UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering Technology

AN EXPERIMENTAL INVESTIGATION ON THE DIMENSIONAL ACCURACY OF MELAKA HISTORICAL ARTIFACT FABRICATED USING ADDITIVE MANUFACTURING SYSTEM

Kerk Zi Ling

Bachelor of Manufacturing Engineering Technology (Product Design) With Honours

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A thesis submitted
in fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering Technology (Product Design) With Honours

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DECLARATION

I declare that this thesis entitled "An Experimental Investigation on the Dimensional Accuracy of Melaka Historical Artifact fabricated using Additive Manufacturing System" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering Technology of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering Technology (Product Design) with Honours. The member of the supervisory is as follow:

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ABSTRACT

The propose of this study is to bring the historical artifacts collections back, producing 3D replicas in order to sustain its cultural value. Reverse engineering and additive manufacturing systems are the technologies applied to execute this project. Apart from that, this research work is carried out based on a case study of an aritifact namely the Dutch Gun that was obtained from Stadthuys Museum. The main issues highlighted in this project is the dimensional accuracy study of 3D printed component. Today, there is a plethora of valuable and precious historical artifacts inherited from ancestors are facing extinction due to uncontrolled environment such as humidity. Other factors include biodeterioration, and destruction by modernization resulting in losing their original appearance. Current basic techniques are also unable to replace the historical artifact due to high cost, material and expert skilled-labor are needed. Based on this research study, plenty of preservation works of historical artifact all over the world proved that a concrete interaction between cultural heritage and modern technology enable to bring these collections back, producing a 3D replica with a close similarity compared to its real product. Hence, in this research project, reproduction of the Dutch Gun using non contact reverse engineering (RE) systems and powder-based additive manufacturing (AM) of selective laser sintering (SLS) techniques. The non-contact RE systems used are the Rexcan and Tscan. Meanwhile, the AM machines are the Projet 460 Plus, and Farsoon Technology SS402P. The collected data were analyzed using statistical analysis. From the observation, it is found that the combination of Tscan and SLS produced a fine detail of the selected features. However, for the dimensional accuracy, the combination of the Rexcan and SLS yielded a better results as compared to the combination of the Tscan and SLS. This meets the expectation as the Rexcan is better in accuracy over the Tscan as per the specifications. As the conclusion higher accuracy of RE system produces a better dimensional accuracy of printed prototype. However, for the special features investigation, the hand held TScan produces a better physical prototype of the Dutch Gun. Thus, 3D scanned data, RE system specifications, and angle of scanning are the significant factors that influence the quality of the printed prototype in terms of asthetics, and dimensional accuracy. Moreover, both RE systems are suitable for 3D data aqusition process since an artifact is not considered as a precision part.

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ABSTRAK

Cadangan projek ini adalah untuk membawa koleksi artifak sejarah kembali, menghasilkan replika 3D melalui untuk mengekalkan nilai kebudayaannya dengan mengunakan reverse engineering dan additive manufacturing. Selain itu, kajian ini akan dijalankan berdasarkan kajian kes mengenai Dutch gun dari Stadthuys Museum Melaka. Isu utama yang diserlahkan dalam projek ini iaitu kajian ketepatan dimensi komponen yang dicetak oleh 3D printer. Sekarang ini, terdapat banyak artifak sejarah berharga yang diwarisi dari nenek moyang telah menghadapi masalah kepupusan sebab bencana alam. Factor yang lain seperti biodeteriorasi, dan dirosakkan oleh manusia akan mengakibatkan kehilangan penampilan asalnya. Melalui projek penyelidikan ini, banyak kerja pemeliharaan artefak sejarah di seluruh dunia telah membuktikan bahawa interaksi konkrit antara warisan budaya dan teknologi moden dapat memulihkan dan menghasilkan replika 3D dengan persamaan bentuk yang dekat berbanding produknya yang sebenar. Oleh itu, dalam projek penyelidikan ini, penghasilan semula Dutch gun menggunakan sistem kejuruteraan reverse reverse (RE) dan pengilangan bahan tambahan berasaskan serbuk (AM) teknik sintering laser (SLS) selektif. Non-contact 3D scanner yang digunakan adalah Rexcan dan Tscan. Sementara itu, mesin AM adalah Projet 460 Plus, dan Farsoon Technology SS402P. Data yang dikumpulkan dianalisis menggunakan analisis statistik. Dari pemerhatian, didapati bahawa kombinasi Tscan dan SLS menghasilkan detail terperinci mengenai ciri-ciri yang dipilih. Walau bagaimanapun, untuk ketepatan dimensi, kombinasi Rexcan dan SLS memberikan hasil yang lebih baik berbanding gabungan Tscan dan SLS. Ini memenuhi jangkaan kerana Rexcan lebih baik ketepatan berbanding Tscan mengikut spesifikasi. Oleh kerana kesimpulan yang lebih tinggi ketepatan sistem RE menghasilkan ketepatan dimensi yang lebih baik dari prototaip yang dicetak. Walau bagaimanapun, untuk penyiasatan ciri khas, tangan yang dipegang TScan menghasilkan prototaip fizikal yang lebih baik dari Gun Belanda. Oleh itu, data yang diimbas 3D, spesifikasi sistem RE, dan sudut pengimbasan adalah faktor penting yang mempengaruhi kualiti prototaip bercetak dari segi asthetik, dan ketepatan dimensi. Selain itu, kedua-dua sistem RE sesuai untuk proses aqusition data 3D kerana artifak tidak dianggap sebagai bahagian ketepatan.

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DEDICATION

To my beloved parents, Kerk Lian Huat and Lim Sai Hong,

To my siblings, Kerk Zi Qi, Kerk Zi En, Kerk Zhi Yuan,

To my supervisor, Ts.Dr. Syahibudil Ikhwan Abdul Kudus,

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LIST OF ABBREVIATION

BDP	Bachelor Degree Project
AM	Additive Manufacturing
CAD	Computer Aided Design
RE	Reverse Engineering
RP	Rapid Prototyping
DG	Dutch Gun
SLS	Selective Laser Sintering
2D	Two Dimensional
3D	Three Dimensional
NC	Numerical Control
APT	Automatic Programmable Tools
SLA	Stereolithography
FDM	Fusion Deposition Modelling (FDM)

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CHAPTER 1

INTRODUCTION

1.1 Research Background

The purpose of this research project is to study the dimensional accuracy of a physical artifact of Dutch Gun (DG) and to identify the built quality of the prototype version of the artifact printed via additive manufacturing (AM) machine: selective laser sintering (SLS). As the higher accuracy offered by processes, the possible that create parts with finer feature (Access, 2018). Another aim of this study is to bring the historical artifacts collections back, producing three dimensional (3D) replicas through 3D scanning and printing in order to sustain the cultural value. This project is carried out based on a case study on a Melaka's historical ornamental components.

Historical artifacts acting as evidences and past records that were created by human in ancient times. However, with time elapsing, countless of historical artifacts are being damaged every single day due to significant causes that lead to their destruction such as natural disaster, biodeterioration and man-made sabotage. Together with modernity, the strategies that evolving protection, conservation of historical object are discerned as a crucial part of the duties of current society. The purpose of this action has been known as culture tradition of mankind since 18^{th} century. Ancient monuments, past masterpieces and even whole territories for different kind of new values created in recent decades have included stage by stage.

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Hence, since the aggrandizing demand of high precision digital reproduction, both reverse engineering (RE) and additive manufacturing (AM) is a perfect combination technology that plays an essential role in replicating historical artifacts. Reverse engineering can be characterized as a methodology that can be used to construct the computer-aided-design (CAD) models of existing part by digitizing a product. By acquiring the CAD model of the existing object, a new prototype of this object can be refabricated (Chen & Ng, 2003). Today, 3D scanning is a well-known technique for the data acquisition of historical artifacts in the field of archaeology (Levoy et al., 2000). Surface reconstruction can be applied to transfer point clouds into a digital form. After scanned data manipulation, it proceeds to fabricate the model by using Selective Laser Sintering machine 3D printing technique enable to improve the quality of artifacts replicate and prevent from damaging in the procedures of printing. In final result, the dimensional accuracy analysis between real product and fabricated prototype will be studied in the researches works.

1.2 Problem statement

Because of nature risks like humidity, the destruction by modernization, and armed conflicts, deterioration, and other reasons, gradually numerous precious artifacts or works of art have been damaged, broken into fragments and even abandoned (Kokilehto, 1999). Moreover, it is difficult to replace the historical artifacts because high cost, material, and expert skills are needed. However, it is crucial to conserve and preserve historical artifacts for new generation in order to contact with their roots and esteem their masterpiece. Such conservation can let everyone from various cultures to know and appreciate the beliefs that have formed an amazing civilization. As the technology developed rapidly in recent years, there are innumerable of devices are invented for restoring the historical artifacts. In this case, it cannot

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be defined that the combination of reverse engineering and additive manufacturing is the perfect match for conservation of historical artifacts. Moreover, Moitinho and Barcelo define RE as the solution of extracting missing information i.e. CAD data from man-made physical object. Apart from that, additive manufacturing can be applied to restore and replicate historical artifacts (Dellepiane et al., 2011). Therefore, there is an opportunity to do research project by cooperating with The Stadthuys Museum of Melaka, focusing on getting CAD data from DG, bringing these collections back and producing 3D replicas to retain its cultural value before it loses its original condition.

1.3 Objective of the project

There are two objectives that have to be achieved in this Bachelor Degree Project:

1. To generate the geometric data of 3D printed prototypes of the DG using 3D scanner and 3D printing system.
2. To analyze the appearance and dimensional accuracy of the original product and 3D printed prototypes

1.4 Scope of the project

The work scopes of this project are:

1. To do a literature search and review
2. To identify the potential scanned object to be studied
3. To familiarize reverse engineering, computer aided design and selective laser sintering
4. To scan a physical object and manipulate the data
5. To verify of the STL data and fabricate a prototype using selective laser sintering

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6. To carry out a comparison of dimensional accuracy analysis between the historical artifact and printed prototypes

1.5 Report Structure

For the report structure of this researches works, the main content of the project should comprises five chapters with the corresponding titles in the report. The usual way of presenting these chapters is given below:

- **Chapter 1:** Introduction. This chapter includes brief background information about the project, problem statement, objective and scope of the project.
- **Chapter 2:** Literature review. In this chapter, the current implementations that solve the previous problems and limitations of the project and focus on the foreknowledge work that carried out by others researchers based on the previous and ongoing works.
- **Chapter 3:** Methodology. This chapter contains the detail information of the process flow of the experimental procedures.
- **Chapter 4:** Results and discussion. This chapter explains the results from the study on the appearance (special features and details), and dimensional accuracy of the prototypes produced from the AM process.
- **Chapter 5:** Conclusion and recommendation. The whole project is summarized in this chapter and recommendation is suggested to overcome the constraints of the project.

1.6 Summary

In this chapter, problem is identified in this research project as countless historical artifacts, monuments and priceless works of art that inherited from ancient times were ruthlessly

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destroyed and damaged. A variety of reasons that result in this issue such as armed conflicts, biodeterioration, natural disaster. Hence, the objective of this research work is to produce prototype of historical artifact, (DG) using 3D scanning and 3D printing technology. Furthermore, another objective is to study and measure dimensional accuracy of the 3D scanned and printed prototype of (DG). A comparison of the dimensional accuracy of the original product and fabricated prototype is needed to create after gathering all the data. In this Bachelor Degree Project (BDP), there are consist of five chapter which are introduction, literature review, methodology, result and discussion, conclusion and recommendation. Nonetheless, for the next chapter will present about the literature review that carried by others researches as the guidelines in order to further explore the historical artifact, use of reverse engineering (RE), computer aided design (CAD) and additive manufacturing (AM).

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter covers explanations of how information is gathered. The information is used as the guidelines in order to accomplish the research work. The main source of information was identified as follows: books, journals and interview. This information was withdrawn from literature search engines such as Google Scholar, ResearchGate and Mendeley. The literature was filtered based on the research topics or areas: dimensional accuracy, reverse engineering, additive manufacturing and any combination of the keywords.

2.1.1 Historical artifacts

The meaning of historical heritage can be explained as the objects of the ancient times. UNESCO, 1989 explained the full fundamental of such heritage:

"The cultural heritage may be defined as the entire corpus of material signs – either artistic or symbolic – handed on by the past to each culture and, therefore, to the whole of humankind. As a constituent part of the affirmation and enrichment of cultural identities, as a legacy belonging to all humankind, the cultural heritage gives each particular place its recognizable features and is the storehouse of human experience."

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