OPTIMIZATION MODEL WITH MULTIPLE CONSTRAINTS USING GENETIC ALGORITHM METHOD FOR CARGO ARRANGEMENT PROBLEM

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A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Mechatronics and Automatic Control)

School of Electrical Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

2021

DEDICATION

This project report is dedicated to my mother and father who have been very supportive in ensuring that I come this far and continually encouraging me to aspire for more. It is also dedicated to all my siblings who were always there to encourage me when the going got tough and supported me through-out.

ACKNOWLEDGEMENT

In preparing this report, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my main thesis supervisor, Dr. Fatimah Sham Bt. Ismail, for encouragement, guidance, critics and friendship, without whose continuous support and interest, this thesis would not have been the same as presented here.

I am also indebted to Universiti Teknologi Malaysia (UTM) for providing me with a conducive learning environment and the necessary facilities to successfully complete my work.

My fellow postgraduate students should also be recognised for their support. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family members.

ABSTRACT

Efficient arrangement of cargo in logistics is crucial in minimizing the operational cost and it can be a complex task as it involves multiple constraints like cargo with various volumes and weights. Therefore, manual cargo arrangement is challenging, especially when the types of cargo and numbers of customer's increase. Cargo arrangement is categorized as a problem that involves mathematical models and efficient optimization algorithms. This project proposes a multi-objective, multi-constraint mathematical model for the three-dimensional optimization problem (3-DOP), with constraints such as packaging volume, weight and quantity of different cargo types. The requirements and characteristics of the container are also considered in establishing the proposed model to achieve the loading optimization objectives of maximizing the utilization and capacity of container space.

This project uses genetic algorithm (GA) as the global search properties to obtain the optimal solution. The proposed model comprised of an objective function and a set of constraints in cargo loading such as weight, rotation, overlapping and stacking constraints. The real coded methods of GA, optimal preservation strategy and Pareto front are introduced. Subsequently, a GA is developed using MATLAB software.

The cargo sizes of different transport companies are used as test samples. The maximum space utilization is achieved up to 77.59%, and the weight maximum is 58.12%. Nevertheless, it is observed that an increase in the number of constraints has a significant effect on the optimization. In short, the effectiveness of the proposed optimization algorithm is verified.

ABSTRAK

Penyusunan kargo logistik yang cekap adalah penting meminimumkan kos operasi keseluruhan dan boleh menjadi sangat komplek jika melibatkan beberapa kekangan seperti kargo yang berbilang isipadu dan berat. Oleh yang demikian, penyusinan kargo secara manual sangat mencabar, terutamanya bila melibatkan saiz bilangan kargo yang besar dan pelanggan yang ramai.

Penyusunan kargo dikategorikan sebagai masalah yang melibatkan model matematik dan algoritma pengoptimumam bagi masalah pemuatan tiga dimensi berserta mengambil kira pelbagai masalah atau kekangan. Penyelidikan ini mencadangkan model matematik pelbagai objektif dan pelbagai kekangan yang mengambil kira kekangan seperti jumlah bungkusan, berat dan kuantiti jenis kargo yang berbeza untuk masalah pengoptimuman tiga dimensi (3-DOP). Keperluan dan ciri muatan kontena juga dipertimbangkan dalam menetapkan model untuk mencapai tujuan pengoptimuman bilangan penggunaan dan kapasiti ruang kontena.

Algoritma genetik (GA) digunakan dalam penyelidikan ini sebagai sifat carian global untuk mendapatkan penyelesaian optimum. Model yang dicadangkan terdiri daripada dua objektif iaitu ruang yang digunakan dan berat berserta satu set kekangan untuk pemuatan kargo seperti berat, putaran, pertindihan dan susunan. Kaedah kod sebenar GA, strategi pemeliharaan optimum dan Pareto Front diperkenalkan. Selepas itu, GA dibangunkan menggunakan perisian MATLAB. Pengesahan hasil penyelidikan ini kemudian dilakukan dengan analisis perbandingan.

Dalam pengesahan keputusan dari GA, ukuran kargo beberapa syarikat pengangkutan digunakan. Penggunaan ruang maksimum masing-masing mencapai 77.59%. Penggunaan maksimum berat masing-masing mencapai 58.12%. Walau bagaimanapun, diperhatikan bahawa peningkatan jumlah kekangan mempunyai pengaruh yang signifikan terhadap pengoptimuman.

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LIST OF ABBREVIATIONS

BP	-	Bin Packing
3-DLP	-	Three-Dimensional Layout Problem
BPP	-	Bin Packaging Problem
3-DOP	-	Three-Dimensional Optimization Problem
GA	-	Genetic Algorithm
3D-BPP		3-Dimensional Bin Packing Problem
RCGA		Real Coded Genetic Algorithm
2-D	-	2-Dimensional
3-D	-	3-Dimensional
NP	-	Nondeterministic Polynomial
VRP	-	Vehicle Routing Problems
TSP	-	Travelling Salesman Problem
EA	-	Evolutionary Algorithms
MA	-	Meta-heuristics Algorithms
3D-CLP	-	3D Container Loading Problem
3L-CVRP	-	3D Loading Capacitated Vehicle Routing Problem
CVRP	-	Capacitated Vehicle Routing Problem
CLP	-	Container Loading problem
LIFO	-	Last in First out
CMOP		Constrained multi-objective optimization problem

LIST OF SYMBOLS

D, d	-	Diameter
F	-	Force
V	-	Velocity
M^3		cuboid
P		Population size
PC		Crossover rate
PM		Mutation rate

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CHAPTER 1

INTRODUCTION

1.1 Problem Background

Nowadays, the demand for global logistics is increasing as more and more people are switching to online purchasing in this modern digital era, especially during a pandemic like COVID-19. Hence, it is crucial to efficiently arrange cargo or goods into the available space of containers or any other types of transportation system to ensure an efficient delivery process.

Cargo refers to any types of boxes or packaging used to wrap the subjects to be delivered. Meanwhile, container, also known as bin, refers to the vehicle compartment used to carry the cargo. Figure 1.1 illustrates the activities in a logistic transportation company.

Figure 1.1 Illustration of activities in a logistic transportation company [1]

Cargo loading and vehicle routing problems are among the main problems faced by the delivery service providers to ensure efficient logistics. Cargo loading problem, or more commonly known as bin packing problem, arises when logistics service providers need to load cargo of different sizes and weights into a finite number of containers with a fixed volume while making sure the number of containers used is minimum. Various considerations need to be taken into account when loading cargo, including 2-dimensional bin packing problem (2D-BPP), 3-dimensional bin packing problem (3D-BPP), packing by volume, packing by weight, packing by cost, packing by priority and packing by fragility [1]. All these are basically the complex constraints that must be handled in cargo arrangement. Figure 1.2 shows the visualization to familiarize the and definition and terminologies used.

Figure 1.2 Visualization for terminologies used in the report [1]

Proper arrangement of cargo is considered as a nondeterministic polynomial (NP) hard problem which involves obtaining efficient optimization algorithms through mathematical models. It is a challenging task because it involves 3D layout design of space utilization which taking multiple dimensions and parameters like weights of cargo into account [2].

Vehicle routing in logistics refers to the determination of the most efficient routes from logistics hub (depot) to customers' sites, i.e. routes with the lowest cost or shortest distance routes. Vehicle routing problem (VRP) generalizes the Travelling Salesman Problem (TSP). Determination of the optimal solution for VRP is also an

NP-hard problem as it may involve both the vehicle constraints and operational constraints [3]. Figure 1.3 illustrates VRP in logistics when determining routes of each vehicle to minimize the cost of global logistics.

In industrial practice, VRP and cargo loading problem should be treated as the integrative part of cargo transportation since they are inherently related to each other as combinatorial optimization problems.

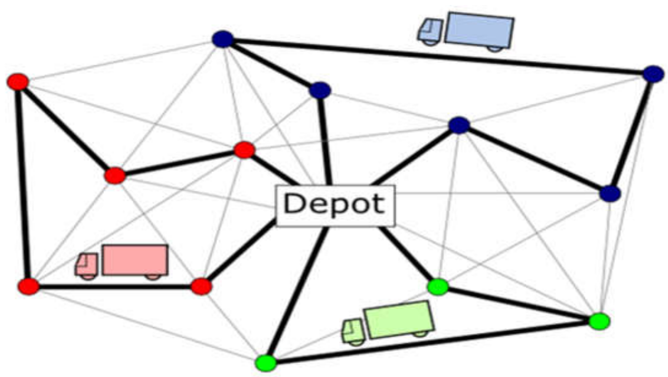

Figure 1.3 Illustration of VRP problem [1]

1.2 Problem Statement

Efficient arrangement of cargo in logistics transport is crucial in minimizing the operational cost and it can be a complex task as it involves multiple constraints like cargo with various volumes and weights. Therefore, manual cargo arrangement is challenging, especially when the types of cargo and numbers of customers' increase. Cargo arrangement is categorized as an NP-hard problem which involves mathematical models and efficient optimization algorithms. In the mathematical models, the volume and weight of the vehicle container (vehicle compartment) and vehicle fuel consumption are used for calculations.

Both heuristic and meta-heuristic approaches are often proposed to solve the cargo loading problem. These approaches utilize evolutionary algorithms and trial-and-error explorative discovery methods to obtain the optimal solution. The main challenge or problem in cargo arrangement is to mathematically formulate multiple inherently related constraints into the optimization algorithm in a mathematical model.

1.3 Research Objectives

The objectives of this research were as follows:

(a) To model a cargo arrangement optimization problem with constraint parameters to achieve maximum space and weight utilization.

(b) To develop a computational optimization method using Genetic Algorithm (GA).

(c) To analyse and evaluate the performance of the developed optimization search method.

1.4 Scope of the Research

This research was limited by the following scopes:

The scopes of this research were as follow:

(a) The mathematical model used different sizes of cargo obtained from delivery service companies.

(b) Involved a fixed number of containers with standard capacity available for delivery.

(c) A container loading optimization system was designed and developed based on the proposed GA with the aim to maximize the loading weight or volume of the container.

1.5 Organization of this Thesis

Chapter 1 presents the introduction, problem statement, and the objectives and scopes of research. Chapter 2 reviews the literature related to cargo loading arrangement, i.e., three-dimensional (3D) bin packing problem and its optimization methods. Chapter 3 discusses the methodology used to achieve the specified objectives. Then, Chapter 4 discusses the establishment of the proposed mathematical model with cargo loading arrangement as the optimization problem. Next, Chapter 5 presents and discusses the data and analysis results of this research in detail. Lastly, Chapter 6 presents the conclusion of this research along with recommendations for future research.

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