Advances in Engineering Software 40 (2009) 407–418

Contents lists available at ScienceDirect

Advances in Engineering Software

journal homepage: www.elsevier.com/locate/advengsoft

# Reverse engineering applications for recovery of broken or worn parts and re-manufacturing: Three case studies

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ARTICLE INFO

*Article history:*
Received 3 May 2007
Received in revised form 17 July 2008
Accepted 21 July 2008
Available online 5 September 2008

*Keywords:*
Reverse engineering
Recovery of damaged part
Digitization method
CAD/CAM
Machining

ABSTRACT

Damaged or broken parts are generally too expensive to replace, or are no longer available. RE can be defined as: 'Systematic evaluation of a product with the purpose of replication. This involves design of a new part, copy of an existing part, *recovery of a damaged* or *broken* part, improvement of model precision and inspection of a numerical model. Advantages of the technique include immediate feedback, data reduction, direct generation of geometry and higher precision of the final product. This paper shows some possibilities of use and benefit from utilising the RE-methodologies and techniques in production process, especially in the case when exists parts without 3D-CAD support.

This paper, which defines obtaining CAD data step by step from damaged three different parts to reproduce or make a new design for some recoveries, has not get any technical drawings. When these parts had been recovered, some problems occurred. These problems have been solved by referring to some practical approaches. Establishing continuity across curve and surface patches is an important concept in the free form surface modeling. The CAD models were recovered and reconstructed to consider parametric and geometric continuity. The iso-phote method was used for surface continuity analysis. Hence, in this work, not only occurring problems but also solving methods were explained. Firstly, CAD models are created from damaged and broken parts by data digitization method by using CMM and the process was explored in detailed. Later, CAD models that had been obtained earlier are transferred into CAM module of the software and G codes are taken by the NC post-processor, and finally, the parts are manufactured by means of CNC milling machine. Additionally, this paper presents a review of the part digitization techniques available for reverse engineering.

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## 1. Introduction

Reverse engineering is a very important branch of geometrically design and manufacture application area, and this technique has been widely recognized as being an important step in the product development cycle. The use of RE will largely decrease the manufacturing time and costs. RE is the process of producing design details in the form of CAD model from the physical part in the process of the product design. In contrast to the traditional production sequence, reverse engineering typically starts with measuring an existing object, so that a solid model can be deduced in order to make use of the advantages of CAD/CAM/CAE technologies [1]. Afterwards, CAD models are used for manufacturing or rapid prototyping applications.

Several authors have researched regarding the reverse engineering, especially by focusing on scanning methods (advantages and weaknesses of different scanning systems) [2–15], reverse engineering applications based on image processing and vision aided [16–19], multi-probing approaches [20,21], integration with rapid prototyping and other processes [22–29], scanning path planning [30–35], data-point preprocessing and reduction methods [36–41], surface fitting algorithms and solving approaches [42–58].

The applications of RE in the industrial area are defined in respect of following aspects: [59]

- *Design of a new component*. The design of new part comes from an existing real part model.
- *Reproduction of an existing component*. Some parts exist for which no design/manufacturing documentation exists but its copy can be obtained by RE approach.
- *Recovery of a damaged or broken component*. If the surface of a part to be measured is damaged or worn away, the reconstructed CAD model may not be precise compared with the true surface of the part.
- *Development of model precision*. The engineer can finish a product concept design based on the requirements of function and aesthetics and then use some soft materials, such as wood or plaster, etc., to fabricate models.

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0965-9978/$ - see front matter Published by Elsevier Ltd.
doi:10.1016/j.advengsoft.2008.07.003

- *Observation of a numerical data.* Scanning the part and reconstructing a 3D-CAD model by the RE approach, the designer can compare this model with the first model.

RE process has following advantages; i.e. fast availability of CAD models, physical model is used as the starting point, shortened development process, fully developed product at the start of production, reduction in product and production costs [60].

Today, the RE technique is commonly applied in many fields: manufacturing engineering, software engineering, film-entertainment industry, chemical engineering, electro technical industry, and recently there are first examples have come forth regarding RE application in industry of Micro-Electro-Mechanical Systems (MEMS). The process of RE can usually be subdivided into five stages, i.e. digitization of the part, data capturing, processing of measured data, Surface approximation—for solid modeling of the part (CAD modeling), technical documentation and NC part programming and CNC milling machine—for the part manufacturing [61,62]. Fig. 1 shows the working processes of RE. The whole process of RE should be computer aided.

Digitization of a part surface in RE can be achieved by utilizing either contact probing or non-contact sensing techniques as shown in Fig. 2 [63]. Contact probing devices are generally more accurate but slow in data acquisition, and vice versa for non-contact type devices. In order to meet the requirements, several types of contactless devices and sensors are lately developed with the wide use of optics and electron elements, such as structured-light sensors [7,8] and Moire topography projectors [12–14], laser beam

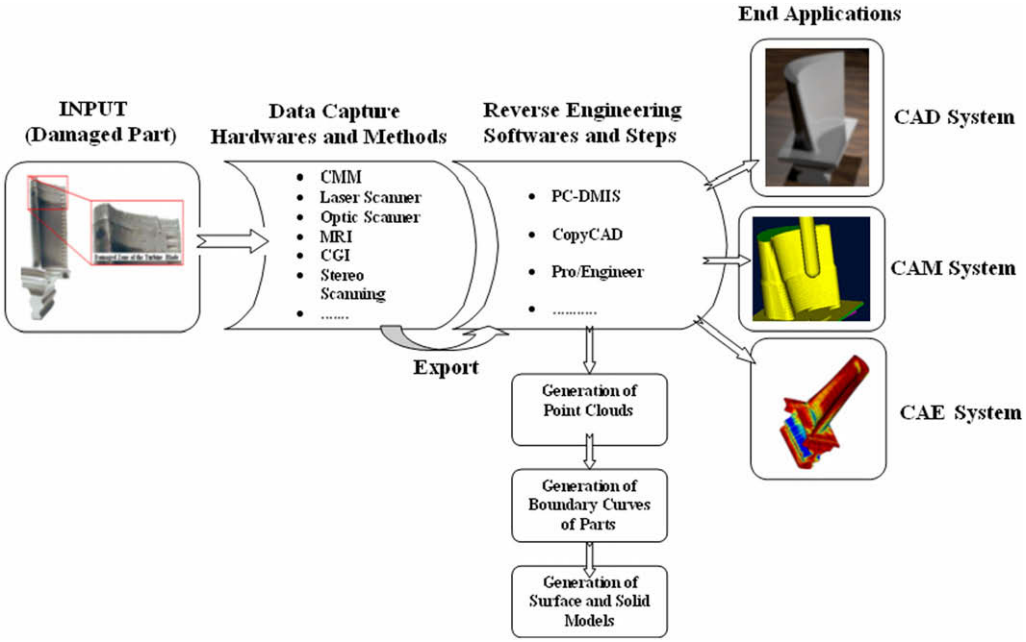


**Fig. 1.** The whole process of RE should be computer aided.

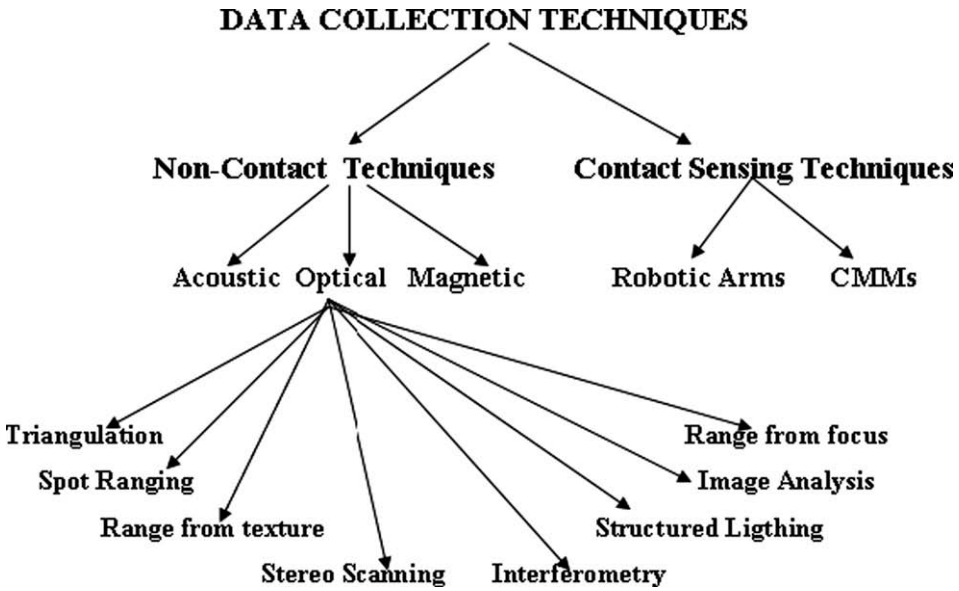


**Fig. 2.** Classification of data acquisition techniques.