A SMART VISION INSPECTION SYSTEM ON STEP-NC MACHINE WITH IOT ENVIRONMENT

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DEDICATION

I would like to dedicate this thesis to

Al-Mighty "ALLAH S.W.T"

Subhanallah, WaAlhamdulillah, for everything since I was born to this beautiful world. Alhamdulillah, through this PhD journey, I learnt a lot about this world and the akhirah world. Alhamdulillah, for his guidance and his mercy to show me the right path all the time.

My beloved

"Wife, Sons, Parents and Family"

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ABSTRACT

Manufacturing metrology is an imperative part of the sophisticated Industrial 4.0-based manufacturing industry. The Vision Inspection System (VIS) of the modern inspection industry is intelligent, broadly associated and flexible. They are completely adaptable, independent and attainable based on the Internet of Things (IoT) environment. The challenges in this issue stemmed from a lack of adequate and appropriate inspection systems. Accordingly, the lighting framework concentrates on these matters top to bottom to further develop lighting capability. The camera and lighting system were utilized to guarantee product quality. Indeed, even light, distance, coordination with camera and lens, angle of illumination and running, and upkeep costs are a portion of the 3SMVI system critical reasonable issues. It's memorable crucial that the camera doesn't involve the ambient light detected by a light meter in a scene. Nonetheless, the camera sees how much-mirrored light from objects in a scene, is impacted by reflectivity levels. This study proposed an approach to develop an automated smart system based on STEP-NC for Machine Vision Inspection with Internet of Things architecture. Case studies were measured with a 3SMVI system and a Coordinate Measuring Machine (CMM). Based on the results of the case studies, the findings were divided into three sections: First, the developed vision system successfully detected surface feature shape, measured the surfaces after machining the Part in the CNC machine, and the data flow appeared in cloud server-based MQTT protocol, and through an integrated with Open CV platform vision inspection system-based on IoT architecture with STEP-NC based Open CNC. Second, the reading of the roundness data between the 3SMVI system measuring and CMM inspections is more accurate for the CMM which takes more time than the new 3SMVI system which takes less time. Third, the data examination utilized the mean and standard error between the 3SMVI system and the CMM based on hole diameters, which measured roundness according to the data, for the validation of the measurement systems. Thus, the CMM model's standard errors were determined to be lower than the 3SMVI model's common errors.

ABSTRAK

Metrologi pembuatan adalah merupakan aspek penting dalam industri pembuatan berasaskan Industri 4.0 yang canggih. Sistem Pemeriksaan Penglihatan (VIS) bagi sektor perindustrian pemeriksaan adalah pintar, bersambung secara meluas dan boleh disesuaikan. Ia boleh disesuaikan sepenuhnya, autonomi dan boleh diakses sepenuhnya berdasarkan persekitaran Internet Perkara (IoT). Cabaran dalam isu ini berpunca daripada kekurangan sistem pemeriksaan yang berkesan dan sesuai. Oleh itu, sistem pencahayaan yang memfokuskan pada setiap kebimbangan ini secara mendalam adalah bertujuan untuk meningkatkan keupayaan pencahayaan. Sistem kamera dan pencahayaan digunakan untuk memastikan kualiti produk. Malah pencahayaan, jarak, penyepaduan dengan kamera dan kanta, sudut pencahayaan dan pengendalian serta kos penyelenggaraan adalah beberapa isu praktikal penting sistem 3SMVI. Adalah penting untuk diingat bahawa kamera tidak menggunakan cahaya ambien yang dirasai oleh meter cahaya dalam adegan. Walau bagaimanapun, kamera sebenarnya melihat jumlah cahaya yang dipantulkan daripada objek dalam pemandangan, yang dipengaruhi oleh tahap pemantulan. Dalam kajian ini, satu metodologi untuk membangunkan sistem pintar automatik berdasarkan STEP-NC berasaskan standard ISO14649 untuk Pemeriksaan Penglihatan Mesin berdasarkan seni bina Internet of things telah dicadangkan. Kajian kes diukur menggunakan sistem 3SMVI dan Mesin Pengukur Koordinat (CMM). Berdasarkan kajian kes yang dijalankan, penemuan dapat diringkaskan kepada tiga bahagian: Pertama, sistem penglihatan yang dibangunkan berjaya mengesan bentuk ciri permukaan, mengukur permukaan selepas pemesinan dalam mesin CNC, dan aliran data muncul dalam MQTT berasaskan protocol pelayan awan, dan melalui sistem pemeriksaan penglihatan platform terbuka CV bersepadu berasaskan seni bina IoT dengan CNC terbuka berasaskan STEP-NC. 3SMVI dan CMM berdasarkan diameter lubang diukur untuk pengesahan sistem pengukuran.

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LIST OF SYMBOLS AND ABBREVIATIONS

3SMVI	-	Smart System based interpreted STEP-NC information for Machine Vision Inspection
2D		Two -dimension
3D		Three-dimension
ANSI		American National Standards Institute
ACAPP		Automated Computer-Aided Process Planning
AAM		Application Activity Model
AIM		Application Interpreted Model
ARM		Application Reference Model
AVCMM		Advanced Virtual Coordinate-Measuring Machines
AP		Application Protocol
AOI		Automatic Optical Inspection
AMQP		Advance Message Queuing Protocol
CLIM		Closed Loop Manufacturing Inspection
CAIP		Computer Aided Inspection Planning
CATIA		Computer Aided Three-Dimensional Interactive Application
CAPP		Computer Aided Process Planning
CAI		Computer Aided Inspection
CAD		Computer Aided Design
CAM		Computer Aided Manufacturing
CMM		Coordinate Measuring Machine
CV		Computer Vision
CNC		Computer Numerical Control
CPMT		Cyber Physic Machine Tool
CoAP		Constrained Application Protocol
CP2MS		Cyber-Physical Manufacturing Metrology system
CC		Cyber Component

CPS	Cyber-Physical System
CCD	Charge-Coupled Device
CMOS	Complementary Metal-Oxide Semiconductor
CDT	Cyber Digital Twins
D&M	Device and Measurement
DML	Dimension Markup Language
FPPI	Feature Process Planning Inspection
Fps	Frame per second
GD&T	Geometric Dimensional and Tolerance
HSS	High-speed steel
IPS	Inspection Planning System
IR 4.0	The Fourth Industrial Revolution
I 4.0	The Industrial 4.0
IoT	Internet of Things
ISO	International Standard Organization
IoS	Internet of Services
KBE	Knowledge-Based Evaluation
KBI	Knowledge Based Inspection
LED	Light-Emitting Diodes
MT	Machine Tool
MTConnect	Manufacturing Technology Connect
MML	Moka Modified Language
MMC	Material and Manufacturing Center
MVIS	Machine Vision Inspection System
MQTT	Message Queuing Telemetry Transport
MIC	Maximum Inscription Radial Circle
MCC	Minimum Circumcision Radius Circle
MZC	Minimum Zone for radial Circles
OMI	Online Measuring Inspection
OMM	Online Measuring Machine
Open CV	Open Camera Vision
OAC	Open Architecture Control
OWL	Ontology Web Language
OOR	Out-Of-The-Round

OLP	Off-Line Programming
OPC-UA	Open Platform Communications United Architecture
PC	Physical Component
QC	Quality Control
RQs	Research Questions
RGB	Three Channel of Color Red, Green and Blue
RAW	Research and Analysis Wing
STEP	Standard for the Exchange of Product Model Data
STEP-NC	Standard for the Exchange of Product Model Data for Numerical Control
SLR	Systemic Review of Literature
SPAIM	STEP-NC Platform for Advanced and Intelligent Manufacturing
SSH	Secure Shell
SFP	Shop Floor Programming
SoV	Stream of Variation
TRL	Traditional Review of Literature
VR-based	Virtual based Reality
VNC	Visual Network Computing
XML	eXtensible Markup Language

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 An Overview

This chapter provides an overview of the existing manufacturing industry of globalized and measurements-based Industrial 4.0 (I4.0). Then, the problem statement discusses the drawbacks of the traditional Coordinate Measuring Machines (CMM) and the future view of the vision inspection system incorporated cloudily with internet of things (IoT) structure using Physical Component (PC) of Computer Numerical Control (CNC) milling machine based on STEP-NC environment. Furthermore, the study's objectives, scope, and significance are addressed. Finally, the thesis structure is described in detail at the end of this chapter.

1.2 Research Background

The manufacturing industry plays a vital role in the current fast-changing industrial environment based on globalization, product customization, and automation. Industry 4.0 (I 4.0) is at the top of the manufacturing industry since it integrates innovative technology and techniques which may change products, processes, and supply chains in every Part of the industrial sector rapidly and effectively. Manufacturing Metrology is a vital aspect of the sophisticated Industry 4.0-based manufacturing industry, seeing as practically everything machined with certain metrological systems has to be measured or inspected. For the time being, Industry 4.0 forces the inspections to engage its significant portion in the digital chain of product capture, consequently by obtaining and feedback information that fulfills the demands for the closed-loop manufacturing sector by [1,2]. Moreover, the information obtained from dimensions and geometric measures is used to develop effective state-of-the-art concepts, such as digitizing twins, real-time inspecting, automatic compensation, and traceability in different processes, including manufacturing additive and subtractive products. These technologies to manage together optimize a product or process aim of providing data that can be used by intelligent technologies to extract knowledge [3],[4],[5].

The industry requires continuously complex Parts manufacturing increasingly pressing needs. It has made rapid progress and changes in manufacturing processes that can promote advances in various fields such as aerospace, robotics, and automotive. However, issues are standing in the way of integration with current digital technologies. From the perspective of the Fourth Industrial Revolution (IR4.0), production processes require considerable adjustments in management data and processing the data obtained within the manufacturing process. Hence, the aim is to link the available digital technologies with the material resources associated with manufacturing processes [6]. Intelligent manufacturing is a new form of production that integrates industrial assets today and tomorrow with technical sensors and computing platforms, communications technology, control, simulation and modeling data-intensive engineering predictive [7]. In globalization, the aviation industry companies tend to improve threefold: cost, time and quality.

Advanced technology in Computer Numerical Control (CNC) has revolutionized manufacturing [8]. Quality control is essential to maintain competitiveness; however, such quality control processes are generally carried out offline [9]. Quality inspection is an important step throughout the production process for free-form surface Parts. In order to be able to monitor the quality dimensions, the registry to fit the software design model of the measurement is usually used [10]. In contrast, the information exchange of CAD-CAM-CAI is integrated within a digital platform, [11],[12]. The integration model defines the path for the computational implementation of the closed-loop inspection system based on the inspection analysis carried out by a coordinate measuring machine [13].

In this study, state-of-the-art links the integration of the closed-loop inspection of both the system planning and the manufacturing system. It offers the challenges of geometric errors, and the difference between the true value of the measurement model and the value shown by the measuring instrument under different conditions is known as dynamic error in the CNC machine, and regarding CMM format based on ISO14649 standards. However, the tasks are to analyse the roundness holes surface of the

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APPENDIX G

List of Publication

i. Adam, Anbia, Yusri Yusof, Maznah Iliyas, Yazid Saif, and Noor Hatem. "Review on manufacturing for advancement of industrial revolution 4.0." International Journal of Integrated Engineering 10, no. 5 (2018).

ii. Saif, Yazid, Yusri Yusof, Kamran Latif, Aini Zuhra Abdul Kadir, and Maznah Lliyas Ahmed. "Systematic review of STEP-NC-based inspection." *The International Journal of Advanced Manufacturing Technology* 108, no. 11 (2020): 3619-3644.

iii. Saif, Y., and Y. Yusof. "Integration models for closed-loop inspection based on step-nc standard." In *Journal of Physics: Conference Series,* vol. 1150, no. 1, p. 012014. IOP Publishing, 2019.

iv. M. Iliyas Ahmad, Y. Yusof, M. E. Daud, K. Latiff, A. Z. Abdul Kadir, and Y. Saif, "Machine monitoring system: a decade in review," *Int. J. Adv. Manuf. Technol.*, vol. 108, no. 11–12, pp. 3645–3659, 2020.

v. Saif, Yazid Abdullsameea, Yusri Yusof, Maznah lliyas Ahmed, Zohaib khan Pathan, Kamran Latif, and Aini Zuhra Abdul Kadir. "A Framework to Develop Intelligent System for Capturing Product Features using Open CV Technique." *Journal of Technology and Operations Management* 15, no. 2 (2020): 42-51.

vi. Ahmad, Maznah Iliyas, Yazid Saif, Yusri Yusof, Md Elias Daud, Kamran Latif, and Aini Zuhra Abdul Kadir. "A Case Study-Monitoring and Inspection Based on IoT for STEP-NC Data Model." (2021).

vii. Pathan, Zohaib Khan, Yusri Bin Yusof, Nor Haslinda Binti Abas, Anbia Adam, and Yazid Saif. "Factors Affecting Implementation of

ISO 9001: 2015 in Manufacturing Sector." *PSYCHOLOGY AND EDUCATION* 58, no. 2 (2021): 883-888.

viii. Saif, Y., Yusof, Y., Latif, K., Abdul Kadir, A. Z., Adam, A., & Hatem, N. (2021). Development of a smart system based on STEP-NC for machine vision inspection with IoT environmental. *The International Journal of Advanced Manufacturing Technology*, 1-18.

ix. Roundness Holes' Measurement for milled workpiece using machine vision inspection system based on IoT structure (2021) submitted the second revision

APPENDIX H

List of Awards

i. **Gold Award** for a smart system based on an interpreted file of STEP-NC for machine vision inspection with IoT environment in Asia International Innovation Exhibition, 2020.

ii. **Bronze Award** for a smart system based on an interpreted file of STEP-NC for machine vision inspection with IoT environment in Asia International Innovation Exhibition, AIINEX 2020.

VITE

The author was born on December 31, 1985, in Taiz, Yemen. he went to a school known on 13 June in ALMAFER, Taiz, for his secondary education. Next, he pursues his studies to graduate from ALNOAMAN secondary school in Aden. Then, he travels to continue his degree studies for bachelor level at Universiti industrial Selangor(UNISEL). After completing his degree in march 2012, he pursued to continue his master's degree at the university Tun Hussien Onn Malaysia in September 2014. During pursuing a master's degree, he began to be a Part-time guide tour from 2011 to 2014 and 2015 to 2017 at golden luster travel and tour. After that, he attended again to continue further study at Universiti Tun Hussein Onn Malaysia. He was admitted to a Ph.D. program in the Faculty of Mechanical and Manufacturing Engineering, funded by the Ministry of Higher Education of Yemen for two years, from March 2019 to March 2021. During this time, he published five articles and co-authored five research articles related to inspection, machining, machine monitoring, and Industry 4.0. He is also an active postgraduate student. He has permanently been joining many events and seminar