IMPROVING THE ACCURACY OF OPEN SOURCE 3D SCANNING MACHINE

NADIA ILYSA BINTI RASIMAN

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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A report submitted
in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this project entitled "Improving the Accuracy of Open Source 3D Scanning Machine" is the result of my own work except as cited in the references.

Signature : ……

Name : NADIA ILYSA BINTI RASIMAN

Date : ……

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical in Engineering (Design and Innovation).

Signature : ……..

Name of Supervisor : …….

Date : ……..

ABSTRACT

In this project, Microsoft Kinect was used as a medium of low cost 3D scanner where the Kinect Xbox 360 was used as a measuring device to scan the frame scene of an object. The objectives of this experiment were to generate the new concept of a low cost active 3D scanner, analyze its structure by using finite element analysis and to produce detail design by using solid modeling software. An engineering design methodology was used as an approach to generate this new concept design. In this method, a brainstorming approach was used to obtain the design with the conceptual design and its specification. Morphological chart was used to generate few design and by using Pugh chart method analysis, the concept design comes out with final conceptual design of rotating platform with complete engineering design characteristic. This platform was used to place the Kinect Xbox which will moves into 360 degree to capture the different types of object in order to analyze the accuracy. Whereby, this accuracy of each data was obtained by using calculation of percentage difference between real object and scanned object. Skanect software was used to capturing the full color of 3D model, where this open source software will transforms Microsoft Kinect into low cost 3D scanner and able to create 3D meshes. From the result, sport shoes has the highest percentage difference of 8.6% followed by chair with 6.25% and the lowest was the shoes box with 1.6%. Thus the present of the open source software and hardware, this Kinect Xbox 360 sensor was able to be used as low cost 3D scanner and by implement the technique of moving sensor can reduced the percentage difference which can make the values near to accurate.

ABSTRAK

Didalam projek ini, Microsoft Kinect merupakan medium yang digunakan sebagai satu peranti pengimbas 3D yang murah dengan mengunakan Kinect Xbox 360 sebagai alat pengukur untuk mengimbas objek. Tujuan utama projek ini ialah untuk merekabentuk satu konsep baru yang berkaitan kepada peranti pengimbas 3D yang murah dan mengkaji struktur konsep tersebut mengunakan analisis unsur terhingga dan seterusnya menghasilkan satu lukisan lengkap mengunakkan perisisan permodelan perpejal. Kaedah yang digunakan dalam projek ini menjurus kepada kaedah lukisan kejuruteaan dimana proses ini bermula daripada menyenaraikan semua idea yag berkaitan dengan projek. Seterusnya, konsep carta morfologi telah diketengahkan untuk menghasilkan beberapa konsep baru dan melalui beberapa konsep baru ini, satu analisis yang dipanggil carta pugh telah dibuat untuk menganalisis konsep yang paling sesuai untuk digunakan dalam projek ini. Setelah itu, konsep baru ini akan digunakan untuk meletakkan Kinect Xbox 360 ini untuk mengimbas bebrapa objek yang statik pada 360 darjah pusingan. Skanect merupakan medium yang digunakan untuk memproses objek ini didalam bentuk maya dalam 3 dimensi.Skanect merupakan satu perisian yang bersifat terbuka dimana perisian ini akan digunakan untuk mengubah fungsi Microsoft Kinect kepada peranti pengimbas 3D yang murah untuk mengimbas keseluruhan data objek termasuk warna asal objek tersebut. Daripada hasil kajian, kasut sukan mempunyai nilai perbezaan yang tinggi antara ukuran asal dan ukuran daripada peranti pengimbas iaitu 8.6% ikuti oleh kerusi dengan nilai 6.25% dan nilai yang terendah merupakan kotak dengan nilai dapatan sebanyak 1.6%. Secara konklusinya, dengan mengunakkan konsep mengerakkan peranti pengimbas dengan mengerakkan secara 360 darjah mengelilingi objek dapat mengurangkan kadar perbezaan antara ukuran asal dan ukuran daripada peranti pengimbas tersebut.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Three dimension scanners (3D scanner) is a device that analysis object or environmental data. The data will be interpreted to produce three dimensional models. The first 3D scanning technology was created in the 1960s whereby early scanners used cameras, projectors and lights (Ebrahim, 2014). Due limitations to scan the object accurately, this scanners were replaced by using white light, shadowing and lasers to captured an object's surfaces after 1985. First application of this 3D scanning is used in capturing human for animation industry by using Head Scanner. However, during this time, even the 3D scanner were developing in high detail scanners, still the degree and accuracy were still hard to achieve.

Nowadays, 3D scanning technology development offers users to capture objects in and outside during the days or night. Even, the Direct Dimension successfully scanned entire airplanes, ships and historic monuments. However, the recently product 3D scanner is too expensive. Moreover, the resolutions of a scanners is limited by the resolution of hardware which affects the depth accuracy of the object's surface (S.M.Emam et al, 2014). Thus, a Kinect sensor was introduced as a low cost 3d sensor scanning. This sensor was used in animation whereby it can provide the depth of the surface.

This Kinect sensor consists of color VGA video camera, depth sensor and multi-array-microphone. It works by inferring body position in two-stage process. This process is by direct compute a depth map and by inferring body position. This data can be stored and generate the 3D model in digital form by manipulating using computer programs.

1.2 PROBLEM STATEMENT

3D scanning technologies nowadays are way too advanced. It comes with high resolutions colors and even exists in portable shapes. However, these high technologies come with high price. This will be the problems for a small company to develop products. They tend to spend a lot of money to buy this kind of technologies. Considering for educational purpose, it is a waste to spend too much money for an expensive 3D scanner machine since in educational purposes, this machine only used to exposed students to know how this machine works and its real applications. Seeing that fact, having a low cost 3D scanner is enough for an educational purpose.

Besides, software is needed to deliver raw scan data. This software is crucial for enabling user to process the data obtained from the 3d scanner. A good software will exposed the user to minimize the spent data processing which makes it more efficient. However, the present software is costly and difficult to use. Mostly the software is designed for engineering or surveyors. Thus, it is not user friendly for the non-engineering sectors. Hence, a remodeling new model to more users friendly needs to be considered.

Next, to obtain 3D scanned object, it needs much work. To get a complete surface of object, the scanning requires distinct range images which must be taken from different viewpoints to measure object with a high quality range data(Martins et al, 2005). Each viewpoint must be properly defined. This viewpoint needed to be combining to form one complete 3D model before converting it into CAD format. Thus, by designing 360 degree rotating platform for scanned object can save time and better results.

1.3 OBJECTIVE

The objectives of this project are:

- To generate new design concept of a low cost active 3D scanner.
- To analyze the structure of the low cost 3D scanner using finite element analysis.
- To produce detail design of 3D scanner using solid modeling software.

1.4 SCOPE OF PROJECT

The scopes of this project are:

1. Microsoft Kinect will be used to capture and detect the object's surface.
2. CATIA will be used as the Computer Aided Design (CAD) drawing. This software will analyze the structure of model object by using Finite Element Analysis (FEA).
3. A rotating platform will be used to place an object to be captured by 3D scanner. This motion will manipulate and generate 3 dimensional models.

1.5 GENERAL METHODOLOGY

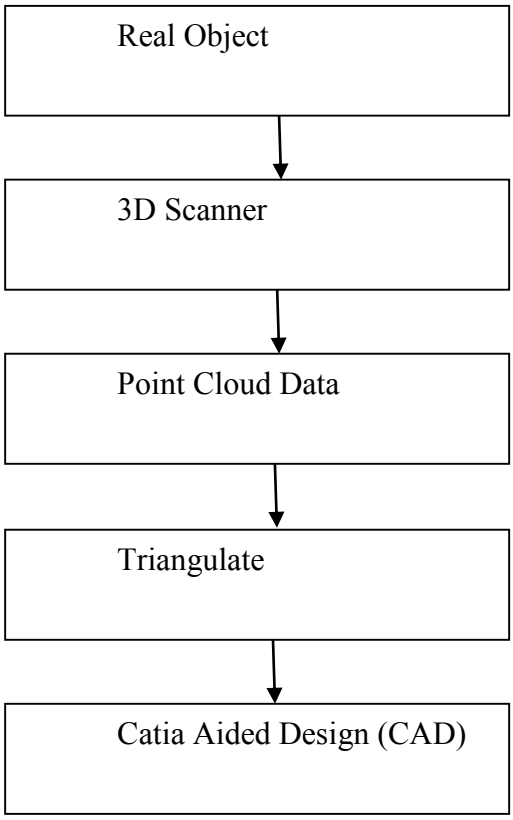

Figure1. Flowchart of Methodology of 3D Scanning Process.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Nowadays, 3D scanners have become more popular and widely used tools. One of its widely field applications are in manufacturing industry, and in reverse engineering. In reverse engineering, these 3D scanners were used to create automotive parts. Basically these devices work to capture a two-dimensional object as an input and will produce a virtual three-dimension object as an output. The data captures were in points which known as point cloud. In detail, these devices will capture the depth of the object and produce a large number of points on the surface of the object. Later, the Standard Tessellation Language (STL) format will be produced by this point cloud whereby, this STL file only describes the surface geometry of the three-dimensional object without considering the colors and textures. Apparently, these devices were capable of representing virtual object with high good accuracy (Reyes et al, 2013). However, the price was extremely expensive making students or academic staffs less affordable to buy and use these devices either in academic or researcher purposed. Thus, a low cost 3D scanner will be proposed and design by using Microsoft Kinect as the 3D sensing device. In this design, some modification is made to make this Microsoft Kinect sensors act as an active 3D scanner. All the information is studied on how to improve the accuracy of this low-cost 3D scanner.

2.2 REVERSE ENGINEERING

Reverse engineering can be referred as consideration of the part objects on how it works in order to enhance or duplicate the objects. However, in 3D scanning, this reverse engineering refers to a process obtaining geometric shape from discrete sample. This discrete sample will be used to create mathematical models the CAD model does not exists. During this process, the product part is produce by extracting surfaces or sketches from the scanned object by using mesh or point cloud. Simply put, this reverse engineering in 3D scanning can produce three-dimensional model even without existing CAD files. The accuracy of the output can achieve up to 100 %. The output files can be transfer to any CAD and this output files can be function as inspection, tool path making, inspection or 3D printing and additive manufacturing.

Basically, the three-dimensional geometry for reverse engineering studies is focuses on distances or images (Herraez et al, 2016). S.M. Emam et al. (2014), have proposed a dithering technique (DT) to improve the accuracy of the laser scanning for three dimensional model reconstruction. This technique used an approach of distance through small movement of either the sensing array or the object and rescanning, and normally applied in signal and image processing application to reduce the amount of the error in the reference image. This DT method reduced the round off error by adding an external noise during the point cloud process. S.M.Emam et al. (2014), proposed this technique on the laser triangulation scanner by shifting the sensing array during capturing the scene. An experiment was carried out by using Sony XC-555P of 7681 (H) and 576(V) pixel with 8.33um pixel size. The output of depth reconstruction was studied by moving the camera sensor into two different positions. Results from the constructed depth were calculated to obtain the experimental depth value. Later, this value was compared with the actual value by using Coordinate Measuring Machine (CMM) with 0.001 mm accuracy. The results show that the accuracy of construction is improved by 50% relative a normal style acquisition.

In reverse engineering process, both software and hardware are needed to work as a team. Whereby, the hardware is used to measure the object and the software is used to create the three-dimensional virtual object. L.M.Galantucci et al. (2015) have implement motorized movements on CNC milling machine which the system is controlled by using Mach3 CNC software. A semi-automatic low cost motorized active 3D slit laser scanning system is used and this 3D

scanner is focuses on its development and implementation through a several testing and experiment. This study shows a relation between hardware of the milling machine (Mach3) and the scanning software of David-LaserScan using an active sensor which is CMOS sensor. Through this experiment, the 3D scanning system can make full 360° rotation scan of the objects. An algorithms code is produce by using Processing software which this algorithm will send a command to David and Mach3 software to control the movements of the CNC machine. From several experimental methods, the accuracy of measurement can be improved by increasing the triangulation base (B1 const) (Figure 2.1) or by using larger sensor.

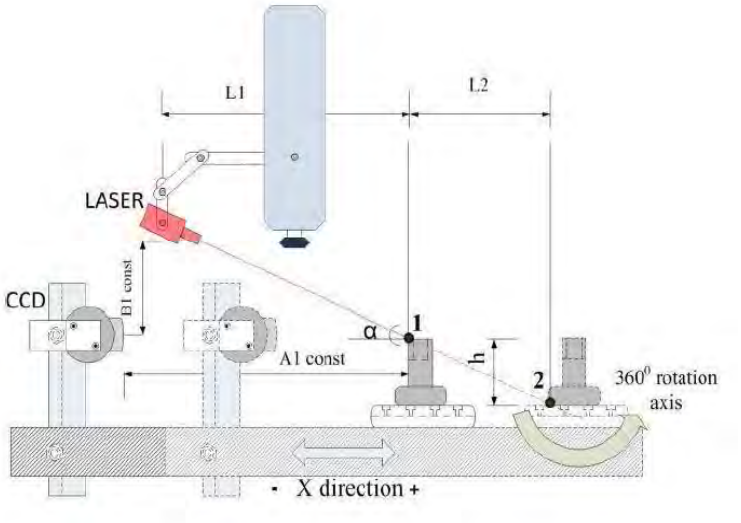

Figure 2.1 Experiment Set-up of Scanning Process.

Sansoni et al. (2005) also have described the rapid prototyping and reverse engineering of 3D optical scanner in automotive history. Sansoni et al. (2005) study shows that how 3d scanner camera and some suitable data modeling can be helpful in reverse engineering in the virtual representation and complex geometry. A Ferari 25MM model was used to produce car body by using non-contact gauging instead of using contact probes. The acquisition of the Ferari was performed by using 280 views at medium resolution. Later, OPL-3D was configured at high resolution to obtain more detail of the car body such as handles and window border. In order to create the replica body, the Ferari was mesh into 1:10 scaled. The result model was accurate and

the measurement of distance between the selected triangle pair using triangulation process is acceptable.

2.3 3D SCANNING SYSTEM

3D scanner is a device that captures two dimensional object data and this data will be used to construct digital three dimensional objects. The data collected was based on the shape geometry without considering the colors of objects. This device commonly used widely in manufacturing, rapid prototyping, reverse engineering and even extensively used in production industry for gaming purpose. Back in 1998, the 3D scanning systems were revealed to be expensive, slow and low resolution (Daanen & Ter Haar, 2013). During this year, the available 3D scanners were only based on laser scanning system, patterned light system, and streophotogrammetry system (Daanen & Ter Haar, 2013). Later, when these devices were progressively increased, new techniques were introduced. The techniques are based on millimeter waves system and infrared waves system. However, in last decade, the use of streophotogrammetry was replaced to scanner laser due to its intensive and accuracy of the data provided (Herraez et al, 2016). Recently, laser scanner is the most preferable tools to be used in many disciplines of works. This devices offers short time in collecting data in engineering works and even in reverse engineering (Herraez et al., 2016). This laser scanner is work by using laser line systems where a laser line is projected on the body from variance of sides and viewed by camera under fixed angle. This system was contributed to reduction of cost and high resolution (Daanen & Ter Haar, 2013). However, this system having some problems in data gathering, data processing and in terms of accuracy (Herraez et al., 2016). Differs from structured light system, this system projects an entire pattern and accurate compute on how the 2D lines transform into 3D surface. This sequential 3D line will form complete three dimensional images. This structured light scanner consist of camera with filter, pattern projector and additional camera to capture the true colors of the 3D scene (Daanen & Ter Haar, 2013). Both of this laser and structured light are classified as an optical measurement of 3D scanning method. This optical measurement method can be classified (Figure 2.2) into two different types which is active method and passive method.

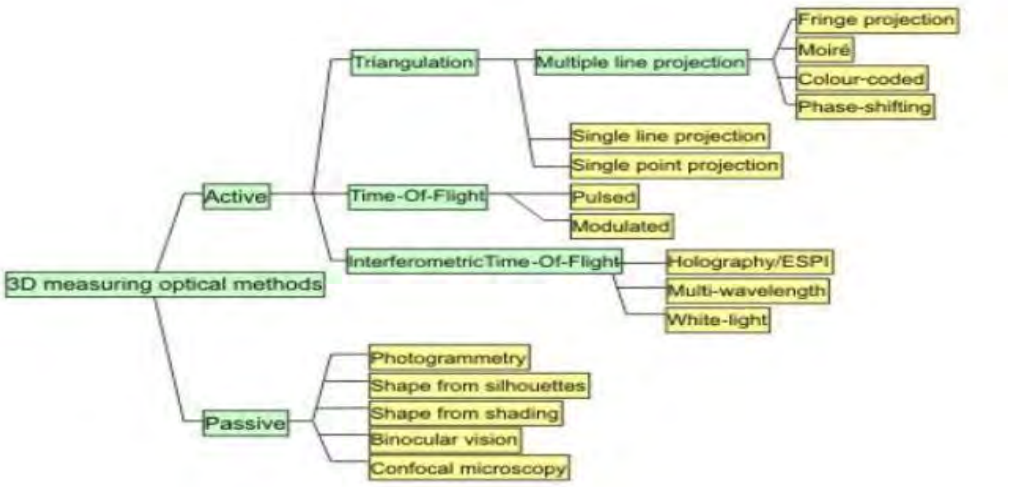

Figure 2.2 Classification of 3D Measuring Optical Method.

2.3.1 ACTIVE METHOD

Active 3D measurement method is a process which employs structure illuminations. This method is categorized as non-contact active optical 3D scanner. Bianco et al. (2013) have conducted an experiment to compare of 3D reconstruction data between active and passive method for underwater conditions. This comparison was conducted under the condition of poor visibility in a laboratory in turbid water by using structured light technique. As for active method, an active stereo technique was used by using hardware which is spatial, time, spectrum discrimination and polarization. From the result, the point cloud obtained from the active stereo technique gives more stables results in turbidity compared to passive stereo technique. In active 3D measurement method, it is require additional measurement to obtain the projected image data and controlled illumination process can be applied to overcome some overlapping image data. This illumination process is referred as structured light illumination (SLI) process. This SLI process is classified as non-contact active 3D triangulation based techniques whereby this process is has similar concept with stereo vision and is used to reduce the computational complexity of similar pixels across the camera view. This complexity is reduced by changing the positions of camera component with a projector that produces a series of

stripped patterns. The derivation data between the camera and projector pixel can be analyze by changing of the pattern at certain point. Basically, this 3D triangulation based technique is known for its low cost and high accuracy result.

2.3.2 PASSIVE METHOD

Passive method is also classified into non-contact optical 3D scanner. This non-contact offers a faster way in scanning object by collecting thousands of point cloud of an object at one time. In contrast with active method, this passive method is based on stereo vision which is more convenient and more applicable due to its less apparatus setup (Muquit, Shibahara, & Aoki, 2006). This passive measurement method only acquire one move or still camera to measure the image data. However, in this 3D measurement of using stereo vision, it is found that it is hard to find accurate corresponding image which makes it become poor to reconstruct the quality of projected image. Abdul et al. (2006) experiment on the 3D reconstruction by using passive 3D measurement method shows a successful result. During the 3D reconstruction, the projection matrices obtained from the camera and about 4000-5000 of corresponding points were used to reconstruct the real object. In this case, the reconstruction accuracy of a passive method system is observed and was compared to the light structured light projection. From the comparison with the structured light projection, the passive method data achieve 0.5mm accuracy in 3D measurement even with the narrow baseline stereo camera head.

Figure 2.3 3D Reconstruct Face Data From Different View of Angle.

Multi-image photogrammetry is one of the passive methods which commonly used for human body measurement. This method utilizes multiple images acquired from multiple directions of the set up camera. The resulting point cloud of each different image is compute by the matching algorithms. In order to compute the 3D coordinates of human body measurement, a ray intersection is made to produce a dense 3D point cloud (Figure2.5). Figure 2.4 shows the result from the passive method of the intersection ray.

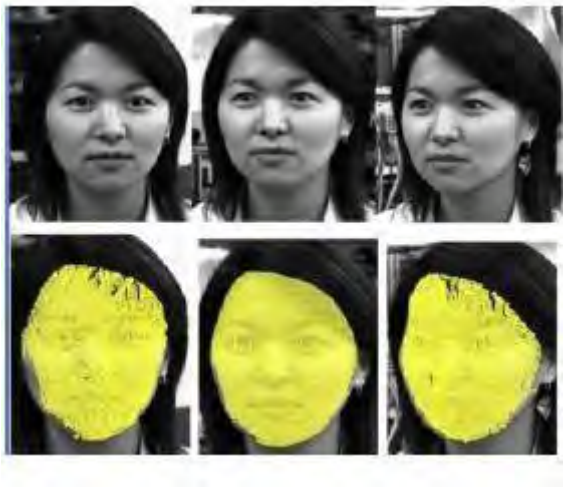

Figure 2.4 Face Scanning Process by Using Multi-image Process.

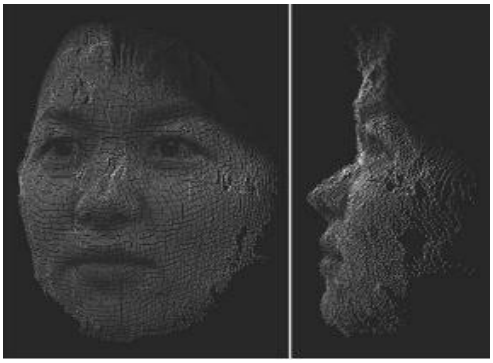

Figure 2.5 Resulting 3D Point Cloud.

2.4 MICROSOFT KINECT

Kinect is a line motion sensor devices introduced by Microsoft company. Initially, this invention is to use with video games for X-box, video game consoles and windows PC's. The introduction of the Kinect camera has open a new impulse for 3D scanners whereby the first distribution of Kinect as 3D whole body scanners was in 2011 and the result shows the system works properly (Daanen & Ter Haar, 2013). In 3D scanning system, this device can be categories as a structural light scanner even though it uses a pattern of near infrared. In early introduction, this device using closed source system software compared to today which the open sources are now available (Daanen & Ter Haar, 2013).

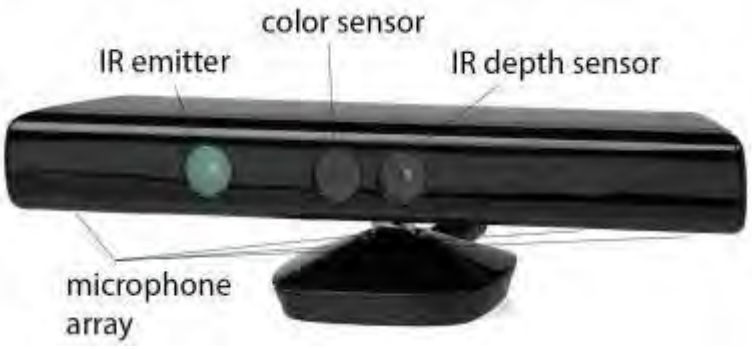

Figure 2.6 Microsoft Kinect for Xbox 360.