UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE INFLUENCE OF MEASUREMENT METHODS ON 3D DIGITIZER ACCURACY

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Process) with Honours.

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirement for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process) with Honours. The member of supervisor committee is as follow:

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Supervisor

ABSTRAK

Reverse engneering (RE) merupakan suatu proses untuk menghasilkan sebuah CAD model terutamanya di dalam produk analisis. Ia juga digunakan untuk meneliti bagaimana produk dihasilkan, komponen yang terlibat, anggaran kos, dan mengenalpasti potensi pelanggaran paten. Proses untuk menghasilkan komponen dan CAD model adalah lebih singkat dan lebih baik berbanding dengan pengukuran secara manual. Namun demikian, ketepatan imbasan 3D diketahui lebih rendah berbanding dengan kaedah sentuh. Dalam kajian ini, penyiasatan dilakukan untuk menganalisis pengaruh jarak imbasan, sudut dan keadaan pencahayaan pada ketepatan 3D digitizer dengan mengunakan Taguchi method. Bagi ujian yang pertama adalah untuk meneliti kesan pada jarak imbasan dengan menukar kedudukan imbasan sesuai dengan jarak yang dikehendaki, ujian kedua pula melibatkan sudut imbasan iaitu kedudukan imbasan diletakkan pada tiga sudut yang berbeza dan ujian terakhir adalah berdasarkan pada keadaan pencahayaan di mana ujian dijalankan di dalam makmal dengan kecerahan lampu yang berbeza. Taguchi method digunakan dalam experiment ini adalah untuk menentukan jumlah imbasan dan analisis pada ketepatan 3D digitizer. Selain itu, keputusan yang terhasil akan mengesyorkan satu parameter yang optimum yang akan digunakan dalam T-test untuk mencari jurang perbezaan anatara 3D digitizer dan CMM dan juga analisis pada modal ketidakpastian utntuk mencadangkan kesalahan yang dihasilkan dari kedua-dua alat pengukuran. Selanjutnya, hasil daripada kajian ini bertujuan untuk mendapatkan parameter yang paling optimum and analisis ketidakpastian yang terhasil daripada 3D digitizer dan CMM.

ABSTRACT

Reverse engineering (RE) is a powerful tool for generating a CAD model especially in product analysis. It is also used to examine how a product works, what components it consists of, estimate costs, and identify potential patent infringement. The process of digitizing a part and creating a CAD model from 3D scan data is less time consuming and provides better accuracy than manually measuring the part and designing the part from scratch. Nevertheless, the accuracy of the 3D scanner is known to be lower compared to contact method. In this study, an investigation is done to analyze the effects of the scanning distances, angles and lighting conditions on 3D digitizer accuracy by using Taguchi method. Firstly, the test is to examine the effects on scanning distances by changing the position of scanning according to desire distance, secondly involved on the scanning angles where the test is undergone with three different angles and finally is based on the lighting conditions as the scanning is done under various brightness at the laboratory. Taguchi method is used in this experiment to determine the test run and also to analyze the accuracy of the 3D digitizer. Furthermore, from the result obtained one optimized parameter which will be used during T-test to find the significant difference between 3D digitizer and CMM together with an analysis of uncertainty model to suggest errors produce by both measuring equipment. As a result, it is found that 3D digitizer is less accuracy compared to CMM, clearly showed that non-contact method has less accuracy than contact method.

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DEDICATION

For my beloved family and friends for their loves and supports.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Reverse engineering (RE) of a mechanical component requires a precise digital model of the objects to be reproduced. Rather than a set of points a precise digital model can be represented by a polygon mesh, a set of flat or curved NURBS surfaces, or ideally for mechanical components, and a CAD solid model. A 3D scanner can be used to digitize free-form or gradually changing shaped components as well as prismatic geometries whereas a coordinate measuring machine is usually used only to determine simple dimensions of a highly prismatic model. These data points are then processed to create a usable digital model, usually using specialized reverse engineering software. 3D scanning or digitizing typical refers to the use of white light scanners or laser based sensors to 'scan' a surface and capture required features and geometry in a digital format. Technology advances in recent years now make it possible to quickly and accurately capture small or large objects using this approach. These can be parts, prototypes, manufacturing tooling, assemblies, carvings, sculptures and many other types of 'physical' applied precision Industry terminology.

There are a variety of technologies for digitally acquiring the shape of a 3D object. A well established classification divides them into two types: contact and non-contact 3D scanners. Non-contact 3D method attains point cloud data by using a non-contact distance sensing unit. An optical distance sensing unit is used as this non-contact distance sensing unit and is fixed to the extreme end of a tracer head, and a tracing is carried out by sensing a distance to a surface of a model, This tracing method eliminates any possibility of damage to a specimen, and accordingly, can be applied to a specimen composed of a soft material, and thus the applications for which a trace machining can be utilized are expected to increase, the optical measuring machine is based on the principle of triangulation to create a point cloud of geometric sample on the surface of the subject for example the Laser Scanner; Konica Minolta (non-contact method) and etc. For the contact method, it requires contact with the object being scanned. Thus, the act of scanning the object might modify or damage it. This fact is very significant when scanning delicate or valuable objects such as historical artifacts (Anon, 2010a). This particular 3D scanner is convenient as it has a portable tripod that can be adjusted accordingly to certain levels, thus this will minimize or eliminate downtime of part traveling from production from the measurement room.

The Breuckmann OPTO-HE is one of those 3D scanners that used non-contact trace control apparatus has been developed to trace a configuration of a model. It uses Fringe-based Projection Techniques where successive images of fringe patterns are projected onto an object, and one or two high-density cameras capture surface images. Enough fringe patterns are projected until a grid of object coordinates can be formed from intersecting reflections on individual camera pixels as shown in Figure 1.1 and 1.2.

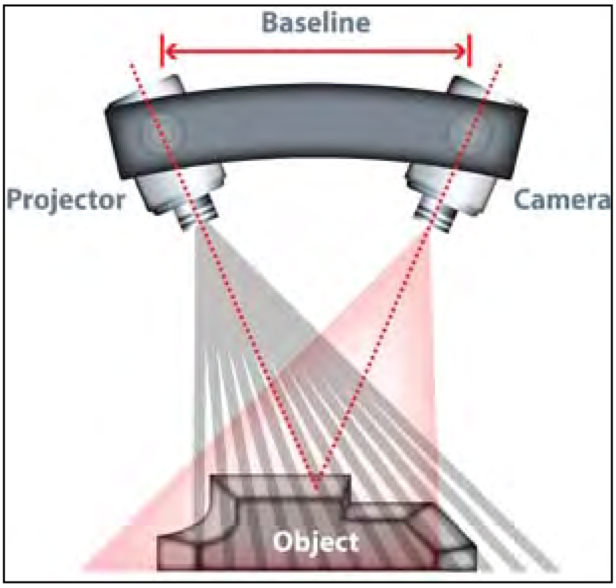

Figure 1.1: The basic geometric principle of fringe-based projection digitizing (Anon, 2010h)

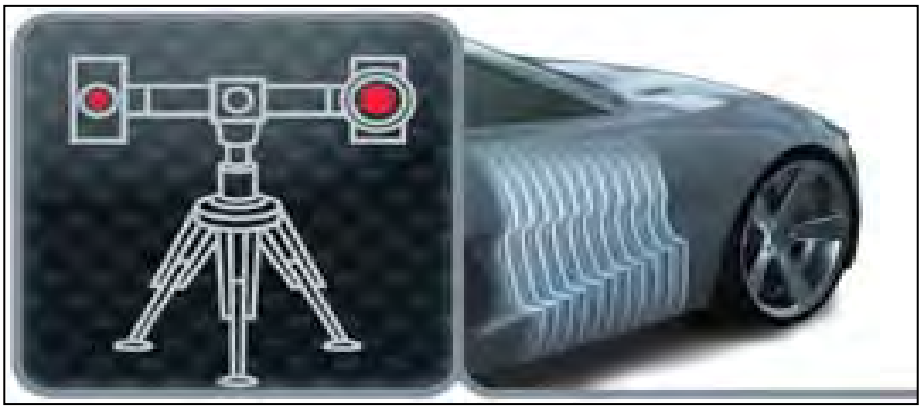

Figure 1.2: This fringe-based white light projection digitizer is combined with optical tracking EFR (Anon, 2010h)

This fringe-based white light projection digitizer is combined with optical tracking EFR. Detailed measurements can be made by taking a series of photos with different stripe pattern widths (phase-shifting), as shown in Figure 1.3. This technique is known as white light time-multiplexed pattern projection. These close-range measurement techniques offer good accuracy and lateral resolution along two axes, and are fast to measure objects with low-curvature surfaces. Important limitations of fringe techniques, however, are that they lack the dynamic range needed to scan shiny finishes, are slow to measure objects with intricate details, and suffer from occlusion effects, requiring additional shots depending on the size of the object (Anon, 2010h).

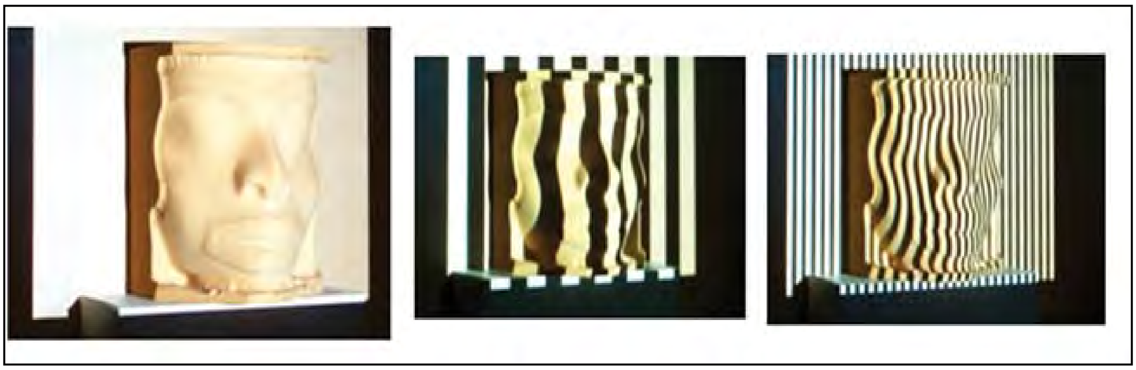

Figure 1.3: Object to digitize with interference fringe patterns for coarse and fine depth measurement (Anon, 2010h)

Even though non-contact method of 3D digitizers has the advantages own its own in terms of the preserve the specimen with the use of non-contact method. However, the main drawback of this method is the accuracy of the measurement taken compared to the contact method for example CMM (Coordinate Measuring Machine). The contact method is more accurate because it uses probe to touch the specimen whereas the non-contact method only used laser triangulation, fringe-based projection techniques and etc which depends on the distance of the measurement taken, the lightning factor and also the angle of the measurement.

1.2 Problem Statement

3D Digitizer or non-contact method is known to be less accurate compared to the contact method. The accuracy is reduced when measurement is done under uncontrolled condition. This uncontrolled condition is defined as production floor. The error produced to be known in order to obtain better measurement results.

1.3 Objectives

The objectives of the experiments are:

a) To study the effects of scanning distances, angles and lighting conditions on measurement accuracy of 3D digitizer.

b) To find the optimize parameter that can produce accurate measurement.

c) To create and compare the uncertainty of 3D digitizer and CMM.

1.4 Scope

The experiment is conducted by using 3D Digitizer “Breuckmann OPTO-HE” and is been done in laboratory at temperature of 22.2 C. In this study, the specimen selected which is 100 mm Gauge Block, the experiment is tested under three parameters based on different scanning distances, angles and lighting conditions with the implementation of Taguchi Method to generate result.

CHAPTER 2

LITERITURE REVIEW

2.1 Introduction

There has been a lot of research has done on the accuracy of 3D Digitizer via comparing method of scanning in developing systematic error. In order to achieve the result stated in research objectives, an overview of 3D scanner technology, methods of finding effect on scanning such as scanning distances, angles and lighting conditions and software use need to be done.

2.2 An Overview of 3D Scanning Technology

There are mainly two methods for obtaining coordinates of an object's geometrical shape. The first one is mechanical method which uses mechanical arms where the object is fixed on a table; the coordinates of the points picked by the inspector by means of touch-probes are transferred to the computer. With this system, measurement of formed and large surfaces may take hours or even days depending on the details of the object and accuracy of the measurement required. Accuracy levels up to 1 μm can be achieved by using this method. This level of sensitivity depends on the experience of the inspector and type of the equipment used. The second one is non-contacting scanning methods which can be classified in to three main categories optical, acoustic and magnetic. (Gastel et al. 2009)

Optical scanning systems based on techniques such as laser scanning, fringe projection, photogrammetry etc. are being applied successfully for the 3D measurement and virtual reconstruction of object surfaces in many areas (Bernard, 1999). Fringe projection scanning systems generally work with white structured light where the light pattern is projected on the object's surface while one or two cameras record the reflected light while laser scanning systems can obtain data by sending laser light onto the object and processing the data obtained from the returning light (Peipe et al. 2005). The advantages of these scanners are that they are more portable compared to contact systems and their sensitivity levels are partially independent of the inspector.

Optical scanning systems, e.g. laser or fringe projection can obtain a large amount of point data in a short period of time and the accuracy of laser systems vary typically from 1 μm up to 20 μm, whereas fringe projection systems have the capability of 10 μm up to 60 μm. Since the accuracy of the non contact systems are continually improving, they are now widely adopted for many applications in the industry (Seokbae et al. 2002). Optical technology is generally preferred method because it gives a greater flexibility in the digitization of surfaces (Tognola et al. 2003) and provides higher resolution and accuracy when compared to mechanical technology (Sokovic et al. 2006). Because of speed of measurement and greater flexibility, there is an increasing demand for optical scanning systems (Gestel et al. 2009). The advantage of contacting devices is that they do not depend on the color and reflective characteristics of the surfaces to be scanned which might be the case with optical scanners.

2.3 Methods of Finding Effects on Scanning

Firstly, the finding is on the scanning distances, according to Konica Minolta non-contact 3D Digitizers (Anon, 2010e), the distance to the object can be obtained by the angle of reflection of the laser, the angle of incidence of the reflected light from the object into the CCD and the fixed distance between Laser and CCD camera. Konica Minolta non-contact 3D Digitizers are based on the principle of laser triangulation. Objects are scanned using a laser light stripe. The light reflecting from the object then enters the CCD camera of the Vivid 910.

Another research done is by using ZScanner 800, (Anon, 2010f), it is handheld scanner used in manufacturing industry for simple data-capture purpose such as documentation. The most suitable scanning distance for this scanner is one foot from the part to be scanned and the green light stays on. The scanning is also offers with dots method which is really helpful and convenient to user.

Riegl Scanner (Reigl LMS) (Yatuka,et al. 2002) was assigned to cover the large area of field and to achieve high efficiency in fieldworks of laser scanning Riegl LMS can yield panoramic range image with almost 360 degree horizontal range. The maximum measurement range reaches 300 m. The accuracy in distance measurement is approximately 2.5cm and accuracy in angular measurement of laser beam is around 0.24 degree. Since the range measurement errors occur randomly when the Riegl LMS-Z210 scans completely flat plane, the outcome looks like bumpy plane with irregular errors. To remove such bumpy errors and to reconstruct smooth and flat plane, filtering techniques are indispensable. Riegl LMS Z-210 is better for covering wider area and recording of the locations and rough shapes of large archaeological structures such as columns and gates, and terrain topography around them.

Cyrax 2500 (Yatuka,et al. 2002) has the measurement range (min to max) 1.5 m to 100 m and the range of accuracy is less than 6 mm. Reflectivity is simultaneously as well as the refection rate of the object surface are obtained. It is more appropriate for obtaining more accurate 3D data of monument and structure.

Secondly is the research about scanning angles, Studied (Mekid et al. 2007) show that there are three methods that can be used in manipulating the scanner position (angle) to perform a scanning. The method is one of the factors that studied in this project to investigate the probability of point detected at the edges of the workpiece. Although the author believe that the laser stripe and digitizing occlusions play an important role in detecting points especially at the edges, the scanner position can be used to manipulate these factors. It is believed, when angle is applied to the scanner position, the percentage of the laser scanner hit the edges of the component are higher. This is because, as shown in Figure 2.1 (a) and 2.1 (c) the potential of the laser strip miss the edges in higher but in 2.1 (b), the percentage is minimum because in angle position. In other words, it is a trade off factors that important to be investigated in order to achieve the accuracy. The laser stripe with different angle of laser scanner position and the angle is also depending on the interface of the laser scanner; in this project the interface of Renishaw PH10 is used.

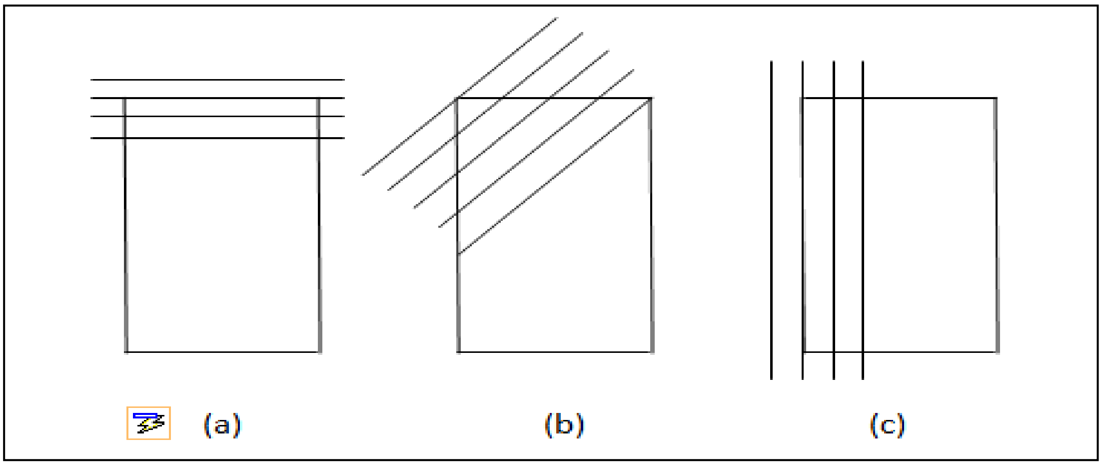

Figure 2.1: (a) The laser scanner in default position, 0°, (b) The laser scanner at applied angle and (c) The laser scanner at vertical position, 90° (Mekid et al. 2007)

Besides that, laser scanners measure the distances between the scanner and the points on surface of measured object by measuring the return time of laser beam emitted from the sensor. At the same time, horizontal and vertical angles of the laser beam are measured. As the result of combining the angles of the laser beam and the distances, 3D coordinates of the object surface are computed. Immediate outcomes of the laser scanners are point cloud data with 3D coordinates (Yatuka,et al. 2002).

Cyrax 2500 (Yatuka,et al. 2002), though it has a limited scanning view with 40 degrees vertically and 40 degrees horizontally, have high accuracy in distance measurement and finer angular resolution. Due to the limited viewing angle, considerable numbers of scans are sometimes necessary in order to cover the whole surface of the object, especially when the object is large or the space for scanning is narrow. In the sense, Cyrax scanner is more appropriate for obtaining more accurate 3D data of monuments and structures.

Lastly is about the lighting condition, based on 3D Scanner Structured Light, with all optical methods, reflective or transparent surfaces raise difficulties. Reflections are causing light either being reflected away from the camera or right into its optics. In both cases, the dynamic range of the camera can be exceeded. Double reflections can cause the stripe pattern to be overlaid with unwanted light, entirely eliminating the chance for proper detection. Reflective cavities are therefore difficult to handle. Transparent or semi transparent surfaces are also causing major difficulties. In these cases, coating the surfaces with a thin opaque lacquer just for measuring purposes is a common practice. For measuring entirely reflective surfaces, the alternative method of fringe reflection has been implemented (Anon, 2010g).

From the finding, it is found that as for the non-contact method is to be dependent on the quality of the reflection which is other types of intrinsic parameters. For example, color of scan object, edges and deep feature. Furthermore, the distances of scanning, angles and lighting conditions also fall under the intrinsic parameter. These depended parameters give an option to the user in making planning and decision prior scanning. To overcome these issues, scanning technique can be used in minimizing the impact of intrinsic parameters from scan object characteristic. For example, the use of coating by using developer enables black and transparent objects to be detected by the laser sensor which introduced error. Table 2.1 shows the extrinsic parameters that suggested by (Mekid et al. 2007) able to be set by user.

Table 2.1: Extrinsic uncertainty parameters

No.	Extrinsic
1.	Distance between points
2.	Depth of scan
3.	Incident angle
4.	Laser scanner position
5.	Distance between strips
6.	Overlap between laser strips
7.	Lighting conditions

2.4 Software

The study from (Joomyung et al. 2002) of measuring the dimensions on the face digitized was performed using Rapidform2000 software. Rapidform is recognized as a comprehensive tool to convert physical data from 3d scanner into digital data for scan data processing, deformation, measurement and format transformation. The definition of 10 dimensions for physical measuring was redefined for digital measuring. With the new definition, 60 each face data was measured. To make sure this new measuring method has reliability, current physical measuring method using sliding caliper (Siber hegner No.104), spreading caliper (Siber hegner No. 106) and measuring tape were performed simultaneously. The two kinds of dimensions were comparatively same in the permissible error 95%.

Based on KONICA MINOLTA Non- Contact 3D Digitizer, mentioned that Polygon Editing Tool (PET) enables to operate automatic 360º acquisition of models. The object data can then be processed with a variety of third party software packages. Besides that, the 3D Digitizer can also be operated with a turntable, allowing faster and better scanning time in order to merge to one complete 3D model (Annon, 2010e). RHINOCEROS 3.0 is a commercial 3-D NURBS (non-uniform rational B-spline) modeling program for Windows. Among its capabilities are: generation of wire frame, generation of solid 3D model, and dimensional measurement (Halim et al. 2003).

PolyWorks is a software created by InnovMetric to do the alignment as after manual selection of three or four corresponding points, PolyWorks aligns simultaneously all the point cloud data automatically by minimizing the sum total of positional errors between corresponding points among overlapping point cloud data. After the alignment PolyWorks merge all point cloud data into one polygon data automatically. Then the data can be transferred to CAD, CG or VR software as shows at Figure 2.2 (Yatuka et al.2002).