DESIGN AND DEVELOPMENT OF MULTIPURPOSE EDUCATIONAL AND RESEARCH PLATFORM (MERP) FOR LEARNING ADVANCE CONTROL AND IOT TECHNOLOGIES

BY

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A thesis submitted in fulfilment of the requirement for the degree of Master of Science (Mechatronics Engineering)

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SEPTEMBER 2018

ABSTRACT

Vision TN50 “Transformasi Nasional 2050” of Malaysia is encouraging institutions to produce more talent for digital transformation of industries and enterprises. One of them is a new domain for Internet of Things (IoT) technologies where the students are required to develop their skills and knowledge in the field of advance control like industrial automation & robotics. Engineering platforms are the key component of engineering labs for teaching the programing and hardware concepts. The existing engineering labs having industrial standard PLC platform, but these platforms are lacking in term of advance control and IoT integration features. Few institutions are offering IoT and its being taught on the prototype scale controllers and microcomputers, which does not fulfil the design of industrial grade applications. In this research, a multipurpose educational and research platform (MERP) for learning advance control and IoT technologies was designed and developed. The MERP is purposely developed for technical institutions to teach and train the undergraduates and postgraduate students. The platform is divided into two parts; 1) the main panel and 2) the application panels (Motor control and Project board). This low-cost developed platform is using industrial standard controller which is suitable for industrial and enterprise applications prototyping. Three modules were designed to teach / train the students on this platform; 1) introduction to Industry 4.0 & IoT, 2) controller programming, configuration and machine to machine (M2M) communication, and 3) design and development of web and mobile application. The integration of MERP is done in engineering degree program at university level purposely to validate the impact of MERP in engineering education using survey. Based on results analysis, students had learnt to use this platform very effectively by developing a real time IoT application. The developed MERP and its contents meet the IoT layers to provide insight of this technology. In conclusion, the developed modules outcome is in-line with course objectives and IoT pillars to enhance student skills in industrial control technique. It is necessary to expose the student with the latest update of control technologies using this latest control platforms to meet industrial demand for marketable student in the future.

خلاصة البحث

ان رؤية التحول الوطني TN50 "Transformasi Nasional 2050" في ماليزيا تشجع المؤسسات على إنتاج المزيد من المواهب من أجل التحول الرقمي للصناعات والشركات. أحدها هو مجال جديد وهو تقنية إنترنت الأشياء (IoT) بحيث يطلب من الطلاب تطوير مهاراتهم ومعارفهم في مجال التحكم المتقدم مثل الأتمتة الصناعية والروبوتات. ان المنصات الهندسية هي المكون الأساسي لمختبرات الهندسة لتدريس مفاهيم البرمجة والأجهزة. ان المختبرات الهندسية الحالية التي تحتوي على منصة صناعية قياسية PLC، ولكن هذه الأنظمة تنقصها ميزات تكامل التحكم المتقدم و إنترنت الأشياء. وهناك عدد قليل من المؤسسات التي تقدم إنترنت الأشياء وتعلّمها على وحدات التحكم في النماذج القياسية والحواسيب الصغيرة، التي لاتفي بالغرض لتصميم مستوى التطبيقات الصناعية. في هذا البحث ، تم تصميم وتطوير منصة تعليم وأبحاث متعددة الأغراض (MERP) لتعلم التحكم المتقدم وتقنيات إنترنت الأشياء. تم تطوير MERP عن قصد للمؤسسات الفنية لتعليم وتدريب الطلاب الجامعيين وطلاب الدراسات العليا. المنصة مقسمة إلى قسمين. 1) اللوحة الرئيسية و 2) لوحات التطبيق (التحكم في المحركات ولوحة المشروع). هذه المنصة المنخفضة التكلفة والمتطورة تستخدم وحدة تحكم صناعية قياسية مناسبة لتطبيقات النماذج الصناعية والمشروعات. تم تصميم ثلاث وحدات لتعليم و تدريب الطلاب على هذه المنصة ؛ 1) مقدمة في الصناعة 4.0 و IoT، 2) برمجة جهاز التحكم والترتيب والية الاتصال لجهاز بجهاز (M2M) ، و 3) تصميم وتطوير تطبيقات الشبكة العنكبوتية والتلفون المحمول. ان تكامل MERP تم في مرحلة دراسة الهندسة على المستوى الجامعي لغرض التحقق من صحة تأثير MERP في التعليم الهندسي باستخدام الدراسة الاستقصائية. استنادًا إلى تحليل النتائج ، تعلم الطلاب استخدام هذا النظام الأساسي بفعالية كبيرة من خلال تطوير تطبيقات إنترنت الأشياء في الوقت الفعلي. ان MERP المطورة ومحتوياتها تلبي طبقات إنترنت الأشياء للتركيز والتبصير بهذه التكنولوجيا. في الختام ، فإن نتائج الوحدات المتطورة تتماشى مع أهداف الدورة وأركان إنترنت الأشياء لتحسين مهارات الطلاب في تقنية التحكم الصناعي. من الضروري تعريف الطالب بأحدث تقنيات التحكم باستخدام منصات التحكم الأحدث لتلبية الطلب الصناعي على الطلاب الذين يتم انتاجهم او تخريجهم في المستقبل.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Mechatronics Engineering).

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Supervisor

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Abd Halim Bin Embong
Co-Supervisor

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Mechatronics Engineering).

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This thesis was submitted to the Kulliyyah of Engineering and is accepted as a fulfilment of the requirement for the degree of Master of Science (Mechatronics Engineering).

……..
Erry Yulian Triblas Adesta
Dean, Kulliyyah of Engineering

DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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Signature ..... Date .....

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To my honourable Father, Mother and Beloved Sheikh.

Also to my siblings, wife and son.

ACKNOWLEDGEMENTS

Firstly, it is my utmost pleasure to dedicate this work to my dear parents, my family and my beloved sheikh, who granted me the gift of their unwavering belief in my ability to accomplish this goal: thank you for your support and patience.

I wish to express my appreciation and thanks to those who provided their time, effort and support for this research work, specially Br. Muhammad Munir Azam and Br. Abdullah Askar. To the members of my thesis committee, thank you for sticking with me.

Finally, a special thanks to Professors Muhammad Mahbubur Rashid and Abd. Halim Bin Embong for their continuous support, encouragement and leadership, and for that, I will be forever grateful.

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LIST OF ABBREVIATIONS

AMS	Automated Manufacturing System
CPS	Cyber Physical System
DES	Discrete-Event System
ERP	Educational and Research Platform
FYP	Final Year Project
GPIO	General Purpose Input Output
HTTP	Hypertext Transfer Protocol
IDP	Integrated Design Project
IoT	Internet of Things
IIoT	Industrial Internet of Things
IoS	Internet of Service
IT	Information Technology
IO	Input Output
IIUM	International Islamic University Malaysia
LAD	Ladder Diagram
MCTE	Mechatronics Engineering
MERP	Multipurpose Educational and Research Platform
M2M	Machine to Machine
MQTT	Message Queue Telemetry Transport
MD	Mean Difference
PLC	Programmable Logic Controller
PAC	Programmable Automation Controller
QoS	Quality of Service
QRI	Questionnaires Regarding Improvement
RPi	Raspberry Pi
SAQ	Self-Assessment Questionnaires
TEQ	Teaching Evaluation Questionnaires

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

In the dramatically changing world of engineering giving rise to the Internet of Things (IoT), a global computing infrastructure of trillions of connected devices that permeate the world we live in (Kortuem, Bandara, Smith, Richards, & Petre, 2013). The term Internet of Things (IoT) was first coined by Kevin Ashton in 1999 in the context of supply chain management (Kevin Ashton, 2009). However, in the past decade, the definition is extending to a wide range of applications like utilities, healthcare, transport, etc. (Sundmaeker, Guillemin, Friess, & Woelfflé, 2010).

The elements of Internet of Things can be realized in three parts namely i) things oriented, ii) internet-oriented and iii) semantic-oriented (Atzori, Iera, & Morabito, 2010). The first layer can be defined as “Hardware”. Sensors, actuators and embedded communication hardware system are the part of this layer. Second layer defined as “Middleware”. It consists of ON-Demand storage and cloud computing tools for data analytics and third layer is defined as “Presentation”. The layer offers visualization and interpretation tools which can be widely accessed on different platforms for different application. (Gubbi, Buyya, Marusic, & Palaniswami, 2013). The architecture of IoT is shown in Figure 1.1.

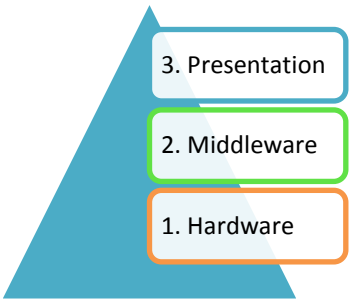

Figure 1.1 Architecture of Internet of Things (IoT)

Although the IoT vision has a tremendous potential towards advance technology, many complex technical, social, and economic questions remain unaddressed. With so many possibilities across the broad IoT realm, the role of hardware and software platforms that expedite the reduction of ideas to working prototypes is an intriguing consideration (Hodges et al., 2013). In the hardware platform, controller is the main part in IoT. As well as in automation and robotic. The study of controller programming is major subject that could help students from all skill levels to develop their logical thinking and propose functional prototypes to solve their everyday life problems. The applicability of these technologies makes them to become excellent in learning objects by allowing interaction from the learners.

The Programmable Logic Controller (PLCs) (Bolton, 2015) is one of the special microprocessor based industrial controller that still popular in the manufacturing industries. PLC programs are typically written through ladder diagram (LAD). Microcontrollers are popular in education and small projects specially Arduino development board (Graven & Bjork, 2017). Microcontroller can be programmed in High-Level Programming languages like; C, C++, and Java. Raspberry Pi is a Linux-based microcomputer (Mhatre, 2017) which is also used for prototyping in engineering education. Python as a High-Level Programming language used for Raspberry Pi.

The IoT controllers, also called IoT Gateways are designed to meet the vision of industrial transformation. IoT controllers / gateways are middle-tier components that primarily collect information from front-end devices and sync to the cloud computing system (Siemens AG, 2016b; Stephen, 2015).

Educational and Research platforms (ERP) are increasingly becoming a key component especially for engineering. The researchers are proposing curriculum and lab development for learning control and IoT technologies. This research focuses to design and develop the hardware platform and curriculum for learning latest control and IoT technologies for undergraduate and postgraduate engineering students.

1.2 PROBLEM STATEMENT

In new technology era, we can highlight the importance of learning technologies in engineering. The Educational and Research Platforms (ERP) in control subjects are designed to improve the programming, logical and hardware skills of engineering students. While many ERP and curriculum techniques was offered in field of control and IoT purposely to train and teach the engineering and polytechnic students. However, there are still lacking of industrial level exposure in their engineering labs and curriculums syllabus to excel the student with real industrial world.

The current PLC learning platforms and curriculum syllabus are lacking in IoT integration. Thus, students are unable to use PLC for their prototypes due to its high cost and high-level programming and installation skills requirement. The arduino and Raspberry Pi microcontroller prototypes helps students in a certain level to develop their IoT prototypes, but still cannot be upgraded into purely industrial level product. This is because, most of the industries more focused toward PLC controller. However, if students tend to use PLC in their learning, they have to deal with two difficulties, high

cost devices and special skills requirement. Besides that, there are also other issues which students and researchers facing nowadays regarding to the common problems in existing control platform and curriculum

1. The existing engineering labs having industrial standard PLC platform, but these platforms are lacking in term of advance control and IoT technologies.
2. Few institutions are offering IoT and its being taught on the prototype scale controllers and microcomputers, which does not fulfils the design of industrial grade applications.
3. The existing PLC based ERP's are expensive, so the institutions having same concept of cost for implementation of IoT platforms.

1.3 RESEARCH OBJECTIVES

To achieve the aim of this research, following objectives have been focused:

1- To design and develop a low cost Multipurpose Education and Research Platform (MERP) for learning control and IoT technologies by giving hands-on experience to students from physical layer to cloud computing layer.

2- To integrate the proposed MERP in an educational environment with suitable syllabus and considering low cost industrial standard IoT controller. Which fulfils the design, development and implementation of industrial grade application.

3- To validate the outcome of proposed MERP on engineering students and compare the developed MERP with other platforms.

1.4 METHODOLOGY

To achieve the stated objectives of this proposal the following steps will be taken:

1. Literature review on existing control and IoT platforms and curriculum.
2. Designing of Multipurpose Educational and Research Platform (MERP) model.
3. Designing of curriculum according MERP model.
4. Development of MERP and integration with curriculum.
5. Validation of proposed MERP model on engineering students to evaluate the performance of platform and curriculum.
6. Comparative analysis of proposed MERP with existing control platforms at educational level.

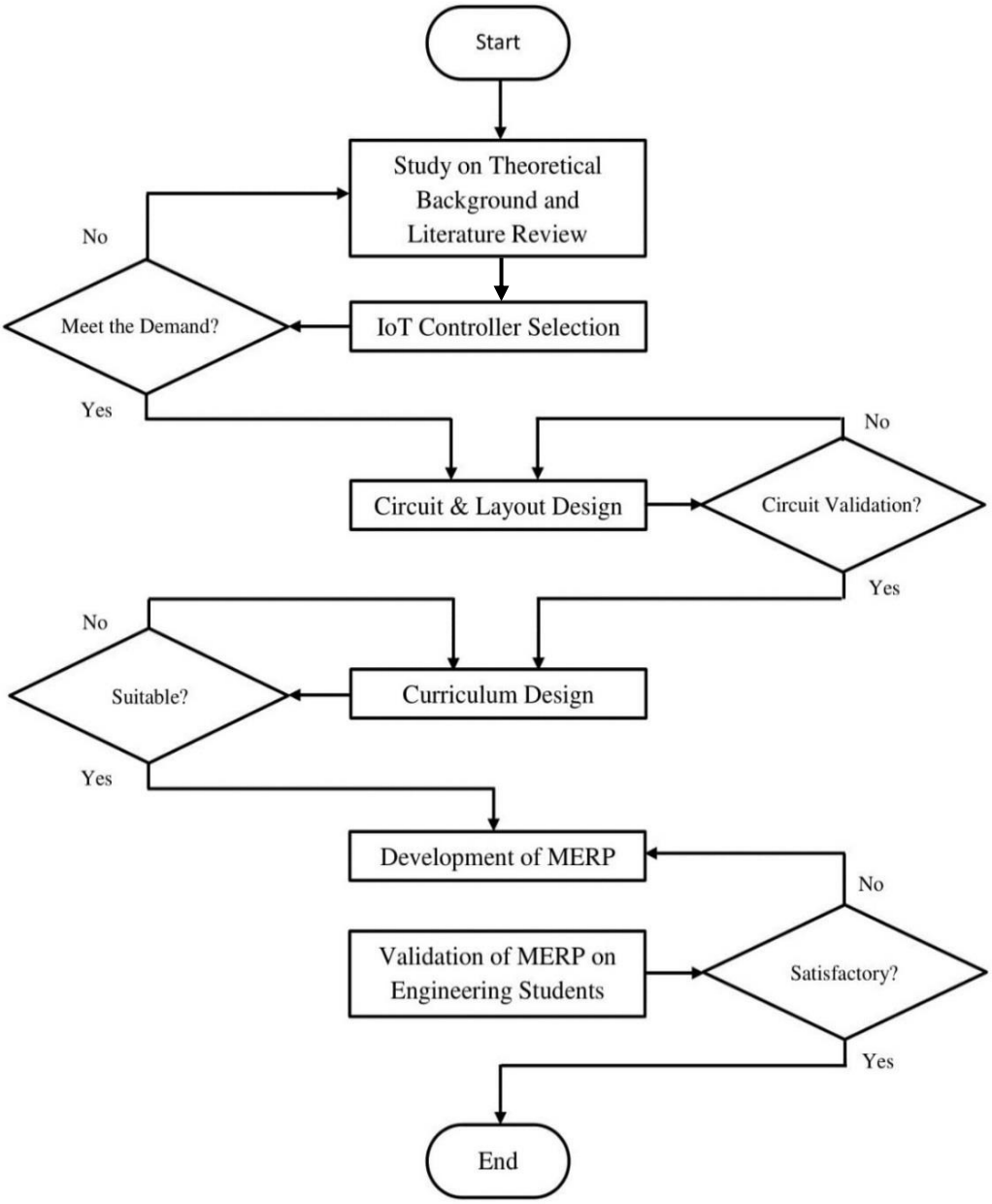

Figure 1.2 Flow Diagram of methodology

1.5 SCOPE OF WORK

The scope of the research can be identified as:

1. Development of platform and curriculum for learning control and IoT technologies.
2. Validation of developed platform and curriculum in engineering education.

1.6 OUTLINE OF THESIS

This thesis is split into six chapters. The brief outlines of each chapter are stated in this section:

1. Chapter 1: background, problem statement, objectives, research methodology, scope of work and the thesis outline are discussed in this chapter.
2. Chapter 2: This chapter focuses on the recent literature, concerning the topic of control and IoT platforms. The curriculum of control and IoT technologies are also introduced in this part.
3. Chapter 3: This chapter concentrates on hardware and software development of multipurpose educational and research platform (MERP). The MERP system design, schematic design, layout design is described in hardware section. The IoT controller programming tool, IoT communication protocol, IoT mobile application and IoT Cloud application are discussed in software section.
4. Chapter 4: The MERP contents design and teaching evaluation techniques are described in this chapter.

5. Chapter 5: This chapter presents the results and discussion. The teaching evaluation results, students feedback and develop prototype applications are shown and discussed.
6. Chapter 6: Conclusion of the research is presented with some recommendation for further study to enhance the research area.