SUPERVISOR ENDORSEMENT

"I hereby declare that I have read through this report entitle "Petri Net Controller Design For Robotic Pick and Place System" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation, and Automation)".

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PETRI NET CONTROLLER DESIGN FOR ROBOTIC PICK AND PLACE SYSTEM

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DECLARATION

I declare that this report entitle "Petri Net Controller Design for Robotic Pick and Place System**"** is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date : …….

DEDICATION

To my beloved mother and father

ACKNOWLEDGEMENT

First of all, I would like to thank almighty God for the strength and blessings. I would like to express my deepest gratitude to my supervisor, DR. SAIFULZA BIN ALWI for guiding me throughout my final year project development. Knowledge and extra input given by them has highly motivated me to successfully complete this project. The information, suggestions and ideas given by them played huge role in developing a fully functional project.

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ABSTRACT

Design methods for sequence controllers are given priority in advancing industrial automation. The expanding unpredictability and fluctuating needs of modern discrete manufacturing system have tested the design methods such as the use of ladder logic diagrams (LLD's) for programmable logic controllers. Traditionally, LLD has lack flexibility, extremely complex to understand the diagram and less adaptability to the current changes. Even for the real time purpose, if there is any problem occurs in the system, it is hard to detect the cause of the problem via LLD. The analysis which has been made shows that robotic controllers have received high attention by academic researchers and industrial engineers in order to design flexible, reusable, and maintainable control software for robotic system. To be more specific, Petri net (PN) are becoming as a very important tool to produce an integrated solution for modelling, analysis, simulation, and control of robotic system. Petri Net is a collection of directed arcs connecting places and transitions. Places may hold tokens. This project identifies the basic operation of the pick and place robotic system, analyse PN simulation for logic control system, model pick and place robotic system using Boolean function and design controller for pick and place robotic system by using PN. The comparison between the LLD and PN made to show the difference in operation and behaviour. The LLD controller which is using currently unable to control the sequence alone, it requires KUKA programming language in order to control the sequence efficiently. The KUKA program for pick and place operation is designed. The control goal is to enforce a set of linear constraints on the marking behaviour or state of the Petri net. The result includes a design and techniques used to satisfy the controller properties such as liveness, reachability, reversibility, safeness and boundedness. The results that presented in this paper will help a) further implementation of PN based controllers for other machines and robots in industries, and b) convince researchers, industrial engineers and robot manufacturers that PN is an effective and worthy controller which is applicable in their industries.

ABSTRAK

Kaedah reka bentuk untuk pengawal urutan diberi keutamaan dalam memajukan industri automasi. Keperluan sistem pembuatan diskret moden telah menguji kaedah rekabentuk seperti penggunaan gambarajah mantik (LLD's) tangga untuk alat-alat kawalan logik boleh aturcara. Secara tradisinya, LLD mempunyai kekurangan fleksibiliti, yang amat kompleks untuk memahami rajah dan kurang keupayaan menyesuaikan diri kepada perubahan semasa. Jika ada apa-apa masalah berlaku dalam sistem, ia adalah sukar untuk mengesan punca masalah melalui LLD. Jurutera untuk merekabentuk perisian kawalan yang fleksibel, boleh diguna semula dan maintainable robot sistem. Lebih spesifik, Petri Net (PN) menjadi sebagai satu alat yang amat penting untuk menghasilkan penyelesaian bersepadu bagi permodelan, analisis, simulasi, dan mengawal sistem robot. Projek ini operasi asas sistem robot memilih dan tempat mengenal pasti, menganalisis PN simulasi sistem kawalan logik, model memilih dan meletakkan sistem robotik dengan menggunakan Boolean pengawal fungsi dan reka bentuk untuk memilih dan menempatkan robot sistem dengan menggunakan PN. Perbandingan antara LLD dan PN dibuat untuk menunjukkan perbezaan dalam operasi dan tingkah laku. Pengawal LLD yang kini mampu mengawal jujukan yang semata-mata, ia memerlukan bahasa pengaturcaraan KUKA bagi mengawal jujukan yang cekap. Program KUKA untuk memilih dan tempat operasi direka. Matlamat kawalan adalah untuk menguatkuasakan suatu set kekangan linear pada tingkah-laku penandaan atau keadaan Petri Net. Hasil termasuk Reka bentuk dan teknik-teknik yang digunakan untuk memenuhi sifat-sifat pengawal seperti liveness, reachability, keterbalikan, safeness dan boundedness. Keputusan yang dibentangkan dalam kertas ini akan membantu a) Pelaksanaan PN berasaskan pengawal untuk mesin dan robot dalam industri-industri lain pada masa depan, dan b) Meyakinkan penyelidik, jurutera perindustrian dan pengeluar robot PN itu pengawal yang cekap dan layak yang terpakai dalam industri.

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CHAPTER 1

INTRODUCTION

In this chapter, project background, problem statement, project overview, objective and the scope of the project will be presented.

1.1 Project background

The logic control system is operate by turning on off motors, switches, valves, and other devices in response to operating conditions and as a function of time. Basically the control problem is to cause/ prevent occurrence of:

i. Particular values of outputs process variables
ii. Particular values of outputs obeying timing restrictions
iii. Given sequences of discrete outputs
iv. Given orders between various discrete outputs

Robotic controls are advancing in capabilities even as other options have been emerging for control. These include open control software that can be used with multiple vendors' robots, Petri Net, Fuzzy Net, programmable logic controllers (PLCs), and other non-robotic controllers.

Robots should be easier to use for more applications, and Southwest Research Institute, SwRI established ROS-Industrial, open source industrial robotic software and working group, to broaden the application of robotics and increase robotic interoperability. ROS stands for robotic operating system. As more manufacturing facilities and distribution centres discover the benefits of robotic material handling solutions, they must decide how best to control the robot. While robot original equipment manufacturers (OEMs) offer their own tightly integrated controller, recent developments have enabled control by a Petri Net.

Adding open-control software such as Petri Net to the convergence of well-known controls principles makes it possible to create machine designs that feature seamlessly integrated robots. This results in game-changing advantages for machine builders and manufacturers and the ability to integrate robot technology into more applications, including those that are traditionally among the most cost-sensitive.

The cost-saving benefits that make this possible include: reduced wiring, network and software platforms that are shared with the overall machine automation system, and a significantly reduced machine footprint. This has led to higher performance mechatronic and robotic solutions, including product packaging with variable product flow and complex material handling lines.

Petri Net is one of several mathematical modelling languages for the description of distributed systems Petri Nets and their concepts have been extended and developed, and applied in a variety of areas. A Petri Net is a collection of directed arcs connecting places and transitions. Places may hold tokens. A design method controller for a manufacturing assembly cell modelled by a Petri net will be presented. The control goal is to enforce a set of linear constraints on the marking behaviour or state of the Petri net. The method discussed here is a powerful means of realizing these constraints because it is simple to calculate, and the Petri net structure of the solution makes the controller easy to implement. The controller computation is derived using the concept of Petri net place invariants. [10]

Last but not least, to be precisely this project is about the KUKA robot pick and place system controlled using PN simulation. This robot is a part from eight stations which available to complete a disc casing loading and unloading assembly line. It is the 7^{th} station of the whole system. The design of the controller using PN will compromise the effective control sequence of the robot. The properties of the design that must satisfy is safeness,

boundedness, reachability, liveness and reversibility. The model of pick and place operation in Boolean function occupies design of robotic arm and position of sensors and axis.

1.2 Problem Statement

Initially, many industries use Programmable Logic Controller (PLC) as controller for their machines. This is because PLC is a microcontroller that can act as a central processor unit to control the sensor and other devices using the program which being design by the user itself. PLC system very precise to be used in the packaging workstation because it can be programmed by the operation of sequence instruction. At the same time, the design of PLC requires to maintain the quality of product and reduce the time to operate. As the complexity of the application increases, it is very crucial to ensure the safeness, liveness and reversibility properties of the system, while to maintain the performance of the system.

Currently, ladder logic diagram (LLD) which is one of the PLC elements used to resemble the operation of KUKA pick and place robot. Traditionally, LLD has lack flexibility, extremely complex to understand the diagram and less adaptability to the current changes. Even for the real time purpose, if there is any problem occurs in the system, it is hard to detect the cause of the problem via LLD. So Petri Net (PN) introduced as an alternative controller for the KUKA pick and place robot. PN act as the controller for the robot and the whole operation can be controlled with the simulation. The new controller design for pick and place robot will reduce the design complexity and able to increase the adaptability of the system to the current changes. Last but not least, PN offers a faster response time in real time response compared to LLD.

1.3 Overview of the project

The project is about designing a controller for the pick and place robotic system using PN. Petri Net still a new software which also able to function as logic controller for the robots. It is more convenient and easy to handle compare to other types of controller which are already in use. In this project, the pick and place operation also modelled in Boolean function. Thus it gives a better view of the process, inputs and outputs of the KUKA robotic arm. In the next chapter, the use advantages and techniques used in Petri Net will be discussed in further.

1.4 Objectives

Objectives of this project are:

1. To analyse the Petri Net simulation for logic control system.
2. To model pick and place robotic system using Boolean function
3. To design a controller for pick and place robotic system by using Petri Net

1.5 Scope

The KUKA pick and place robot is a part of the disc casing loading assembly line. The experiment is carried in Faculty of Electrical Engineering (FKE), Universiti Teknikal Malaysia Melaka (UTeM). The model of the robot is RB-CIM-UL-03 which used to pick and place the souvenir at the pallet area position. The robot is manufactured in the year 2011 and replaced the robot which used previously. PLC and KUKA programming language used as the controller for the RB-CIM-UL-03 robot. The scope includes generate a KUKA robot program and PLC using LLD for pick a souvenir from base position and

place it at pallet area position. The Petri net is a simulation software which is used to design a controller for the robot. The function and the operation of the Petri Net identified clearly and controller for pick and place system design using Petri Net. Model for the KUKA pick and place operation also generated using Boolean function. The modelling for the pick and place robot includes the inputs and outputs of the system.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter present about some basic principle and theories in the project and review of previous journals about the Petri Net (PN), Boolean function for pick and place robot system, KUKA pick and place robot, KUKA programming language and the PN controller design for KUKA pick and place robot system. In addition, the history of PN and KUKA pick and place robot also provided in this chapter. Besides that, this chapter also explained the implementation of PN in discrete control system. Last but not least, the comparison between PN and other types of controller are also included in this chapter.

2.1 Theory of basic principle of Petri Net

In this section basic principle such as basic operation and usage of PN are discussed. The theory involved in analysis of the PN as a controller for pick and place robot.

2.1.1 Study of PN

There are many techniques used for mathematical modelling of system. Which are namely basic queuing networks, queuing system with MM1 queuing, Fuzzy Net and close doing networks. Petri Net is another form of mathematical modelling to formally specify a particular system. Petri Net (PN) was invented by Carl Adam Petri in his PhD thesis in 1962 and initially had the form of Condition/Event Systems with simple arcs and binary marking. After that, there are a few modification of the basic system model done, which includes the integer markings and weighted arcs. [10]

PN used to model the functionality and behaviour of a system. It also can derive some performance result. In term of application, it can use in computer systems, computer networks and protocols, manufacturing system, production system, scheduling systems and controllers. PN also used to combine the computer system and manufacturing system by testing or checking the behaviour of certain components and parts. [1]

PN is a formal language to represent system and also a graphical language for modelling systems with concurrency. PN have an exact mathematical definition of their execution semantics, with proper mathematical theory for process analysis. Indirectly, a Place/Transition (P/T) Petri net is known as a bipartite graph. It consists of two types of nodes places and transition. Places typically drawn as circles and transition represented by bars or rectangles. Place represent condition where the condition needs to be full filled and the transition is described as an event that occur or processing activity. When condition is satisfied transition will trigger. Then, there is a changing in system from one state to another by transition. Symbols used in PN are given in Table 2.1.

Table 2.1: List of Input/output and symbol

symbol	Name	Function
	Transition	Event/Activity
	Place	Condition
	Arc	Connector

	Token	Number of resourses

Places and transitions are interconnected by directed arcs. Arcs only exist in between places and transition or vice versa. Arc always connects two nodes of different types. Arc can be weighted, which is representation of set of parallel arcs. There are tokens exist between the places and transitions. It circulates in this system via the transitions.

2.1.2 Concepts and examples of Petri Net

A marked Petri net (PN) Z = (P, T, I, O, m) is a five tuple where

1. P is a finite set of places
2. *T* is a finite set of transitions with *P* U *T*≠ 0 and *P* ∩ T=0
3. *I: P* x *T* →N, is an input function that defines the set of directed arcs from P to T where N = (0, l, 2,. . .}
4. O: P x T→ N, is an output function that defines the set of directed arcs from T to P
5. m: P→ N**,** is a marking whose i^{th} component represents the number of tokens in the i^{th} place. An initial marking is denoted by mo.

Example 1: A marked PN is shown in figure 2.1 and its formal description is given as follows:

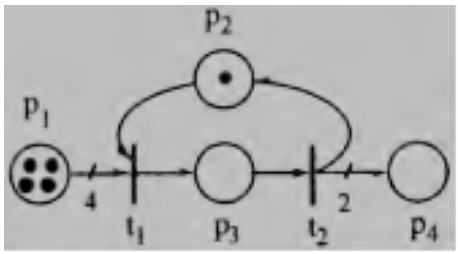

Figure 2.1: A Petri net modelling one operation stage requiring a single resource.