UNIVERSITI PUTRA MALAYSIA

OPTIMIZATION OF TWO-DIMENSIONAL DUAL BEAM SCANNING SYSTEM USING GENETIC ALGORITHMS

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OPTIMIZATION OF TWO-DIMENSIONAL DUAL BEAM SCANNING SYSTEM USING GENETIC ALGORITHMS

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

OPTIMIZATION OF TWO-DIMENSIONAL DUAL BEAM SCANNING SYSTEM USING GENETIC ALGORITHMS

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January 2008

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This thesis presents a new approach to optimize the performance of a dual beam optical scanning system in terms of its scanning combinations and speed, using Genetic Algorithm (GA). The problem has been decomposed into two sub problems; task segregation, where the scanning tasks need to be segregated and assigned for each scanner head, and path planning where the best combinatorial paths for each scanner are determined in order to minimize the total motion of scanning time. The knowledge acquired by the process is interpreted and mapped into vectors, which are kept in the database and used by the system to guide its reasoning process. Also, this research involves in developing a machine-learning system and program via genetic algorithm that is capable of performing independent learning capability and optimization for scanning sequence using novel GA operators. The main motivation for this research is to introduce and evaluate an advance new customized GA. Comparison results of different combinatorial operators, and tests with different probability factors are shown. Also, proposed are the new modifications to existing genetic operator called DPPC (Dynamic Pre-Populated Crossover) together with modification of a simple method of representation, called MLR (Multi-Layered Representation). In addition, the performance of the new operators called GA_INSP (GA Inspection Module), DTC (Dynamic Tuning Crossover), and BCS (Bi-Cycle Selection Method) for a better evolutionary approach to the time-based problem has been discussed in the thesis. The simulation results indicate that the algorithm is able to segregate and assign the tasks for each scanning head and also able to find the shortest scanning path for different types of objects coordination. Besides that, the implementation of the new genetic operators helps to converge faster and produce better results. The representation approach has been implemented via a computer program in order to achieve optimized scanning performance. This algorithm has been tested and implemented successfully via a dual beam optical scanning system.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENGOPTIMUMAN SISTEM PENGIMBAS DWI ALUR DUA-DIMENSI MENGGUNAKAN ALGORITMA GENETIK

Oleh

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January 2008

Pengerusi: **Professor Madya Ishak bin Aris, PhD**

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Tesis ini memperkenalkan satu langkah baru untuk mengoptimakan prestasi sistem pengimbas dwi-alur optikal dalam kombinasi imbasan dan kepantasannya menggunakan algoritma genetik. Kerumitan projek telah diasingkan kepada dua pecahan masalah; pengasingan tugasan, di mana tugasan imbasan perlu diasingkan dan diagihkan kepada setiap modul pengimbas, begitu juga dengan pelan gerakan di mana kombinasi gerakan terbaik untuk setiap pengimbas akan ditentukan untuk tujuan meminimakan jumlah masa pergerakan imbasan. Sebahagian daripada kajian ini membabitkan pembangunan sistem mesin-belajar dan program melalui algoritma genetik yang berupaya untuk menunjukkan kebolehan untuk belajar secara tersendiri dan pengoptimuman tatasusun imbasan menggunakan operator-operator baru genetik. Motivasi utama kajian ini adalah untuk memperkenal dan menilai cara terbaru algoritma terkhusus. Keputusan perbandingan untuk pelbagai operator kombinatorial dan ujian-ujian dengan pelbagai faktor kebarangkalian telah

ditunjukkan. Begitu juga yang dicadangkan adalah modifikasi baru kepada operator genetik yang sedia ada dinamakan “DPPC (Dynamic Pre-Populated Crossover)”, dan modifikasi kepada cara mudah untuk mewakili penyelesaian, dinamakan “MLR (Multi-Layered Representation)”. Tambahan, prestasi untuk operator-operator baru dinamakan “GA_INSP (GA Inspection Module)”, “DTC (Dynamic-Tuning Crossover)” dan “BCS (Bi-Cycle Selection Method)”, untuk langkah evolusi yang lebih baik bagi masalah berasaskan masa tersebut telah dibincangkan dalam tesis ini. Keputusan simulasi menunjukkan algoritma tersebut berupaya mengasingkan dan mengagihkan tugas-tugas untuk setiap modul pengimbas dan juga berupaya untuk mencari gerakan imbasan yang terpendek untuk berlainan jenis koordinasi objek. Selain itu, penggunaan operator-operator genetik baru membantu keputusan yang baik diperolehi dengan cepat. Langkah perwakilan ini telah diimplementasi melalui program komputer untuk tujuan mencapai prestasi yang optima. Algoritma ini telah diuji dan berjaya diimplementasi menggunakan modul pengimbas dwi-alur optikal.

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It is my hope that this thesis would contribute to the organizations in furthering their research.

I certify that an Examination Committee has met on 10th January 2008 to conduct the final examination of Johnny Koh Siaw Paw on his Doctor of Philosophy thesis entitled "Optimization of Two-Dimensional Dual Beam Scanning System Using Genetic Algorithms" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the degree of Doctor of Philoshophy.

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

____

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
BCS	Bi-Cycle Selection
DCGA	Dynamic Characterized Genetic Algorithm
DFC	Dynamic Fixed Crossover
DIST	Distance
DPPC	Dynamic Pre-Populated Crossover
DSGA	Dynamic Search Genetic Algorithm
DTC	Dynamic Tuning Crossover
DTSP	Dual Travelling Salesmen Problem
EA	Evolutionary Algorithm
GA	Genetic Algorithm
GA_INSP	Genetic Algorithm Inspection Loop
GRGA	Generational Replacement Genetic Algorithm
GUI	Graphical User Interface
LK	Lin-Kernighan Algorithm
MLR	Multi-Layered Representation
MST	Minimum Spanning Tree
NN	Nearest-Neighbour Heuristic
OPT	Optimal
PC	Personal Computer
SHGA	Standard Hybrid Genetic Algorithm
SSGA	Steady State Genetic Algorithm
TSP	Travelling Salesman Problem

CHAPTER 1

INTRODUCTION

1.1 Introduction

Malaysia's dynamic industrialization has been realized in part by advances in science and technology, both acquired through technology transfer or through local innovations. Thus, the national awareness and interest in science and technology must be enhanced, as this constitutes a prerequisite for an inventing society. Inventing is a suitable approach to help make science and technology more interesting and relevant to the Malaysia industries and onwards towards the economy at large. The spirit of inventiveness should be inculcated among Malaysians.

There are various types of inventions ranging from the simple to extremely complex based on its functionality and needs by the various industries. One of the quite prominent types of inventing is machine invention. In this era of rapid industrialization, machines and artificial intelligence have certainly played a very important role not only in minimizing and easing the workers work burden but also to the extent of increasing productivity without compromising on products' quality. This reality has certainly brought prosperity to many countries such as the Western countries and in the East, Japan and Korea, which machine technology and the usage of artificial intelligence has transformed the industrial landscapes by leaps and bounds. In order to "mimic" this significant achievement especially by the Asian industrial powerhouses, Malaysia had launched the "Look East" policy in which it is hoped that cooperation with these countries can and have resulted in the transfer of vital technologies especially in factory automation.

Malaysia has progressed tremendously since its independence nearly fifty years until today. Many Malaysian skilled and semi-skilled workers have benefited from programmes where technology transfer is involved especially during the period of the Look East policy. Many Malaysia industrial conglomerates have utilized the spin-offs from this transfer of technology and have created a local industrial base. One such company is HICOM Sdn. Bhd which concentrates on the automotive industrial and shipbuilding.

Even though artificial intelligence (AI) and automation systems are not new in Malaysia, there is a dearth of statistical information and data collated as to the design and development of AI-based machine systems here. In Malaysia, the industrial environment is undergoing rapid changes. With the development of new system and technologies, new ways or methods of solving workflow problems are being introduced. Besides practicing the system analysis methodologies in problem solving and heuristics, technologies for material handlings such as automation is of great importance as well. It is therefore vital for Malaysian entrepreneurs not only to know, adopt and adapt this technology but also be able to invent the related functional technology in enhancing its production.

Vision 2020 recognises the importance of AI and automation and the government is calling on local retailers and distributor to implement this system. Among the steps includes the licensing of companies like Pentamaster Sdn. Bhd., and Intellogic Sdn. Bhd. to provide machines to local industries. However, this only contributes a small percentage of automation systems implementation in Malaysian industries.

A decade ago the prediction was that AI machines would begin to grow in popularity about the year 2000. This was after the general public as well as engineers and scientists have learned to routinely accept AI-based machines in their work environments. Today, the primary driving force behind research in AI-based machines is based on lowering their per-unit costs, optimizing their performance as well simplifying their working operations.

Several types of approaches have been taken to optimize the performance of these industrial machines. When solving search problems with computers, a common approach is to calculate every possible solution and then choose the best of those as the answer. Unfortunately, some problems have such large solution spaces that this it is practically impossible to do so. These are the problems where the solution set grows exponentially with the amount of inputs. These problems are referred to as n-p hard or n-p complete problems.

Several approaches have been taken towards providing a solution to these problems such as heuristic approaches, fuzzy logics, ant colony optimizations, simulated annealing, genetic algorithms and neural networks. These approaches would not always result in finding the true optimal solution but rather would often consistently arrive at good solutions to the problem. These good solutions are typically considered to be the optimal simply because they are the best that can be found.

1.2 Problem Statement

Currently, most of the companies in Malaysia have to import and use ready-made application-specific laser systems, primarily for cutting, marking, engraving and welding applications in the manufacturing environment. The single-beam laser scanner has been commonly used for these applications. Due to increasing productivity and reducing its development cost, the dual beam laser scanner has been introduced. In the absolute majority of cases the imported dual beam laser systems are narrowly specialized and inflexible as they can only perform independent scanning operation. The proposed laser system is expected to overcome major limitations inherited in the currently locally available ones. The new system would be more flexible in terms of its scanning control as each of the scanning head in the proposed dual beam scanner system is able to work together intelligently.

The number of possible solutions increases exponentially with the number of objects to be scanned. Thus, it is hardly to be solved using normal means such as random method. This system would adopt the advantages of genetic algorithm to optimize the system performance in terms of its operating speed. In addition, optical error compensation would be introduced. In overall the system would provide higher precision and better marking quality at high scanning speed.

The problem can be stated as: Given two scanning heads H_1 and H_2, a set of known fixed objects coordinates with the initial and final configurations of H_1 and H_2, find a coordinated motion plan for the scanning head from their initial configuration to their final configuration, optimizing the overall time taken for the dual beam optical scanning system as shown in Figure 1.1.

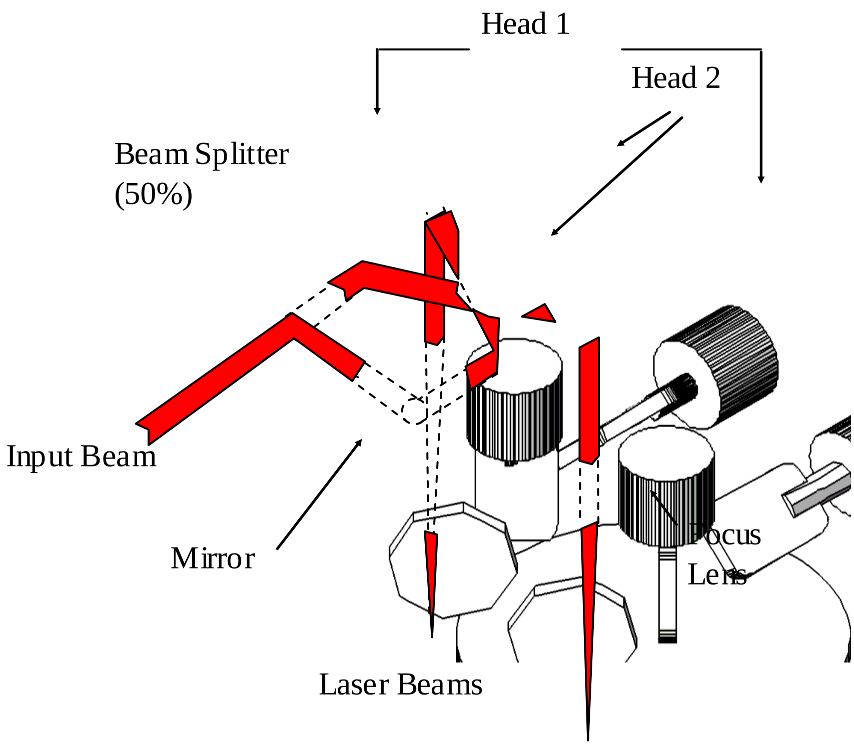

Figure 1.1: Two-Dimensional Dual Beam Optical Scanner

To give an idea of the complexity of the problem, lets consider a number of *n* coordination points and two origin points for each scanning head fixed at positions (x_1,y_1) and (x_2,y_2). The solution adopted here is to consider variable-length chromosomes. The length of the chromosomes, h_1 and h_2 define the number of synchronization points of the sequence for each scanning head where $h_1+h_2 = n$. The number of potential solutions, q for this problem can then be computed as in Equation 1.1, where m is integer number from $0,1,2,3,.....,n$.

$$q = \sum_{m=0}^{m=n} (n-m)!\, m! \tag{1.1}$$

Each solution for this problem can be obtained as two random successions of synchronization points in such a way that a synchronization point is the pair (x_i, y_i) coordinate and the probability, b for each solution is given in Equation 1.2, where C is the combination possibility.

$$b = \sum_{m=0}^{m=n} {}^{n}C_{m}\, (½)^{m}\, (½)^{n-m} \tag{1.2}$$

In the case of the h-scanning head with n number of coordination points, the number of possible solutions is given in Table 1.1.

Table 1.1: Number of Possible Solutions

No of Objects (n)	No of Scanning Head (h) 1	2
5	120	312
10	3628800	8254080
50	3.04E+64	6.21E+64