A DEVELOPMENT OF MODULAR AUTOMATED STORAGE AND RETRIEVAL SYSTEM

This report is submitted in accordance with the requirements of Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor's Degree of Manufacturing Engineering (Robotics and Automation)(Hons.)

by

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I hereby declare that this report, entitled “A Development of Modular Automated Storage and Retrieval System”, is the result of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirements for Degree of Manufacturing Engineering (Robotics and Automation) (Hons.). The members of the supervisory committee are as follows:

……………………….................................

(Ir. Dr.-Ing. Azrul Azwan bin Abdul Rahman CEng)

ABSTRAK

Laporan ini mendokumentasikan perjalanan projek bertajuk "Pembangunan Sistem Automasi bagi Penyimpanan dan Dapatan Semula yang Berkonsep Modular". Dalam projek ini, sebuah AS/RS modular dicadangkan untuk menangani masalah AS/RS yang dipasang tetap dan tidak mudah diubah secara fizikal. Objektif projek ini adalah mereka bentuk sebuah AS/RS modular yang senang dipasang dan ditanggalkan, menghasilkan AS/RS yang telah direka bentuk, dan mensimulasikan kawalan sistem tersebut. AS/RS ini direka bentuk sebagai komponen individu dengan menggunakan SolidWorks. Kemudian, perisian yang sama digunakan untuk menghimpunkan komponen menjadi suatu reka bentuk yang lengkap. Apabila mereka bentuk sistem, pelbagai konsep reka bentuk dinilaikan dan dibandingkan demi memilih konsep yang terbaik untuk reka bentuk sistem. Sejurusnya, aspek-aspek rekabentuk dan modular reka bentuk akhir dibincangkan dan dibandingkan dengan AS/RS bukan modular. Melalui perbandingan setiap bahagian, sifat modular sistem yang telah direka bentuk dibuktikan. AS/RS yang telah direkabentuk juga dibina sebagai sebuah produk fizikal dengan aluminium sebagai bahan utamanya. Akhir sekali, simulasi kawalan sistem menggunakan perisian Automation Studio dibentangkan dan dibincangkan. Sebuah panel kawalan maya, grid maya, dan perwakilan sistem dibentangkan. Pengaturcaraan logik di sebalik kawalan sistem juga dibentangkan dan dijelaskan. Dengan pengaturcaraan yang disediakan, sistem tersebut mampu bergerak ke mana-mana kedudukan pada grid, serta mengambil dan meletakkan barang dari grid. Logik yang digunakan dalam kawalan sistem ini juga mampu dikembangkan.

ABSTRACT

This report documents the progress of the project "A Development of Modular Automated Storage and Retrieval System". In this project, a modular AS/RS is proposed in order to counter the problem of AS/RS being permanent fixtures and unwelcoming to physical changes. The objectives of the project are to design a modular AS/RS that is easy to install and remove, fabricate the designed AS/RS, and simulate control of the system. The AS/RS is designed as individual parts in SolidWorks. Later on, the same program is used to assemble the parts into the complete design. When designing the system, various design concepts are proposed, evaluated, and compared in order to select the best concepts for the design of the system. The various design and modular aspects of the final design are then discussed and compared with non-modular AS/RSs. Through a section-by-section comparison, the modularity of the system that has been designed is proven. The designed AS/RS is also fabricated in the form of a physical product, with its main material being aluminium. Finally, the simulation of the system's control in Automaton Studio is presented and discussed. The virtual control panel to control system, virtual grid, and representation of the system are presented. The ladder logic programming behind the control of the system is also presented and explained. With the ladder programs in place, the system is able to move to any position on the virtual grid, as well as store and retrieve virtual items from the grid. The logic used in the control of the system is also expandable to accommodate larger grids in the future.

DEDICATION

This project is dedicated to my parents. To my mother, for her unending support throughout my time studying here in UTeM. And to my father, who could not be here to witness me complete my studies.

ACKNOWLEDGEMENT

A thousand and one thanks go out to all the people that have contributed to the completion of this project.

The first and biggest “thank you” goes to my supervisor, Dr.-Ing Azrul Azwan. His guidance and advice helped me to undertake this project in the best way I could. I would also like to thank him for his tolerance towards my many shortcomings.

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Finally, I would like to thank my family, for all their support throughout the journey of the project.

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LIST OF ABBREVIATIONS

AS/RS	-	Automated Storage and Retrieval System
CAD	-	Computer Aided Design
CAE	-	Computer Aided Engineering
CNC	-	Computer Numerically Controlled
DCV	-	Directional Control Valve
ERP	-	Enterprise Resource Planning
FOSH	-	Free and Open-Source Hardware
FOSS	-	Free and Open-source Software
FYP1	-	Final Year Project 1
FYP2	-	Final Year Project 2
N/O	-	Normally Open
PC	-	Personal Computer
PLC	-	Programmable Logic Controller
RGV	-	Rail-Guided Vehicle
RPD	-	Rack and Pinion Drive
UML	-	Unified Modeling Language
VLM	-	Vertical Lift Module

LIST OF SYMBOLS

A_U	-	Aisle unit
A_W	-	Aisle width
C_A	-	Capacity per aisle
C_M	-	Capacity of each storage/retrieval machine
L	-	Length of storage rack
W	-	Width of storage rack
H	-	Height of storage rack
L_{SY}	-	Overall length of system
W_{SY}	-	Overall width of system
H_{SY}	-	Overall height of system
l	-	Length of load
b	-	Width of load
h	-	Height of load
x	-	Length clearance of load
y	-	Width clearance of load
z	-	Height clearance of load
L_{SS}	-	Length of storage space
W_{SS}	-	Width of storage space
H_{SS}	-	Height of storage space
L_C	-	Length of storage compartment
L_{SS}	-	Length of storage space
x_1	-	Thickness of support column
W_C	-	Width of storage compartment
y_1	-	Thickness of support column
H_C	-	Height of storage compartment
z_1	-	Storage rack centre-to-centre height
$N_{SR/M}$	-	Number of storage racks per storage/retrieval machine
N_M	-	Number of storage/retrieval machines
N_{SR}	-	Number of storage racks

SS_{SR}	-	Number of storage spaces per storage rack
N_A	-	Number of aisles
R_{SY}	-	Total number of rows
B_{SY}	-	Total number of bays
N_R	-	Number of rows
N_B	-	Number of bays
ηhr	-	Approximate hourly throughput of the system
N_{SS}	-	Number of storage spaces required in the system
T_{SC}	-	Single command cycle time
T_{DC}	-	Dual command cycle time
$T_{SC(MAX)}$	-	Maximum single command cycle time
$T_{DC(MAX)}$	-	Maximum dual command cycle time
$\eta_{hr/SC}$	-	Hourly throughput based on single command cycle
$\eta_{hr/DC}$	-	Hourly throughput based on dual command cycle

CHAPTER 1

INTRODUCTION

1.0 Background of Study

Automated storage and retrieval systems (AS/RS) (MHI, 2012) are systems that automatically place and retrieve loads from pre-defined storage locations. These systems are generally computer-controlled. AS/RS systems are prized for their high rate of storage and retrieval. The installation of these systems also allows for higher storage density in warehouses and other storage locations compared to traditional storage layouts that employ forklift trucks for storage and retrieval.

Originating in the 1960s, the technology evolved from its initial focus on heavier pallet loads to become smaller and more compact (Rogers, 2012). As a result, there exists a wide variety of AS/RS systems that cater for anything from pallet loads weighing a few tonnes to mini AS/RS systems that can be efficiently and effectively used to store and retrieve small loads.

In an article by Stephen (2012), it is mentioned that AS/RS systems allows for simpler tracking of stocked products. This includes their respective suppliers, the time and duration they were stored, as well as their locations. The author went on to elaborate that such information allows for better planning and management of warehouse space.

There are two main types of AS/RS systems: Vertical lift module (VLM) and horizontal carousels. VLM type AS/RS systems store items in vertical racks. The storage and retrieval system is able to move on a horizontal or vertical (usually both) axis to store and retrieve products from individual rack spaces.

Horizontal carousel type AS/RS systems, on the other hand, feature a series of bins mounted onto an oval track. Each bin is a registered location in the system. Storage and retrieval, usually done by human workers, is done by inputting the desired location. The track will then rotate to present the appointed bin to the user.

A different approach of categorizing AS/RSs is single command cycle or dual command cycles. Single command cycle type AS/RS only handles the storage or retrieval of one item in one command cycle. On the other hand, dual command cycle AS/RSs can handle more than one storage and/or retrieval command per command cycle.

AS/RS systems, since their creation, have helped to improve the effectiveness and efficiency of storage and retrieval work in warehouses. Of course, the uses for such a system are not limited to industrial sectors only. In the future, these systems are sure to play an even larger role as industries worldwide continuously strive for a more automated workforce.

1.1 Problem Statement

Traditional AS/RS systems are usually considerably large in size, due to their major use case being factory warehouses and storage areas. As a result of this, and the fact that they usually include complex interfaces with other systems, AS/RS systems tend to be difficult to install and remove. AS/RS systems are also usually made to order. This causes the system to not accept physical changes easily. For example, if a client wishes to replace the current storage rack with a new one of different dimensions, many components of the ASRS may need to be replaced as well.

To overcome this, a modular AS/RS is proposed. The system should be adaptable (within a reasonable range) to changes in the dimensions of the storage rack. Such a system would also minimize the need to custom-make components for different clients. The system should also be easy to install and remove from the storage rack.

1.2 Objectives

Throughout the course of this project, there are 3 main objectives that need to be met.

1. To design a modular AS/RS system that is simple to install and remove from the storage racks.
2. To fabricate the AS/RS system that has been designed.
3. To simulate the control of the AS/RS.

1.3 Scope

In Section 1.0, it was mentioned that there are two main types of AS/RS systems, VLM type and horizontal carousel. In this project, only the VLM type of AS/RS systems will be approached. This is due to the vastly different form factors of the two types of AS/RS, which does not allow for both types to be incorporated into the same system effectively.

The work for this project will include designing a single command cycle AS/RS using computer aided design. The designed system will also be fabricated and assembled. Control of the system will also be simulated using relevant software.

CHAPTER 2

LITERATURE REVIEW

2.0 Overview for AS/RS

Ku *et al.* (2016) discussed the possibilities of developing software for the control and monitoring of AS/RS systems. The authors described automated storage systems as a vital part of logistics. Due to the current trends in consumer lifestyles, large quantities of goods are required for a short time. To this effect, AS/RS systems contribute immensely in conserving human capital and present higher reliability.

In Slovakia, there is a large demand for new modelling and control methods for AS/RS systems, especially in the automotive industry. However, the purchase and installation of these systems are costly, excluding the development of suitable software that is required for the functioning of the systems.

According to Ku *et al*. (2016), AS/RS systems usually consist of racks, aisles, cranes, input and output points, and interoperable transport. First, they describe racks as "mostly metal structures where pallets with items are placed." In other words, racks are where the products are stored in an AS/RS system. Naturally, racks usually represent most of the volume of any AS/RS system.

Aisles are the empty spaces between racks. Aisles tend to have two main purposes. The first is to allow human workers to walk between the racks. This can be for doing stock checks, or repairs and maintenance of the AS/RS system. The second purpose is for the movement of the cranes (Ku *et al.*, 2016). As the cranes do not sit flush with the racks, they require space to move around and pick or place pallets from the storage racks.

Cranes, as mentioned in the paragraph above, are fully automated devices that store and retrieve pallets from the racks of a storage system (Ku *et al.*, 2016). These cranes can be based on a variety of platforms, including rack and pinion, ball and screw, Stewart-Gough Platform, etc. Each different platform of crane has its own benefits and drawbacks to be considered.

The last part of AS/RS systems mentioned by Ku *et al*. (2016) interoperable transport, is sometimes not a part of the AS/RS system itself. However, it remains an essential part of automated storage systems. Interoperable transports are the part of the system that provides transportation of items from the storage area to other parts of the company or plant (and vice versa). One example of such a part provided by the authors are rail-guided vehicles (RGV). Figure 2.1, shows an illustration of a typical layout of an AS/RS system.

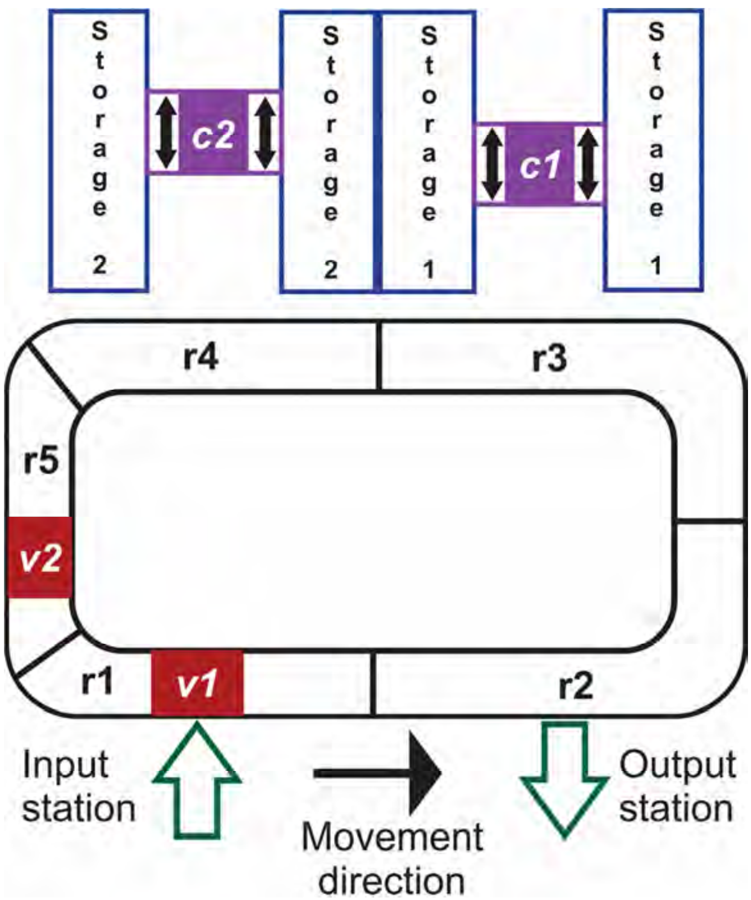

Figure 2.1: Typical layout of an AS/RS system (Ku *et al.*, 2015)

Guanxiang *et al.* (2010) described AS/RS systems as an evolved form of warehouses. Figure 2.2 shows an illustration that includes some of the parts of an AS/RS as described by the authors.

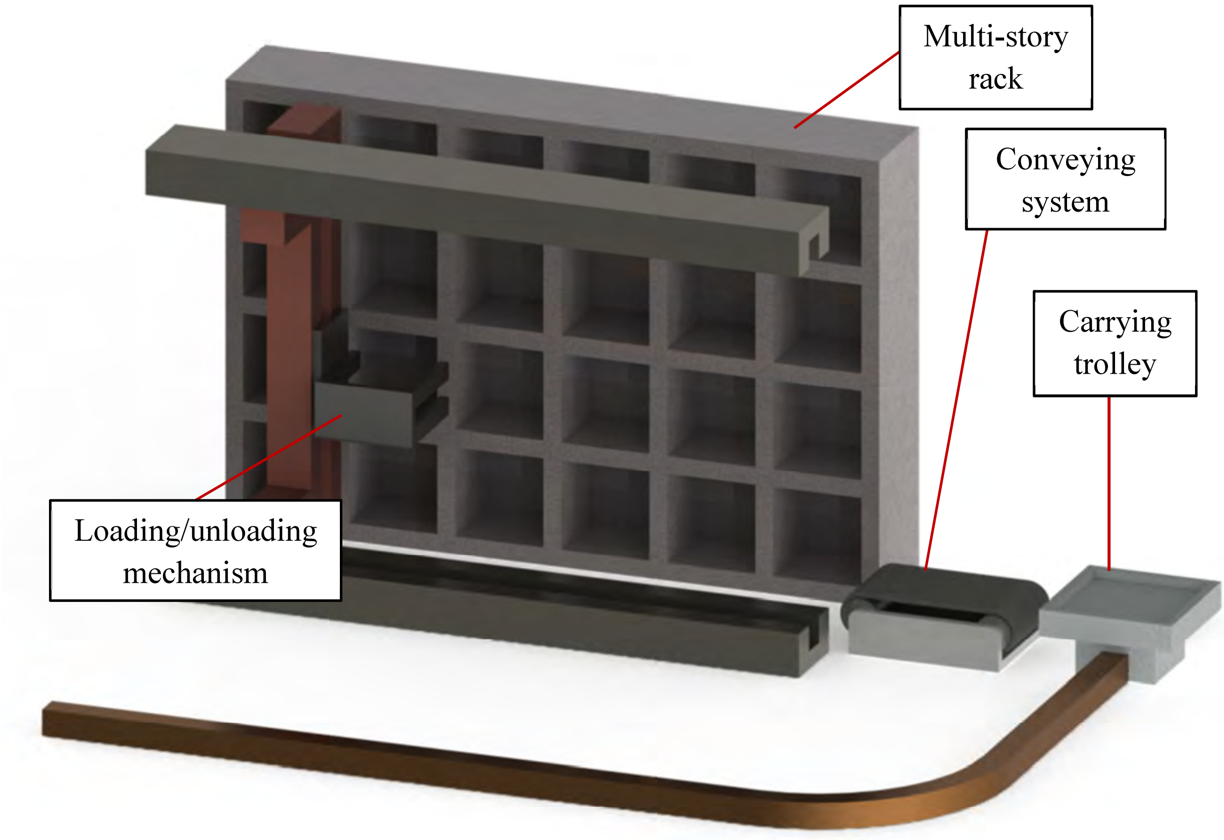

Figure 2.2: Illustration of AS/RS system

Other parts of AS/RS as listed by Guanxiang *et al*. (2010) that are not shown in Figure 2.2 include the following:

1. Tunnel type stackers
2. Container or pallet facilities
3. Communication systems
4. Information systems
5. Control systems
6. Computer management and monitoring system