# DEVELOPMENT OF A LOW COST 3D SCANNER

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**SUPERVISOR DECLARATION**

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

Signature: ……

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Date: 22 JUNE 2015

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**This report is submitted in fulfillment of the requirement for the award Bachelor of Mechanical Engineering (Design and Innovation)**

**Faculty of Mechanical Engineering**
**Universiti Teknikal Malaysia Melaka**

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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: ……..……

Author: Muhammad Musfarezal bin Mustafa

Date: 22 JUNE 2015

Dedicated to Allah S.W.T

My beloved parents

Mustafa Salleh and Norizam Abdullah

My siblings that give me support to finish my study at Universiti Teknikal Malaysia Melaka (UTeM)

My beloved lecturers

My supervisors,

My friends,

PTPTN

My love Nabilah Zafirah

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# ABSTRACT

In this project, an approach to use Microsoft Kinect as a scanner where the function is to scan an object and convert it into CAD format. The objective of the project to design the low cost 3D scanner and have turning capabilities during the scanning process. In the development process it involved design process which is morphological chart, 3D drawing by using Solid Work and ANSYS software as the FEA analysis tools, programing, fabrication and testing. There are two sizes of gear which is 40 teeth and 20 teeth, both of the gear have been printed using 3D printer with ABS material. The Arduino UNO board has been coded by using open source software. The result of the analysis between the pulse of the servo and the depth image of the object, the results shows 1650 μs servo speed is ideal the speed of scanning process to get the best result. For the complex object the, the analysis has been done by using a kettle as the object and based on the result other problem has been found such as hole on the depth image of the surface causes from glare and light reflecting on the surface give the not satisfied result. In conclusion, the low cost 3D scanner performance is good enough in term of result produce compared to others expensive 3D scanner.

# ABSTRAK

Dalam projek ini, satu pendekatan untuk menggunakan Microsoft Kinect sebagai pengimbas di mana fungsi ini adalah untuk mengimbas objek dan menukar ke format CAD. Objektif projek untuk mereka bentuk pengimbas 3D kos yang rendah dan mempunyai keupayaan mengubah semasa proses imbasan. Dalam proses pembangunan ia melibatkan proses reka bentuk yang carta morfologi, lukisan 3D dengan menggunakan SolidWork dan perisian ANSYS sebagai alat analisis FEA, pengaturcaraan, fabrikasi dan ujian. Terdapat dua saiz gear iaitu 40 dan 20 gigi, kedua-dua gear yang telah dicetak menggunakan pencetak 3D dengan bahan ABS. Lembaga Arduino UNO telah dikodkan dengan menggunakan perisian sumber terbuka. Hasil analisis antara nadi servo dan depth image objek, keputusan menunjukkan kelajuan 1650 μs servo sesuai untuk kelajuan proses pengimbasan untuk mendapatkan hasil yang terbaik. Untuk objek yang kompleks, analisis yang telah dilakukan dengan menggunakan cerek sebagai objek dan berdasarkan keputusan masalah lain yang telah dijumpai seperti lubang pada imej kedalaman permukaan menyebabkan daripada silau dan cahaya mencerminkan pada permukaan memberikan tidak hasil berpuas hati. Kesimpulannya prestasi kos rendah pengimbas 3D adalah cukup untuk menghasilkan berbanding dengan orang lain pengimbas 3D mahal.

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| CMOS | Monochrome Complementary Metal Oxide Semiconductor |
| IR | Infrared |
| CAD | Computer Aided Drawing |
| IDE | integrated development environment |
| FEA | Finite Element Analysis |
| ABS | Acrylonitrile butadiene styrene |
| PLA | Polylactic acid |

# CHAPTER 1

# INTRODUCTION

## 1.0 PROJECT BACKGROUND

3D scanner is the device that record the surface of the object, the other function is analysis the surface object and converts the data into three dimensional digital data. The collected data can be converted into digital form to construct a 3D model. This device mostly uses for new development product, gaming, bio medic and historical person. Even the price of this device is too expensive and most of the vendors offering affordable 3D scanner with better hardware and software. To be a good product in the global market the vendor need to compete in term of efficiency of resolution, speed and cost.

Now days, technology rules the device, without technology inside the device, the device become useless. In 3D scanner development currently product is too expensive until the price of the product can achieve until thousand dollars. Since the introduction of Microsoft Kinect use for playing game or as a low cost 3D sensor, the introduction of this sensor can provide the depth data of the object surface.

Kinect works by inferring body position in two-stage process, which is firstly, Kinect compute a depth map and secondly is inferring body position. The depth map is built by using monochrome complementary metal oxide semiconductor (CMOS) sensor and an Infrared (IR) -Pass filter and it generated by analyzing the distance between dots and an object. This data can be stored and can generate the 3D model in digital form by manipulating using computer programs.

## 1.1 PROBLEM STATEMENT

The problems are firstly, most of the current product of 3D scanner too expensive, the price for the device almost reaches thousand dollars for the software and the hardware. It will be the problem for the new or small company to develop new product, need to spend a lot of money to buy the high end computer and the high end technology. Moreover, for education purpose university, college or school, no need to spend much money for an expensive 3D scanner, because it uses as the educational purpose is to expose the student to know how the 3D scanner use and how to apply it. It is just enough to expose the student with the lowest cost 3D scanner.

Secondly, is about the high end technology use in modern 3D scanner. Most of the current product provides device with high technology to achieve the best output. But the problem is not most of the users know how to use it and just for who is an expert in scanning can use it. By redesigning and makes the new model which is more user friendly not just for industrial use, but also can use for educational and hobby.

Lastly, scanning process will take time to complete a full body scan, it is because of time needed to combine all picture to become one good picture before converting it into CAD format. This is because by design auto capture 360 degree rotation can reduce the time during scanning and patching.

## 1.2 OBJECTIVE

The objectives of this project are:

- To Design a Low cost active 3D scanner.
- To analyze the structure of the low cost 3D scanner using finite element analysis using SolidWork and Ansys.
- To fabricate the prototype of low cost 3D scanner.

## 1.3 SCOPE OF THE PROJECT

The Scope of this project is to design low cost active 3D scanner using used Microsoft Kinect as the sensor and the camera to capture the object surface and design the active rotating base. Other than that, Open source video rendering will be used to manipulate and generate the 3D model.

Other hand, SolidWork will be used as the CAD drawing and it will use to analyze the structure of the product using finite element analysis, this will test on the strength of the structure and use for the material selection.

Lastly, in this project, open source software such as Arduino IDE software to set the configuration for the Arduino board to control the rotating base which is powered by a servo motor and OpenNI driver where is driver for Kinect where it allow the computer access the Kinect and Processing software will be used as the main software to interact between Kinect and computer.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 INTRODUCTION

In the development of the product most of the technology used to obtain the best result of the product, rapid development of 3D sensing technology most of the technology used in now day development such as reverse engineering. 3D scanner or 3D scanning is one of the parts in reverse engineering, which is has been used to capture the depth image of the object to obtain the point cloud and convert the point cloud into.STL format. Most of the 3D scanner is used to scan complex object, for example, after doing a mockup of a certain product, for example car bumper, to obtain the dimension of the mockup, 3D scanner is used to obtain the dimension base on point cloud and convert it into CAD format. In other word 3D scanner can use a three dimensional measurement. It will help the engineer to obtain the dimension of the mockup and it will reduce the time of the job. To design the low cost 3D scanner Microsft Kinect will be used as the 3D sensing device and with some adjustment and modification needs change the connect as active 3D scanners. With the advance of sensing sensor in Kinect, it is able to capture the depth image to obtain the point cloud of the object.

## 2.2 REVERSE ENGINEERING

Reverse engineering is a process of obtaining geometric shape from discrete samples in order to create mathematical models when the CAD model does not exist. Huang et al. presented models and algorithms for 3D feature localization and quantitative comparison They developed fast and robust algorithm for comparison of two free-form surfaces. Kase et al. Presented local and global evaluation methods for shape errors of free-form surfaces These methods were applied to the evaluation of sheet metal formed by using numerical simulation data and coordinate measurement data. Sansoni and Docchio described in a very special and suggestive example of optical 3D acquisition, reverse engineering and rapid prototyping of a historic automobile. They demonstrated the ease of application of the optical system to the gauging and the reverse engineering of large surfaces, as automobile body press parts and full-size clays, with high accuracy and reduced processing time, for design and restyling applications. Huang and Menq proposed a novel approach to reliably reconstruct the geometric shape of an unorganized point cloud sampled from the boundary surface of a physical object. These techniques are still developing, in terms of hardware.

## 2.3 TYPE OF 3D SCANNER

3D scanner is the device to obtain the object information about the real world object and to collect the data of the object appearance such as color of the object. This device is the most useful for development of new product. Most of the technology will apply in the development process include in industrial design, reverse engineering and rapid prototyping, quality control and some for documentary of historical artifacts. In terms of reverse engineering is the process of extracting the design from an existing product and for the purpose to modify and improve the design for better than existing products (S. Baid, 2011). This technology will reduce the time to develop new projects. Each technology comes with different advantages and costs. Even that each technology will face with the problem, not all the 3D scanner is perfect. There are two types of 3D measuring optical methods which are

active and passive, figure 2.1 shows the classification of optical 3D measuring main techniques

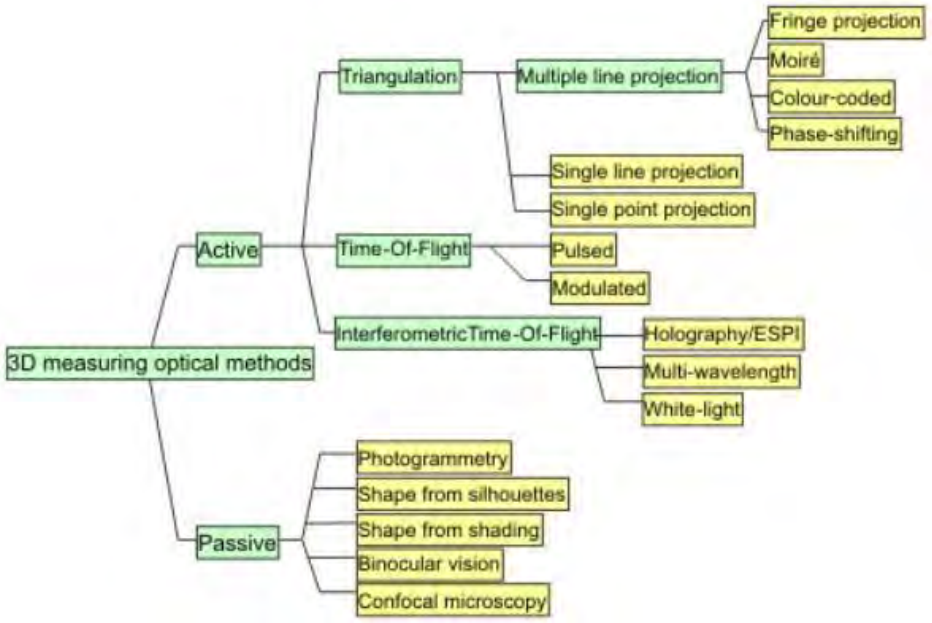


**Figure 2.1** Classification of optical 3D measuring main techniques (Pezzati, Lica Fontana, Raffaella 2008)

Passive method can be categorized as non-contact optical scanner which is can be categorized by the degree of the 3D scanner which is controlling the illumination (D. Lanman, G. Taubin, 2009). The Passive measurement methods only image data acquired by one or multiple cameras. To obtain the 3D data from the image, Photogrammetry, computer vision and image processing technique needed to process the 3D data. For example, in figure 2.2 usage of multiple image Photogrammetry used to obtain the 3D surface coordinate before create the point cloud of the surface.

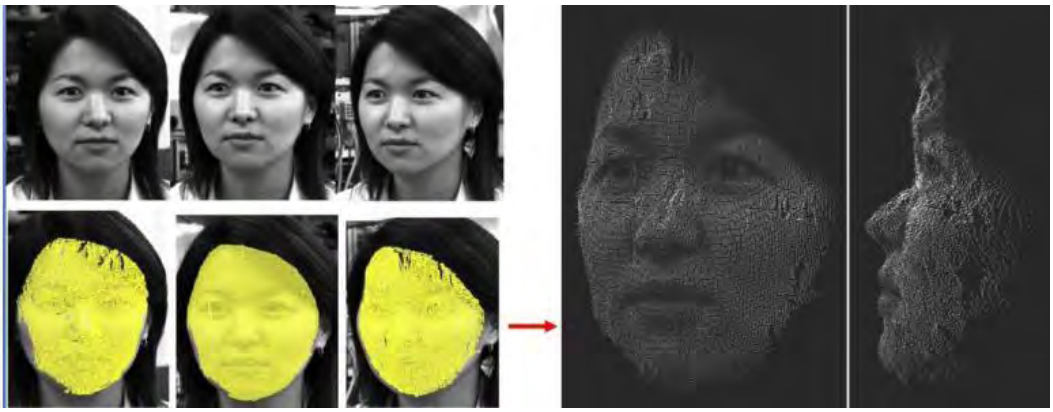

**Figure 2.2** example of face scanning system based on multiple image Photogrammetry, (V. Hull)

Moreover, for active 3D scanner, most of the scanner is an optical type which is non-contact, by active optical scanner it requires additional measures to obtain the point cloud data such as problematic subject. The benefit of active 3D scanner it can overcome the correspondence problem using controlled illumination, compare to non-contact

Passive method, it more sensitive to surface material properties. The example of the active 3D scanner as shown in figure 2.3 where the diagram show the concept of 3D slit scanner, single laser point and the camera had been used to scan laser spot across a surface of the object

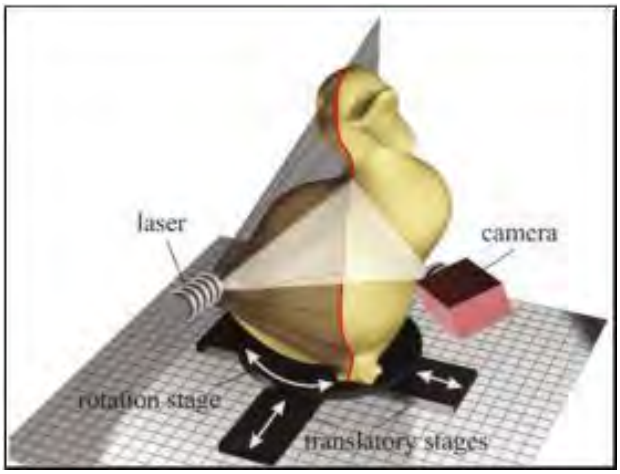


**Figure 2.3** Concept of active 3D scanner with rotating base and translate stage. (Lanman,Douglas Taubin, Gabriel, 2009)

## 2.4 MICROSOFT KINECT

Microsoft Kinect (figure 2.4) is a device used for gaming and it was designed to revolutionize the way people play games and for experience entertainment. Some of the game design needs to use human body language where Kinect is needed as the device to convert from the language to digital form. The Kinect sensor lets the computer directly sense the third dimension of the player and environment. Kinect device consist of sensing hardware such as depth sensor, a color camera and a four-microphone array (F. Joensuu, 2013). That provides full-body 3D motion capture, facial recognition and voice recognition capabilities as shown in figure 2.5. In the depth sensor it consists of IR projector combine with the IR camera, which is CMOS sensor.

**Figure 2.4** Microsoft Kinect for Xbox 360


**Figure 2.5** Picture of infrared projector, RGB camera and Infrared camera inside the Microsoft Kinect. ( W. Zeng, Z. Zhang, 2012)

The basic principle behind the Kinect related with depth sensor is from the emission of IR pattern and the simultaneous image capture of the image with CMOS camera that is fitted with IR-pass filter (M.R Andersen et al, 2012). The relative geometry between the IR projector and the IR camera has dotted pattern, if we can match a dot observed in an image with a dot in the projector pattern, we able to reconstruct it in 3D using triangulation (W. Zeng, Z. Zhang, 2012). From the projection of IR dot Kinect sensor able to construct a depth image, for an example as show in figure 2.6 and 2.7 where the IR dot seen by the Kinect IR camera and the Kinect sensor depth image will produce the depth image of the project.