STUDY ON THE REVERSE ENGINEERING (RE) MEASUREMENT TECHNOLOGY

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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged."

Signature: ....
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Date: ………………………

Specially dedicated to:

My beloved father, Abu Hassan bin Lakim; mother, Zainah binti Kassim; siblings, lecturers and all my friends for their eternal support, encouragement and inspiration throughout my journey of education in Universiti Teknikal Malaysia Melaka.
May Allah bless us.

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ABSTRACT

Many specialized applications such as engineering, industrial, medical, etc require precise dimensional measurement and three dimensional (3D) computer models of the real objects. The required precisions range is from micron to cm. This study focuses on the precision of non-contact measurement methods by using 3D Digitizer application (using ATOS) and close range digital photogrammetric measurement techniques (using Tritop) for dimensional measurement of a car rim. The accuracy were checked and verified with the Coordinate Measuring Machine (CMM), indicating precision of mm-level or better. The results obtained show the practicality of both systems, with accuracy ranging from several microns (for 3D Digitizer system) to several mm (for digital close range photogrammetric systems). The analysis shows at the datum for bolt holes (C-F) the design accuracy using ATOS is 0.03% while Tritop is undetectable, which is the maximum measuring area for Tritop is 10 x 10 m^2 and the minimum measuring area is 0.1 x 0.1 m^2. However ATOS and Tritop are faster than CMM in term of data processing and information gathering with percentage time reduction 75% (ATOS) and 63% (Tritop). The outcome from this research shows the practicality of the approach for many high precision applications.

ABSTRAK

Kebanyakan aplikasi khususnya kejuteraan, perindustrian, perubatan dan lain-lain memerlukan pengukuran yang tepat dan model komputer tiga dimensi (3D) melalui objek yang sebenar. Ketepatan yang diperlukan adalah dari micron kepada cm. Kajian ini menekankan tentang ketepatan dengan menggunakan kaedah pengukuran tanpa sentuhan melalui kaedah *3D Digitizer* (menggunakan ATOS) dan kaedah pengukuran *close range digital photogrammetric* (menggunakan Tritop) bagi mengukur dimensi rim kereta. Ketepatan diperiksa dan disahkan oleh *Coordinate Measuring Machine* (CMM), bagi menunjukkan ketepatan dari *mm-level* atau lebih baik. Hasil dari kajian ini menunjukkan kepraktisan kedua-dua sistem dengan ketepatan dari beberapa microns (bagi sistem 3D Digitizer) kepada beberapa mm (bagi sistem *close range digital photogrammetric*). Merujuk kepada datum yang sama untuk lubang skru (C-F), analisa yang dijalankan menunjukkan bahawa ketepatan pengukuran dengan menggunakan ATOS adalah 0.03% manakala Tritop tidak boleh mengukur pada lubang skru iaitu luas pengukuran maksimum bagi Tritop adalah 10 x 10 m^2 dan luas pengukuran minimumnya adalah 0.1 x 0.1 m^2. Dari segi kepantasan, ATOS dan Tritop jauh lebih pantas dari CMM dari segi pengolahan data dan mengumpul maklumat dengan peratusan pengurangan masa sebanyak 75% (ATOS) dan 63% (Tritop). Secara keseluruhannya, kajian ini dapat menunjukkan kesesuaian penggunaan pelbagai jenis aplikasi yang mempunyai ketepatan yang tinggi.

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CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Reverse engineering is the process of discovering the technological principles of a device, object or system through analysis of its structure, function and operation. Acquisition of physical data with high precision is a key step in reverse engineering. It is an important stimulative for the progress of reverse engineering with which various digitizing devices are invented, developed and made applicable. This project is focuses on the precision of non-contact measurement methods by using 3D Digitizer application and close range digital photogrammetric measurement techniques for dimensional measurement a car rim

1.2 PROBLEM STATEMENT

Much research work in the domain of coordinate metrology over the past few years has dealt with how to increase still further the accuracy of coordinate measurement by improvements in equipment and software. The emergence and development of non touch (3D scanner and photogrammetry) technology has recently opened the door to many new applications in the automotive and aeronautic industries. The latest ground-breaking innovation in the inspection and quality control world is the capability to replicate a series of measurements, traditionally obtained by various tools such as physical gages and CMMs, using a 3D digitizer and high-density point cloud inspection software.

Since the accuracy, inspection time, cost, and measuring errors depend on the employed automated inspection systems; the development of an optimal inspection strategy is required to speed up the inspection and accuracy. Currently, there are numerous method and software available for reverse engineering measurement technology. This project used ATOS 3D digitizer, Tritop and CMM to determined accuracy and differences based on the touch method and non-touch method. The 3D digitization of a part or a whole surface can be achieved by using either contact probing or non-contact sensing techniques. A Coordinate Measuring Machine (CMM) represents an example of the contact-probing device.

1.3 PROJECT OBJECTIVES

The main objective of this project is to study the accuracy level in various reverse engineering technology. The accuracy and differences based on the touch method and non-touch method can be determined by using the Coordinate Measuring Machine, ATOS 3D digitizer and Tritop.

1.4 SCOPE OF PROJECT

The scope of this project will be the guidelines throughout this project to ensure the project is conducted within it"s intend objectives. At the end of the project, it should be eventually achieved. The scopes are:

- Literature study on the measuring machine (ATOS, Tritop and CMM).
- Analyze the accuracy and differences based on the touch method and non-touch method.
- To differentiate the relationship between CMM, ATOS and Tritop.

CHAPTER 2

LITERATURE REVIEW

Conducting the literature review is done prior to undertaking the project. This will critically provide as much information as needed on the technologies available and methodologies used by other research counterparts around the world on the topic. This chapter provides the summary of the literature reviews on topics related to the reverse engineering measurement technologies.

2.1 AN OVERVIEW OF REVERSE ENGINEERING

The term "reverse engineering" includes any activity that determine how the product works, or to learn the ideas and technology that were originally used to develop the product. Reverse engineering is a way to redesign a product to reconstruct a new product which has similar functions and to improve the ability of the original product (Zainal Ab A. 1994). Reverse engineering can be use to study the design process, or as an initial step in the redesign process, in order to do any of the following:

- Observe and assess the mechanisms that make the device work
- Dissect and study the inner workings of a mechanical device
- Compare the actual device for observations and suggest improvements

Before deciding to do reverse engineering to a component, be sure to have sufficient information on the existing technical data of the component. For example, the process of reverse engineering can be use if the replacement parts of the component are required and the associated technical data is either lost, destroyed, non-existent, proprietary, or incomplete.

Reverse engineering initiates the redesign process, wherein a product is observed, disassembled, analyzed, tested, "experienced," and documented in terms of its functionality, form, physical principles, manufacturability, and ability to be assembled.

2.1.1 Applications Using Reverse Engineering

The intent of the reverse engineering process is to fully understand and represent the current instantiation of a product.

Here are just a few examples of how reverse engineering is making its presence felt in today"s manufacturing environment. In the automotive world, Japanese manufacturers are using reverse engineering to shorten the process of developing a full-scale car design from three months to three days. Racing teams are using new digital processes to capture, recreate, and test engine and body parts that are critical to a car's on-track performance.

In the medical market, reverse engineering processes are the foundation for mass manufacturing of hearing instruments, orthodontic devices, and dental appliances that are custom-made to fit an individual perfectly. These new products look better, feel comfortable, and are more effective in treating medical conditions.

2.1.2 Measurement in Reverse Engineering

As computer-aided design (CAD) has become more popular, reverse engineering has become a viable method to create a 3D virtual model of an existing physical part for use in 3D CAD, CAM, CAE and other software. The reverse-engineering process involves measuring an object and then reconstructing it as a 3D model.

In general, measurement systems comprise of contact and non-contact methods (Cho, M. W. et al. 1995). The contact methods vary from simple measurement using tape to the sophisticated Coordinate Measuring Machine (CMM). These two methods are commonly used in mechanical engineering. Measurement using tape is conventional and subject to errors. The efficiency is low. Though CMM is totally automated and its measurement accuracy is 0.02mm, CMM requires a stable platform and the object‟s size is limited.

Technology of non-contact measurement is a result of the development of computer graphic and vision, acoustics, optics and related equipments. Non-contact methods include laser scanning system (e.g. VIVID910 laser scanner), geodetic total station system (e.g. AXYZ system, the accuracy is about 0.05mm), close range photogrammetric system (e.g. V-STARS system, its accuracy is better than 0.05mm), and structured light system (e.g. Eyetronics‟ ShapeCam, whose accuracy is up to 0.5mm based on how tight user focuses his grid),etc (Halim SETAN et al. 2004). The usage of that equipment depends on how complex or difficult the product is. The physical object can be measured using 3D scanning technologies like CMMs, laser scanners, structured light digitizers or computed tomography. The measured data alone, usually represented as a point cloud, lacks topological information and is therefore often processed and modeled into a more usable format such as a triangular-faced mesh, a set of NURBS surfaces or a CAD model.

2.1.3 Why Use Reverse Engineering?

Even though reverse engineering services could appear to be a really fascinating thought, it canister be pretty challenging to work out how these services canister become useable for business outside of corporate espionage. Although it is surely legal that reverse engineering often canister be used by corporations to get an edge over each other in the R&D of new wares, this is definitely not the only usage it has: reverse engineering is pertinent to many designs ranging from redoing old technology to exploring the purposes of ancient artifacts. Following are some of the reasons for using reverse engineering:

a) The original manufacturer no longer exists, but a customer needs the product, e.g., aircraft spares required typically after an aircraft has been in service for several years.
b) The original manufacturer of a product no longer produces the product, e.g., the original product has become obsolete.
c) The original product design documentation has been lost or never existed.
d) Creating data to refurbish or manufacture a part for which there are no CAD data, or for which the data have become obsolete or lost.
e) Inspection and/or Quality Control–Comparing a fabricated part to its CAD description or to a standard item.
f) Some bad features of a product need to be eliminated e.g., excessive wear might indicate where a product should be improved.
g) Strengthening the good features of a product based on long-term usage.
h) Analyzing the good and bad features of competitors‟ products.
i) Exploring new avenues to improve product performance and features.
j) Creating 3-D data from a model or sculpture for animation in games and movies.
k) Creating 3-D data from an individual, model or sculpture to create, scale, or reproduce artwork.
l) Architectural and construction documentation and measurement.

m) Fitting clothing or footwear to individuals and determining the anthropometry of a population.
n) Generating data to create dental or surgical prosthetics, tissue engineered body parts, or for surgical planning.
o) Documentation and reproduction of crime scenes.

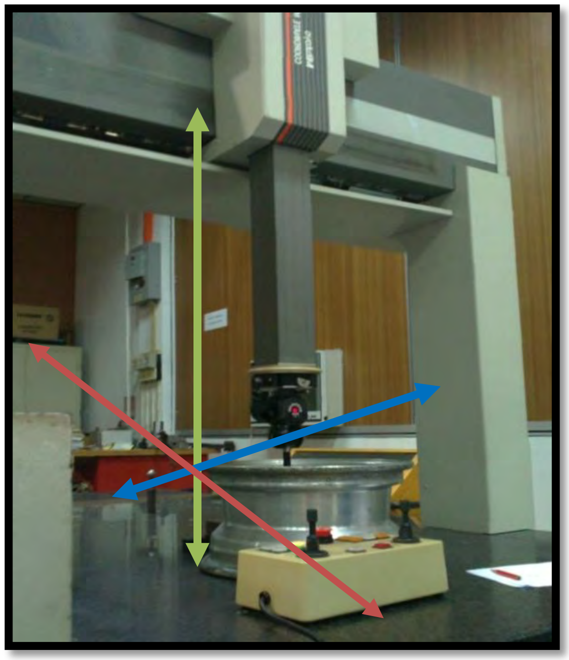
2.2 COORDINATE MEASURING MACHINE (CMM)

A coordinate measuring machine is a device for measuring the physical geometrical characteristics of an object. This machine may be manually controlled by an operator or it may be computer controlled. It is often preferred above other length measuring tools because of its versatility, ease of use, and its uncertainty which is nevertheless a few micrometres only.

Generally CMM is designed to move a probe that measures and determines the coordinate of an object. CMM is not object dependent and can be widely used on any type of object. CMM can be fully automated and the output could easily be linked to a CAD system.

Typical precision of a coordinate measuring machine is measured in Microns, or Micrometres, which is 1/1,000,000 of a metre. A probe system, attached to the CMM, can be moved in a well known way in a certain measuring volume. It can be actuated either manually or by servo motors. Servo controlled axes give better reproducing probing, and therefore higher accuracy, and possibilities for automation. The probe, under computer control, touches a sequence of points in the surface of a physical object to be measured, and the CMM produces a stream of x, y, z coordinates of the contact points.

However, using a CMM can be very complicated and it requires training. Using the touch-trigger probe for measuring complex shape objects requires full attention for the probe might be broken when touching and retracting the difficult parts. The same attentions are also needed when using the displacement measuring probe; the possibility of breaking the probe is high while scanning the difficult surface. Mostly, the technician who is responsible for handling the CMM is an expert in the machine and the measuring probe only. Usually the technician must have little knowledge of the computer system and the computer software, which are attached to the CMM.



Legend:

Blue arrow : X axis

Red arrow : Y axis

Green arrow : Z axis

Figure 2.1: Coordinate in CMM

Measurements are defined by a probe attached to the third moving axis of this machine. Probes may be mechanical, optical, laser, or white light, among others. They are often used for:

- Dimensional measurement
- Profile measurement
- Angularity or orientation measurement
- Depth mapping
- Digitizing or imaging
- Shaft measurement

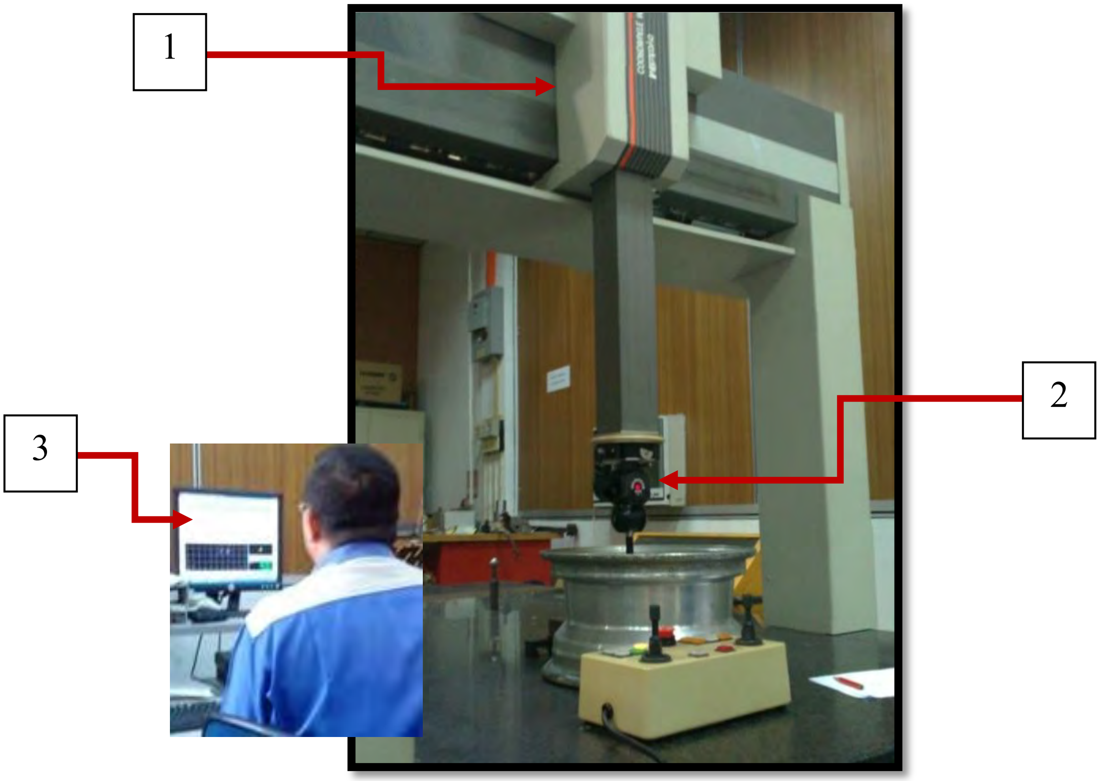


Figure 2.2: Main Component of CMM

Coordinate-measuring machines include three main components:

1) The main structure which include three axes of motion
2) Probing system
3) Data collection and Reduction system typically includes a machine controller, desktop computer and application software

The use of a CMM has been widely accepted for dimensional inspection of objects with complex surfaces. There exist several terms of automated inspection systems for complex surfaces using CMM. For example, (Ziemian, C. W., et al. 1997) refer to it as automated inspection planning; (Kim and Kim Kim, et al. 1996) refer to it as CAD-directed measuring strategy; (Ip, W. L.R. et al. 1996). refer to the system as the surface coordinate measurement method; (Skalski et al. 1998) call it the scanning measurement technique; (Hsieh et al.1993), just refer to it as reverse engineering that uses CMM; (Huang, X., et al. 1998) refer to it as CAD-model based inspection; (Yau,