

REVERSE MODELING OF CAR DOOR USING
LASER SCANNING METHODOLOGY

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REVERSE MODELING OF CAR DOOR USING LASER SCANNING
METHODOLOGY

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Report submitted in fulfilment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering with Automotive Engineering

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I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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My kindly supervisor, Professor Dr Rosli Abu Bakar

My patiently co-supervisor, Mr Gan Leong Ming

My beloved mother Rohayati Binti Abdul Rashid

My lovely, brothers and sisters

All my friends

May Allah bless all of you

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ABSTRACT

Reverse engineering was not commonly known by other people and mainly employed for shape design applications. By use of this method, under developed countries can decrease the technologic gap between itself and industrial countries. 3D scanner is one of the tools in the reverse engineering. The recent advancement of 3D non-contact laser scanners enables fast measurement of parts by generating a huge amount of coordinate data for a large surface area in a short time. Although the scanning process itself is not new, the processing power requirements of the captured cloud data is enormous, and only now, with the development and affordability of high powered computers, can the software be used effectively and efficiently. Complied with the demanding of the environment in the industry, each company will arrange the strategy to increase their quality. One of the alternatives that can be developed to improve the quality is research in the curvature surface. So, the objectives of the project are to scan and gather 3D point's clouds of car door and to generate and analyze the quality of car door 3D model. Firstly the door panel needs to be uninstalled from the car body to make the scanning process become easier. Then the surface of the door is altered because the scanner is using reflection concept. A density of a material can be determined by the reflection also act as the medium to get the true image for an object. Lastly, start scanning and then edit the scanned product using Polywork software as a way to condition the result obtained. Thus a lot of quality improvement can be developed in any sector by using the data of the 3D model such as important in study of safety.

ABSTRAK

Kebiasaannya kejuruteraan unduran masih lagi kurang diketahui oleh orang lain dan ia terutamanya digunakan untuk membentuk aplikasi rekabentuk. Dengan menggunakan cara ini, negara-negara maju dapat mengurangkan jurang teknologi antara mereka dan negara industri. Imbasan 3D adalah salah satu daripada alatan kejuruteraan unduran. Kemajuan terkini pengimbas lazer 3D bukan jentera membolehkan ukuran cepat untuk bahagian-bahagian dengan mewujudkan jumlah yang sangat besar untuk data setara untuk kawasan yang luas dalam masa yang singkat. Walaupun proses imbasan ini bukan baru, keperluan kuasa proses untuk rangkuman adalah besar, dan hanya dengan kemajuan dan kemampuan komputer berkuasa tinggi, membolehkan perisian itu digunakan secara efektif dan efisien. Dengan mematuhi permintaan industri, setiap syarikat akan menyusun strategi dalam meningkatkan kualiti. Satu daripada alternatif yang boleh dimajukan untuk meningkatkan kualiti ialah kajian dalam permukaan lengkung. Oleh itu objektif projek ini ialah untuk imbas dan kumpul rangkuman titik 3D dari pintu kereta dan untuk menghasilkan model 3D pintu kereta. Permulaannya, pintu ditanggalkan daripada kereta untuk memudahkan proses imbasan. Kemudian, permukaan pintu dikemas kerana pengimbas itu menggunakan konsep pantulan. Ketumpatan, sesuatu bahan boleh ditentukan oleh pantulan yang juga berperanan sebagai medium untuk mendapatkan imej sebenar untuk sesuatu objek. Akhirnya, imbasan dimulakan dan kemudian hasilan imbasan disunting menggunakan perisian Polywork sebagai langkah untuk memperelokkan hasil yang diperolehi. Oleh itu, banyak peningkatan kualiti dapat dimajukan dalam pelbagai sektor dengan menggunakan data daripada model 3D yang mana penting contohnya di dalam pengajian keselamatan.

TABLE OF CONTENT

	Page
SUPERVISOR'S DECLARATION	ii
STUDENT'S DECLARATION	iii
ACKNOWLEDGEMENTS	iv
ABSTRACT	v
ABSTRAK	vi
TABLE OF CONTENTS	vii
LIST OF TABLES	x
LIST OF FIGURES	xi
CHAPTER 1 INTRODUCTION	
1.1 Reverse engineering	1
1.3 Problem Statement	2
1.3 Objectives	3
1.4 Scopes of project	3
CHAPTER 2 LITERATURE REVIEW	
2.1 Introduction	6
2.2 Type of 3D Scanner	6
2.2.1 Contact 3D scanner	8
2.2.2 Non Contact Active	10
2.2 2.2.3 Non Contact Passive	16
2.3 Measurement efficiency between contact and non contact	16
2.4 Importance of using 3D model	17
2.4.1 Cultural Heritage	18
2.4.2 Civil Engineering (Construction)	20

2.4.3	Design Education	22
2.4.4	Automotive Industry	23
2.5	Dynamic surface reconstruction	26
2.5.1	B-spline Surface	26
2.5.2	Kalman Filter	27

CHAPTER 3 METHODOLOGY

3.1	Introduction	30
3.2	Literature review	30
3.3	Uninstall the door panel	31
3.4	Alter surface of the door panel	32
3.4.1	Door surface cleaning	32
3.4.2	Selection of the best surface	34
3.5	Modelling door panel using 3D scanner	37
3.5.1	Setup for scanning material	37
3.5.2	Scanning and editing using Polywork software	41

CHAPTER 4 RESULT AND ANALYSIS

4.1	Introduction	48
4.2	Modeling 3D door using the scanner	48
4.3	Selection of the best surface	49
4.3.1	Masking tape	49
4.3.2	Spray	50
4.3.3	Sand paper	51
4.4	Setting	51
4.5	Scanning and editing	54
4.5.1	Reconstruct the mesh	54
4.5.2	Full fill the holes	55
4.5.3	Alter unwanted surface	56
4.5.4	Touch up the edge	56

4.5.5	Size of the mesh	57
4.5.6	Export to the design and analysis environment	58
4.5.7	Overlapping file	61

CHAPTER 5 CONCLUSION AND RECOMMENDATION

	Introduction	62
	Conclusion	62
	Recommendations	63
	REFERENCES	64
	APPENDICES	65
A	Gantt chart Final Year Project 1	66
B	Gantt chart Final Year Project 2	67

LIST OF TABLES

Table no	Title	Page
2.1	Measurement time comparison	17
4.1	Result after scan for masking tape	50
4.2	Result after scan for spray	51

LIST OF FIGURES

Figure no	Title	Page
1.1	The division of work and study	4
2.1	Measure direction density for (a) raw scan and (b) spherical point subsampling	8
2.2	Coordinate measuring machine	9
2.3	Example of 3D scanner using time of flight	11
2.4	Principle of a laser triangulation sensor. Two object positions are shown point cloud generation using triangulation with a laser stripe.	12
2.5	Difference principle between triangulation and conoscopic holography	13
2.6	Example of hand held laser	14
2.7	Arrangement of structured light 3D scanner and the image result	15
2.8	Optical components of a laser scanning system	18
2.9	Measurement of Gedongsongo which is left image shows location of the laser scanner	20
2.10	Performance of the proposed approach for automated recognition of 3D CAD model objects in large construction site laser scans	22
2.11	Surface modeling procedure from scanned data: a) Point cloud, b) polygon meshes, c) mesh treatment, d) surface modeling	25
3.1	Original position and after uninstall from car body	31
3.2	Inner and outer of door panel	32
3.3	Cleaning process	33
3.4	Door panel surface after cleaning	33
3.5	Fill up all the holes	34

3.6	Two type of masking tape, a) Light color and b) Dark color	34
3.7	Process cover the door panel surface with masking tape	35
3.8	1) Silver color. 2) Grey color	36
3.9	Process during use the sand paper	37
3.10	Controller box	38
3.11	3D scanner	38
3.12	Joint locations on CimCore arms	39
3.13	Position indicator for V5 sensor	40
3.14	Position of the door panel	41
3.15	Import project	42
3.16	Combine the project	43
3.17	IMAlign to the IMerge process	44
3.18	The 3D model	45
3.19	Scan part by part	46
3.20	Reducing the mesh	47
4.1	Defect during the scan	52
4.2	Before (a) and after (b) probe setting	53
4.3	Before (a) and after(b) probe setting	53
4.4	Surface of the solid model before and after reconstruct	54
4.5	Fill hole process	55
4.6	Hole and crack	56
4.7	Not smooth edge	57
4.8	Reduction of mesh	58
4.9	In Solidwork	59
4.10	In ALGOR	59

4.11	The complete 3D model	60
4.12	The curvature of 3D model	60
4.13	Portion to scan and overlapping area	61

CHAPTER 1

INTRODUCTION

1.1 REVERSE ENGINEERING

At the beginning reverse engineering was not commonly known by other people and mainly employed for shape design applications. Right now the situation has become quite different, showing a wide spread of possible other applications like medical and archaeological. But unfortunately while the work done in the mechanical shape design has created a certain level of expertise, that right now could help the digitizing operators in the right acquisition system choice and working parameters setting, these new working fields are plagued by a certain number of questions and problems that come from the inexperience, for the first time approaching this technology.

By use of this method, under developed countries can decrease the technologic gap between itself and industrial countries, but use of this method must be responsible to requirements and has development and application affect and performs innovation in these countries. The most important advantages and applications of reverse engineering are as follow (Radfar and Khamseh, 2006):

- (i) The primary benefit of reverse engineering is new product development.
- (ii) Transforming absolute products into useful ones by adopting them to new systems and platforms.

- (iii) The primary objective of reverse engineering is the development of unrestricted technical data, adequate for competitive procurement, through engineering evaluations of existing hardware.

One of the tools in the reverse engineering is 3D scanner. The recent advancement of 3D non-contact laser scanners enables fast measurement of parts by generating a huge amount of coordinate data for a large surface area in a short time. In contrast, traditional tactile probes in the coordinate measurement machines can generate more accurate coordinate data points at a much slower pace. Therefore, the combination of laser scanners and touch probes can potentially lead to more accurate, faster, and denser measurements.

1.2 PROBLEM STATEMENT

Advanced 3D Laser Scanning processes have developed over the last decade and are now available and affordable for medium to large companies as well as education. Although the scanning process itself is not new, the processing power requirements of the captured cloud data is enormous, and only now, with the development and affordability of high powered computers, can the software be used effectively and efficiently. In virtually all applications, a 3D laser scanner will improve speed and accuracy thereby improving productivity (Ertu et al, 2006). This has led to an increase in the potential of 3D modeling and animation via cloud data capture.

Complied with the demanding of the environment in the industry, each company will arrange the strategy in increase their quality. One of the alternatives that can be developing to improve the quality is research in the curvature surface. However the ability to integrate 3D scan data with 3D software and technology now gives users in all design fields the potential to construct complex organic shapes, which may only possible when using advanced 3D surface modeling software in the past. There are many difficulties in modeling 3D shapes for use in design work. Thus it need to be overcome because importance for communication between engineer, vendor and the production itself.

The data can be used to make major improvement for the quality and also it can become the long distance of quality guarantee for each product. In addition the data also can be use to make improvement on the safety and weight reduction for the part. According to the condition the importance of the data will be interpret at one of the part at the body car which is door panel. Because of that, this study is to develop the significance techniques of scanning a car door as one of the dimensional control component for cars, where is must be able to install for all same model car.

1.3 OBJECTIVES

- (i) To scan and gather 3D points clouds of car door.
- (ii) To generate and analyze the quality of car door 3D model.

1.4 SCOPES OF PROJECT

There are seven scopes of project to do this project. The scopes are

- (i) Literature review on 3D scanning technology.
- (ii) Car door surface preparation.
- (iii) 3D scanner system setup.
- (iv) Acquiring 3D point clouds model.
- (v) Transformation to surface model.
- (vi) Development of 3D model and surface quality.
- (vii) Final report preparation.

Figure 1.1 shows the flow chart resemble the divisions of works and study have been made in all the way of achieve the objective of the project.

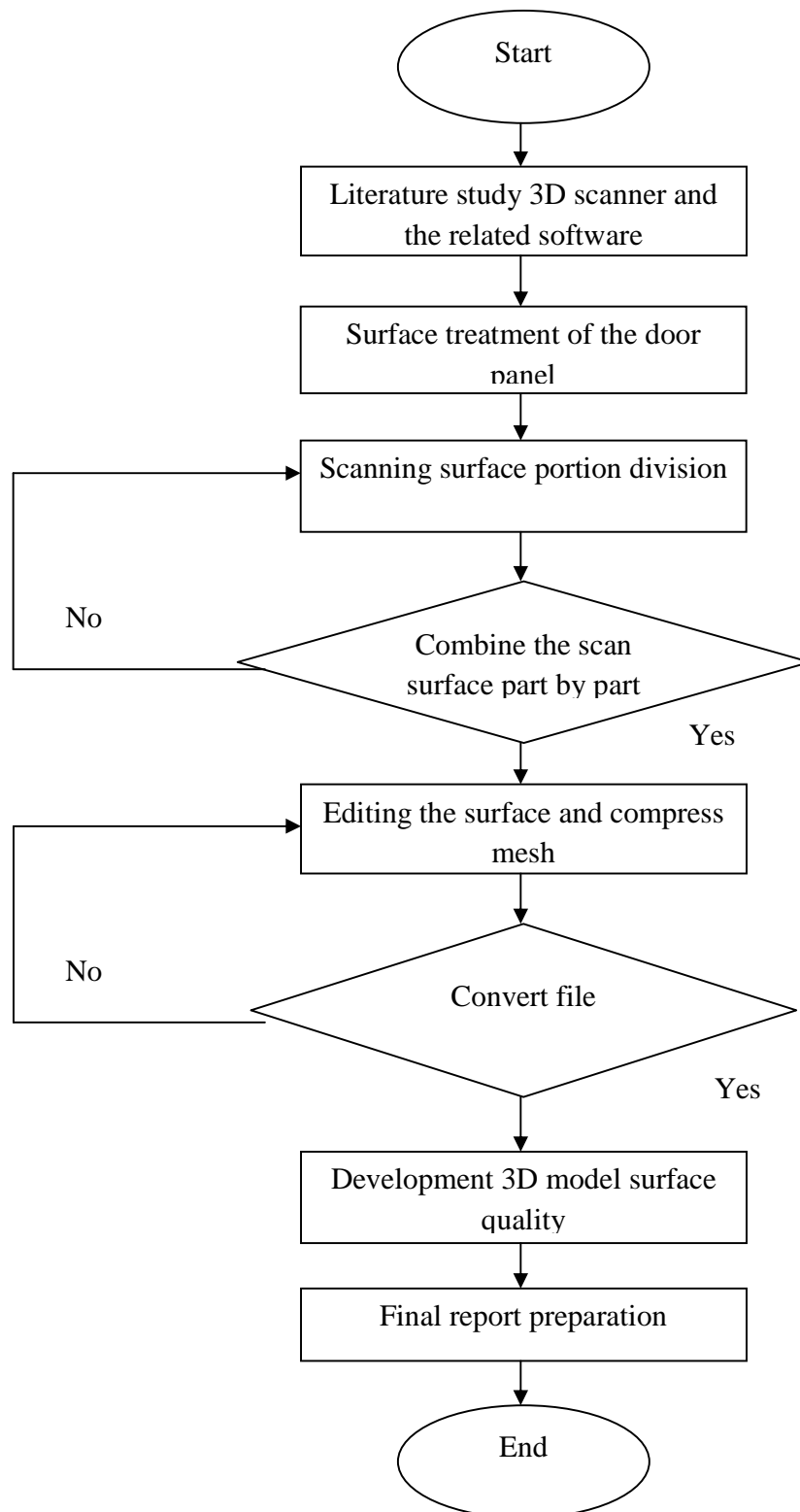


Figure 1.1: The division of work and study

However to complete this project must have proper planning time to ensure it works accordingly in schedule. This can avoid this project out of schedule because of constraint time. The planning of time was prepared in Gantt chart. Both of final year projects 1 and 2 Gantt chart is attached at appendix A and B.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Rapid development of 3D sensing technology has led to the growing use of massive point data in product development, such as reverse engineering, rapid prototyping, manufacturing, and metrology. Such wide use of massive point data necessitates the research on direct processing of massive point data into suitable geometric models that can be used in downstream product design, analysis, and manufacturing. Existing approaches to path generation from massive point data face a dilemma better quality curvature adaptive paths but with painstaking computer-aided design CAD model reconstruction or easy direct path generation but without guarantee on accuracy or efficiency.(Dongdong et al,2009)

2.2 TYPES OF 3D SCANNER

A 3D scanner is a device that analyzes a real-world object or environment to collect data on its shape and possibly its appearance (i.e. color). Common applications of this technology include industrial design, orthotics and prosthetics, reverse engineering and prototyping, quality control/inspection and documentation of cultural artifacts.Many different technologies can be used to build these 3D scanning devices; each technology comes with its own limitations, advantages and costs. It should be remembered that many limitations in the kind of objects that can be digitized are still present: for example optical technologies encounter many difficulties with shiny, mirroring or transparent objects.

The purpose of a 3D scanner is usually to create a point cloud of geometric samples on the surface of the subject. These points can then be used to extrapolate the shape of the subject (a process called reconstruction). If color information is collected at each point, then the colors on the surface of the subject can also be determined. The “picture” produced by a 3D scanner describes the distance to a surface at each point in the picture. If a spherical coordinate system is defined in which the scanner is the origin and the vector out from the front of the scanner is $\varphi=0$ and $\theta=0$, then each point in the picture is associated with a φ and θ . Together with distance, which corresponds to the r component, these spherical coordinates fully describe the three dimensional position of each point in the picture, in a local coordinate system relative to the scanner.

For most situations, a single scan will not produce a complete model of the subject. Multiple scans, even hundreds, from many different directions are usually required to obtain information about all sides of the subject. These scans have to be brought in a common reference system, a process that is usually called alignment or registration, and then merged to create a complete model. This whole process, going from the single range map to the whole model, is usually known as the 3D scanning pipeline.

According to the Mandow et al (2009), two scanning procedures are usually employed for 3D data acquisition. First, a 2D laser device can be displaced either by an automated system, for object modeling or by a vehicle, for urban modeling. Second, ranges can be obtained from a fixed pose by composition of two rotations of the laser beam, which renders spherical coordinates. With spherical scanners as showed in Figure 2.1 , commonly found in mobile robotics, certain scene regions are scanned with a higher density, which can distort the registration optimization process. Registration is an optimization problem that searches for the spatial transformation of a source range image that produces maximum overlap with a destination scan.

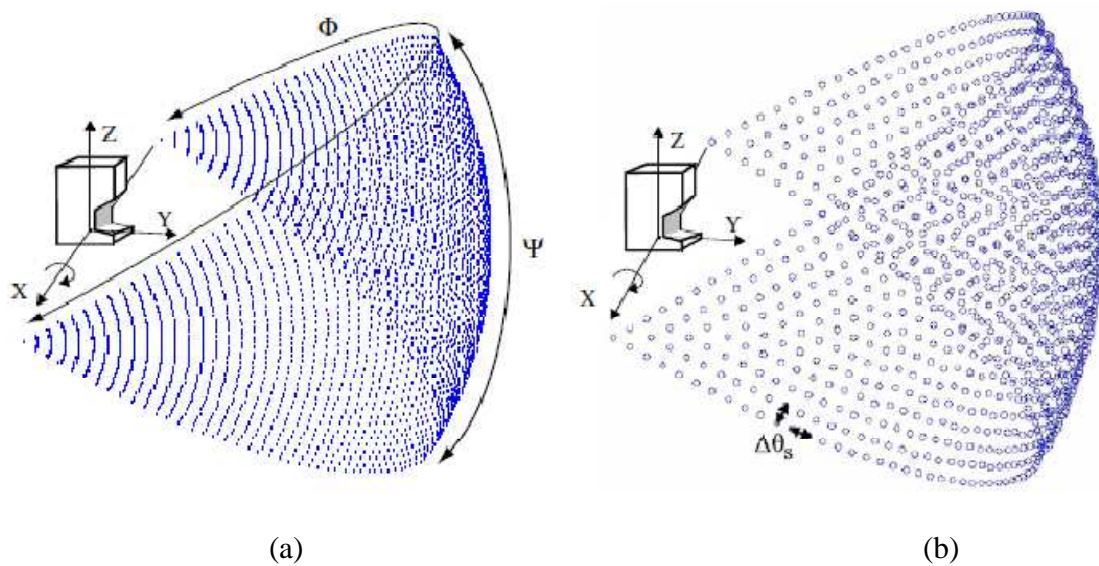


Figure 2.1: Measure direction density for (a) raw scan and (b) spherical point subsampling

Source: Mandour et al (2009)

The classification of this technology can be divided into two types which are contact and non-contact 3D scanners. However, for non-contact 3D scanners can be further divided into two main categories, active scanners and passive scanners.

2.2.1 Contact 3D scanner

Contact 3D scanners probe the subject through physical touch. A CMM (coordinate measuring machine) is an example of a contact 3D scanner as showed in Figure 2.2. It is used mostly in manufacturing and can be very precise. The disadvantage of CMMs though, is that 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. The other disadvantage of CMMs is that they are relatively slow compared to the other scanning methods. Physically moving the arm that the probe is mounted on can be very slow and the fastest CMMs can only operate on a few

hundred hertz. In contrast, an optical system like a laser scanner can operate from 10 to 500 kHz.

The touch probes can only generate coordinate points approximately at the speed of 60 points per minute with accuracy ranging from hundreds of nanometers to several micrometers. Although faster analog probes are also available, it's still much slower than optical area sensors. However, due to the contact mode and the small probe size of tactile sensing, touch probes are not sensitive to surface reflection conditions and able to produce more reliable results on the high curvature areas. Therefore, due to the complementary characteristics of area laser scanners and point touch probes in sensing speed, coverage, accuracy, accessibility, surface conditions, and surface geometry, the integration of a laser scanner with a touch probe can potentially dramatically improve the ways that parts are currently measured. An integrated multisensory coordinate measurement system can benefit in measurement accuracy from touch probes, in measurement speed from area laser sensors, and in part versatility from the availability of multiple sensors.



Figure 2.2: Coordinate measuring machine

Source: www.google.com

2.2.2 Non Contact Active

Active scanners emit some kind of radiation or light and detect its reflection in order to probe an object or environment. Possible types of emissions used include light, ultrasound or x-ray. The types of this category can be determined into seven types which are

Time of flight

The time-of-flight 3D laser scanner is an active scanner that uses laser light to probe the subject. At the heart of this type of scanner is a time-of-flight laser rangefinder. The laser rangefinder finds the distance of a surface by timing the round-trip time of a pulse of light. A laser is used to emit a pulse of light and the amount of time before the reflected light is seen by a detector is timed. Since the speed of light c is known, the round-trip time determines the travel distance of the light, which is twice the distance between the scanner and the surface.

The accuracy of a time-of-flight 3D laser scanner depends on how precisely we can measure the t time: 3.3 picoseconds (approx.) is the time taken for light to travel 1 millimeter. The laser rangefinder only detects the distance of one point in its direction of view. Thus, the scanner scans its entire field of view one point at a time by changing the range finder's direction of view to scan different points. The view direction of the laser rangefinder can be changed either by rotating the range finder itself, or by using a system of rotating mirrors. The latter method is commonly used because mirrors are much lighter and can thus be rotated much faster and with greater accuracy. Typical time-of-flight 3D laser scanners can measure the distance of 10,000~100,000 points every second.



Figure 2.3: Example of 3D scanner using time of flight

Source: www.google.com

Triangulation

The triangulation 3D laser scanner is also an active scanner that uses laser light to probe the environment. With respect to time-of-flight 3D laser scanner the triangulation laser shines a laser on the subject and exploits a camera to look for the location of the laser dot as showed in Figure 2.4. Depending on how far away the laser strikes a surface, the laser dot appears at different places in the camera's field of view. This technique is called triangulation because the laser dot, the camera and the laser emitter form a triangle. The length of one side of the triangle, the distance between the camera and the laser emitter is known. The angle of the laser emitter corner is also known. The angle of the camera corner can be determined by looking at the location of the laser dot in the camera's field of view. These three pieces of information fully determine the shape and size of the triangle and gives the location of the laser dot corner of the triangle. In most cases a laser stripe, instead of a single laser dot, is swept across the object to speed up the acquisition process.

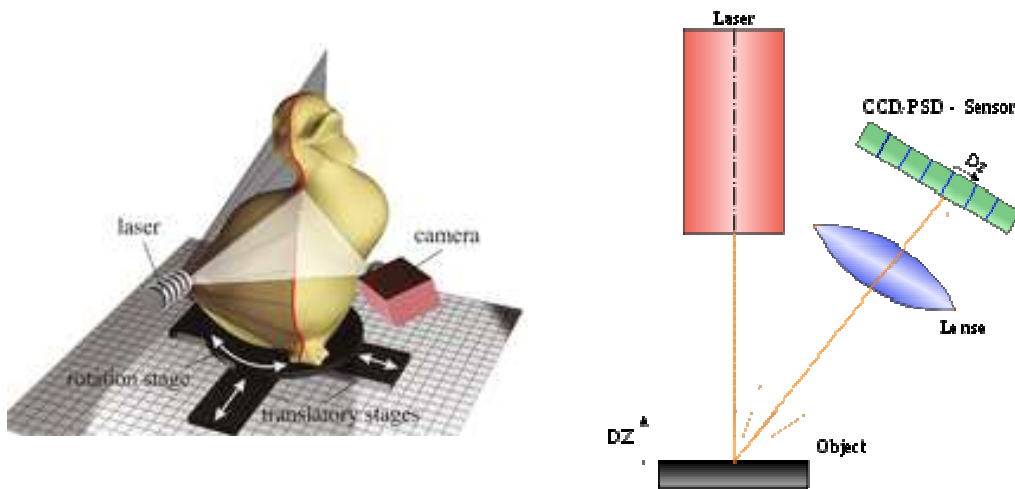


Figure 2.4: Principle of a laser triangulation sensor. Two object positions are shown point cloud generation using triangulation with a laser stripe.

Conoscopic Holography

In a Conoscopic system, a laser beam is projected onto the surface and then the immediate reflection along the same ray-path are put through a conoscopic crystal and projected onto a CCD. The result is a diffraction pattern, frequency analyzed to determine the distance to the measured surface. The main advantage with Conoscopic Holography is that only a single ray-path is needed for measuring, thus giving an opportunity to measure for instance the depth of a finely drilled hole.

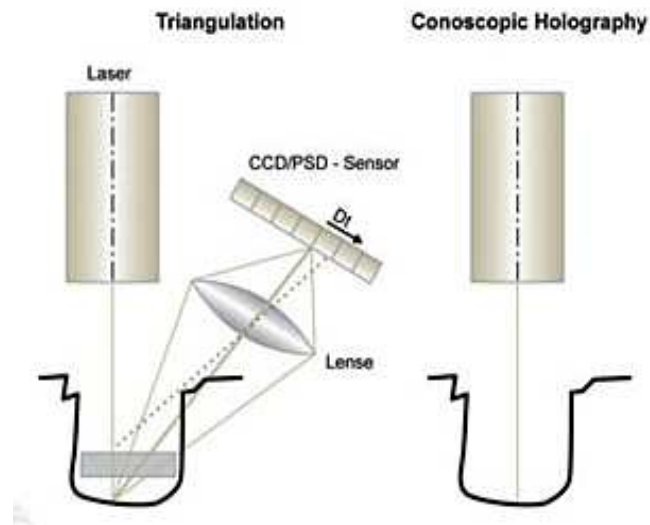


Figure 2.5: Difference principle between triangulation and conoscopic holography

Source: www.google.com

Hand held laser

Hand-held laser scanners create a 3D image through the triangulation mechanism described above: a laser dot or line is projected onto an object from a hand-held device and a sensor (typically a charge-coupled device or position sensitive device) measures the distance to the surface. Data is collected in relation to an internal coordinate system and therefore to collect data where the scanner is in motion the position of the scanner must be determined. The position can be determined by the scanner using reference features on the surface being scanned (typically adhesive reflective tabs) or by using an external tracking method. External tracking often takes the form of a laser tracker (to provide the sensor position) with integrated camera (to determine the orientation of the scanner) or a photogrammetric solution using 3 or more cameras providing the complete six degrees of freedom of the scanner.

Both techniques tend to use infrared Light-emitting diodes attached to the scanner which are seen by the camera(s) through filters providing resilience to ambient lighting. Data is collected by a computer and recorded as data points within three-dimensional space, with processing this can be converted into a triangulated mesh and then a Computer-aided design model, often as Nonuniform rational B-spline surfaces (NURBS). Hand-held laser scanners as Figure 2.6 can combine this data with passive, visible-light sensors - which capture surface textures and colors - to build a full 3D model.

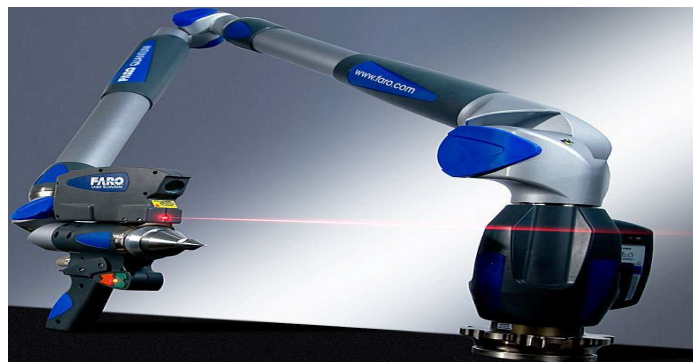


Figure 2.6: Example of hand held laser

Source: www.google.com

Structured light

Structured-light 3D scanners project a pattern of light on the subject and look at the deformation of the pattern on the subject as showed in Figure 2.7. The pattern may be one dimensional or two dimensional. The advantage of structured-light 3D scanners is speed. Instead of scanning one point at a time, structured light scanners scan multiple points or the entire field of view at once. This reduces or eliminates the problem of distortion from motion. Some existing systems are capable of scanning moving objects in real-time.

A real-time scanner a using digital fringe projection and phase-shifting technique (a various structured light method) was developed, to capture, reconstruct, and render high-density details of dynamically deformable objects (such as facial expressions) at 40 frames

per second. Recently, another scanner is developed. Different patterns can be applied to this system. The frame rate for capturing and data processing achieves 120 frames per second. It can also scan isolated surfaces, for example two moving hands.

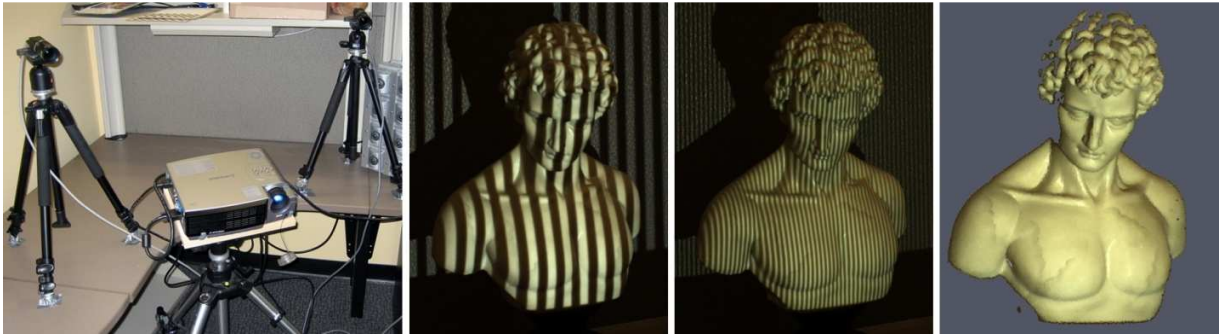


Figure 2.7: Arrangement of structured light 3D scanner and the image result.

Source: www.google.com

Modulated light

Modulated light 3D scanners shine a continually changing light at the subject. Usually the light source simply cycles its amplitude in a sinusoidal pattern. A camera detects the reflected light and the amount the pattern is shifted by determines the distance the light traveled. Modulated light also allows the scanner to ignore light from sources other than a laser, so there is no interference.

Volumetric light

Computed tomography (CT) is a medical imaging method which generates a three-dimensional image of the inside of an object from a large series of two-dimensional X-ray images, similarly magnetic resonance imaging is another a medical imaging technique that provides much greater contrast between the different soft tissues of the body than computed tomography (CT) does, making it especially useful in neurological (brain), musculoskeletal,

cardiovascular, and oncological (cancer) imaging. These techniques produce a discrete 3D volumetric representation that can be directly visualized, manipulated or converted to traditional 3D surface by mean of isosurface extraction algorithms. Although most common in medicine, Computed tomography, Microtomography and MRI are also used in other fields for acquiring a digital representation of an object and its interior, such as nondestructive materials testing, reverse engineering, or the study biological and paleontological specimens.

2.2.3 Non Contact Passive

Passive scanners do not emit any kind of radiation themselves, but instead rely on detecting reflected ambient radiation. Most scanners of this type detect visible light because it is a readily available ambient radiation. Other types of radiation, such as infrared could also be used. Passive methods can be very cheap, because in most cases they do not need particular hardware but simple digital cameras. As the example are stereoscopic, photometric and silhouette.

2.3 MEASUREMENT EFFICIENCY BETWEEN CONTACT AND NON CONTACT

However in order to quantify the time saving of multisensor inspection, a two-criteria comparison is made between the multisensor inspection and the single tactile probe inspection since tactile sensing in CMM is still the prevalent coordinate measurement tool. The first criterion is that the number of measured points should be ten times the number of parameters. . The second criterion is based on the fact the uncertainty is inversely proportional to the number of points N and the surface uncertainty is proportional to the uncertainty of measurement.

With these two criteria, the time of single touch probe sensing to produce the required number of measurement points can be compared with the combined time of 3D laser scanning and dynamic CMM probing. To estimate the time for the synthetic surface,

we assume the laser 3D scanner scanning speed is 10,000 points per second and one point per second for CMM probe.(Refer to table 1).

Table 2.1: Measurement time comparison

	Sensing method	Number of measured points	Estimated time (min)
Simulation surface	3D laser scanner and CMM	102,063 + 31	0.68
	CMM Criterion I	19 x 19 x 10 = 3610	60.10
	CMM Criterion II	102,063 / 100 + 31 = 1052	17.50
Shiny part	3D laser scanner and CMM	74,675 + 67	3.20
	CMM Criterion I	35 x 35 x 10 = 12250	204.166
	CMM Criterion II	74,675 / 100 + 67 = 814	13.06
Nozzle part (considering two surface)	3D laser scanner and CMM	21,763 x 2 + 38	2.117 x 2 + 0.63 = 4.867
	CMM Criterion I	(35 x 19 x 10) x 2 = 13,300	221.67
	CMM Criterion II	21,763 x 2 / 100 + 38 = 785	7.888

Source: Yunbao and Xiaoping (2007)

2.4 IMPORTANCE OF USING 3D MODEL

Reverse engineering (RE) is a powerful tool for generating a CAD model from the 3D scan data of a physical part that lacks documentation or has changed from the original CAD design of the part. The process of digitizing a part and creating a CAD model from 3D scan data is less time consuming and provides greater accuracy than manually measuring the part and designing the part from scratch in CAD. 3D optical scanning technology is one of the measurement methods which have evolved over the last few years and it is used in a wide range of areas from industrial applications to art and cultural heritage.

2.4.1 Cultural Heritage

Surveys and mapping activities are not limited to conventional works for mapping the earth surface. One of the latest technologies is measurement and 3D modeling of cultural heritage object using terrestrial laser scanner instrument. In study of Adi and Fahmi (2009) three dimensional (3D) models of cultural heritage objects are needed to document people's collective memory about the objects. When unwanted condition, like earthquake, flood, volcanic eruption, or vandalism, takes place so that the objects are destroyed, then the reconstruction of the objects can be done accurately.

In principle laser scanners have five components,

- (i) a transmitter, laser pulse in HDS-3000
- (ii) a transmitter optics, two rotating mirrors in horizontal and vertical direction in HDS-3000
- (iii) a receiver optics
- (iv) a detector
- (v) an electronic system for data acquisition, processing, evaluation, display, and storage as showed in Figure 2.8.

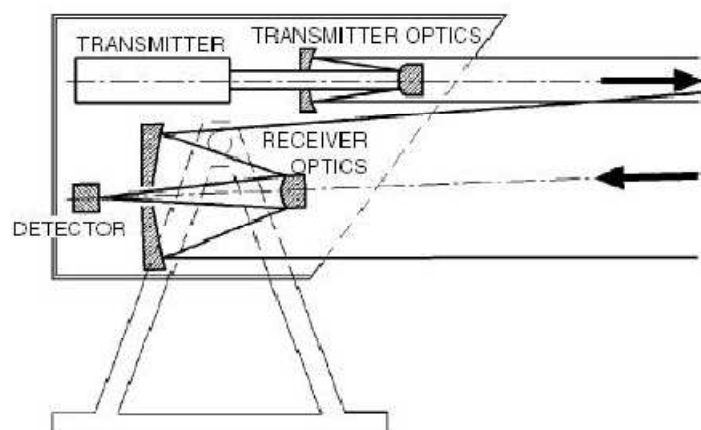


Figure 2.8: Optical components of a laser scanning system

Source: Adi and Fahmi (2009)

3D laser scanner works using high-speed laser to scan the surface of objects which can capture a huge amount of 3D coordinate points of the surface model. These 3D coordinates can be integrated to form “point clouds” and high-resolution 3D models by using certain software. The distance of an object is determined by measuring the time difference of the emitted laser pulse and its return signal travel to and from the objects and the instrument. The angle of emission is controlled by two rotating mirrors.

As example of study that had been conducted by Adi and Fahmi (2009), Borobudur HCO mapped Borobudur Temple, Prambanan Temple and other temples using HDS-3000 to identify the damage on the temples. Therefore the measurement of Gedongsongo temple as selected cultural heritage of their study becomes an important study to test the capability of laser scanning technique to map the temples and its surrounding topography. (Refer to Figure 2.9)

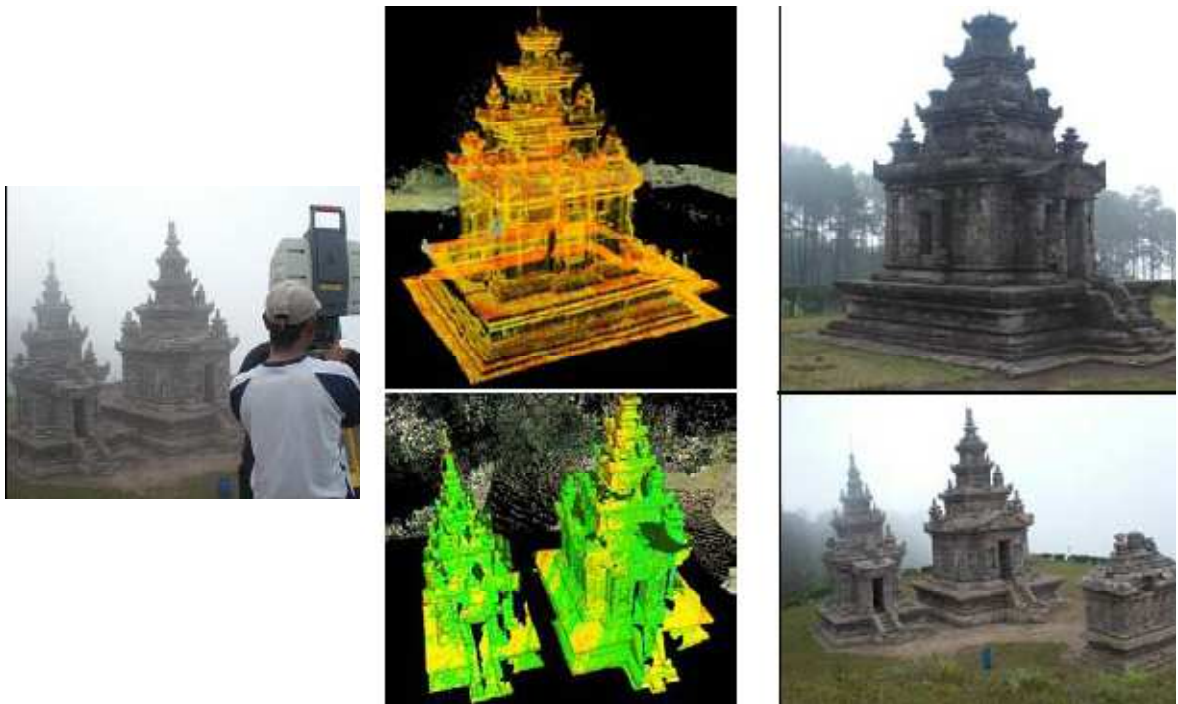


Figure 2.9: Measurement of Gedongsongo which is left image shows location of the laser scanner.

Source: Adi and Fahmi (2009)

2.4.2 Civil Engineering (Construction)

The construction industry lacks solutions for accurately, comprehensively and efficiently tracking the three-dimensional (3D) status of buildings under construction. Such information is however critical to the successful management of construction projects. Current techniques for project 3D status tracking are based on manual measurements that are time and labor demanding, and therefore too expensive and often too unreliable to be comprehensively applied on sites. There is therefore a need for effective and efficient project 3D status tracking.

Many research initiatives are investigating the use of remote sensing technologies, in particular digital imaging and terrestrial laser scanning, to improve the efficiency and effectiveness of site 3D data collection for project control activities, in particular progress

tracking and dimensional compliance control. In existing research contrary to digital imaging, laser scanning actually acquires 3D data, and with good accuracy (e.g. 12 mm at 100 m with the scanner used in this research) and high point density (e.g. maximum horizontal/vertical resolutions of 60 micron rad with the scanner used in this research, which results in about one point per 3 mm at 50 m).

Shapes are recognized by representing, and subsequently matching, model and sensed data using local surface descriptors called spin-images. This approach is very general and can be very robust to occlusions because it is based on local features. However, its performance significantly decreases in complex situations, such as in construction sites where search objects do not necessarily have very distinctive features.

Bosche (2009) has studied that once the as-built poses of all recognized objects are calculated; it can be compared to their as-designed poses in order to infer some information on the compliance of the project with respect to dimensional tolerances. More exactly, the differences between many as-built and as-designed dimensions (within and between objects) can be calculated and compared to their corresponding tolerances defined in the project specifications, which may be specific to the project or refer to industry standards such as AISC 303- 05 and MNL 135-00. For example, the verticality of a column can be compared to its designed true verticality and the difference compared to the specified verticality deviation tolerance. Similarly, the distance between two adjacent columns can be easily calculated from the as-built poses of both columns and then compared to the designed distance.

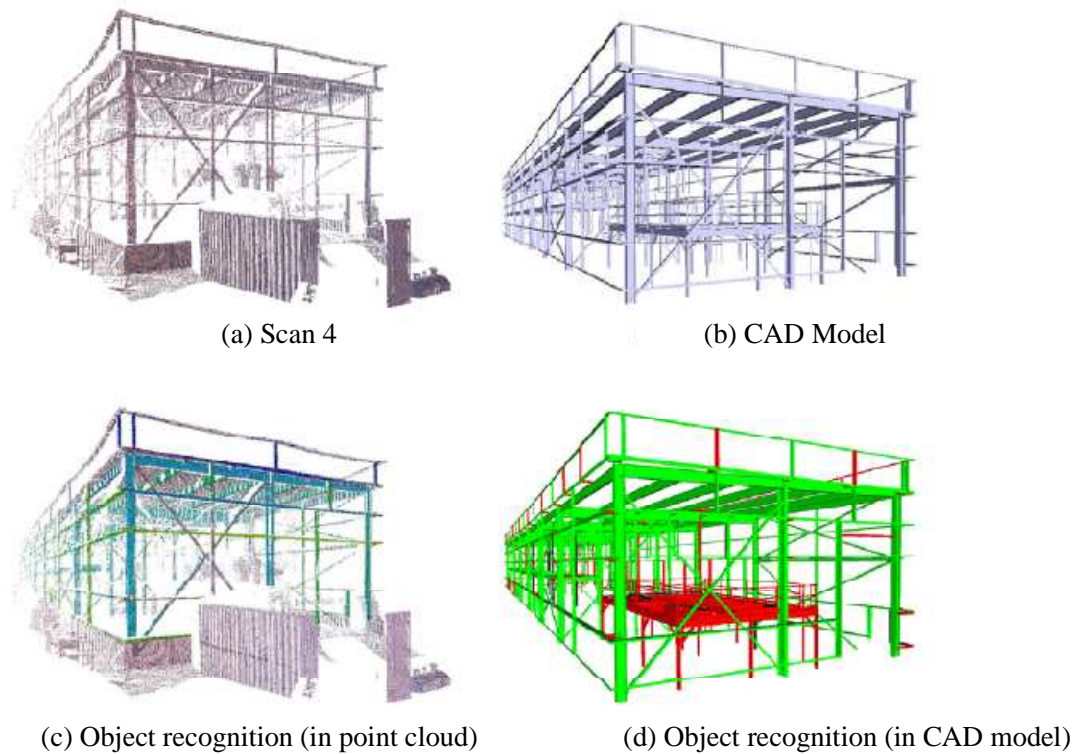


Figure 2.10: Performance of the proposed approach for automated recognition of 3D CAD model objects in large construction site laser scans.

Source: Bosche.F (2009)

2.4.3 Design Education

The use of 3D laser scanned data for building 3D models is not as widespread in education as the use of 3D modeling software. The ability to integrate 3D scan data with 3D software and technology now gives users in all design fields the potential to construct complex organic shapes, which may only possible when using advanced 3D surface modeling software in the past. Complied to the Ertu et al (2006) was studied that There are many difficulties in modeling 3D organic shapes such as gloves, shoes, human faces, etc. for use in design work the following approaches to design are usually taken depending on experience and capability levels:

- (i) The use of more freehand drawing and model making to keep creativity as the top priority.
- (ii) Simplification of the project resolution according to the limitations of available software and manufacturing process.
- (iii) The use of appropriate 3D design software to model design proposals.

Even use the full potential of appropriate software, there are still many design limitations in using solid and surface modeling applications. For example, in transport design the general approach is to use clay modeling to explore surface form, while in other design disciplines, students have a wider choice of strategies. The ability to capture complex shapes easily would enable students combine the best of both worlds, allowing them to achieve a higher resolution of their design within existing project time spans while maintaining the benefits of more traditional creative techniques.

Laser scanning is a terrestrial laser-imaging system that quickly creates highly accurate three-dimensional data (Cloud Data) of an object for use in standard computer-aided design software packages. The potential effectiveness of connecting 3D scanning methods to 3D CAD packages and Rapid Prototyping technology in an attempt to develop new learning and teaching methods to enhance the future of 3D Design education.

2.4.4 Automotive Industry

3D optical scanning used extensively in the automotive industry for applications such as part inspections, scanning of tools without CAD definition, scanning the casting for definition of the stock (i.e. the amount of material to be removed from the surface of the castings) model for CAM programs and reverse engineering. Reverse engineering (RE) is a process of building from an existing physical object an identical 3DCAD model, which can be used for manufacturing or other applications. An example application is where CAD data is not available, unusable, or insufficient for exiting parts that must be duplicated or modified. One of other practical applications is tool and die-making in automotive industry.

Optical scanning systems are one of the widely used 3D scanning systems in a wide range of areas such as automotive industry, medical applications, architectural and historical preservation. 3D Optical scanning systems can capture millions of points in a second to create point clouds data. The resulting 3D data can then be transferred to a CAD system for 3D surface or solid modeling, finite element analysis, tool design and tool path generation. Abdil Kus (2009) said that today in the automotive industry, 3D scanning is used in many different fields. Some examples of these typical applications are

- (i) 3D-optical scanning systems which can use to obtain geometrical data where technical drawings or 3D CAD data of the parts are not available.
- (ii) Inspection and Quality control.
- (iii) Reducing production time by minimizing the non-machining time of CNC machines by identifying STL data obtained from scanning of casting parts as stock model to CAM software.
- (iv) Reverse engineering and rapid prototyping

In reverse engineering software there are many operations to improve the scanned point cloud data. Noisy data can be improved and the size of the data set reduced (Figure 2.11a). Triangulation process begins after improving the point data set (Figure 2.11b). In mesh treatment, the process is specific to working with the polygonal mesh model, such as cleaning abnormal polygon meshes, redefining the surface by smoothing, re-meshing, or decimation and to prepare the polygonal model for rapid prototyping or NURBS surfacing (Figures 2.11c-d).

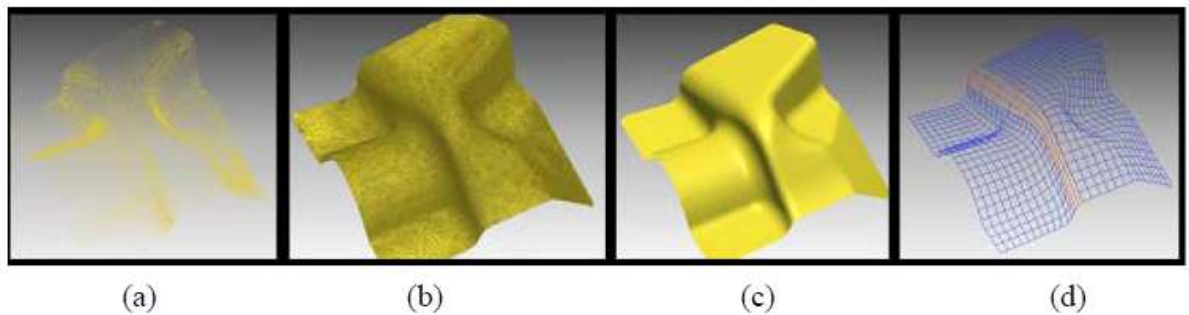


Figure 2.11: Surface modeling procedure from scanned data: a) Point cloud, b) polygon meshes, c) mesh treatment, d) surface modeling.

Source: Abdil Kus (2009)

Furthermore contact scanning Coordinate Measuring Machines (CMMs) are widely used in the creation of the surface models in many industries. As already mentioned, however, the primary disadvantage of this approach is the relatively longer measuring times needed to complete the process. On the other hand, the use of 3D optical scanning allows the collection of large amounts of dimensional data in reasonably shorter times.

3D CAD definitions of products or dies may not be available, not be up-to-date, or may not be achievable for many reasons (i.e. very old dies, bankrupt suppliers, lost data, etc). This is when 3D scanning technologies are indispensable for creating the required 3D definitions of the product models, samples or damaged die surfaces. 3D optical scanning systems can also be used by companies where a new 3D CAD system is introduced. All existing products must be modeled in order to have a fully digital archive. This 3D data then can be directly utilized in further CAD/CAM/CAE applications. These numerical applications enable product optimizations to improve the final product quality and, to increase the competitiveness of the products.

2.5 DYNAMIC SURFACE RECONSTRUCTION

According to the Yunboa and Xiaoping (2007) this section gives the mathematical basis for the dynamic surface reconstruction, which is B-spline surface representation and Kalman filter. This study had refer to a surface reconstruction process in which the surface is dynamically constructed or updated based on piror information.

2.5.1 B-spline Surface

The B-spline surface has been widely used in product design and manufacturing. Therefore, it is selected to represent the surface reconstructed from the point-cloud. A bi-cubic B-spline surface has the form

$$S(u, v) = \sum_{i,j}^n N_i(u)N_j(v) P_{ij} \quad (1)$$

where N is B-spline shape function and P_{ij} is the ij th control point. The equation can also be expressed in matrix form

$$S(u, v) = A(u, v) P \quad (2)$$

where $A_{u,v}$ is the B-spline shape function matrix, and P means the collection of control points.

To model the surface from the point-cloud, most shape reconstruction methods are based on least-squares fitting, and they do not explicitly consider data noise incurred during the measurement process. It is often assumed the noise corrupting the data is of zero mean. This has two immediate ramifications. First, reconstructing surfaces from measurement data would lead to inaccurate surfaces if data uncertainty is not properly accounted for. Numerous studies have shown that least-squares estimates may be completely perturbed when the data contains noise of different variances, or non-Gaussian. Therefore, such single

surface representation without quality description is not sufficient for many subsequent applications. To account for data uncertainty and to result in more robust surfaces, the Kalman filter is introduced to produce the optimal estimate of the surface and its uncertainty (Yunboa and Xiaoping, 2007).

2.5.2 Kalman Filter

The Kalman filter was first proposed by Kalman in 1960. It is a method to recursively estimate the internal state of a system based on the observation of the system's external behaviors. To do this, a state-space model needs to be first set up to describe the system.

i. State Space Model

A mechanical or electrical system can be characterized by several finite variables, which are called the internal state. Usually, the internal state cannot be directly measured but its external behavior can be sensed. The Kalman filter addresses the general problem of trying to recursively estimate the state of a discrete-time controlled process that is governed by the linear stochastic difference equation

$$x_l = Cx_{l-1} + Bu_{l-1} + w_{l-1} \quad (3)$$

where x_l and x_{l-1} are the states of the time step l and $(l-1)$, respectively, C is the state transition matrix of the process from previous time step $(l-1)$ to the current step l , and u_{l-1} is the system input of the time step $(l-1)$. Matrix B relates the system input u_{l-1} and the state x_l , and w_{l-1} is the associated independent, white, and Gaussian noise. Observations on the internal state can be modeled in the form

$$z_l = Hx_l + v_l \quad (4)$$

where z_l is the external measurement of x at the l th time step, H is the measure matrix relating the current state x_l to the external measurement z_l and v_l is the associated measurement error, which is again assumed to be independent, white and Gaussian.

ii. Kalman Gain

With the state-space model, Kalman filter optimally estimates the internal state using the Kalman gain. The Kalman filter estimates the state by using a form of prediction and correction, which includes predictor equations and corrector equations. Predictor equations have the following form.

The a priori state prediction equation:

$$\hat{x}_{l|l-1} = C\hat{x}_{l-1} + Bu_{l-1} \quad (5)$$

The a priori state uncertainty equation:

$$\Lambda_{x_{l|l-1}} = C\Lambda_{x_{l-1}}C^T + Q \quad (6)$$

where Q is the uncertainty covariance of process noise w_{l-1} . When $l=1$, the initial state estimate \hat{x}^0 and its uncertainty Λ_{x^0} can be given by prior information, which is able to integrate a priori estimate of internal state. Corrector equations have the following form.

Kalman gain:

$$K_l = \Lambda_{x_{l|l-1}}H^T(H\Lambda_{x_{l|l-1}}H^T + \Lambda_{z_l})^{-1} \quad (7)$$

The estimate updating equation with measurement z_l :

$$\hat{x}_l = \hat{x}_{l-1} + K_l(z_l - H\hat{x}_{l-1}) \quad (8)$$

The state uncertainty updating equation:

$$\Lambda_{x_l} = (I - K_l H)\Lambda_{x_{l-1}} \quad (9)$$

The predictor and corrector equations form a basis for recursive updating. The predictor equations are to predict the a priori state and its uncertainty based on the previous state estimate. The a priori state estimate is then corrected in the corrector equations by the new measurement to obtain a posteriori state estimate. This recursive nature of Kalman filter is a very appealing feature, which makes it possible to apply newly measured data for state updating without requiring all previous data kept in storage. In addition, The Kalman filter combines all available measurement data, plus prior knowledge about the system and measuring devices, to produce an estimate of the desired internal state in such a manner that the error is minimized statistically (Yunboa and Xiaoping, 2007).

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Several stages has been identified and conducted to achieve the objective s of this project. The stages in completing this project consist of

Stage1: Uninstall the door panel

Stage 2: Alter surface of the door panel

Stage 3: Modeling door panel using 3D scanner

All of this stage should be followed to ensure that simulation analysis will perform successfully and without any error would occur. Generally, the door panel needs to uninstall from the main body of the car. But because of the constraint with the 3D scanner application, the door panel surface has to be altering to achieve the requirement of the 3D scanner application. The purposes of the altering the surface will be discuss in the stage 2 and also the procedure. In stage 3 will discuss how to perform modeling door panel using the 3D scanner. This 3D scanner will use Polywork software to generate the solid model of door panel.

3.2 LITERATURE REVIEW

In literature review, need to study about the 3D scanner itself also the realted software that will be use during the scan.

3.3 UNINSTALL THE DOOR PANEL

For the first stage the door panel needs to be uninstalling from the car body to make the scanning process become easier. This condition are related to the limitation of the 3D scanner machine that the ability of the scanner to scan the door accurately.



(a) Original position



(b) Position after uninstall

Figure 3.1: Original position and after uninstall from car body

However this door panel already had been uninstall previously because of that several equipment or compartment that attached to the door panel had been removed. Figure 3.1 is show the original position at the car body and the new position for the door panel according to the environment to scan it. While the Figure 3.2 is show the inner and outer of door panel which is the exactly surface that will be scan to be a solid model using 3D scanner.



Figure 3.2: Inner and outer of door panel

3.4 ALTER SURFACE OF THE DOOR PANEL

The next stage is altered the surface of the door. The 3D scanner is using reflection concept. A density of a material can be determined by the reflection also act as the medium to get the true image for an object. Complied with the situation the object which is needed to scan should be not very opaque and transparent. It will cause some errors for the object image scanned result. According to the constraints of the concept the surface of the door panel need to be altered to remove the shining which is occur at door panel.

3.4.1 Door Surface Cleaning

First of all after removal the parts and place on the table, door goes through cleaning process. The cleaning process is using detergent as solvent to remove all the rubber glue that holds plastic cover to body. All small particles and trim outer panel also must be removed by using detergent soak with water to get exactly only surface of inner and outer panel. Then door surface is drying using dry cloth and allow overnight before scanning process can be done.



Figure 3.3: Cleaning process

Cleaning process is important as to get good similarity duplication door model in scanning process. Figure 3.3 is showed during the process of remove all the dirt and glue at the surface of the door panel. Figure 3.4 below is the surface of the door panel after process cleaning.



(a) Front door panel

(b) Rear door panel

Figure 3.4: Door panel surface after cleaning

All the hole and open space at the door panel need to be close. In addition the dull surface such as the waist seal also must be covered. A4 paper and masking tapes were used to closed all the unnecessary holes and open space as showed in Figure 3.5.

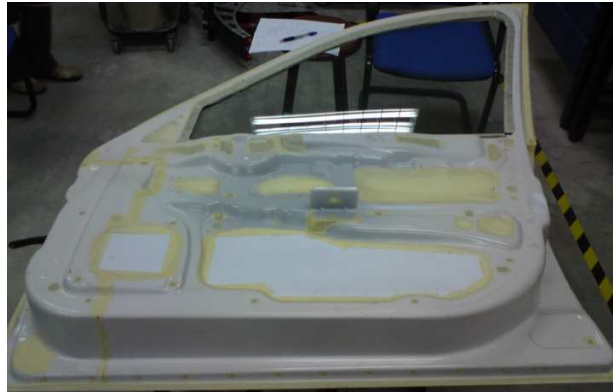


Figure 3.5: Fill up all the holes

3.4.2 Selection of The Best Surface

This part is one of the tough sections before get starting to scan the door panel. This is because the surface needs to be altered to remove the shining of the door. There are three trial had been done before selected the best solution to cover the door panel surface. The three trials were using masking tape, spray and sand paper the surface.

i. Masking tape

The first solution that had been made is to cover overall of the door panel surface with the masking tape. Several type of the masking tape had been tested using the 3D scanner to see the result whether it can be use during the scanning process.



a)



b)

Figure 3.6: Two type of masking tape, a) Light color and b) Dark color

Figure 3.6 is showed that two types of masking tape had been used to cover the surfaces which were light color and dark color. First of all both of them must be scan to know the capability and acceptance of the 3D scanner requirement. Figure 3.7 is showed that the particular work very need in cover the surface of door panel with the masking tape.



Figure 3.7: Process cover the door panel surface with masking tape

ii. Spray

The second choice was to spray the surface of door panel using the silver or grey color as showed at Figure 3.8. As usual to know the best result either silver or grey both of this color need to be scanned before applied it to the surface.

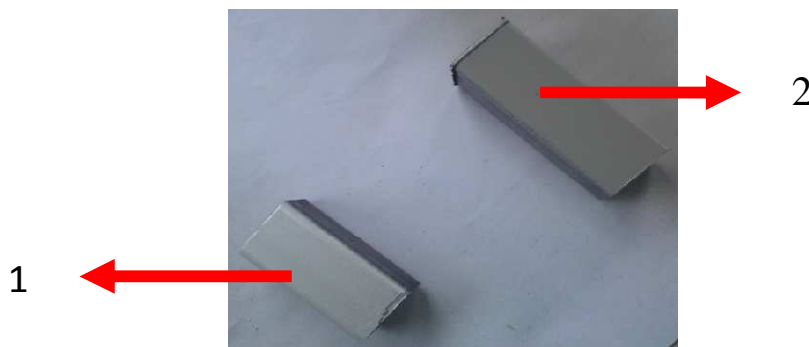


Figure 3.8: 1) Silver color. 2) Grey color

iii. Sand paper

The last option remove the shining of the paint is use the sand paper. With using the sand paper grade 1000 to 1200 all the surface of the door panel had been sanded. However it still needs certain skill to apply which is the circulation movement will be implemented to ensure the surface is smooth fairly. In addition the pressure while sanded the surface must be constant. Figure 3.9 is showed during the process when using the sand paper.

The best result from the choices was using the sand paper. This is because it more easy and economic. Otherwise the surface of door panel totally can reduce the shining fairly. To get better result use the sand paper with grade 500-600 then finishing with grade 1000-1200.

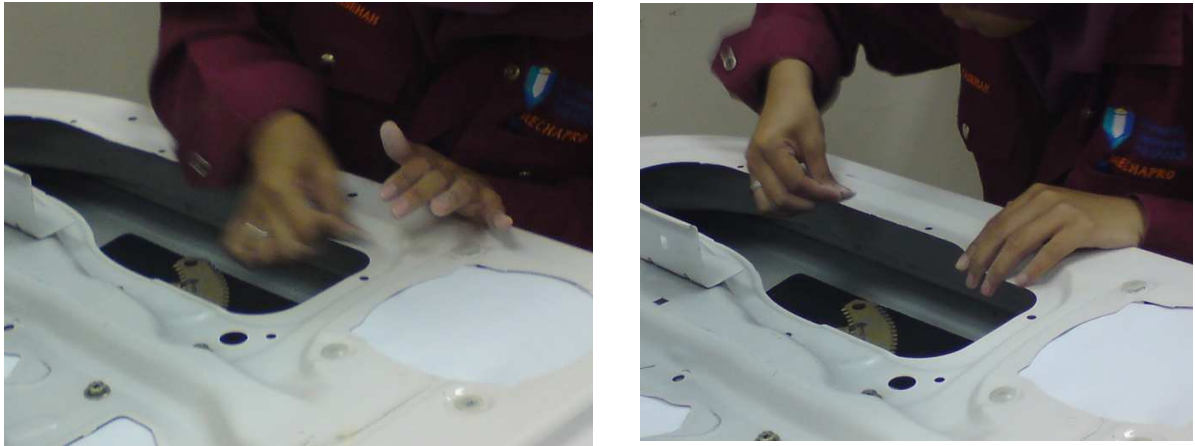


Figure 3.9: Process during use the sand paper

3.5 MODELING DOOR PANEL USING 3D SCANNER

For modeling the door panel need followed several steps to get the result. The steps are

- 3.5.1 Setup for scanning material.
- 3.5.2 Scanning and editing using Polywork software.

All this steps must be done accordingly to ensure the modeling door can be performing successfully.

3.5.1 Setup for Scanning Material.

First of all the connection at the 3Dscanner need connected to the 3D scanner laptop which is as the workstation. Start it with all the cable must connect by following the instruction manual. Switch on the laptop after all cable has been connected. Then switch on controller box by press the ON/OFF button. Figure 3.10 is showed the cable at the control box. For caution must be notified between main switch ON/OFF controller box with ON/OFF sensor power. Next switch on the scanner which is the button behind the scanner.

(Refer to figure 3.11). With refer to the figure 3.10 needs to be waiting until the LED for 'Ready' is light on to press the ON/OFF button at the sensor power.

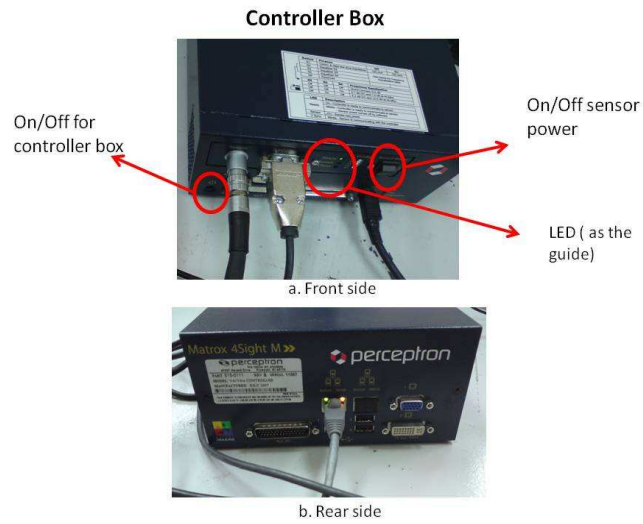


Figure 3.10: Controller box

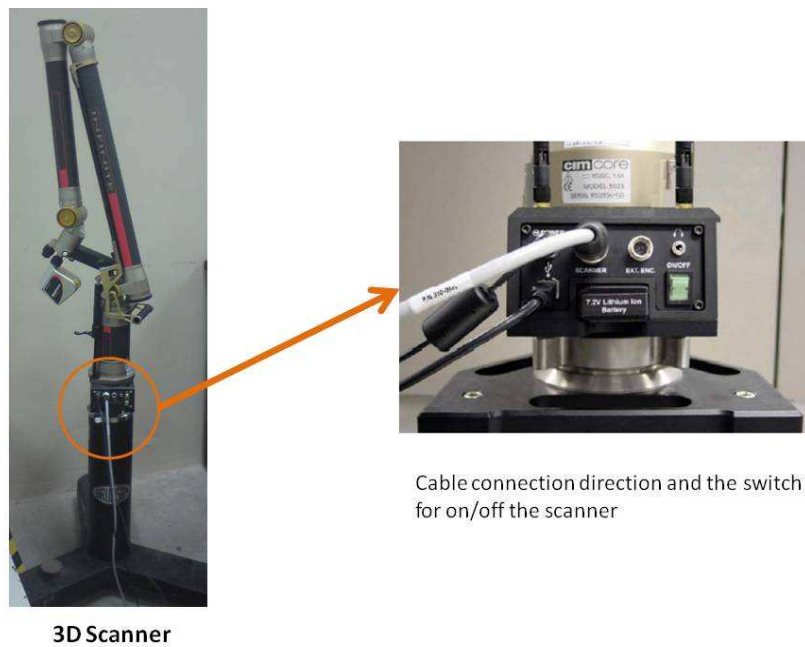


Figure 3.11: 3D scanner

After completed installation of the cable to the laptop open the Scanwork V5.2 software to check the function ability of the arm sensor. There are seven arms (A to G) which are CMM mover need to be check by make several movements such as up, down, right and left until all the alarm at the monitor will be detected. (Refer to Figure 3.12, the INFINITE arm also has an optional G joint at the end that allows the probe shaft to rotate.).

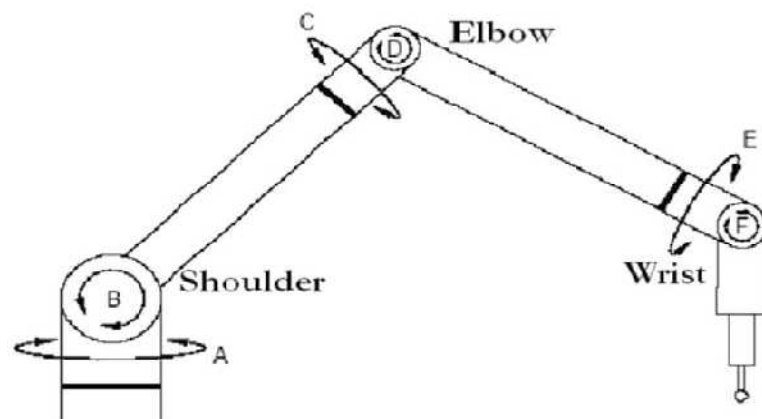


Figure 3.12: Joint locations on CimCore arms

The Calibration wizard through the calibration procedure, controlling the capture of images called Shots collected in five positions oriented around a calibration sphere, as showed in Figure 3.13 and the position including

- (i) Positions 1 through 3 are three views, approximately 120° apart, around the equator of the sphere.
- (ii) Position 4 is at the top of the sphere.
- (iii) Position 5 is at the top of the sphere, rotated 90° from Position 4.

The application displays the position for which shots are being collected in the upper left hand corner of the calibrate window.

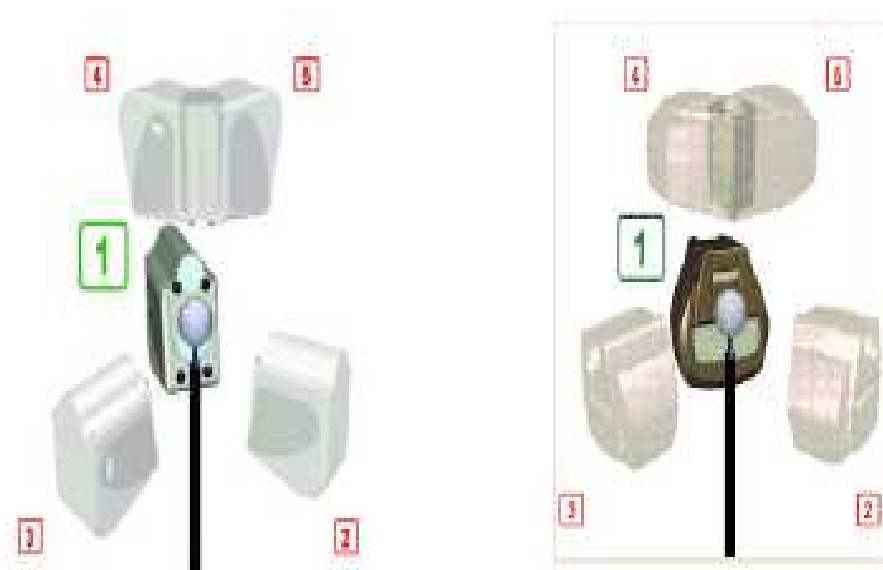


Figure 3.13: Position indicator for V5 sensor

The arrows represented the positions for which calibration shots must be taken and the active orientation (the one for which data is currently being collected) is green; all other arrows are red. The system will display the calibration results after all position had been completed. The display includes the average and maximum residual errors to indicate how well the calculated solution fit the raw data. For manual movers, the average residual error should be less than 0.100 mm and the maximum residual error should not be much greater than 0.350 mm.

The last step in this part is fixed the door panel to reduce the vibration scanning process. The door had been placed on the table for reachable all the angle of points. Also the bottom of the door need to attach with block that make by steel to ensure the door floating without vibration occurred. (Refer to the figure 3.14).



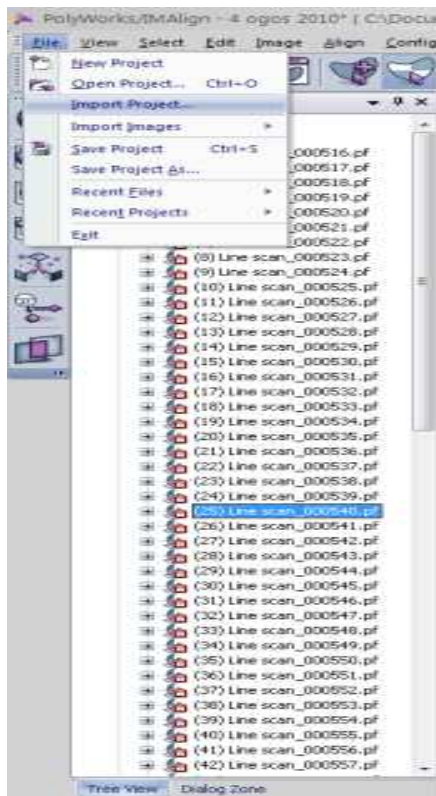
Figure 3.14: Position of the door panel

3.5.2 Scanning and Editing Using Polywork Software.

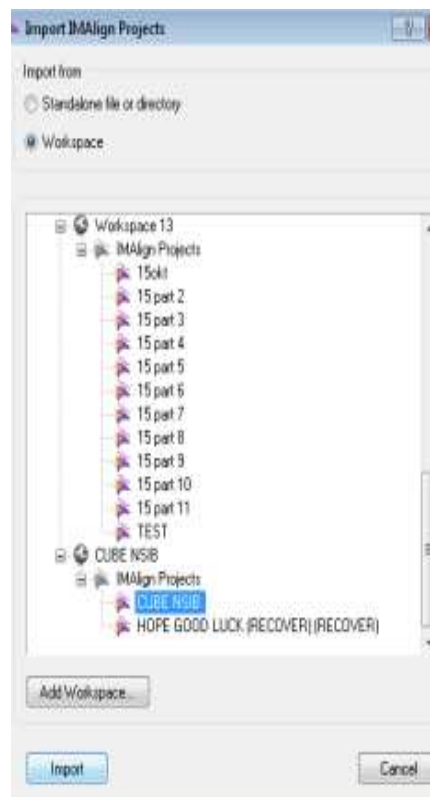
General step is the door panel will be scanned part by part which is generated under IMAlign. Continue process with meshing and merging the scanned part into IMerge. From IMerge solid model will be formed into IMEdit. Here the editing work can be done such as fill up the hole, terminate the unwanted surface, smoothing the surface and reduce mesh of the part. Then the object is ready to be converting into the simulation environment. The model is saved in IGES file. Picture shows the outer panel of door with smooth surface, same in dimension and shape. However if the file cannot open the model need to be compress using IMCompress. In this section the determination number of triangle and tolerance must be identified. Then select the best result to redoing the editing project until the file can be open to proceed the next step.

There are two types in using the IMAlign which are scan, import project and combine in difference workspace and other one is scan and combine. For more safety second way is the better and faster. Figure 3.15 and 3.16 are showed the step of scan, import project and combine. There is a minor step which is differing with scan and combine. The difference only at first step which is the second scan is use the same workspace. Which mean did not need to import other project and can be use direct with other process.

As showed in figure 3.15 the previous work scanned had been import from other workspace to be combined. After imported the file, all the scan line must be form in a group which is this will be affected to the number of iteration in other steps. Also the current scanned file must be lock to prevent the scan file moved. Then the figure 3.16 is showed to view two images under one view to plot the reference point at the current and previous scanned file. After plotted had been done right click the mouse to gave command meshing for the both file.



a) Import project



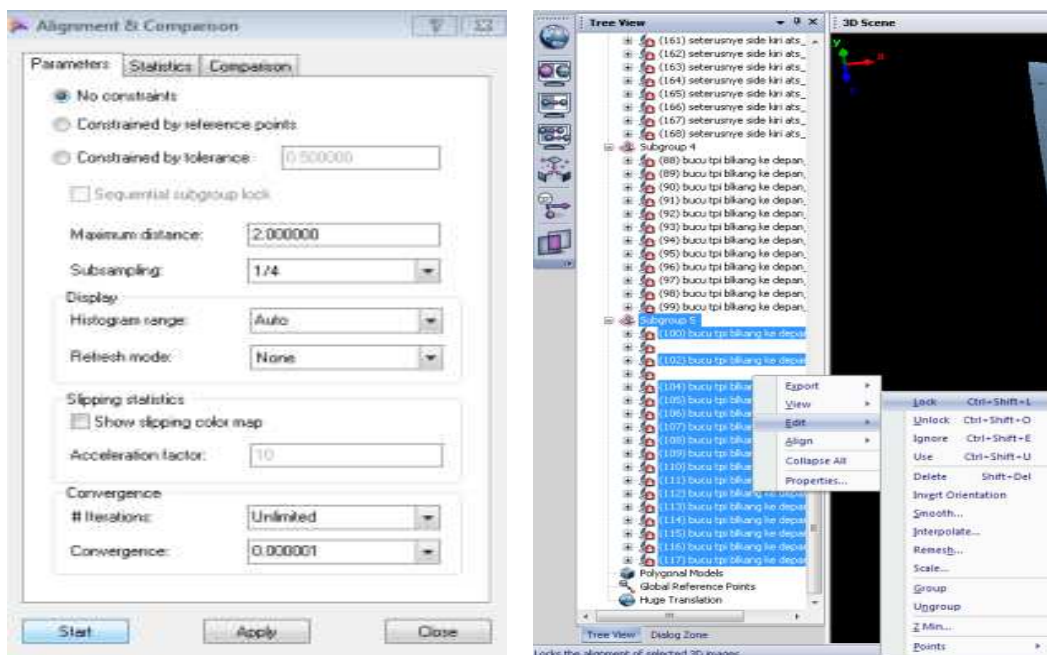
b) Select the workspace and file

Figure 3.15: Import project



a) View two image under one workspace

b) Select the reference point



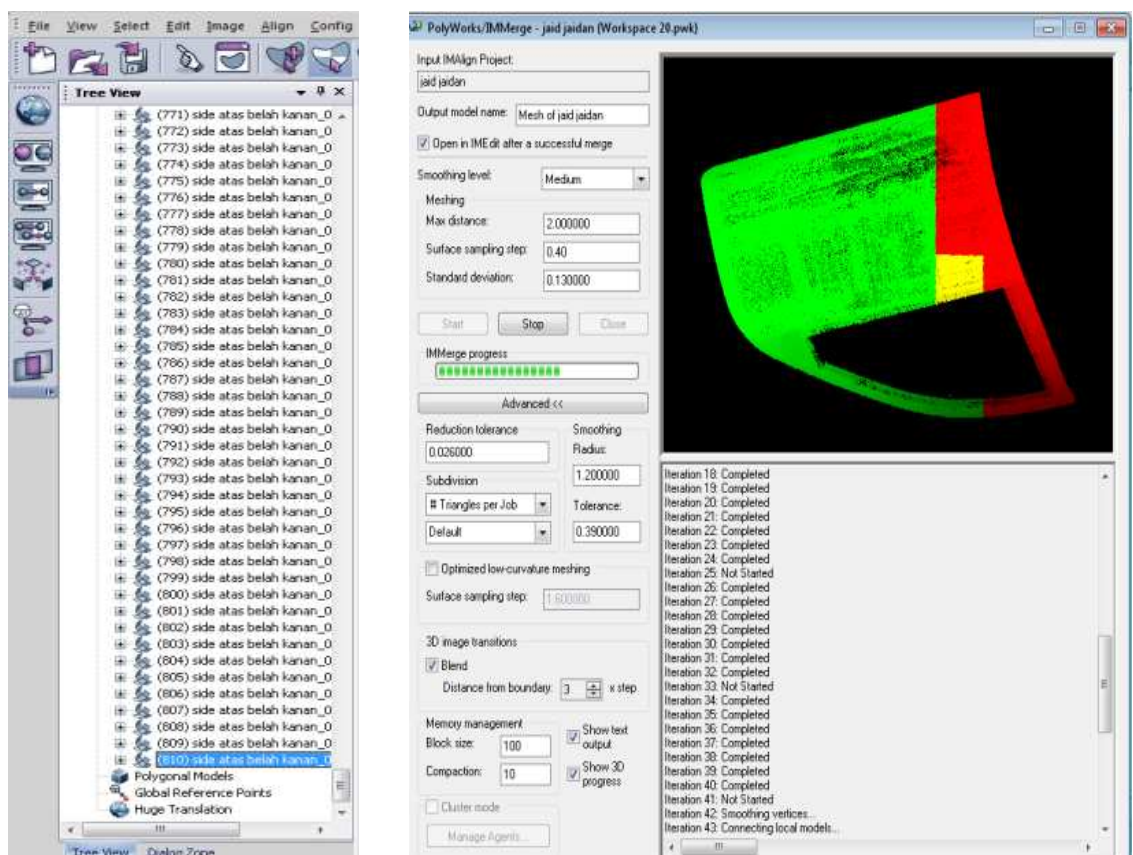
c) Best fit and alignment

d) Lock the model

Figure 3.16: Combine the project

Now the files are already combined each other but it still needs alignment. According to the requirements, best fit and alignment were selected to get the best result of combination image. The last step in this process is locking the image. This process will be continuing until the whole door panel image is performed. It must be implemented step by step to reduce the error.

After the overall of door panel surface had been successfully scanned, the model from IMAlign will be needed to merge using the IMerge. (Refer to Figure 3.17)



a) Total file of scan

b) Merging process

Figure 3.17: IMAlign to the IMerge process

Figure 3.18 shows the process of completion of the door panel after scanning. After completion in IMAlign, the model can be merged by using the IMerge. However, it must be

remembered before merging the model, all the scan file must be in a group. Then merge entire scan file. In this process will take long processing time because it will depend on the size of the scanned file. Each color during the merge was showed the difference stage of process merge. After merge process was completed automatically the IMEdit will open which is will include the 3D model. Now the 3D model still needs to have further process. The 3D model will be through the editing process using the IMEdit.



Figure 3.18: The 3D model

In this study, to scan the surface of the door panel need to divide part by part. As showed in Figure 3.19 which is the front of door panel need to divide to the several part to continue and get the complete part of scanned. The scan part will be combine one by one using procedure scan and combine. This is method had been explain in previous subchapter. For the rear door panel also will do in the same concept to get the complete scan part. If the problem occurs during the combination, the part needs to be re-scanning until get the best result.

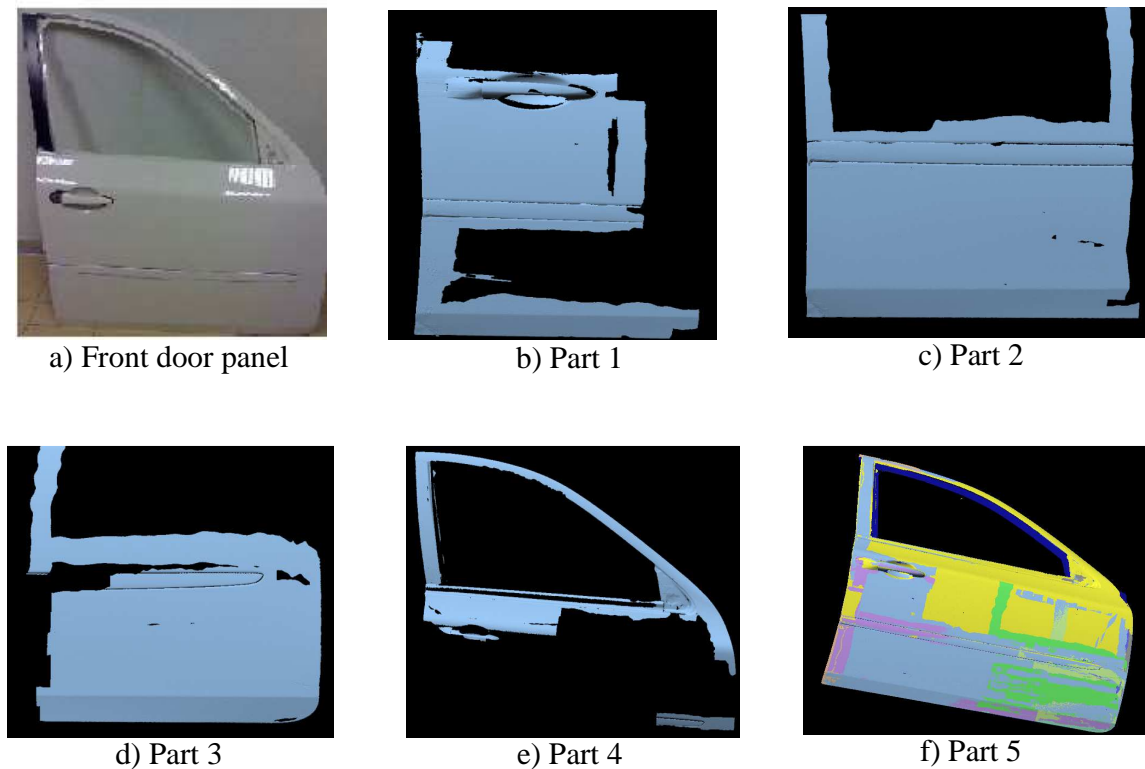


Figure 3.19: Scan part by part

In IMedit all editing process will be making by check one by one for any circumstances. After editing process is completed the solid model are ready to convert to the simulation environment which is the file of 3D model must be convert to the IGES file. In addition if the file cannot be open that will require to compressed the IMerge file. Then select the best mesh to redoing all the editing process. Normally it will happen if the file is too huge which is related to the size of meshing for the solid model as showed i

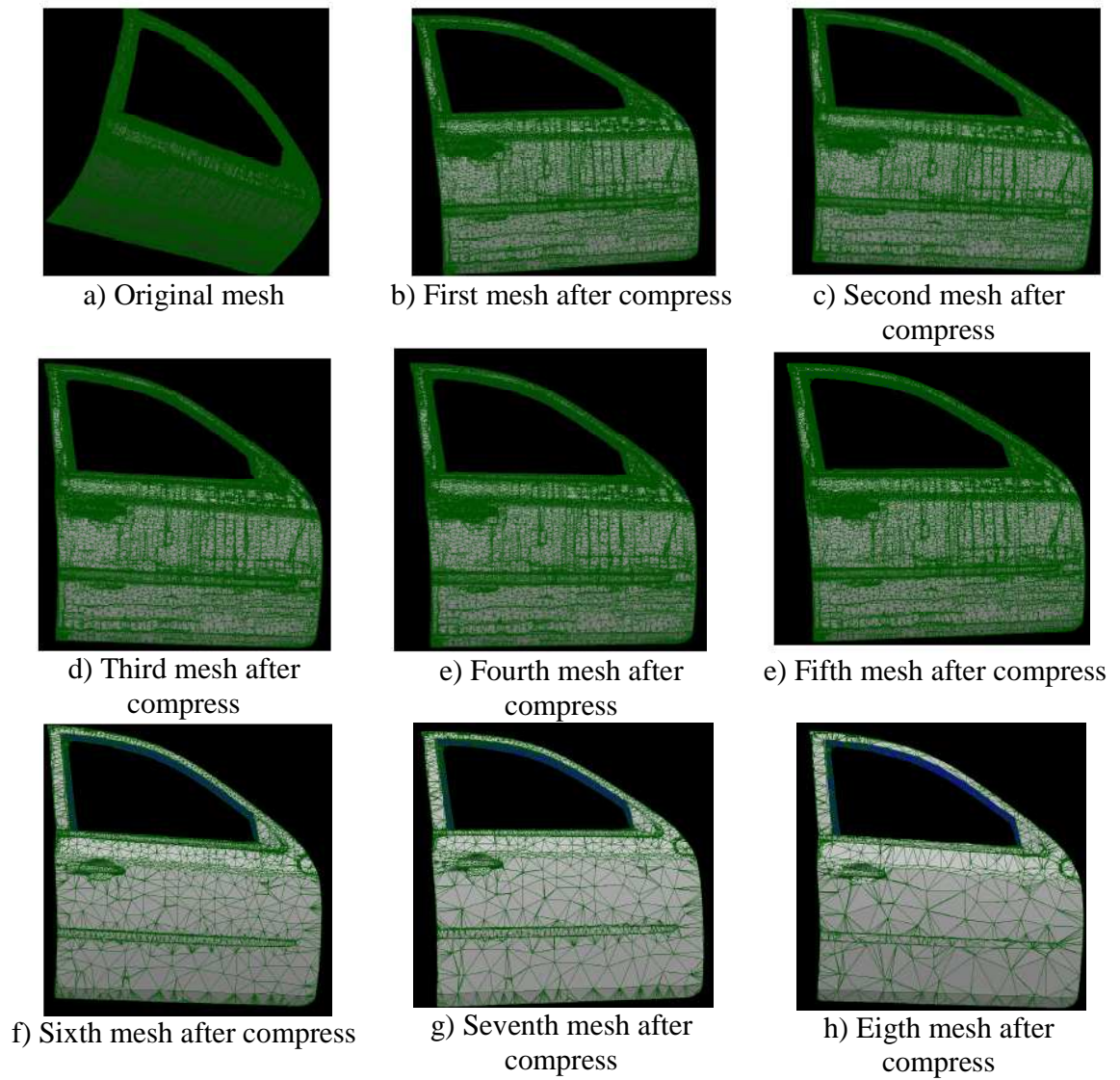


Figure 3.20: Reducing the mesh

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

In this chapter will discuss on the result of the scan door panel. It will be elaborate about the problem of the surface that need to be make improvement and how to countermeasure the problem. This step very important before converting to the another environment such as to make a simulation, check the dimension and analysis.

4.2 MODELING 3D DOOR USING THE SCANNER

Achievement of both of objectives are depend on the successful scanning the door panel into the 3D model. However constrain of the limitation of the skill to scan the door panel also use the software of scanner it will be affected to the result of the image in produce the solid model. Because of that several problem had occurred when the solid model image was produced. Here are the problems that need to be countermeasure before the solid model can be converting to the reverse engineering environment. The problems are consist of

- (i) Not smooth surface on the solid model image
- (ii) The unfilled of hole at the surface solid model
- (iii) Reduce the unwanted crack that occur at the surface
- (iv) Touch up the edge of the surface
- (v) Export to the design and analysis environment

(vi) Overlapping file

All of these problems must be counter measure to give the accurate and best result. As the previous information this project used Polywork software to scan the surface and with this software also can use to edit the surface to make correction of the occurred error.

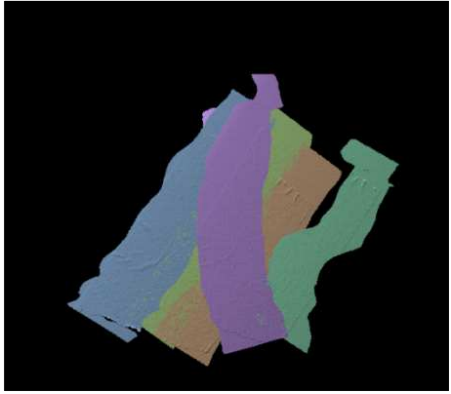
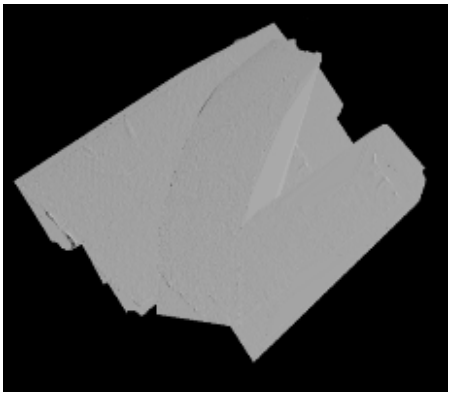
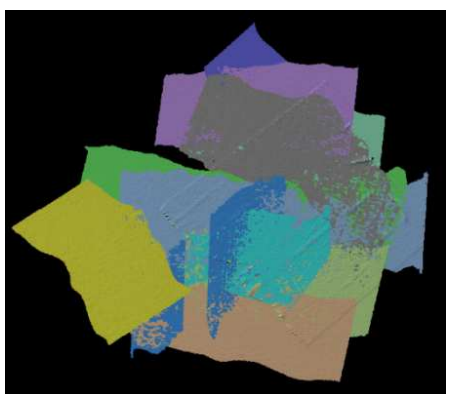
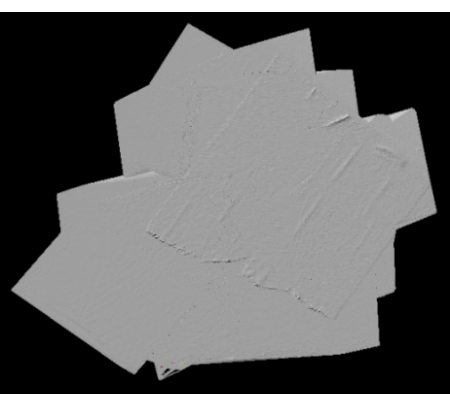
4.3 SELECTION OF THE BEST SURFACE

In section 3.4.2 had been discussed the choices that have to alter the surface of the door panel. Here is the result of each choice.

4.3.1 Masking Tape

As the result showed in table 4.1 that both of them can be detect by the 3D scanner. Otherwise the best result is showed at type number 1 which is light color. Unfortunately after revise again type number 1 more difficult to attach at the door panel surface. Finally the second type had been choosing to use it. During attachment to the surface has to ensure that the masking tape is not retardant each other to give the smooth surface

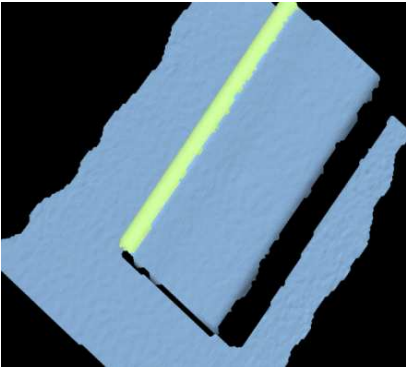
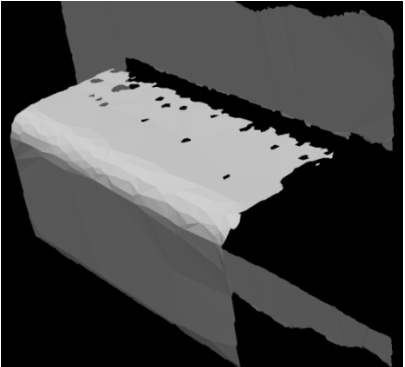
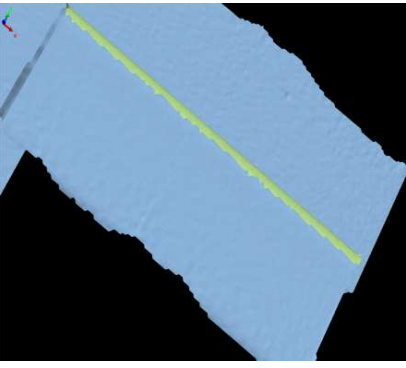
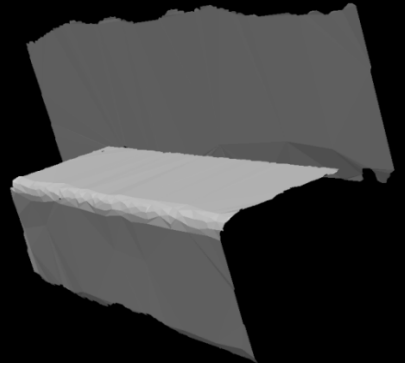
Table 4.1: Result after scan for masking tape

TYPE	IMAlign	IMEdit
1) Light colour		
2) Dark colour		

4.3.2 Spray

Table 4.2 is showed the result of two difference colors of spray which were grey and silver. As the result the grey color gave the better surface than silver color. This is because certain part that had been spray with silver color cannot be detected by the 3D scanner. However after considering the need of skill during the process of spray, this option had been terminated. The skill that is need when to spray is the constant of pressure when press the spray button and also the distance of nozzle spray to the surface must be consistence. If not the surface that had been spray will be overlapping and increase the density of the surface.

Table 4.2: Result after scan for spray

TYPE	IMAlign	IMEdit
1) Silver colour		
2) Grey colour		

4.3.3 Sand Paper

As the final result is choose to use sand paper. The surface of the door panel more smooth nut still can remove the shining f the lighting. With using the sand paper also can reduce the time to alter the surface. The surface can be complete alter with fairly but adequate with several technique while in the process as been discussed in Chapter 3.

4.4 SETTING

Scanning result is based on the setting of the scanner and lighting source. The first phase of scanning is without the probe setting. The result of the scanning process is many of holes and unscans parts due to lighting reflection. Laser light cannot be reflected in some

of angle as can be seen in Figure 4.1. After some adjustment and setting again the probe, the result of scanning is better.

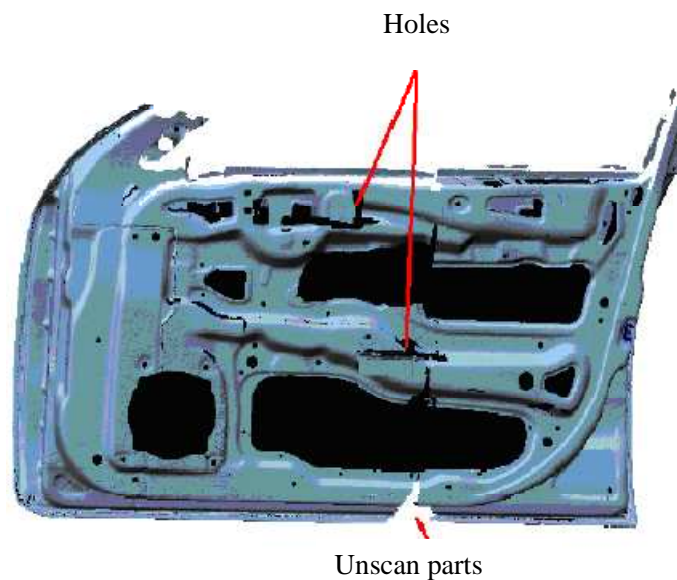


Figure 4.1: Defect during the scan

Probe has to be adjusted to lighting of working environment. If scanning work is done in open area or in door with adequate light, the setting is different. The scanning works refer to Figure 4.2 and Figure 4.3 is totally different. As can be seen, Figure 4.2 (a) and Figure 4.3(b) show the scanned result before the probe setting. The quality of scanning model is not good. Many of holes in the complex curve. The scanning process has to be done many times to cover the entire surface.

On the other hand, the outer panel also have similar problem especially at the center of door and around the door handle. Mean while, after the probe is set to more proper setting, Refer to Figure 4.2 (b) and Figure 4.3 (b), after the probe setting changes have been made, final decision is satisfactory result with clean and without holes on the surface model.

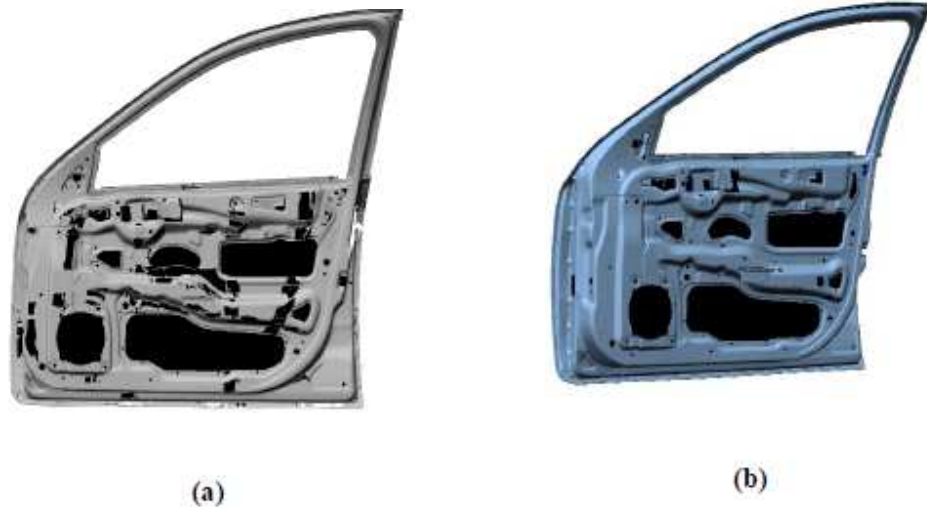


Figure 4.2: Before (a) and after (b) probe setting



Figure 4.3: Before (a) and after (b) probe setting

4.5 SCANNING AND EDITING

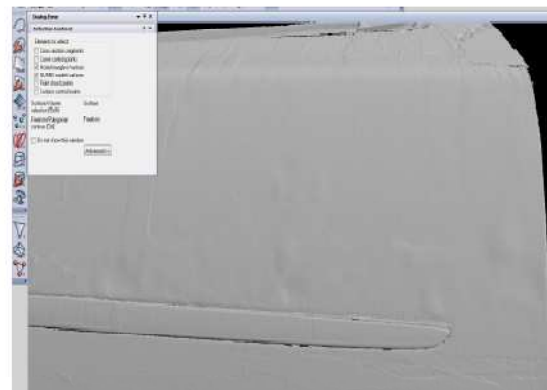
As the full result there are 92518 triangles, 810 scan lines and 10 subgroup had been produce to get a complete 3D model of door panel. Because of that it had been use seven workspace to accomplish the scanning process. However finished the scan process did not mean the result of surface is successful. The surface still need the editing process.

4.5.1 Reconstruct the mesh

Furthermore the surface of 3D model also needs to reconstruct again. This is because the surface was not smooth and layers of each part that had been scanned were appeared as showed in Figure 4.4. For reconstruct the solid model mesh might be use command such as reconstruct and reduce mesh.



a) Before reconstruct

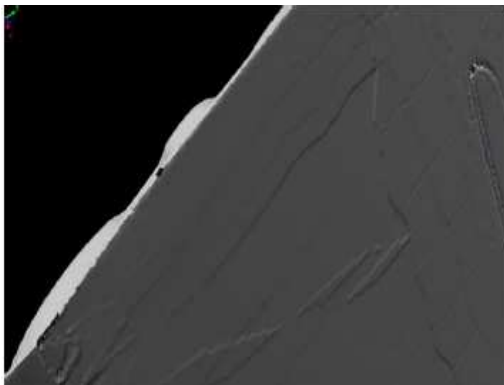


b) After reconstruct

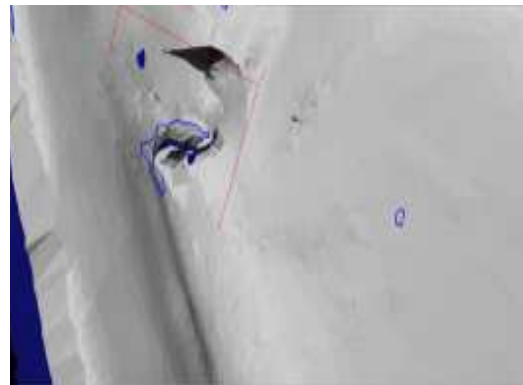
Figure 4.4: Surface of the solid model before and after reconstruct

4.5.2 Full Fill The Holes

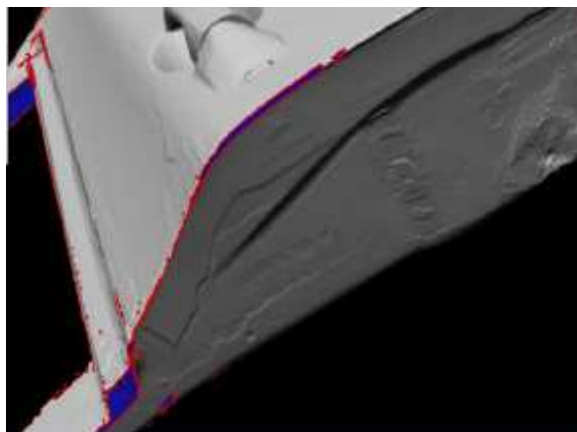
When zoom out the 3D model also can find certain part were still had the holes. All these holes need to fill up by using the command fill up hole as showed in Figure 4.5. In this command will have several further type of process need to follow and select. Actually is not easy as imagine especially when it related to the big triangle that has in the mesh. If just a small of need to big fill but the triangle in the mesh is big than the size of hole, it will followed the size of triangle in the mesh. However it can be fixing it but need to redoing many times.



a) Small hole at the edge



b) Holes at the surface



c) Several positions that still have holes

Figure 4.5: Fill holes process

4.5.3 Alter Unwanted Surface

For this case there are crack and hole that need to be altered by using the boundary holes filling. This result occurred after fill holes automatically which is not only fill the hole but also clean the hole according to the triangle in the mesh as showed in Figure 4.6. To edit it need to create the new boundary at the hole to close it. For the cracking surface can use the reconstruct or reduce mesh. By the way it will affect the triangle in the mesh.

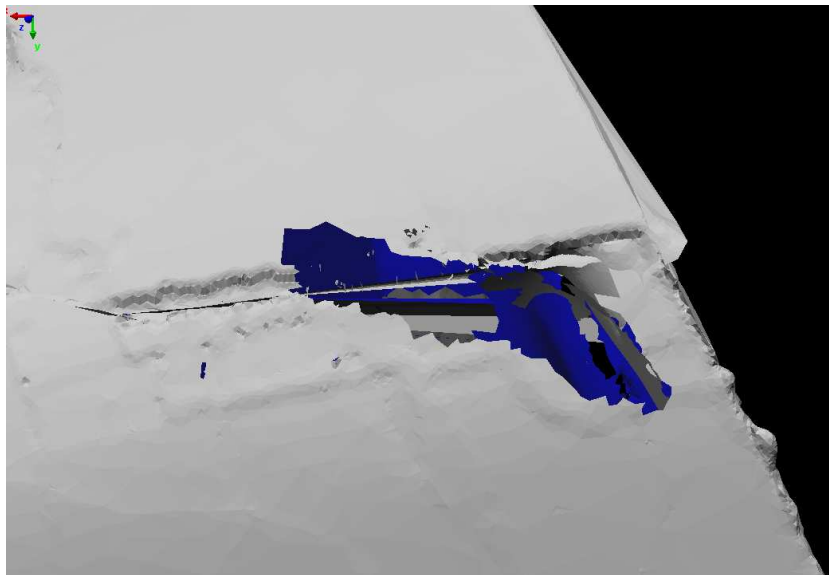


Figure 4.6: Hole and crack

4.5.4 Touch up the Edge

Certain of the edge at the surface need to touch up as showed in Figure 4.7 by using sharp edge insertion. This insertion is where triangles are added or modified to include a specific curve in a polygonal model. This result may occur because of the surface part itself or because of the overlapping while scanning.

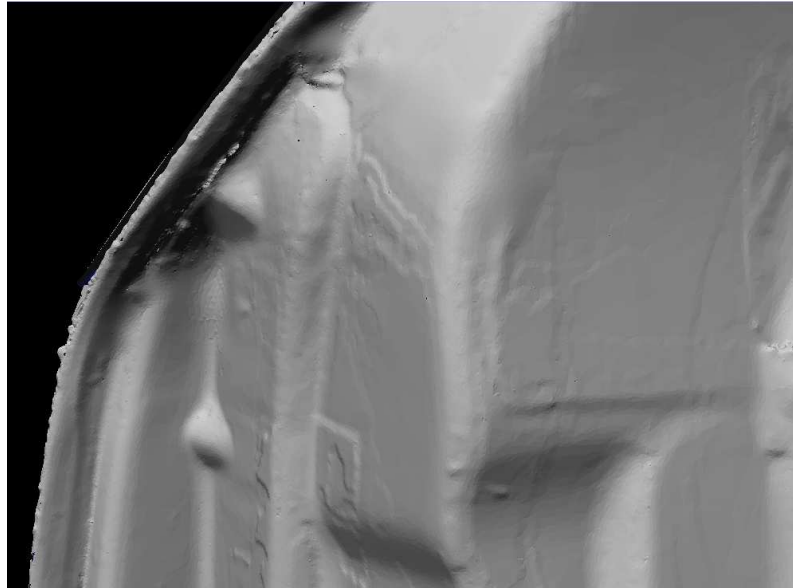


Figure 4.7: Not smooth edge

4.5.5 Size of the Mesh

Reducing the mesh is an operation where triangles are removed from the mesh without changing the accuracy of the overall model. Triangles are removed over flat areas and small triangles are kept in the highly curved or highly detailed areas. The result is reduced vertex and larger triangles on the flat areas, while preserving curvature. The boundary will preserve during the reduction process as showed in Figure 4.8.

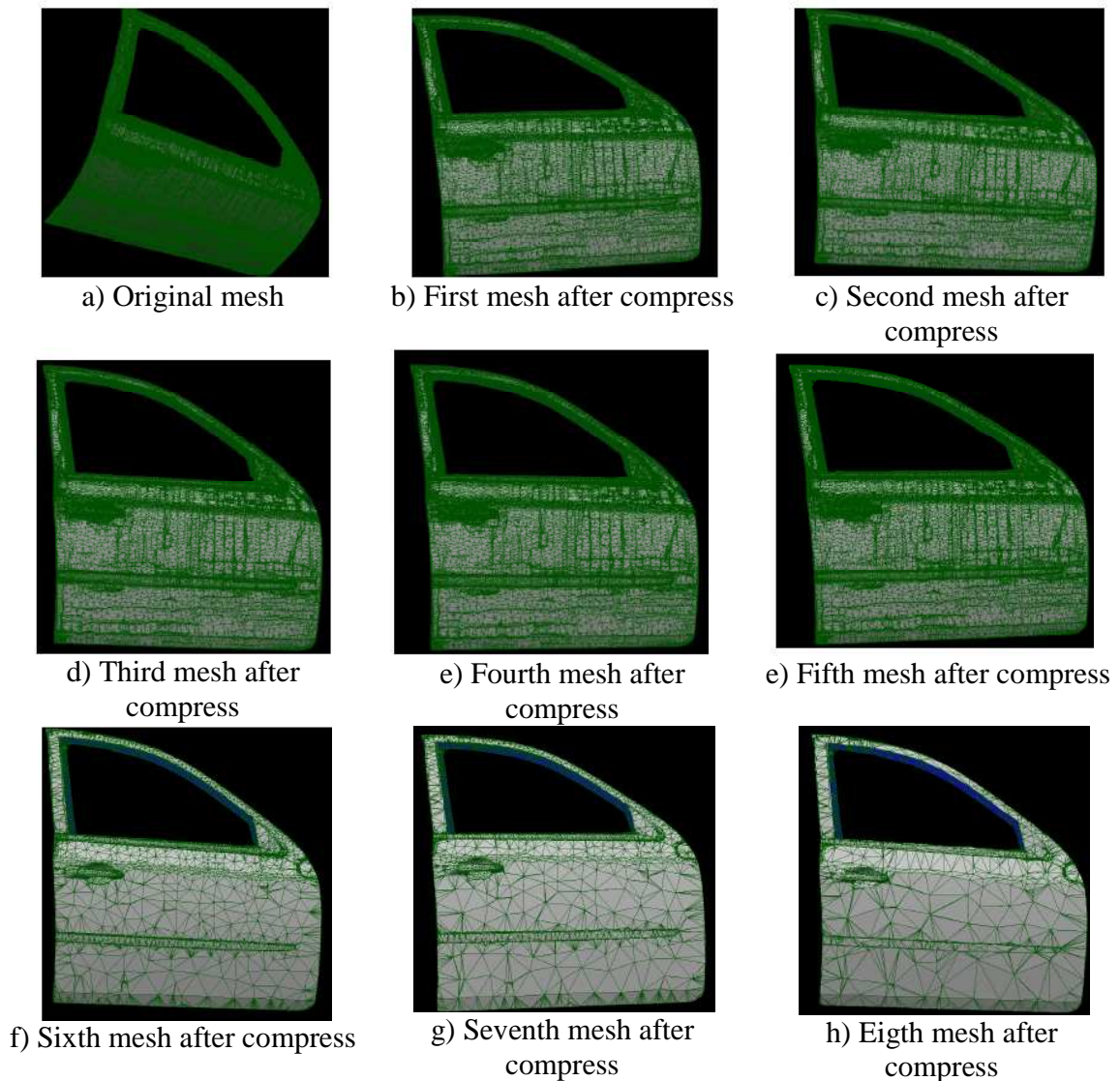


Figure 4.8: Reduction of mesh

4.5.6 Export to the Design and Analysis Environment

This problem will be related to the size of mesh. This is because huge size of mesh will have much of triangle. This can effected to the long operation time and will take much of memory to the other software. As the example 92518 of triangle will take 5 hours to open in the Solidwork as showed in Figure 4.9 which is use 12Gb of RAM and 64 bits. Even though successes open in the selected software, the software will run slowly. For this

case LS-DYNA cannot open this file according to the big size of the file. ALGOR has showed in Figure 4.10 need half a day to open the file. So before open to the any software to continue the next work ensures the size of the file has been compressed.

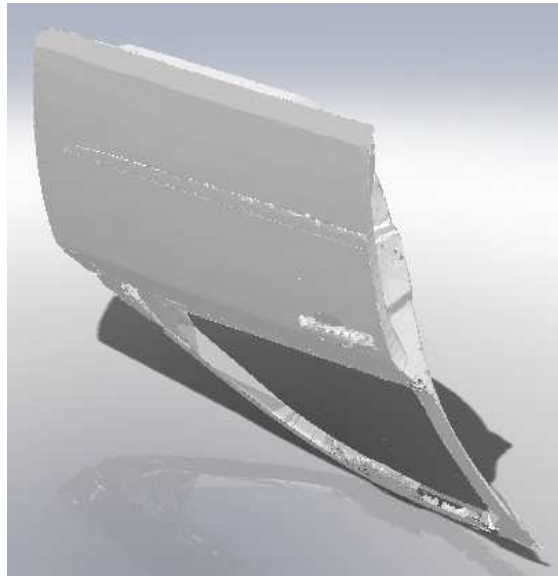


Figure 4.9: In Solidwork

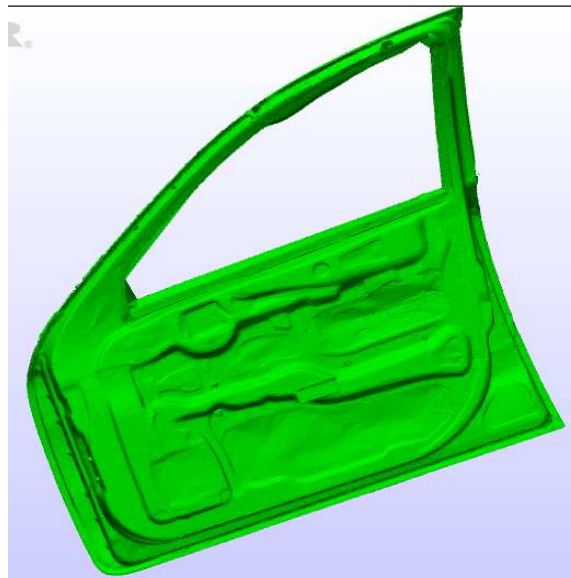


Figure 4.10: In ALGOR

Figure 4.11 is showed the overall result after all the editing process and compressed the mesh. Finally the part is successful open in two softwares which are Solidwork and ALGOR. Figure 4.12 is curvature of the surface car door in 3D model. The surface is do not have any constraint because in a single model without any part at it.

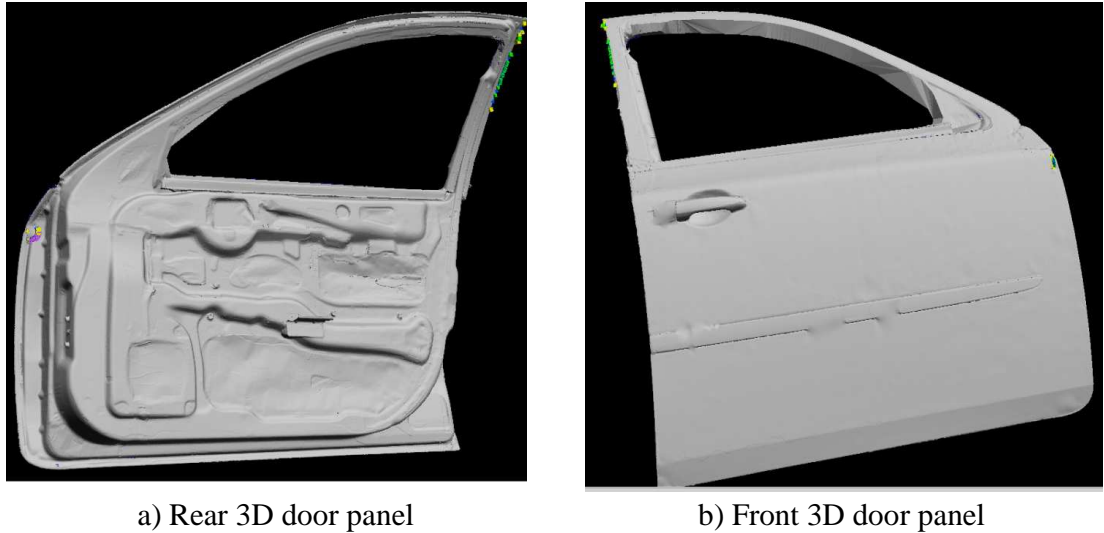


Figure 4.11: The complete 3D model

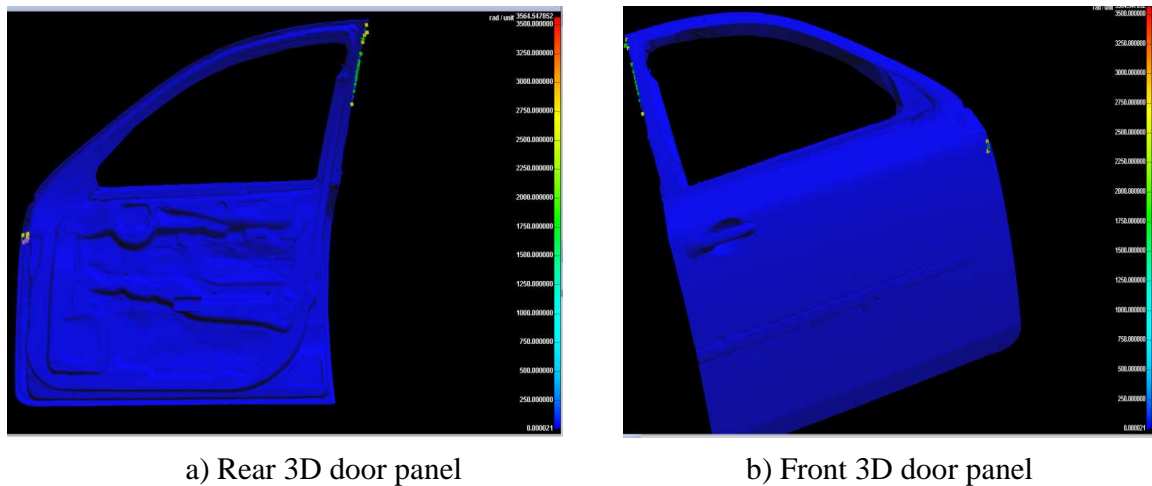


Figure 4.12: The curvature of 3D model

4.5.7 Overlapping File

This problem cannot be avoided but can be minimize it. As inform in the previous chapter that the surface of the door panel will scan part by part or portion. To combine one part to the other part will be need reference point. The reference point is subjected to the lines or scans that already exist at the previous scan which is will be appoint together when to combine with the new scan. But the problem will occur when it too much overlapping as showed in Figure 4.13.

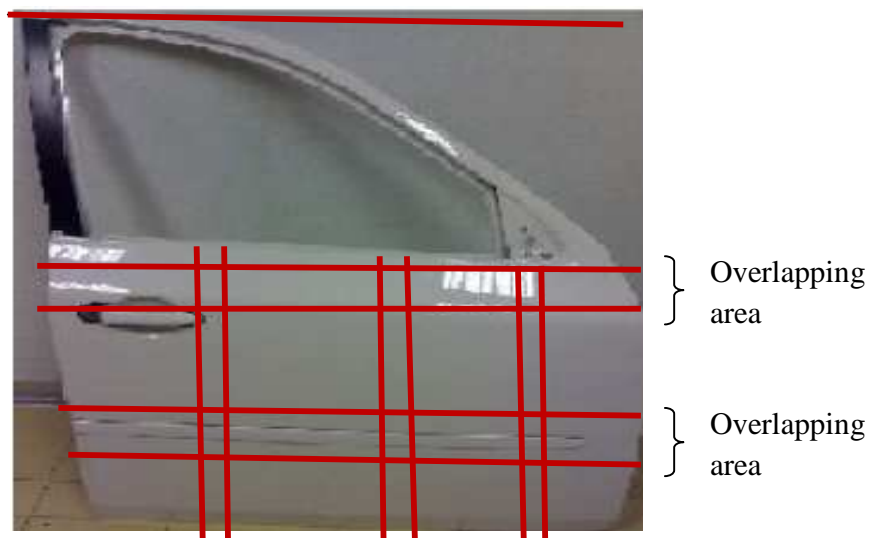


Figure 4.13: Portion to scan and overlapping area

When too much of overlapping area occur it will make the mesh of the scan also increase. In the other hand, it also will increase the size of file. That entire factor will be affected to the duration of the time. The time to do for the next scan of the part will be longer and make the file become weight in the RAM of the laptop that receive and display the input. It also will hang the laptop. But need to remember when to reduce the reference point has to ensure that scan part 1 can detect the scan part 2. So when appoint the reference point need to very carefully and must be precise.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

Both of objectives are successfully achieved instead have many constraint need to be overcome. From this project the conclusion can be make also the recommendation accordingly.

5.2 CONCLUSION

For the conclusion to model a part due to the complex of curvature surface is important to remain the performance and increased the production. To produce the successfully of 3D model this project have been go trough to scan and gather 3D points clouds of car door. In this project car door has been selected to model the 3D model from the real model. From the result of scanning, the 3D model will be needed to generate and analyze the quality of car door. In Chapter 4 have been explained deeply the difficulties during producing the best 3D model by using Polywork software.

As stated in the literature review of this project a lot of quality improvement can be developing in any sector by using the data of the 3D model such as can be use to create more creative invention or design without need to re-do the drawing. It simply can be use directly to the new design with modify it. From the 3D model also the door panel can be done a lot of improvement such as in determine the selected material to get the better result in weight consideration. When it related to the weight consideration it mean , the manufacture need to know the thickness part of the door panel to get the best result by applying the selected material.

In addition awareness of safety can use the 3D model door panel to simulate the collision prediction especially for the side impact collision.

Nowadays many virtual tests have been implemented to produce the high quality of product. With factor of time the result of this study can keep continuously use to the important development for the long lasting to keep good relationship between the engineer, vendor and also the business of the industry itself. It also can improve cooperation in switching the transfer technology to built better product and gain a lot of business each other.

5.3 RECOMMENDATION

However to this study, recommendations that can be taking according to problem occur during this project. The constraint of time will be affected to the skill of the researcher during the process of the project. In addition the researcher must clearly understand and know how to use the equipment and the software. A lot of practice and alert with the limitation of the machine such as reflection of light and the position of the laser scan. Also it needs high performance of personal computer to run the chosen software to make a analysis and simulation. The software of the laptop scanner itself must be upgrade and use the high performance RAM to support the scan file. The bigger part will produce the bigger file.

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