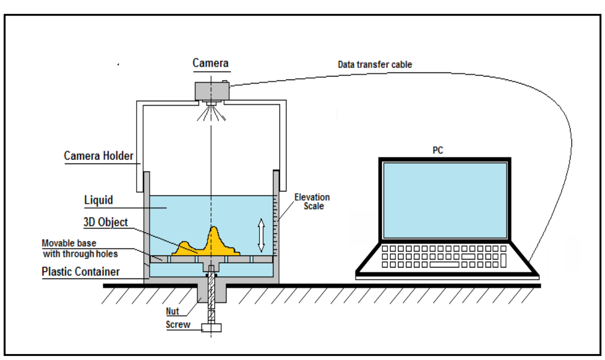


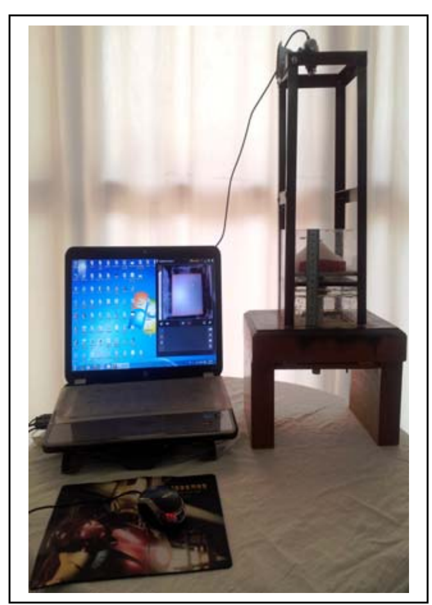
Fig.(1) 3D shape recovery system

System Setup and implementation

As shown in Fig.(2), the proposed method for performing 3D object reconstruction can be achieved by capturing the cross-sections of an experimental object located in the liquid container, and the 3D shape recovery can be achieved by integrating each of these layers (cross section) into a 3D model.

The intersection of the liquid level with the 3D object as the moveable base rises upward can be captured by the camera fixed in top of the container and then the image processed as a 2D image, this process will be repeated until all the depth of the 3D object be covered. The depth information can be recorded by the side scale for each captured image.





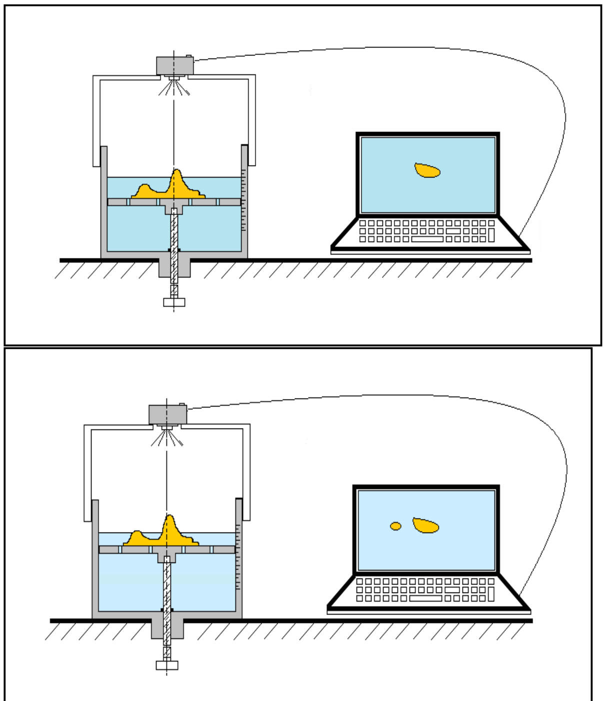


Fig.(2) Slice capturing

The actual processing steps are illustrated as a flowchart in Fig.(3)

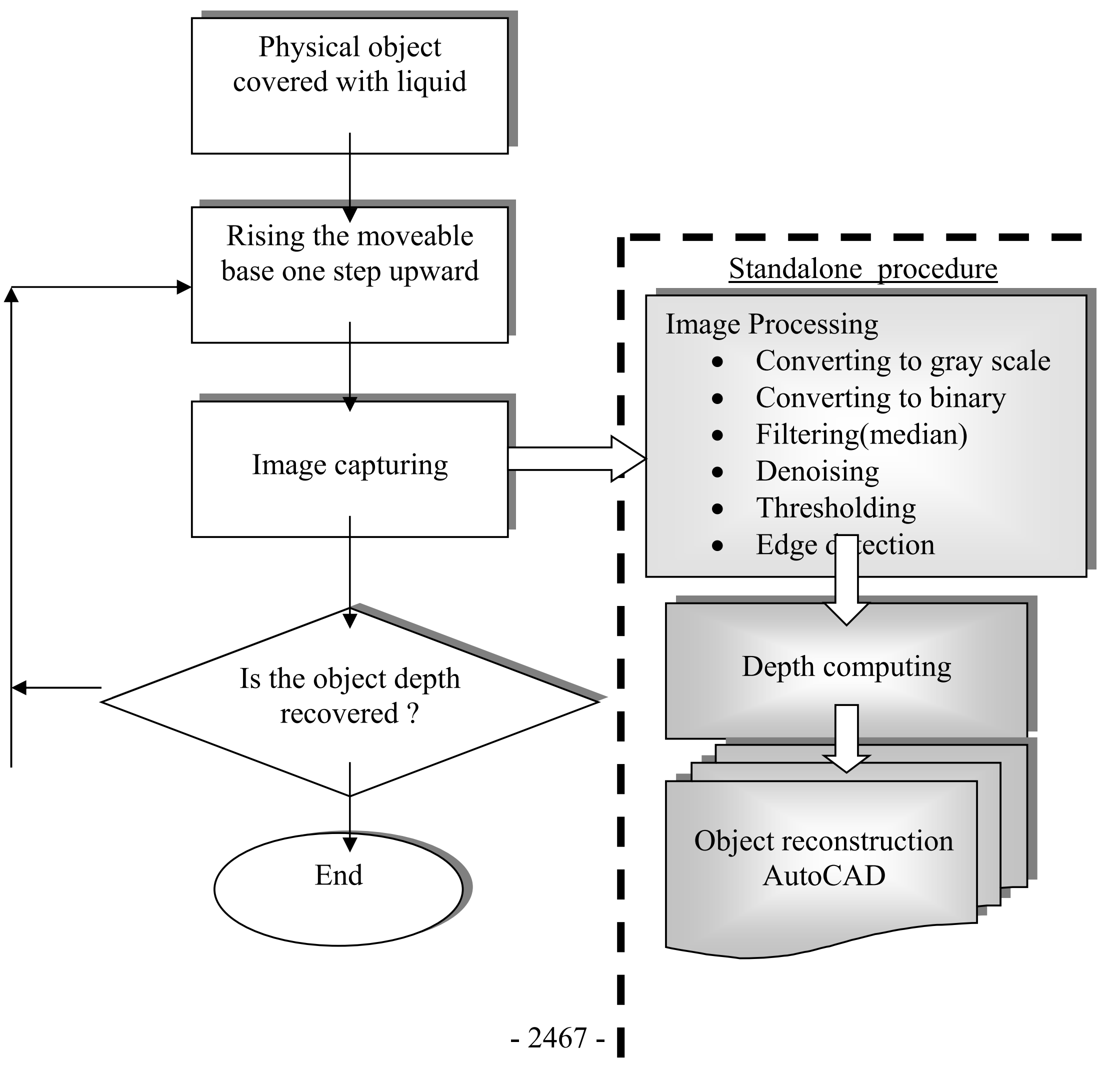
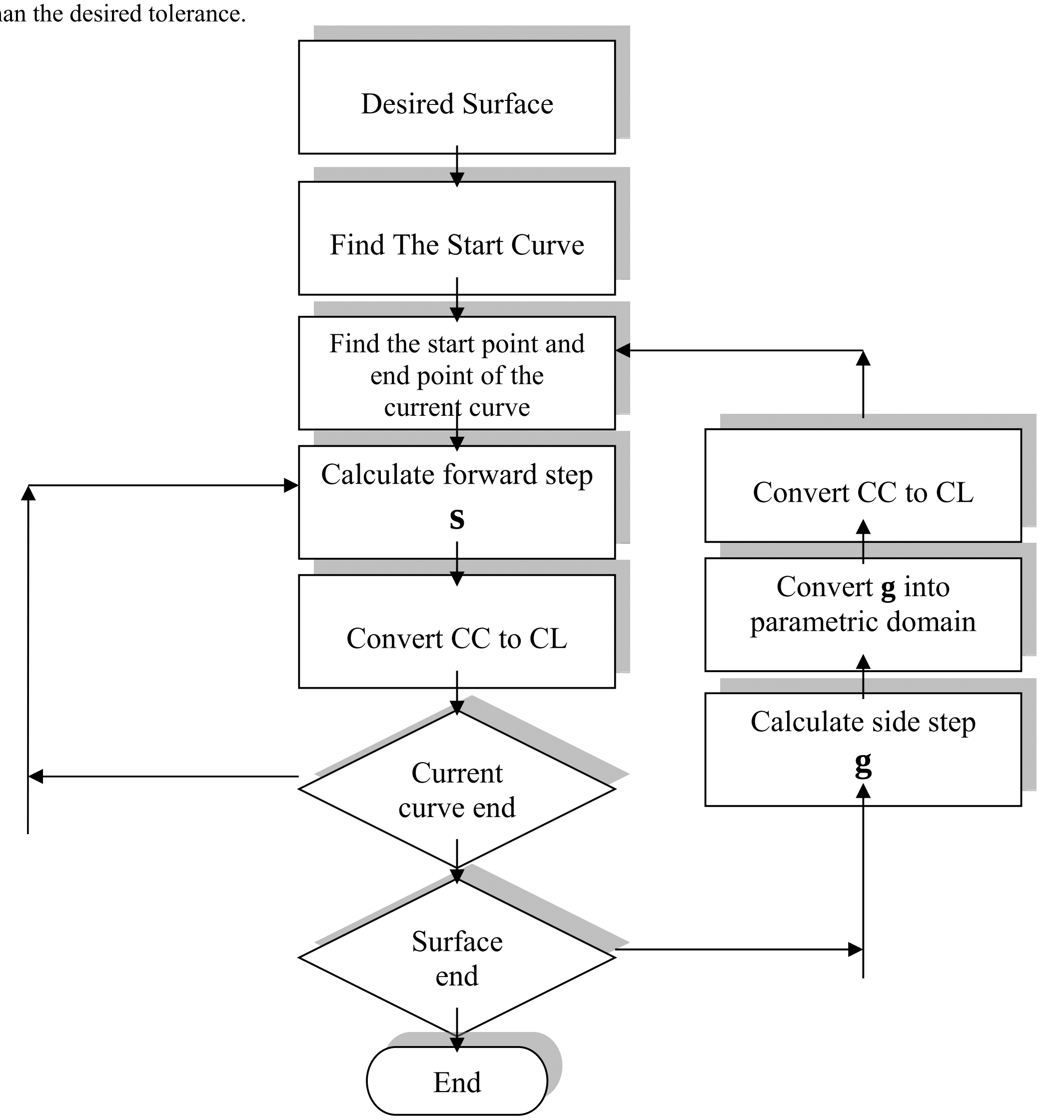


Fig.(3) System Algorithm

Firstly, the background removal has been performed for obtaining more accurate result of edge extraction. The background removal is performed by the procedure outside the system that is a standalone procedure. We use the Matlab as image processing software. After the background has been removed, a step of edge detection is used to obtain the edge of the cross-section area between the liquid level and the test object. After performing all steps stated before, the depth information of the each cross-section is recorded by observation the elevation scale fixed on the side of the container. Finally, integrating all the computed depth information of each cross-section, by the exactly the same way described before with each cross-section input image sequentially, can achieve the complete 3D shape. In this paper, there are two reconstructed results have been performed, the obtained 3D shape of a wire frame and a solid model. There are 36 images used as input. We use a simple scale to control the object elevation at each upward step and an online digital camera connected directly to a personal computer to capture an image for each intersection. Along with the elevating the object to a new level, the image is captured and so on until the depth of the object be covered.

Tool Path Generation:

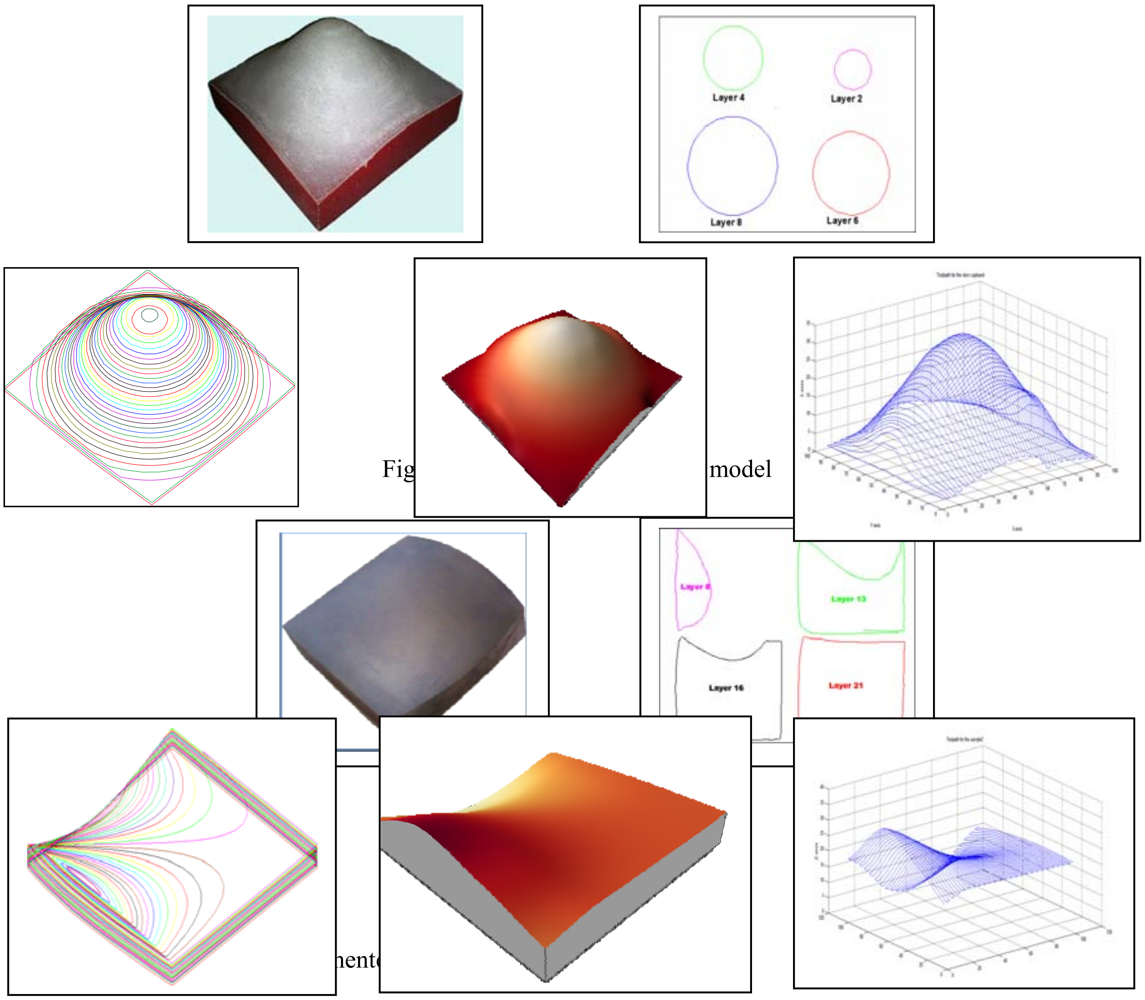
The simplest approach used in finish machining is iso-parametric tool path generation. Surface points are calculated as a function of (***u, w***) parameter space, the tool is then indexed along the surface by incrementing (***u***) and (***w***). Tool path planning is accomplished by holding the ***w*** parameter constant and indexing the ***u*** parameter. Step-forward increments in ***u*** must be carefully chosen since tool movements are linearly interpolated and the chordal deviation between the straight lines and the actual surface must be less than the desired tolerance. Step-over increments in ***w*** must be small enough to keep the cusps between the spherically shaped cutter paths to less than the desired tolerance.



Implementation

Based on upper solution, an experimental prototype for free form surface model reconstruction, and tool path generation for mechanical products manufacturing has been developed and implemented based on slicing image techniques.

The intersections of the tested objects with the liquid level have been captured as pictures as the object rises with the moveable base . The depth information have been recorded to each image, as can be seen in the pictures observed experimental results have been performed by using 36 captured serial images captured along with the rises of the object upward in step by step manner. Two types of the reconstructed presentation are available for each tested object which are: wire frame and solid model as illustrated in Figs.(5) and (6).



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Conclusion

The main contribution of our work is that we present a method and implement a simple system to perform the 3D shape recovery with relatively low-cost hardware equipments, and less complicated algorithm.

Experiments show that the method is applicable for reverse reconstruction and modeling of objects containing freeform surface and submit a practical application in reverse engineering and tool path generation for machining .

Recording the depth of each cross section directly from the elevation scale, are greatly simplified the computing of the depth information, this procedure different from the traditional methods that use algorithms such as pose from ellipse to calculate the surface normal of ellipse and then calculate the rotational angle in the three directions, with an important reduction of the hardware costs and time.

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