Faculty of Mechanical Engineering

A FAULT DIAGNOSIS EXPERT SYSTEM ON BUILDING AIR CONDITIONING SYSTEM FOR CONSTRUCTION 4.0

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A FAULT DIAGNOSIS EXPERT SYSTEM ON BUILDING AIR CONDITIONING SYSTEM FOR CONSTRUCTION 4.0

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DECLARATION

I declare that this thesis entitled "A Fault Diagnosis Expert System on Buiding Air Conditioning System for Construction 4.0" is the result of my own research except as cited in references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :...

Name :...

Date :...

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Engineering.

Signature	:………………..
Supervisor Name	:………………………....................................
Date	:………………………..

DEDICATION

Special gratitude to my beloved mom, Mdm Wong Yuet Choo for her enduring love, tenacity and patience throughout all my walks of life. And also to my siblings, Tan Chee Ling, Tan Chee Chee and Tan Chee Li who have motivated and supported me throughout my life. And my dearest friend Gan Yen Li on her spititual support.

I love you all.

ABSTRACT

Building air conditioning systems are in high demand nowadays. They provide maximum comfort for occupants by reducing indoor temperature and providing acceptable indoor air quality. Air conditioning also comprising of fresh air ventilation for better air quality and ensuring relative humidty in the building. Building air conditioning sytems rely heavily on technical expertise for service and maintenance which could be costly. The aim of this research project is to develop a prototype knowledge based system for the fault diagnosis of building air conditioning systems. With the developed system, the diagnosis process for building air conditioning systems can be standardised, making them faster and more precise as compared to conventional systems by 566.5%. The developed system is also useful for inexperienced personnel as it can be used as a training module as well. Hence, the development of a fault diagnosis system is a significant contribution in air conditioning service operations. In this research work, the fault diagnosis system was developed by using the Kappa-PC expert system shell. It is supported by object-orientated technology for the MS Windows environment. It uses backward chaining for inferencing. In order to select the faults of the air conditioning components, a few specifications are laid out as constraints. The constraints for this developed expert system are based on the air conditioning system design data and expert's experience. Two case studies were also conducted to verify the capability of the developed system.

ABSTRAK

Penggunaan pendingin hawa untuk bangunan merupakan trend yang amat diperlukan pada masa kini. Ia memberikan keselesaan maksimum untuk penghuni dengan mengurangkan suhu dalaman dan menyediakan kualiti udara dalaman yang boleh diterima. Pendingin hawa juga terdiri daripada pengudaraan udara segar untuk kualiti udara yang lebih baik dan memastikan kelembapan relatif dalam bangunan. Perkhidmatan dan penyelenggaraan untuk mesin pendingin hawa amat bergantung berat kepada tenaga pekerja yang mahir dan pakar. Projek ini menerangkan penggunaan sistem shell pakar untuk membangunkan satu sistem diagnosis kerosakan untuk sistem pendingin hawa. Dengan sistem yang dibangunkan, proses diagnosis untuk sistem pendingin hawa adalah lebih seragam, tepat dan cepat 566.5% jika dibandingkan dengan cara biasa. Sistem yang dibangunkan adalah amat berguna kepada individu yang kurang berpengalaman dan ia boleh dijadikan sebagai modul latihan. Oleh itu, pembangunan sistem diagnosis ini merupakan satu sumbangan yang penting untuk perkhidmatan dan penyelenggaraan mesin pendingin hawa. Dalam kerja penyelidikan ini, Kappa-PC sistem pakar shell telah digunakan untuk membangun sistem diagnosis ini. Sistem ini disokong oleh teknologi berorientasi objek untuk MS Window. Sistem ini menggunakan backward chaining untuk proses inferensia. Bagi memilih kerosakan komponen pendingin hawa, beberapa spesifikasi telah diletakkan sebagai kekangan. Namun, sistem yang dibangunkan ini adalah terhad kepada data reka bentuk sistem bangunan pendingin hawa dan pengalaman pakar. Dua kajian kes telah dijalankan untuk mengesahkan keupayaan sistem tersebut.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

AC	-	Air- Conditioning
ACCU	-	Air Cooled Condensing Unit
ACMV	-	Air-Conditioning and Mechanical Ventilation
AHU	-	Air Handling Unit
AI	-	Artificial Intelligence
ASHRAE	-	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BIM	-	Building Information Modeling
BMP	-	Bitmap
BTU	-	British Thermal Units
CAV	-	Constant Air Volume
CIDB	-	Construction Industry Development Board
CFM	-	Cubic feet per minute
CHW	-	Chilled Water
COP	-	Coefficient of Performance
CW	-	Cooling Water
db	-	Decibel
ECBC	-	Energy Conversation Building Code
et al	-	Et Alia
etc	-	Et Cetera

IoT	-	Internet of Things
FAHU	-	Fresh Air Handling Unit
FCU	-	Fan Coil Unit
HVAC	-	Heating, Ventilation and Air Conditioning
KAL	-	Kappa-PC Application Language
KBS	-	Knowledge Based System
M&E	-	Mechanical and Electrical
MS	-	Microsoft
OOP	-	Object-Oriented Programming
Pa	-	Pascal
PAHU	-	Primary Air Handling Unit
RA	-	Return Air
RPM	-	Revolutions per minute
TR	-	Ton of Refrigeration
VAV	-	Variable Air Volume
VFD	-	Variable Frequency Drive
VRF	-	Variable Refrigerant Flow
VRV	-	Variable Refrigerant Volume
WCPU	-	Water Cooled Packed Unit

LIST OF PUBLICATIONS

[1] Tan, C. N., Tan, C. F. & M. A. Abdullah, 2017. A Fault Diagnosis Expert System for Building Chillers. *International Review of Mechanical Engineering (IREME)*, 11(4), pp. 270-277. *(Scopus-indexed)*

[2] Tan, C. N., Tan, C. F., M. A. Abdullah, M, Mohd. Rayme., A. Luqman. and S. H. Tang., 2016. A Fault Diagnosis Expert System for Building Cooling Tower. *5th International Conference on Advance Mechanical Engineering (ICAME)*, 13(2), pp. 10-20. *(Scopus-Indexed)*

[3] Tan, C. N., Tan, C. F. and M. A. Abdullah., 2017. A Fault Diagnosis Expert System for Water Cooled Packed Unit. *Jurnal Teknologi (Sciences and Engineering)*, 80(1), pp. 179-186. *(Scopus-Indexed)*

CHAPTER 1

INTRODUCTION

1.1 Background

Digitalization in Construction 4.0 is giving a great impact in the construction industry in ways to improve their productivity. Potential in digitalization in industry of construction can be seen in line with Industry 4.0 from four main aspects: digital data, digital access, automation and connectivity (Mario et al., 2016; Malte et al., 2014; Brodtmann, T., 2016). Digital data is the collection of electronics and analysis of data to get every new insight into every link in the value chain and then put these new insights to good use whereas digital access covers the mobile access to the internet and internal networks. Automation is the latest technologies that create autonomous and self-organizing systems. Connectivity explores the possibilities to link up and synchronize hitherto separate activities (Roland Berger., 2016).

The forth industrial revolution lies in the powerhouse of German manufacturing and widely adopted by nations such as China, India, and other Asian countries via the Internet of Things (IoT) and Internet of services becoming integrated with the manufacturing environment (Einsiedler, I., 2013; Hans et al., 2014; Katiya, G., 2016). However, in Construction 4.0, construction business will have a strong global networks to connect their transporting materials, running errands, cleaning up, rearranging the building site and looking for materials and equipment. This will bring a huge improvement in the industrial and construction processes within engineering, material usage, supply chains and product lifecycle management. It is therefore perfectly understandable that many businesses see a need for optimization in construction 4.0 (Roland Berger., 2016).

For building construction and services which along the lines of construction 4.0, it is a upcoming trend that construction companies nowadays concentrate on the digitalization of planning, construction and logistic with building information modeling (BIM). BIM is a 3D modeling that can provide professional building design, construction, facility operations service and physical characteristics of places as shown in Figure 1.1 (Zhang et al., 2013; Migilinskas et al, 2013; Kalinichuk, S., 2015). With the help of BIM technology, an accurate virtual model of a building is digitally constructed. It helps architects, engineers and constructors visualize what is to be built in a simulated environment to identify any potential design, construction or operational issues (Salman, A., 2011). The use of building information modeling (BIM) is compulsory by 2020 for every public infrastructure in Germany, Netherlands, Denmark, Finland and Norway. For Malaysia, led by the Construction Industry Development Board (CIDB) under the construction master plan 2016-2020, it is hoped more emphasis on technology adoption across the project life cycle will induce higher productivity (Volk et al., 2014).

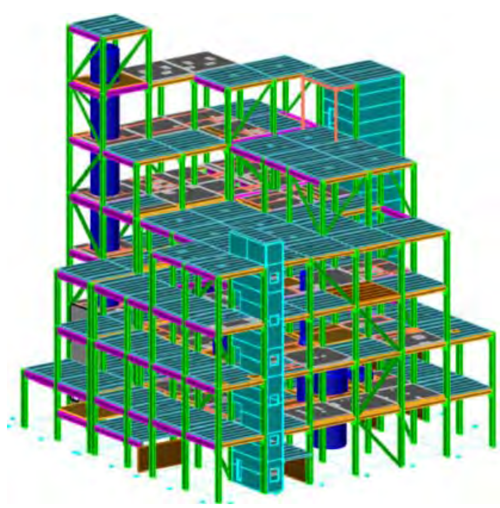

Figure 1.1: The building information modeling model (Migilinskas et al, 2013)

On the other hand, energy is an imperative component for the development of a country as it is essential in various industries. Nowadays, non-renewable resources all over the world is diminishing at an alarming rate to meet the essential needs of mankind. According to a study by Vakiloroaya et al., 2014; Chua et al., 2013, air conditioning consumes the most energy in buildings, households or even office workstations. Air conditioning in buildings and office workstations is a demanding trend as provides a comfortable environment for occupants by reducing indoor temperature.

Since humans are highly dependent on this cooling device especially in countries with tropical weather, it usually needs to operate for extended periods of time. Hence, device failure or system breakdowns may occur anytime. When the air conditioning system breaks down, it can be very costly to hire technicians to carry out repair work. Therefore, preventive action is better than repair works as the later cost more money and time. Thus, the expert system developed significantly reduces air conditioning maintenance cost, also it promotes pro-active solutions.

Regular maintenance and repair of air conditioning systems are generally carried out by experienced technicians and engineers. Building air conditioning and mechanical ventilation (ACMV) experts are not available all the time to advise and review possible references and data when the units break down (Mansyur et al., 2013). In other words, there will be lost of expert knowledge when human expertise is not available. Thus, to keep all the information and data of a field permanently, an expert system is required.

An expert system is a computer that emulates the behaviour of human experts within a well-defined, narrow domain of knowledge (Liebowitz, 1995). The expert system will provide guidance and recommendations according to the situation based on engineering knowledge and experience. Besides, an expert system is one of the artificial