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A project report submitted in partial fulfilment of the
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FEBRUARY 2024

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ACKNOWLEDGEMENT

In preparing this thesis, 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, Professor Dr. Mohd Shariff Nabi Baksh, for encouragement, guidance, critics and friendship. I am also very thankful to my co-supervisor Professor Dr Awaluddin Mohd Shaharoun and Associate Professor Dr. Hishamuddin Jamaluddin for their guidance, advices and motivation. Without their continued support and interest, this thesis would not have been the same as presented here.

I am also indebted to Universiti Teknologi Malaysia (UTM) for funding my Ph.D study. Librarians at UTM, Cardiff University of Wales and the National University of Singapore also deserve special thanks for their assistance in supplying the relevant literatures.

My fellow postgraduate student 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 member.

ABSTRACT

The purpose of this study is to investigate the application of genetic algorithm (GA) in modelling linear and non-linear dynamic systems and develop an alternative model structure selection algorithm based on GA. Orthogonal least square (OLS), a gradient descent method was used as the benchmark for the proposed algorithm. A model structure selection based on modified genetic algorithm (MGA) has been proposed in this study to reduce problems of premature convergence in simple GA (SGA). The effect of different combinations of MGA operators on the performance of the developed model was studied and the effectiveness and shortcomings of MGA were highlighted. Results were compared between SGA, MGA and benchmark OLS method. It was discovered that with similar number of dynamic terms, in most cases, MGA performs better than SGA in terms of exploring potential solution and outperformed the OLS algorithm in terms of selected number of terms and predictive accuracy. In addition, the use of local search with MGA for fine-tuning the algorithm was also proposed and investigated, named as memetic algorithm (MA). Simulation results demonstrated that in most cases, MA is able to produce an adequate and parsimonious model that can satisfy the model validation tests with significant advantages over OLS, SGA and MGA methods. Furthermore, the case studies on identification of multivariable systems based on real experiment t al data from two systems namely a turbo alternator and a continuous stirred tank reactor showed that the proposed algorithm could be used as an alternative to adequately identify adequate and parsimonious models for those systems. Abstract must be bilingual. For a thesis written in Bahasa Melayu, the abstract must first be written in Bahasa Melayu and followed by the English translation. If the thesis is written in English, the abstract must be written in English and followed by the translation in Bahasa Melayu. The abstract should be brief, written in one paragraph and not exceed one (1) page. An abstract is different from synopsis or summary of a thesis. It should states the field of study, problem definition, methodology adopted, research process, results obtained and conclusion of the research. The abstract can be written using single or one and a half spacing. Example can be seen in Appendix 1 (Bahasa Melayu) and Appendix J

ABSTRAK

Kajian ini dilakukan bertujuan mengkaji penggunaan algoritma genetik (GA) dalam pemodelan sistem dinamik linear dan tak linear dan membangunkan kaedah alternatif bagi pcmilihan struktur model menggunakan GA. Algorithma kuasa dua terkecil ortogon (OLS), satu kaedah penurunan kecerunan digunakan sebagai bandingan bagi kaedah yang dicadangkan. Pcmilihan struktur model mengunakan kaedah algoritma genetik yang diubahsuai (MGA) dicadangkan dalam kajian ini bagi mengurangkan masalah konvergens pramatang dalam algoritma genetik mudah (SGA). Kesan penggunaan gabungan operator MGA yang berbeza ke atas prestasi model yang terbentuk dikaji dan keberkesanan serta kekurangan MGA diu t arakan. Kajian simulasi dilakukan untuk membanding SGA, MGA dan OLS. Dengan meggunakan bilangan parametcr dinamik yang setara kajian ini mendapati, dalam kebanyakan kes, prestasi MGA adalah lebih baik daripada SGA dalam mencari penyelesaian yang berpotensi dan lebih berkebolehan daripada OLS dalam menentukan bilangan sebutan yang dipilih dan ketcpatan ramalan. Di samping itu, penggunaan carian tcmpatan dalam MGA untuk menambah baik algorithma tersebut dicadang dan dikaji, dinamai sebagai algoritma mcmetic (MA). Hasil simulasi menunjukkan, dalam kebanyakan kes, MA berkeupayaan menghasilkan model yang bersesuaian dan parsimoni dan mcmenuhi ujian pengsahihan model di samping mcmperolehi beberapa kelebihan dibandingkan dengan kaedah OLS, SGA dan MGA. Tambahan pula, kajian kes untuk sistcm berbilang pcmbolehubah menggunakan data eksperimental sebenar daripada dua sistem iaitu sistem pengulang-alik turbo dan reaktor teraduk berterusan menunjukkan algoritma ini boleh digunakan sebagai alternatif untuk mcmperolehi model termudah yang memadai bagi sistcm tersebut.

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LIST OF TABLES

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LIST OF ABBREVIATIONS

ANN	-	Artificial Neural Network
GA	-	Genetic Algorithm
PSO	-	Particle Swarm Optimization
MTS	-	Mahalanobis Taguchi System
MD	-	Mahalanobis Distance
TM	-	Taguchi Method
UTM	-	Universiti Teknologi Malaysia
XML	-	Extensible Markup Language
ANN	-	Artificial Neural Network
GA	-	Genetic Algorithm
PSO	-	Particle Swarm Optimization

LIST OF SYMBOLS

δ	-	Minimal error
D, d	-	Diameter
F	-	Force
v	-	Velocity
p	-	Pressure
I	-	Moment of Inersia
r	-	Radius
Re	-	Reynold Number

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Problem Background

Video provides a powerful way to help you prove your point. When you click Online Video, you can paste in the embed code for the video you want to add. You can also type a keyword to search online for the video that best fits your document. To make your document look professionally produced, Word provides header, footer, cover page, and text box designs that complement each other. For example, you can add a matching cover page, header, and sidebar. *"For the first paragraph, use 'Para 2 lines' style"*

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1.2 Problem Background

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1.3 Problem Statement

1.4 Research Goal

1.4.1 Research Objectives

The objectives of the research are :

(a) To estimate the parameters

(b) Item 1

(c) Item 2

(d) To define the best parameter estimate.

1.5 Captions

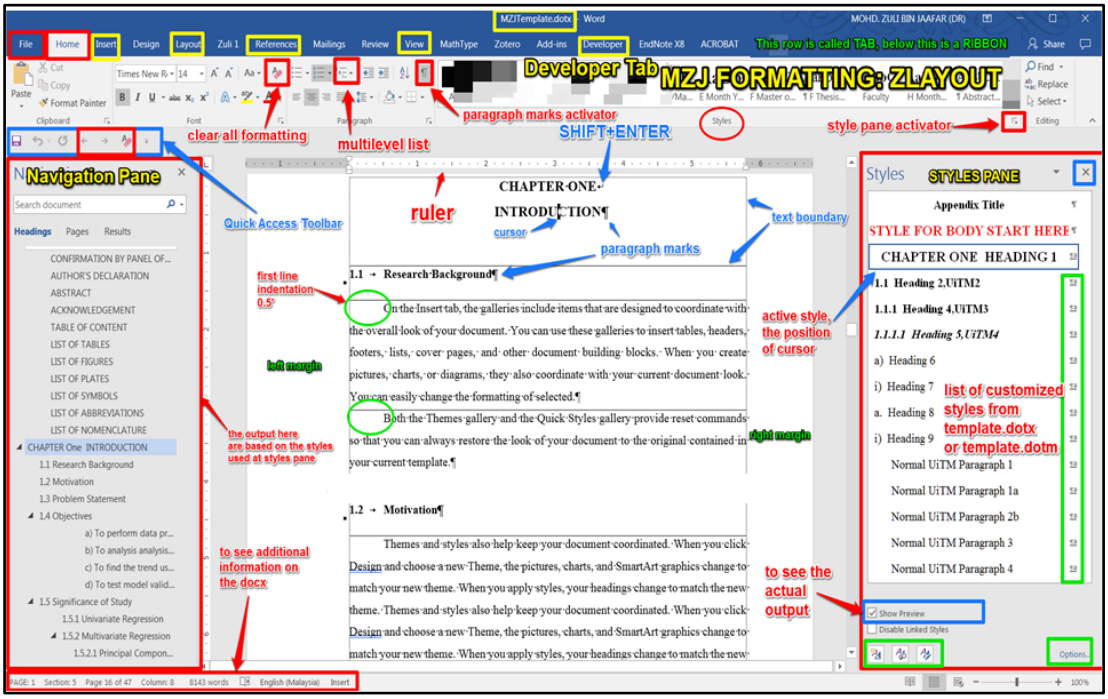

Figure 1.1 Trends leading to the problem using MZJ Formatting Method

(If the caption is written in a single line, use Caption for Figure UTM)

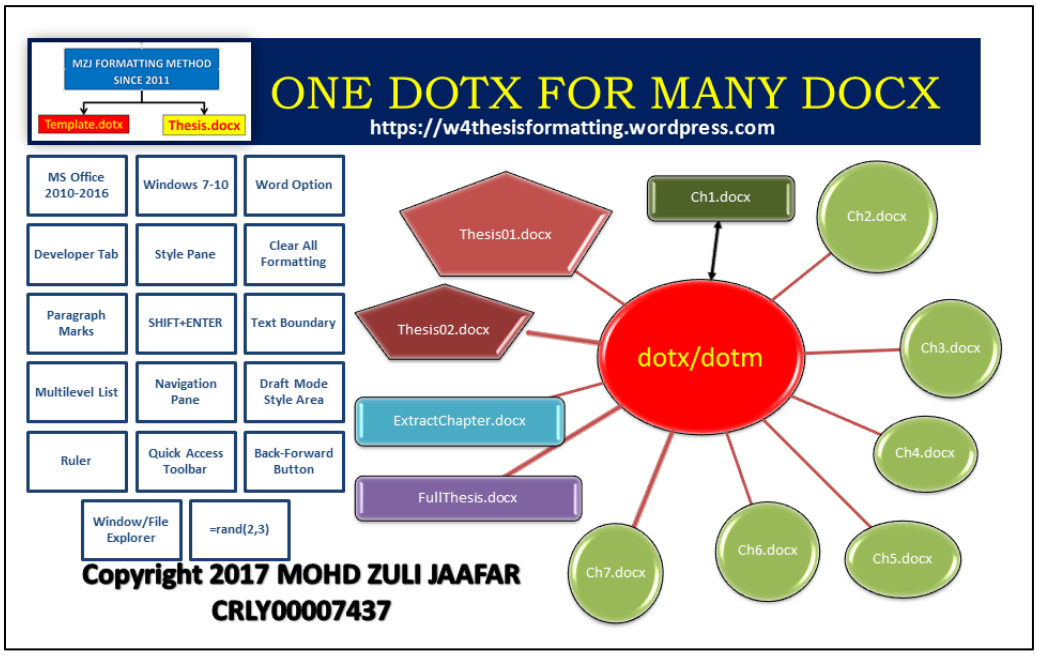

Figure 1.2 Design and development phases of the proposed scheme (Muhamad, 2018)

(If the caption is written more than one line, use Caption for Figure UTM 2 line)

Table 1.1 The role of statistical quality engineering tools and methodologies

(If the caption is written in a single line, use Caption for Table UTM)

Table 1.2 Basic ANN models used for control chart pattern recognition

(If the caption is written more than one line, use Caption for Table UTM 2 line)

1.6 Quotation

After deliberating on doctoral education in Australia in the 1990s, one observer I Australia writes:

> The lack of any significant formal course work within our Ph.D. and master degrees by research has continued for three decades. The focus of our Ph.D. research type degrees continues to be the research project, and this is almost the only medium by which education is accomplished.
>
> (Stranks, 1984:171)

1.7 Equation

$$y = mx + c \tag{1.1}$$

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

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2.1.1 State-of-the-Arts

2.2 Limitation

2.3 Research Gap

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CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

On the Insert tab, the galleries include items that are designed to coordinate with the overall look of your document. You can use these galleries to insert tables, headers, footers, lists, cover pages, and other document building blocks. When you create pictures, charts, or diagrams, they also coordinate with your current document look. You can easily change the formatting of selected text in the document text by choosing a look for the selected text from the Quick Styles gallery on the Home tab.

3.1.1 Proposed Method

On the Insert tab, the galleries include items that are designed to coordinate with the overall look of your document. You can use these galleries to insert tables, headers, footers, lists, cover pages, and other document building blocks. When you create pictures, charts, or diagrams, they also coordinate with your current document look. You can easily change the formatting of selected text in the document text by choosing a look for the selected text from the Quick Styles gallery on the Home tab.

3.1.1.1 Research Activities

On the Insert tab, the galleries include items that are designed to coordinate with the overall look of your document. You can use these galleries to insert tables, headers, footers, lists, cover pages, and other document building blocks. When you create pictures, charts, or diagrams, they also coordinate with your current document

look. You can easily change the formatting of selected text in the document text by choosing a look for the selected text from the Quick Styles gallery on the Home tab.

3.2 Tools and Platforms

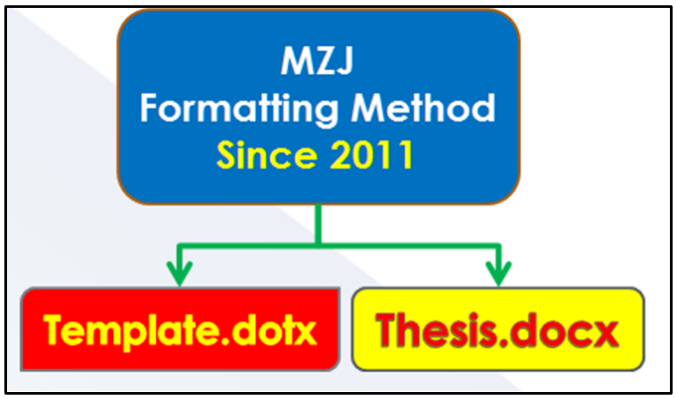

Figure 3.1 Example of Formatting Method

3.3 Chapter Summary

(a) Video provides a powerful way to help you prove your point.

(b) When you click Online Video, you can paste in the embed code for the video you want to add.

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(e) For example, you can add a matching cover page, header, and sidebar.

CHAPTER 4

PROPOSED WORK

4.1 The Big Picture

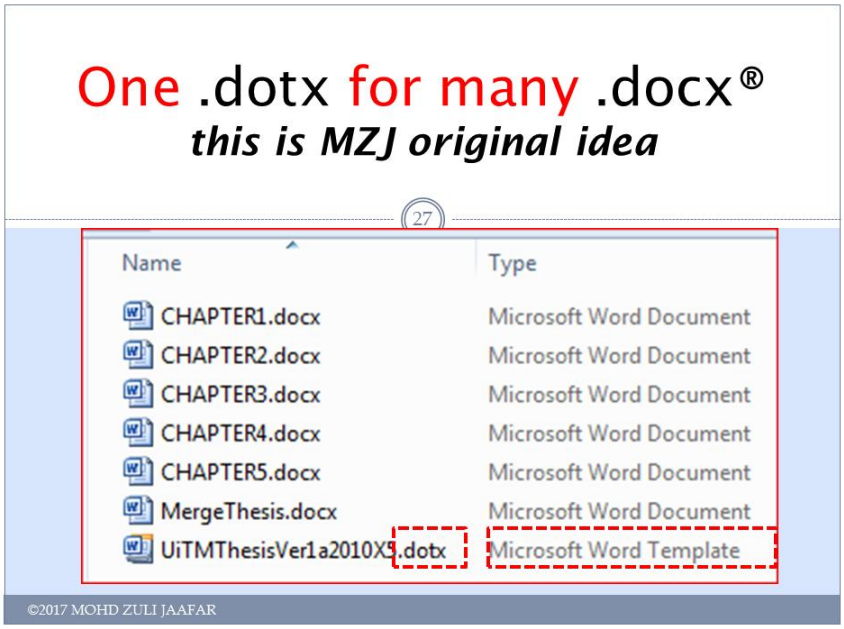

Figure 4.1 This is MZJ original idea

4.2 Analytical Proofs

(a) Video provides a powerful way to help you prove your point[1]

[1]Mary Duncan Carterand Rose Mary Magrill, “Building Library Collections" Fourth edition. (Metuchen, N. J.: Scarecrow Press, 1974), pp.61 - 66.

(b) When you click Online Video, you can paste in the embed code for the video you want to add.

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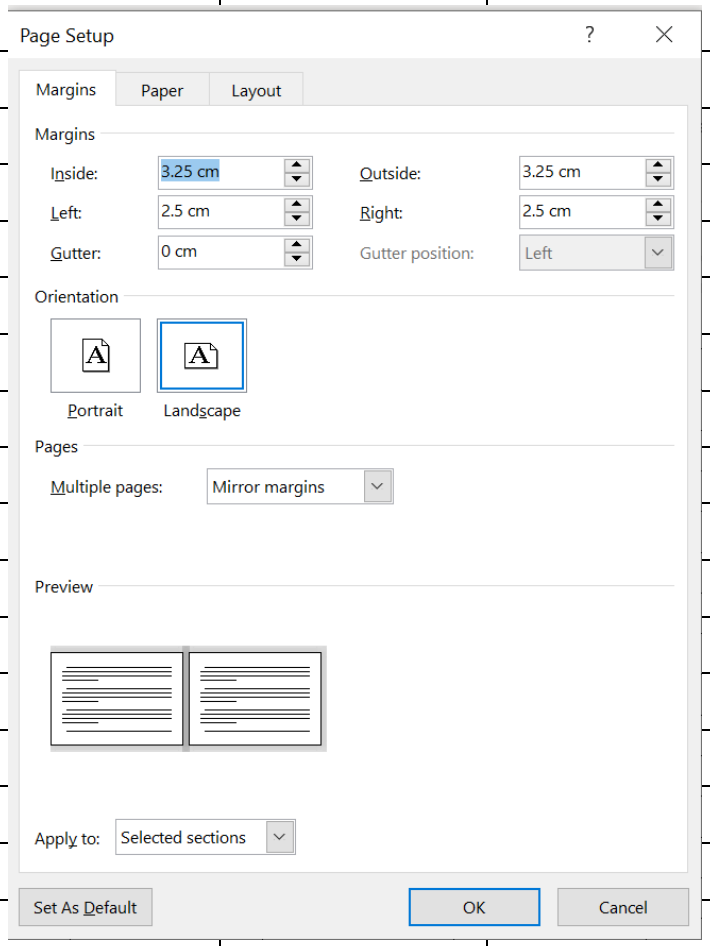
(e) For example, you can add a matching cover page, header, and sidebar.

4.3 Result and Discussion

Figure 4.2 The method for hig performance formatting

4.4 Chapter Summary

Title	Title	Title	Title	Title	Title	Title



CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Research Outcomes

5.2 Contributions to Knowledge

5.3 Future Works

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Table 5.1 Example Repeated Header Table

Title	Title	Title	Title

Title	Title	Title	Title

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Appendix A Mathematical Proofs

Appendix B Psuedo Code

Appendix C Time-series Results Long Long Long Long Long Long Long Long Long Long

LIST OF PUBLICATIONS

Journal Articles

Qasem, S. N., Shamsuddin, S. M., Hashim, S. Z. M., Darus, M., & AlShammari, E. (2013). Memetic multiobjective particle swarm optimization based radial basis function network for classification problems. Information Sciences, 239, 165–190. https://doi.org/10.1016/j.ins.2013.03.021. (Q1, IF: 4.305)

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Conference Proceedings

Muhamad, W. Z. A. W., Jamaludin, K. R., Ramlie, F., Harudin, N., & Jaafar, N. N. (2017). Criteria selection for MBA programme based on the mahalanobis Taguchi system and the Kanri Distance Calculator. In 2017 IEEE 15th Student Conference on Research and Development (SCOReD) (pp. 220–223). IEEE. https://doi.org/10.1109/SCORED.2017.8305390. (Indexed by SCOPUS).