

# **DESIGN IMPROVEMENT FOR REPLICA TROPHY USING REVERSE ENGINEERING AND CNC MACHINING**

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## **LIST OF ABBREVIATIONS**

2D	Two Dimensions
3D	Three Dimensions
AHP	Analytical Hierarchy Process
ASCII	American Standard Code for Information Interchange
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CCD	Charge-coupled device
CMM	Coordinate Measure Machine
CNC	Computer Numerical Control
CATIA	Computer Aided Three-Dimensional Interactive Application
EDM	Electrical Discharge Machine
NC	Numerical Control
RE	Reverse Engineering
STL	Stereolithography

## **ABSTRAK**

Trofi melambangkan pencapaian atau kemenangan seseorang atau pasukan dari suatu acara. Seiring dengan teknologi, pembuatan trofi telah menjadi lebih mudah, lebih cepat dan kos rendah yang diperlukan untuk menghasilkan produk. Replika Trofi adalah produk yang diperlukan untuk menghasilkannya mengikut tema acara. Oleh itu, kejuruteraan songsang adalah cara yang paling sesuai untuk membantu mempercepat pembangunan produk baru dengan menggunakan objek sedia ada. Ini boleh mengurangkan masa yang diperlukan untuk melukis atau mereka bentuk produk baru. Dengan bantuan pengimbas 3D dapat membantu mendapatkan data struktur kompleks dan mengurangkan masa untuk mengukur objek. Dalam kajian ini, ia dikehendaki menghasilkan trofi replika untuk acara Sanggar Sanjung USM yang merupakan peristiwa penghargaan kakitangan USM. Projek ini adalah untuk mengenal pasti jenis produk yang sedia ada dan berkaitan dengan tema acara dengan menggunakan pengetahuan tentang reka bentuk produk. Kajian dijalankan ke pasaran sasaran untuk menganalisis tindak balas pelanggan. Beberapa konsep yang dihasilkan untuk pemilihan, kajian mengenai keupayaan dan ketepatan pengimbas laser Next Engine 3D perlu dipertimbangkan. Hasil pengimbasan dapat ditingkatkan dengan meningkatkan kecepatan dan masa pengimbasan untuk memperoleh data padat titik awan. Pembinaan semula permukaan dilakukan setelah mendapat hasil imbasan. Data CAD diperlukan untuk mengoptimalkan dimensi dan kedudukan objek ke hasil yang diinginkan. Reka bentuk konsep perlu menyertakan reka bentuk penggunaan banyak trofi replika untuk meningkatkan fungsi trofi. Konsep produk akan direka dengan menggunakan pemesinan CNC dengan bantuan perisian CAM. Pendekatan ini boleh membawa kepada penggunaan masa yang singkat berbanding menggunakan kaedah kejuruteraan hadapan.

## **ABSTRACT**

Trophy represents of achievement or victory of a person or team from an event. Along with the technologies, the manufacturing of a trophy has become easier, faster and low cost needed to produce a part. Replica Trophy is a product that required to produce according to the theme of the event. Therefore, reverse engineering is the most suitable way which helps to accelerate the development a new product with using the existing object. This can reduce the time that needed to sketch or design a new product. With the help of 3D scanner can help to obtain the data of complex structure and reduce the time to measure the object. In this study, it is required to produce the replica trophy from the event of Hall of Fame USM (Sanggar Sanjung USM) which is an appreciation event of the USM staff. This project is to identify the existing type of product which relate to the theme of the event by using the knowledge of product design. The survey is conducted to the target market to analyze the customer response. Few concepts are generated for selection, the study regarding the ability and accuracy of the Next Engine 3D laser scanner need to be considered. The scanning result can improve by increasing the scanning speed and time to obtain a dense data of point of cloud. Surface reconstruction is undergone after obtaining the scan result. The CAD data required to optimize the dimension and positions of the object to the desired result. The design of the concept needs to include the design of the multiple usage of the replica trophy to increase the functionality of the trophy. The product concept will be fabricated by using CNC machining with the aid of CAM software. This approach could lead to shorter time-consuming as compared with applying forward engineering method.

# CHAPTER 1

## INTRODUCTION

### 1.1 Background

Trophy is an object that symbolizes the victory or achievement of a person or team from an event. A trophy can be applied at all kinds of competition or event such as sports, music, appreciation award and acting awards. The design of trophy usually using objects that according to the suitability of theme of the event such FIFA world cup that have football on the trophy. Along with the technologies, the manufacturing of a trophy had become easier, faster and less cost required. To produce a trophy using reverse engineering, it needs to obtain the suitable structure of trophy and improve the design of the trophy. Therefore, a design study is required to improve the replica trophy of the event Hall of Fame USM (*Sanggar Sanjung USM*).

The event of Hall of Fame Universiti Sains Malaysia (*Sanggar Sanjung USM*) is an annual event to celebrate the contribution and achievement of the staff in USM which was proposed firstly in the year 2000. This event is to award the best contribution of USM in term of research, publication, personality, creativity, academic, service and the connection of industry and community. The mission of USM can be achieved by recognizing the future talents and allows the new generation to transform their social and economic well-being. The logo of Sanggar Sanjung Award is shown in Figure 1.1. It is decided to use this logo as the official logo in 2013 while in the previous years the logo change every year [1]. However, there is required to improve the existing trophy that able to represent the event.



Figure 1.1: Logo of Sanggar Sanjung Award [1]

Improvement of the trophy is needed to meet the customer objectives. It can help to increase the usage of the product by adding features or function of the new product. To start up a brand-new product usually takes long time to design. To shorter the developing time of a new product, it is usually improved the existing product in the market by adding more value into current trophy. Adding value of a product can be done by improving feature from customer feedback, adding new functionality, or improve the appearance.

To design a trophy, it is essential to understand the event and analyze the market needs to obtain the suitable object that able to fit into the theme of the event. Therefore, the survey is a common method to collect the feedback of the targeted market. Different types of survey method can be done such as interview, online and hardcopy. The survey results can help to analyze the scope that the target market focus and elements that suitable to the theme of the event.

Reverse engineering has been widely using in the part of design due to the competitiveness of the industries. To meet the demand of the market, it requires a faster way to design and manufacture a product. Compared with forward engineering, reverse engineering start with a part that need to be redesigned to a new concept of the model while forward engineering start with design a new concept to a final product. By applying reverse engineering, it can save a lot of time to redesign a new product from an existing product with the aids of Computer Aided Design (CAD) and development of 3D scanner. Reverse engineering allows users to improve the design of the existing product by modifying the existing design after 3D scans. This can help to accelerate the process of developing a new product while at a same time can meet the demand of the customer.

The first step of reverse engineering is to find a part to scan by using a 3D scanner which to obtain the data of the object. This is to digitize the geometry of the part into the CAD software using CATIA V5. It is followed by processing the data and then segmentation and surface lifting of the CAD model. From the process it had shorten the time of redesign because of the application of 3D scanner able to scan the complex part in and digitized it into STL files which is soon transferred in CAD. With the development of technology, many different types of 3D scanners are available in the market. Such as laser scanner and optical scanner. Different types of scanner can

produce different quality of outputs based on the user preferences. In this case, Next Engine 3D laser scanner is applied in this research.

CNC machining is applied after the process of improving the design of the replica trophy. After digitizing the object with using 3D scanner, the point of clouds that generate the need to further process to help in manufacturing the product by using CNC machining with the aid of Computer Aided Manufacturing (CAM) software. Using the application of CATIA can help to preview the suitable process to fabricate the product.

## **1.2 Problem Statement**

The existing type of trophy mostly only represents as a sign of victory and without fulfill the theme of the event and the needs of the market. Improvement of replica trophy that represent the event of Sanggar Sanjung USM required to produce. Moreover, the functions of existing trophy in the market can use as display. Reverse Engineering can help to reduce the time use to design a new product. Therefore, a design improvement needs to apply in this research using reverse engineering and knowledge of CNC machining.

## **1.3 Objective**

1. To identify the existing type of product which related to the theme of *Sanggar Sanjung USM* by data collection using customer survey.
2. To redesign the most suitable way to produce a replica trophy using the knowledge of reverse engineering.
3. To fabricate a multiple usage of the replica trophy using CNC machining and fabrications tool.

## **1.4 Scope of work**

Define the possible element that related to the event of Sanggar Sanjung USM. Customer survey form about the trophy of Sanggar Sanjung USM event is prepared and conducted to the targeted market, which is the staff of USM includes the category of execution and category of profession and management. A list of the suitable object is analyzed. Few concepts were generated and undergoes selection.

The concept is further analyzed with morphology chart. Screening and scoring matrix were conducted to select the suitable concept. The suggested objects had

undergone 3D scanning to identify the scanner output. The 3D Scanner of Next Engine was used to scan the object. The data acquisition is obtained by the scanner. The cloud of points is then modified and filter to obtain better output of result. Surface reconstruction is continued with using CAD software of CATIA V5.

It is continued with material selection, then manufacturing process selection and tooling selection. By using CATIA Process, suitable tool path and tool is selected in machining and preview the machining works. Lastly fabricates by using 5 axes CNC milling machine and other fabrication tools.

## **1.5 Outline of Thesis**

### Chapter 1

- Describes the project background, definition of research, such as design improvement using reverse engineering and CNC machine, problem statement, objectives and scope of the project.

### Chapter 2

- Includes the review of other literature such as journal, book, and websites that related to study project.

### Chapter 3

- Describe about the methodology of the project. Including the customer survey form, finalize the element, concept selection, scanning procedure, editing process using CATIA, material selection, CNC Process simulation, fabricates process and assembly process.

### Chapter 4

- Analyse and interpret the result from the customer survey form, final concept description, discuss the scanned and edit the output result fabricate output result and cost estimation.

### Chapter 5

- Conclude about the project and future work to further improve the project.



## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Overview

In this chapter reviews about the published journal of different project using the method of reverse engineering, such as redesign the generator engine components and remanufacture car volume buttons. It is also reviewed about type of 3D scanners used, compare the result between optical scanner and laser scanner and develop a 3D scanner that ability to represent virtual 3D objects from distance measurements obtained by a 1D optical distance sensor. This includes of the review from CNC machining of optimization method to processing the complexes 3D solid surface on CNC machining and decision-making tool to support the selection process between 3-axes CNC milling machine or a 5-axes milling machine.

#### 2.2 Reverse Engineering

Vijaya Ramnath et al. [2] had applied analytical hierarchy process (AHP) to break down the problems and analyze then give out solutions. It is to analyze the suitability of using reverse engineering to compare with re-engineering and conventional design. there are 4 important factors are measured by using AHP, which is the cost of processing, time of processing, flexibility of processing, accuracy of processing. The results show RE is suitable to redesign the generator engine components. The process of RE system has divided into three main parts which is digitization of the part, processing of the measured data, creation of a CAD model of a part. It is then continued redesign each of the components to improve the performance of the parts. The dimension of broken or damage parts can be known using RE. Pro E software is used to create the exact model.

Paulic et al. [3] applied reverse engineering to re-manufacture car volume button. By using reverse engineering procedure, it can manufacture the existing object to produce a similar product when the original CAD is not available. It begins with 3D scanning the object to obtain the digitized data of the object. After the scanning it can obtain the point of clouds of the car volume button. The CAD model of the object is obtained, it is required to repair the mesh for parts that had broken. It then continues

with using feature surface wizard to create the surfaces automatically after mesh. Lastly, it is manufactured by using selective laser sintering Formiga P 100.

Várady et al. [4] had concerned about shapes in reverse engineering. The procedure of reverse engineering is classified into four steps which are data acquisition, preprocessing, segmentation and surface lifting and CAD model creation. Data acquisition is the crucial part of reverse engineering, which the data structure can affect the results of point of cloud obtain. Data acquisition can classify as shown in Figure 2.1. Várady had also listed out the practical problem and data acquisition. Such as calibration, accuracy, accessibility, occlusion, fixtures, multiple views, noises and incomplete data, statistical distributions of parts and surface finish. There is two difference approaches of segmentation, edge based and faced based method in which edge based is to find the edge boundaries while faced based is to determine the connected region of the same surface. For free form segmentation there have four important ways which are global approximating surface, curve network-based surface, arbitrary topology surface and functionally decomposed surfaces. Each of the pro and cons are described in the text and more research need to be done before starting the reverse engineering process to obtain the best quality of shape.

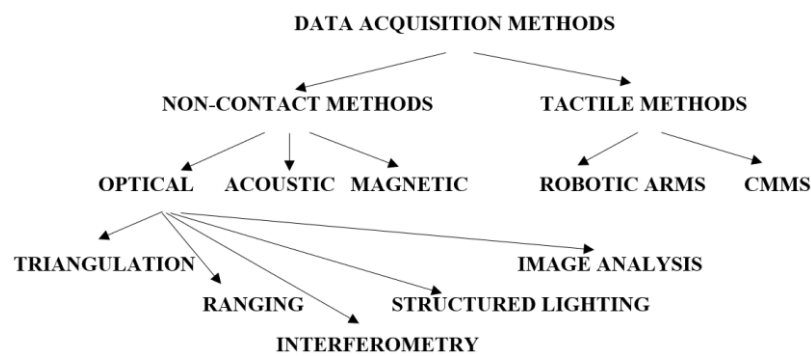


Figure 2.1: The classification of data acquisition [4]

Anwer and Mathieu [5] had studied the shape representation and shape processing (Figure 2.2) of geometric reverse engineering. In geometric reverse engineering, there are three steps which are product digitization, shape reconstruction and 3D CAD modelling. The proposed method used a discrete shape representation, a curvature-based description and a shape clustering approach to illustrate the shape related concept. It is also related to the four steps of shape segmentation, discrete curvature estimation, boundary identification, vertex clustering and connected region

generation. The result of the proposed method had come with four limitations, non-smoothness of the boundaries of the shapes (complex object), sampling from rough surfaces, noise and sparsity of data, processing large flow of date and lack of knowledge from external source.

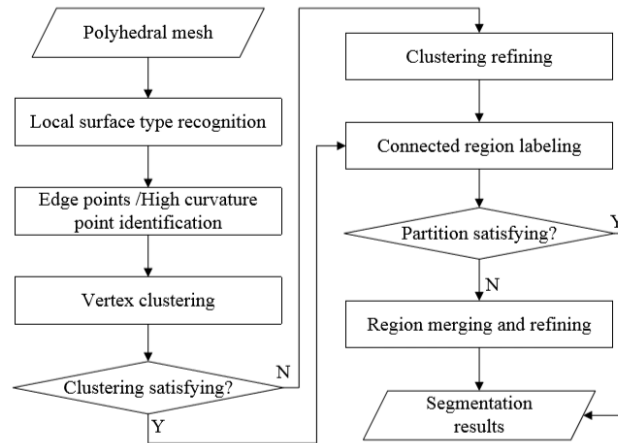


Figure 2.2: Shape segmentation process [5]

Anggoro et al. [6] had investigated to find a new design that fit with Low Sag body characteristic. It is also proposed to use CMM (Coordinate Measuring Machine) for data acquisition of CNN plate diameter 220 mm. The data are digitized and used in CAD software of CAD-Power Shape 2015. A new design is introduced based on the analysis result at the rim section. The rim of the plate is spring about 9 degrees to make the rim drop at the right place during firing. CNN plate diameter 220 mm that have rolled edge shape which will give more strength to the structure of clay.

Durupt et al. [7] had proposed a semi-automated rebuild methodology which is to reduce the time to reconstruct a model after obtaining the point of cloud. Durupt had classified the CAD model feature into two, which is functional and structural skeleton. In the state of arts had shown some segmentation techniques and knowledge that can possibly change based on different types of project preference. It is required to build a system define the group of the type of the skeleton. This is the essential part to apply the knowledge which can help to reduce the set of driving parameters. With the collection of knowledge, it can help to develop the geometrical recognition such as functional and structural skeleton. The combination of knowledge management and geometrical recognition helps to develop a CAD model.

Benko and Várady [8] had used the segmentation method in reverse engineering to reconstruct the CAD model. Segmentation can be done by splitting large point of cloud into smaller regional or connect both smaller regions to form a connected form model by smoothing the mesh or reduce the dense of point of clouds. There are two types of segmentation which is edge based and face based. Different types of indicators are used to test in this project. the type of indicator can relate to filter that used in the test. This is to classify the unstable data of points. The author also shares the three phases of direct segmentation which is disjoint, planar and multiple ruled and doubly-curved regions which need to consider during the filter of the edges.

Dúbravčík and Kender [9] had applied reverse engineering techniques in mechanic system services. A damaged gear wheel component had undergone 3D scanning to obtain a new gear wheel using rapid prototyping. During the 3D scanning process the points of cloud occurred some unadjusted surface due to the tooth system. To encounter the problems, the unwanted points had eliminated to reduce the problem of reconstructing the surface. CAD is applied to design the missing part of the component. Decrease the number of points is to provide an accurate surface. This had shown the importance of editing the points of cloud to provide better surface and a close relationship between digitization and rapid prototyping.

### **2.3 3D Scanner**

Vijaya Ramnath et al. [2] had classified that there are two main types of 3D scanners non-contact 3D scanners and the contact 3D scanners. The non-contact type 3D scanners usually emitting radiation, such as light, laser and X-ray over the surface of the object. The object normally mounted on a stand. For contact type 3D scanners, it is also known as coordinate machines (CMM). CMM are in contact with the object that needs to be scanned. These scanners have highly precise in their images with their limitations since not all objects are suitable to scan. In this case the generator engine component is scanned by ‘Surveyor model 4000’ 3D laser measurement system. The existing model will have scanned by this device and the output is in a curved form.

Tóth and Živčák [10] had proposed to compare the result of 3D scanning by using Steinbichler Comet L3D optical scanner and the Creaform EXAscan laser scanner. This proposed idea is continuing by determining the parameters that can be applied on both scanners based on the data acquisition result. A specimen was designed to fulfill

the parameter to be measured. The specimen was scanned by both scanners for three times. And the obtained data is saved in STL files which is then evaluated by using Volume Graphics VGStudio MAX 2.2 software. The criteria of dimension, shapes and orientational deviation had considered of the evaluations. The results had shown in which Creafom EXAscan system shows a more consistent value and the variation range of angles is smaller while Comet shows a better result for perpendicularity which have smaller variation range.

Xua et al. [11] has derived a new color 3D measurement and proposed a rapid calibrating method to measure the system parameters. The color 3D laser scanning system contain a line laser light emitter, one color CCD camera, a motor driven rotary filter, a circuit card, and a computer (Figure 2.3) in which there are two steps to capture an image of the object. The color CCD camera captures the color image of the object after the laser light emitter is shut down and file is opened. All the color data will have recorded and ready for post-processing. Then the filter is closed, and monochrome data of an object is captured by a CCD camera. The laser light emitter is started at a same time an undulating line is from which an image is form on the CCD sensor. It described of optical plane 3D measurement model has two part which is a CCD camera perspective transform model and the optical plane equation measurement model. A calibrating drone is introduced and advances a n auto-merging method for multi-frame. A rapid method of multi-frame merging is also proposed. 3D digital color model is developed by the rapid merging using curvature and color information.

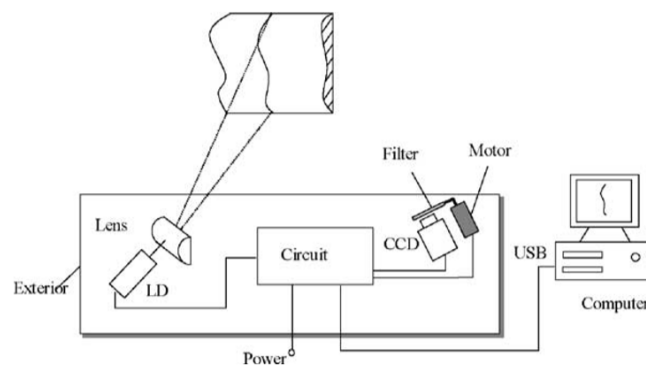


Figure 2.3: Principle of color 3D laser scanning measurement system [11]

Vagovský et al. [12] had proposed to evaluate the measuring capability of GOM ATOS Triple Scan II optical 3D scanner. It is proposed to measure a small object which is a hard metal rod to measure the tool diameter with using different measuring volumes. A quality characteristic of the scanner can be considered from the experimental statistical value. It can be evaluated by obtaining the functional capability in repeated measurement (precision) which is in stable conditions. However, from the results it had shown that ATOS scanner unable to measure a small and precise object and the tolerances of scanned object is narrow. The major use of this ATOS scanner suitable for medium or large size object. Therefore, choosing the correct scanner or object to scan is an essential step before begins with the project.

Reyes et al. [13] had proposed a methodology go develop a prototype of a 3D scanner device that able to represent virtual 3D objects from distance measurements obtained by a 1D optical distance sensor. It consists three elements to accomplish the goal which is an electromechanical structure, a data acquisition hardware (controlled by the PIC18F4550 microcontroller) and a graphical user interface that programmed in MATLAB language. Few small prototypes are used to test the functionality of the proposed 3D scanner which is one plastic cylinder, two toy heads and one mannequin head. The result is shown that the cylinder is well present, but with some protuberances on the surface while the mannequin head have difficulties to scan due to the porosity of the texture material. While the last mannequin able to obtain a slight detail output. The overall result is compromising as the cost of the device was under 500 USD.

Uyar and Erdoğan [14] had used a 3D scanner to estimate the surface area and volume of the product in the food process industry. Different shapes of food had used to scan to obtain the digitized data, it is further modeling using SolidWorks software to prepare the mesh model. 3D scanner can help to demonstrate the surface irregularities comparability with assuming the object is axis-symmetrical. It had shown that the accuracy of using a 3D scanner to measure the surface area and volume of the food with the calculated results only deviates 1% throughout the experiment. This also expected of have further improvement on process simulation from geometrical modelling.

Kus [15] had implemented 3D scanning technology in the automotive industry. There are two scanning experiments had conducted to examine re-manufacturing the sheet metal cutting die by scanning, while the second experiment is to compare the point of clouds for inspection usage. The output point of cloud result saves in the STL or ASC format to inspections. It is a result of the edge detection of STL file format and caliper results is compared and the difference is within the require tolerance. This had shown that 3D scanner can provide an effective and high accuracy in a short period of measuring time.

Voisin et al. [16] had studied the ambient light that introduce errors into data for 3D scanner based on structured light. The light illumination shows a small deviation from the original colour. As a result, they had explained the systematic error source that occurs from the colour patches. The error that appears is denoted come from the projected pattern itself. Lemeš and Zaimović-Uzunović [17] had conducted a study of ambient light that will influence the quality of 3D scanned using a laser 3D scanner. In the study different type of colour sample was scanned in two conditions, which is normal daylight and in dark conditions. By using desktop laser 3D scanner NextEngine it is found out that ambient light can influence strongly to which yellow and green surface. While the most ideal scanned result scan object that have a light grey surface, which will not affect by the ambient light and program setting.

With the future research, Zaimović-Uzunović and Lemeš [18] had investigated the influences of the surface parameter such as scanned surface color, glossiness and geometry that will affect the quality of 3D scanned data. The same laser 3D scanner NextEngine is used in the experiment and the result had shown that strong red component (red, yellow and white) can provide a better point of clouds results, while black and green surfaces have poor results in light setting condition. In dark setting the blue surface provides better results. In conclusions gray is the most suitable surface color for 3D scanning.

## 2.4 CNC Machining

Dubovska et al. [19] had improved the methodology to implement the virtual simulation of turning and milling technological process. The help of virtual simulation can improve the machining efficiency. Dubovska [20] also share about the quality control of machining processes with CAD/CAM system CATIA. This can help to reduce the purchase, maintenance of the cutting fluid or tools that use to support the machining. It is important to apply into precision engineering components that can help to provide the possible error that may occur during the real machining time. It helps to reduce the handling into minimum, provide the choice of material to determine the performance of machining. This method can help to provide a most suitable path to use to determine the shortest machining time. It is also helping to reduce the production cost and time.

Sood et al. [21] had proposed to convert a 2D digital image human portrait to a 3D Freeform surface in the form of point of clouds and the surface data is used to generate an efficient tool path using machining simulation-based 3D graphical simulator ToolSim. The process of the 2D grayscale image to a 3D surface consists of three steps, digital image to 3D Freeform surface generation, toolpath generation, and tool path efficiency improvement. to process the image of human portrait, the background needs to identify so that it can be processed separately for better output. It shows that point cloud data can be used to generate a tool path efficiently only if the point cloud is dense. As a result, the developed application can generate accurate CNC machining tool path while significantly decreasing the total number cutter location points. Edge detection and other advanced image processing algorithms can be implemented for enhancing the developed application.

Tosun et al. [22] had studied workpiece surface roughness in wire EDM varies based the effect of cutting parameters. The cutting parameters that experimented are pulse duration, open circuit voltage, wire speed and dielectric flushing pressure. With the used for analysis of variance (ANOVA) and F- test had shown that the pulse duration, the open circuit voltage is the most effective parameters while the wire speed and dielectric flushing pressure shows less effective. To reduce the surface roughness, the two factors should concern and provide the suitable input value during the fabrication process using wire EDM machine.



Wagner [23] had proposed a new optimization method to processing the complex 3D solid surface and reduce the number of tools to obtain high complexity profiles. In this case, 5 axes CNC machine of ZAYER KP 6000 AR is chosen for the testing while the machine is tooled with two processing head, vertical immovable and circular head to provide stability of the machine. The result had shown that process trapezoidal threads of big sized able to minimize the number of tool positioning. It also provides the possibility of manufacturing threads with different angle of flank leaning.

Mahapatra and Patnaik [24] had proposed an optimization of wire EDM process parameters to provide a better metal removal rate, surface finish and cutting width using Taguchi method. The control factor selects the most suitable process that can perform instability throughout the experiment, while the noise factor represents the cause of the variation. In results, the factors of dielectric flow rate, discharge current, and pulse duration can help to provide the most ideal result in a better metal removal rate, surface finish and cutting width.

Bologa et al. [25] proposed a decision-making tool to support the selection process between 3-axes CNC milling machine or a 5axes milling machine. Fuzzy Logic Toolbox and the fuzzy graphical user interface (GUI) within the MATLAB software package is used to build the decision-making tool. The six variable that used to determine the input and output is setup time, staff, geometry of the parts, accuracy of parts, cost with CAM software and utility of 5 axes CNC machine. This tool can also provide a fast result based upon real or simulated inputs.

# CHAPTER 3

## RESEARCH METHODOLOGY

### 3.1 Overview

This chapter explains the method use to complete the research. This includes to identifying the existing type of product use to scan, finalize the element, concept generation, then continued with scanning process using Laser 3D scanner Next Engine. After obtaining the scan output of the product, further edit process using CATIA V5 software. The material selection is considered and the method to generate the CNC process is shown. Steps to fabricate and assembly the product had also included in this chapter. The overall process flow of the research is shown on Figure 3.1.

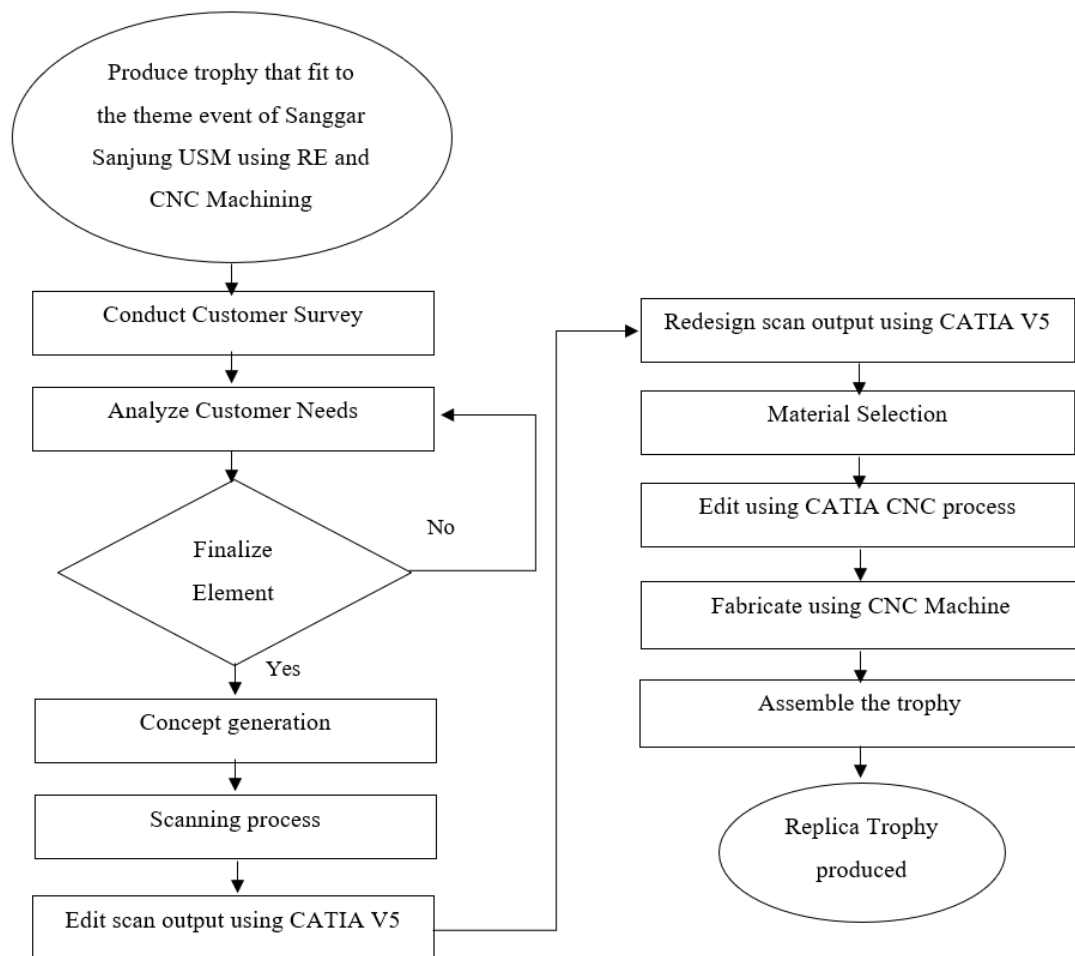


Figure 3.1: Overall Process Flow Chart

### 3.2 Identify the existing type of trophy

The first steps to design a new trophy, it is essential to identify the existing type of trophy in the current market. Therefore, benchmarking had done to study the existing trophy in the market as shown in Table 3.1. For example, the FIFA World cup is one of the famous replica football tournament trophies which is manufactured in 1973 with design of two human figure lifting the earth.

Table 3.1: Existing Trophy Benchmarking in the market

Existing Trophy	Description of Existing Trophy
FIFA World Cup™  Image of FIFA World Cup	Date of manufacture :1973 Weight (g) :6175g Height (cm) :36.8cm Maximum width (cm) :15cm Material: 18-carat gold and two rings of malachite stones Design Description: Two athletes lifting the earth which symbolize victory [26].
Nobel Prize Medal  Image of Nobel Prize Medal	Date of manufacture :2012 Weight (g) :Average 175g Thickness (cm) :0.24cm Diameter(cm) :6.6cm Material: 18-carat green gold which plated with 24-carat gold Design Description: The image of Alfred Nobel in left profile on the obverse is displayed on the medal with the years of his birth and death [27].
Oscar Award  Image of Oscar Statuette	Date of manufacture :1983 Weight (g) :3855.5g (8.5 pounds) Height (cm) :34.3cm (13.5 inch) Material: 24-carat gold-plated solid bronze Design Description: A human figure that depicts a knight holding a crusader's sword standing on a reel of film with five spokes symbolize the five original branches of the Academy [28].

### **3.2.1 Preparation of customer survey form**

Next, it is required to study the feedbacks from the targeted market. Sanggar Sanjung USM is the appreciation of the annual event for the contribution of staff. Hence, the target market in this research is the staff of Universiti Sains Malaysia which include the office staffs and the lecturers. The email of the targeted market is collected, and the content of the customer survey form is prepared as shown in Appendix A.

The content of the survey form had classified into three parts which are personal data, concept of trophy and feature of trophy. Personal data is used to identify the category of the respondent which is categorized of profesional and management or category of execution. In the concept of trophy, the way of display the trophy, place to locate the trophy and 4 types of elements which are element A (Type of award of the event), element B (USM logo element), element C (HEBAT USM), element D (APEX Logo). The feature of the logo such as preferred size, type of impression and level of importance to consider according to the features of the trophy.

The survey form is created using Google form and sent to the targeted market on 1<sup>st</sup> of December 2018 which is open for response for five days using student email. The survey data are collected and shown in Chapter 4.

### **3.3 Finalized Element**

After the survey analysis the object that chooses to include in the design of the trophy is finalized. Hibiscus is chosen for the object to scan. Hibiscus resembles the Malaysia's national flower. The choose of hibiscus had included the element A of creative and innovation and element B which had USM logo element. The element of creative and innovation in hibiscus is included the transformation a thin structure and irregular shape into a manufacturability part which involved with the method knowledge of reverse engineering while element B is available in the element of logo USM (Figure 3.2). This is able to meet with the theme of the event of Sanggar Sanjung which is resemble the whole USM.

Hand structure is included from the survey analysis (Figure 3.3). It can be represented as holistic from element C due to hand structure can able to connect other element by holding another part to show a better interpretation of the holding part. This is also linked as thinking in a big picture. For example, holding the part of hibiscus can bring up a concept as bringing up the nations. In this case, the real hand structure is used to increase the realism of the trophy while the element of the shield will represent protection.



Figure 3.2: The Crest from logo of USM [29]



Figure 3.3: Real hand structure

### **3.4 Concept Generation**

Concept generation contains the detail description that how the trophy can meet the customer needs. This trophy concept is a brief description of technology, form of the structure, and way of it working principle. Concept generation begins with identifying the customer needs and obtain target specification, then list out the set of the product concept from the list of needs and proceeds to the final selection. There is a five-step concept generation method that can break a complex problem into simpler sub problems, then the team can reflect on the validity and applicability of the results.

#### **3.4.1 Step 1: Clarify the Problem**

Clarify the problem help to develop the understanding and classify the problem into different sub part then focus on the design of the trophy according to the parts such as main body, base of the trophy and height of trophy.

Sub parts to concern of trophy are as listed below:

1. The trophy is smaller in size
2. The material of trophy is not fragile.
3. The trophy as an attractive design
4. The trophy has multi-function.
5. Reduce/ eliminate the height of based of the trophy.

### 3.4.2 Step 2: Search Externally

External search is to search for existing solution that suitable to the subpart of the clarify of problem list.

#### 1. Search Google patents

There are existing patents such as the sample search for Baseball Trophy Candle (Figure 3.4) that can be folded in for ease of storage the trophy and the open design of candle display [30]. The trophy mount (Figure 3.5) is also able to hang on the wall with the combination of shield and reindeer design [31].

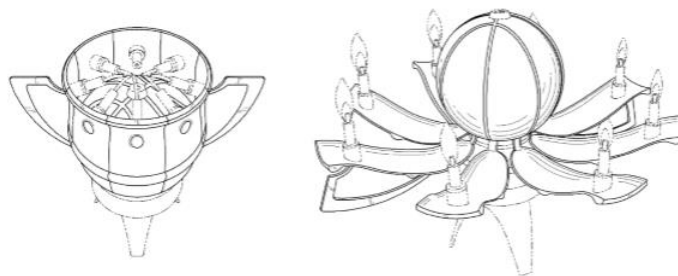


Figure 3.4: Patent Search Of Baseball Trophy Candle [30]

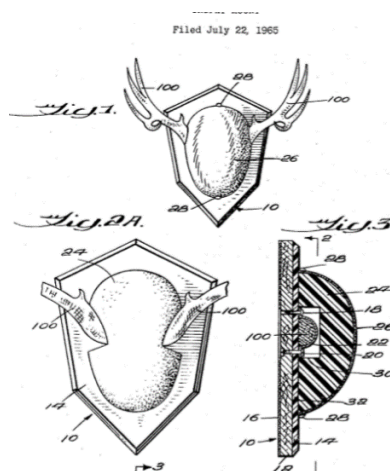


Figure 3.5: Patent Search of Trophy Mount [31]

## **2. Search published literature**

Example of published literature includes journals, trade magazines, market, product information. The most efficient way is searching using electronic sources. It is a very wide source for us to get solutions we need. From the article finding we can see that the price-giving had grown up to RM 84 billion in the global industry and trophy is the most common way to represent the celebration of success [32]. It has become a new industry for the number of cultural trophies grow.

## **3. Benchmark related existing products.**

Benchmarking is the study of existing products with its function like the subpart problems that are focused on. It reveals the existing concepts that have been implemented as well as information on the strengths and weaknesses of the competition. Benchmarking had shown in Table 3.1 .

### **3.4.3 Step 3: Search Internally**

Internal search is the use of personal knowledge and creativity to generate solution concepts. Brainstorming is the essential part generate solutions to adapt customers' needs from the survey results.

Suspend evaluation for days or weeks to generate a large set of alternatives. Concept generation sessions, suggestions are mainly commenting for improvements or alternative concepts instead of critics. It has helped to generate a lot of ideas to think of all the solutions available. Allow suggestion of ideas that may seem infeasible as it can be improved, "debugged" or "repaired". Sketching is used to deliver more effectively and understandable to people.

### 3.4.4 Step 4: Explore Systematically

There are a lot of concepts and solutions for sub problems generated after the external and internal searches. They are arranged and shown in Table 3.2 There are 4 types of sub-function which is main body, elements, way of display and function. The main body has three types of concepts which include constant design with elements, changeable design and design that fit to a function, while the elements divided into two parts, detachable element and non-detachable. There are many ways to display the trophy which can be hung on a wall or door, place on table or personal carry item. Four types of function are classified, light, clock , air humidified and calendar.

Table 3.2: Concept for sub function

Sub-function	Concepts
Main body	<ul style="list-style-type: none"> <li>➤ Constant Design with elements</li> <li>➤ Changeable Design</li> <li>➤ Fit to a function</li> </ul>
Elements	<ul style="list-style-type: none"> <li>➤ Detachable element</li> <li>➤ Non-detachable</li> </ul>
Way of display	<ul style="list-style-type: none"> <li>➤ Hanging on wall</li> <li>➤ Hang on Door</li> <li>➤ Place on Table or shelf</li> <li>➤ Personel Carry Item - Accessories</li> </ul>
Function	<ul style="list-style-type: none"> <li>➤ Light</li> <li>➤ Clock</li> <li>➤ Air Humidifier</li> <li>➤ Calendar</li> </ul>

### 3.4.5 Step 5: Reflect on The Solutions and The Process

Based on the different types of concept had listed out in Table 3.2, the advantage and disadvantage are analyzed and shown in Table 3.3. according to each of the alternative concept from each sub-function.




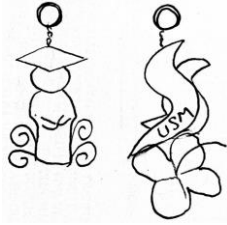


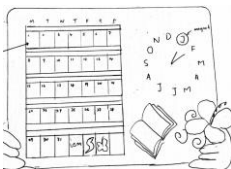
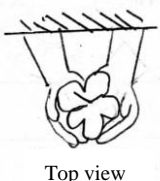




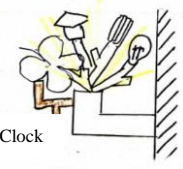


Table 3.3: Advantage and disadvantage for each sub-function

<b>Sub-function</b>	<b>Alternative</b>	<b>Advantages</b>	<b>Disadvantages</b>
<b>Main body</b>	Constant Design with elements	<ul style="list-style-type: none"> <li>As a signature structure of the event</li> <li>Less reproduction cost</li> </ul>	<ul style="list-style-type: none"> <li>Not unique</li> <li>Common design</li> </ul>
	Changeable Design of element	<ul style="list-style-type: none"> <li>Detachable of elements</li> <li>Able to fit to different theme of event</li> </ul>	<ul style="list-style-type: none"> <li>More cost, time needed for redesign</li> </ul>
	Fit to a function	<ul style="list-style-type: none"> <li>Easy understanding of function</li> </ul>	<ul style="list-style-type: none"> <li>Less related to the theme of event</li> </ul>
<b>Elements</b>	Detachable element	<ul style="list-style-type: none"> <li>Changeable element based on different type of award</li> <li>Creative</li> </ul>	<ul style="list-style-type: none"> <li>High cost</li> </ul>
	Non-detachable	<ul style="list-style-type: none"> <li>Low cost</li> </ul>	<ul style="list-style-type: none"> <li>Fix to main body</li> <li>Common design</li> </ul>
<b>Way of display</b>	Hanging on wall	<ul style="list-style-type: none"> <li>Unique design</li> </ul>	<ul style="list-style-type: none"> <li>Fit to limited area</li> </ul>
	Hang on Door	<ul style="list-style-type: none"> <li>Noticeable</li> </ul>	<ul style="list-style-type: none"> <li>Common design</li> </ul>
	Place on Table or shelf	<ul style="list-style-type: none"> <li>Easy to manufacture</li> </ul>	<ul style="list-style-type: none"> <li>Common design</li> </ul>
	Personel Carry Item - Accessories	<ul style="list-style-type: none"> <li>Unique</li> </ul>	<ul style="list-style-type: none"> <li>High machining cost</li> <li>Less noticeable</li> </ul>
<b>Function</b>	Light	<ul style="list-style-type: none"> <li>Wide in use</li> </ul>	<ul style="list-style-type: none"> <li>Common function</li> </ul>
	Clock	<ul style="list-style-type: none"> <li>Wide in use</li> </ul>	<ul style="list-style-type: none"> <li>Common function</li> </ul>
	Air Humidifier	<ul style="list-style-type: none"> <li>Unique function</li> </ul>	<ul style="list-style-type: none"> <li>Less in use</li> </ul>
	Calendar	<ul style="list-style-type: none"> <li>Wide in use</li> </ul>	<ul style="list-style-type: none"> <li>Common function</li> </ul>

### 3.4.6 Morphology Chart

The morphology chart of each alternative concept had shown in Table 3.4.

Table 3.4: Morphology Chart

Sub-function	Alternative			
<b>Main body</b>	Constant Design with elements 	Changeable Design 		Fit to a function 
<b>Elements</b>	Detachable element 		Non-detachable (Engrave) 	
<b>Way of display</b>	Hanging on wall 	Hang on Door 	Place on Table or shelf 	Personel Carry Item Accessories 
<b>Function</b>	Light 	Clock 	Sound Amplifier 	Calendar 

### 3.5 Concept Selection

The set of concepts will narrow down the alternatives after considering the customer needs and a final product is selected based on concept selection sketches and concept screening (Appendix B)

### 3.5.1 Concept Screening

Based on the list of concepts, concept screening is conducted to consider the rating of concept with the selection criteria of the trophy as shown in Appendix C. the selection criteria of the concept screening are the design of the trophy, base of trophy, functionality of trophy, material of trophy, size of trophy, maintainability of the trophy, location of trophy and sustainability of trophy. Each of the advantage of the concept will represented by “+” while in disadvantage state will show in “-”. No differences will show in “0”. It then sums up the total of “+” and “-” and finalize the net score.

$$\text{Net score} = (\text{Sum of } +) - (\text{Sum of } -)$$

Concept 1 has the highest score followed by concept 4 while concept 5 will not continue to the next section of concept scoring.

### 3.5.2 Concept Scoring

To further investigate the rating of each concept, concept scoring can help to determine the weight of each of the selection criteria that will contribute to the selection of concept. In this selection method, each of the criteria had weighted in different score, which is 20% for design of trophy, 5% of base of trophy, 15% for the functionality of trophy, 15% for material of trophy, 10% of the size of trophy, 10% of maintainability of trophy, 10% of location of trophy and 15% for sustainability of trophy. with the rating of each concept will multiply with the weight of the criteria and the sum of the score will be calculated. The result analysis had shown in Appendix D. Concept 1 contains the highest score among four concepts. Therefore, concept idea of concept 1 is chosen to the trophy design. The part that use to include into the design is searched.

$$\begin{aligned} \text{Total score} &= (\text{Weight of Criteria } 1 \times \text{Rating of Criteria } 1) + \dots \\ &+ (\text{Weight of Criteria } n \times \text{Rating of Criteria } n) \end{aligned}$$

### 3.6 Scanning Procedure

In this process, Next Engine 3D scanner had chosen to scan the objects. The apparatus used to start the scanning process is a 3D scanner connected with a part gripper, a desktop that connected with the Next Engine 3D scanner software (Figure 3.6). First to set up the scanning process, the object needs to fix on the part gripper and as it has adjustable part holding fixture. The Hibiscus is placed on the fixture with the additional tape to fix the position of the flower. The parameter of the hibiscus is set

which the target is set to neutral, with a wide range and 16 divisions of scanning with positioning of 360°. It required 54 minutes to complete the scanning (Figure 3.7). All the object setup and output is shown in Chapter 4 Table 4.3.

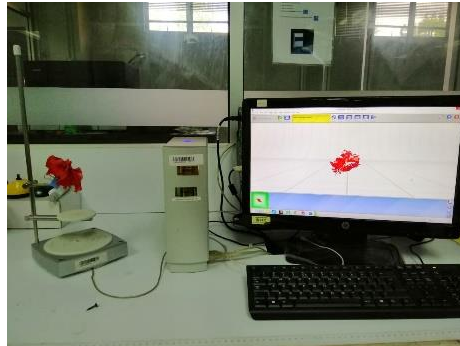


Figure 3.6: Set up of Scanning process

The setting of target is important to define the colour of the object before scanning. In the ambient light of condition object of red component can show a better result [18]. The parameter of the range is needed to set the distance of the scanner and the object. For Wide setting, the ideal distances between the object and 3D scanner is 13 inches. Positioning setting of the scanner is set as 360° to allow the part gripper to rotate in according to the number of divisions that set in the scanning process. The higher the number of divisions, the more accurate data can be obtained. This is also requiring a longer time to complete the scanning process.



Figure 3.7: Parameter of Hibiscus set in Next Engine 3D scanner

In the setting of the scanning of real hand structure, it requires a wider space as the part gripper will rotate in 360°. In the consideration of scanning period, it is