SPIRAL DYNAMIC OPTIMIZATION ALGORITHM FOR ENGINEERING APPLICATION

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DECLARATION

I declare that this thesis entitled "SPIRAL DYNAMIC OPTIMIZATION ALGORITHM FOR ENGINEERING APPLICATION is the result of my own research except as cited in the 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 checked this report entitled "SPIRAL DYNAMIC OPTIMIZATION ALGORITHM FOR ENGINEERING APPLICATION" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature : .....

Supervisor Name : .....

Date : .....

DEDICATIONS

I am grateful to Allah SWT, my creator, my strong pillar, my source of inspiration, wisdom, knowledge and understanding. Never forget, peace and prayers to the Prophet Muhammad s.a.w. I also dedicate this work to my lovely father, Shamshol Ali Bin Abdul Rahim and appreciated mother, Robaee Binti Md Salleh who has encouraged me all the way and whose encouragement has made sure that I give it all it takes to finish that which I have started. To all my sister; Nur Ayunni, Nur Aimii and Nur Aqilah who have been affected in every way possible by this quest. Thank you. My love for you all can never be quantified. God bless you.

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ABSTRACT

This project presents the optimization technique. Optimization of a design could be simply to minimize the cost of production or to maximize the efficiency of production. While in optimization algorithm is a strategy to find the best or an optimal solution for any real world problem such as engineering problem. This project is focused on Spiral Dynamic Optimization Algorithm (SDA) which is a natured-inspired metaheuristic concept. The algorithm was inspired by spiral phenomena in nature that commonly found in nautilis shells, whirling currents and spiral galaxy. In SDA has two specific setting parameter which are the convergence rate and the rotation rate whose values shows its trajectory. The common centre of trajectory is the best point in all search points. The search points moving toward the common centre with logarithmic spiral trajectories [1]. The algorithm is tested using several benchmark functions and is used to optimize the PI, PD and PID controller of a flexible manipulator system. The results show that the algorithm surpass the SDA and is able to tune the controller parameter to their optimum value.

ABSTRAK

Projek ini membentangkan teknik pengoptimuman. Pengoptimuman reka bentuk boleh jadi semata-mata untuk meminimumkan kos pengeluaran atau untuk memaksimumkan kecekapan pengeluaran. Algoritma pengoptimuman adalah strategi untuk mencari penyelesaian terbaik atau penyelesaian yang optimum untuk masalah dunia sebenar seperti masalah kejuruteraan. Projek ini difokuskan pada Algoritma Pengoptimuman Dynamik Spiral (SDA) yang merupakan konsep metaheuristik. Algoritma ini diilhamkan oleh fenomena lingkaran dalam alam yang biasa dijumpai dalam kerang nautilus, arus berputar dan galaksi spiral. Dalam SDA mempunyai dua parameter penetapan khusus yang merupakan kadar penumpuan dan kadar putaran yang menunjukkan trajektorinya. Pusat trajektori umum adalah titik terbaik di semua titik carian. Titik carian yang bergerak ke arah pusat bersama dengan trajektori logaritmik. Algoritma diuji menggunakan beberapa fungsi penanda aras dan digunakan untuk mengoptimumkan pengawal PI, PD dan PID sistem manipulator yang fleksibel. Keputusan menunjukkan bahawa algoritma SDA dapat diselarikan dengan parameter pengawal ke nilai optimum.

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LIST OF SYMBOLS AND ABBREVIATIONS

SDA	-	Spiral Dynamic Algorithm
D	-	Dimension
Np	-	Number Of Points
I	-	Iteration
Kp	-	Propotional gain
Ki	-	Integral gain
Kd	-	Derivative gain
PI	-	Propotional-integral
PD	-	Propotional-derivative
PID	-	Propotional-derivative-integral

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CHAPTER 1

INTRODUCTION

1.1 Background

Optimization is a wide, fast and interdisciplinary research area, whose knowledge topics such as mathematics, computer science and art is required. In optimization issues, it is a method which is executed iteratively by comparing various solutions until an optimum or a good solution is found. For example, in the mathematics , it is a way to find a minimum and maximum solution of a certain mathematical function with or without the presence of a constrain such as boundary or the solution. While in computing, it is the process of modifying a system to make some features of it work more efficiently or use a few resources.The optimization can have sense at different levels, from the lowest (development of circuits, writing of machine code designed especially for the architecture) up to the highest levels of making of implementation, use or design of algorithms.

In the context of problem-solving application, optimization is seen as a method to find the best or an optimum solution for a given world problem or whatever, which is naturally more complex and challenging [2]. As always, the solutions found by the optimization algorithm is decisive solution and practically can be used to achieve good result. Furthermore, the number of dimensions is high in problems and incorporation of objective functions also increase the difficulty of finding an optimum solution for the problem. Therefore, there is a need for further research to find a better optimization strategy in order to achieve a good result. In real world optimization, there could be more than one objective that the designer may want to optimize simultaneously. The multiple objective optimization algorithms are complex and computationally expensive. Therefore the most important objective is chosen as the objective function and the other objectives are included as constraints by restricting their values within a certain range.

Metaheuristic optimization algorithms have gained a lot of interest between world researchers. These algorithms are inspired from biological phenomena or natural phenomena. Algorithms that based on natural are such as firefly optimization algorithm , galaxy-based search algorithm and spiral dynamics inspired optimization (SDA)[3] . The SDA is a metaheuristic algorithm inspired from spiral phenomena in nature such as tornado, nautilus shell, low pressure fronts, spiral of waves and galaxy. Spiral dynamic algorithm has a simple structure compared to other algorithms, hence the total computation time to complete the entire search process is relatively short and easy to program[2]. Spiral dynamic algorithm applies diversification in early stage of the search where the aim is to find better solution in a large area during exploration. Spiral dynamic algorithm will perform the search for better possible solution around good solution found during exploration phase. This intensive search toward best possible solution is called intensification. The main component of spiral dynamic algorithm is a spiral model, which can determine the shape, and characteristic of a spiral. It has two specific setting parameters : the convergence rate and the rotation rate whose values characterize its trajectory. The common centre is defined as the best point in all search points. The search points moving toward the common centre with logarithmic spiral trajectories can find better solutions and update the common centre [4].

1.2 Project Motivation

Nowdays, there are many method to solve any problem one of them by using optimization method such as optimization spiral dynamic optimization algorithm. The main aim of the research is to investigate the concept of Spiral Dynamic Algorithm on how it find the best optimal value and to solve engineering problems.The flexible manipulator system is selected as the target application and platform to test the performance of the algorithm. The algorithm is tested using several benchmark functions and is used to optimize the PI, PD and PID controller of a FMS.

1.3 Problem Statement

There a lot of method to be used in solving a problems such as " try and error" method but it is not guarantee to solve it. There are some example that have faced on daily life such as in business optimization need to measure the efficiency, productivity and performance of a business while in mathematical optimization need to find a minimum or maximum solution of a certain mathematical function. So by using SDA it can help to solve that problem. The problem that related to this research which is to find the optimum value that can be practically use to achieve a good outcome.

1.4 Objectives

The objectives of this project are:

1. To investigate the performance of the SDA with various parameter setting by using 10 numerical benchmark functions.
2. To investigate the most suitable controller for flexible manipulator based on error criteria.
3. To investigate the performance of SDA with various parameter setting in tuning propotional-integral-derivative (PID) based on error criteria for application flexible manipulator system

1.5 Scope Of Research

This project is focused on the investigating the performance of the SDA with parameter setting by using 10 numerical benchmark function. Performances of the algorithm that will statistically analyze in terms of convergence speed that will graphically presented. Then, spiral dynamic optimization algorithms will be discussed with applications to various domains. An important aspect of the optimization algorithm is its parameter set, which needs careful analysis for deployment in various domains such as its effectiveness as an optimization technique and applications to engineering problems. Flexible manipulator system is selected as the target application and platform to test the performance of the algorithm. It has been chosen to investigate the most suitable controller with different error criteria. Three common controller been

used in this research are PI, PD and PID controller that will be tuned with different error criteria. The performance of SDA with parameter setting in tuning propotional-integral-derivative (PID) with error criteria for application flexible manipulator system also in scope of research. The performance of SDA are graphically presented.

1.6 Report Outline

A brief description of this report is described in this section. Generally, this report contains five chapters in total and all these chapters will deliver the overall information about this report, consequently.

The first chapter of this report will contain the introduction of this project. The overall idea of the project is briefly explained in this chapter.

This second chapter in this report will deliver the information on literature review of this project. This previous work related to the project will be analyzed in detail as guideline to improve the current project so that it will be much better.

The third chapter in this report will explain about the methodology that is being implemented to execute this project. All the formulas and theory used will be explained in this chapter.

The fourth chapter in this report will show the early results of the progress from the methodology used for this project. The data obtained from the results will be analyzed further to verify either the desired outcome of this project is achieved or not and the results gain will be used for the next phase of the project.

Lastly, the fifth chapter in this report will summarize the overall conclusion obtained from this project. The further work will be planned for the next step of this project and all the references source will be cited in this chapter

CHAPTER 2

LITERATURE REVIEW

2.1 Theory of Meta-Heuristic Algorithm

In recent years, meta-heuristic algorithms have attracted more attention in recognition their versatility and concepts since real-world systems seeking optimization have tended to get greater and more complicated. Most of meta-heuristics are constructed on the analogy of physical phenomena or natural phenomena. Meta-heuristic is a heuristic approach strategy for continuous or discontinuous optimization problems[3]. Two main categories of meta-heuristic algorithm are bio-inspired and nature-inspired algorithms. A bio-inspired algorithm is an optimization algorithm where formulation and philosophy inspired by behavior of living organisms while a nature-inspired algorithm is constructed from natural phenomena other than living organism. Some of bio-inspired algorithm are genetic algorithm that imitate the process of natural and genetic evolution, bacterial foraging algorithm inspired by the natural way of Escherichia coli bacteria searching for food throughout their life cycle, ant colony algorithm adopted from the behavior of ants seeking for food sources through the most effective path, particle swarm optimization based on social behavior of bird flocking and bee colony algorithm that is inspired based on the foraging and swarming behavior of honey bee. Examples of nature-inspired algorithms are chemical reaction optimization, simulated annealing and spiral dynamic algorithm that inspired from spiral phenomena in nature.

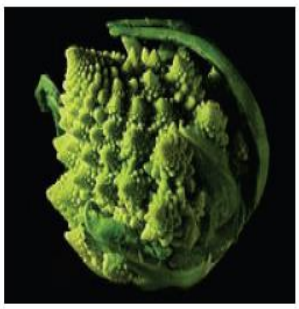
2.1.1 Theory of SDA

K. Tamura and K. Yasuda recently introduced a new metaheuristics method (in 2010) for continuous optimization problems based on analogy of spiral phenomena in nature which is called Spiral Dyamic Algorithm (SDA). Spiral phenomena commonly found on earth and the universe such as nautilus shells, whirling currents (hurricanes and tornados) , shape of DNA molecule and spiral galaxy[2].

a)Nautilus Shell

b)Whirling Currents

c) Spiral Galaxy



d) Romanesco Broccoli

Figure 2.1 : Spiral Shapes In Nature [6]

Spiral dynamic algorithm is relatively simple, easy to program, has relatively low computation time for the whole search operation and it has few parameters on the initialisation thus making it practical and easy to use for real world applications. This algorithm is a multipoint search for continous optimization problems (no objective function gradient).

The spiral dynamic algorithm model is composed of plural logarithmic spiral models and their common centre. In this algorithm as search points follow logarithmic spiral trajectories toward the common center defined as the current best point,better solution can be found and the common centre can be updated. Two important features of spiral dynamic algorithm are the diversification and intensification that occur at the early and final phases of the search operation respectively[5].

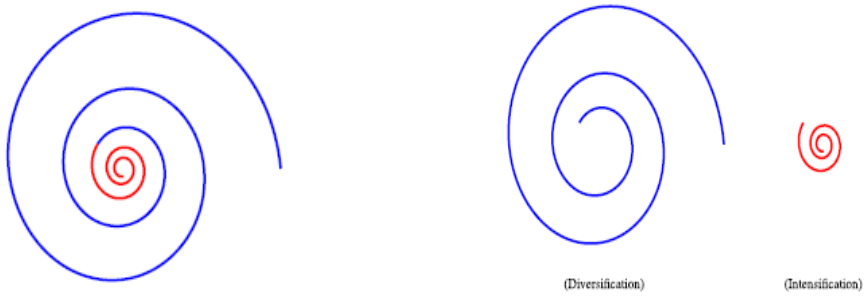


Figure 2.2 : Interpretation Of Logarithmic Spiral [5]

Diversification is the representation of the exploration strategy in which the search point moves from each other to cover the entire search area globally and evaluate the possibility of optimal point locations. Intensification is the strategy searching a better solution by searching around a good solution intensively under a practical concept that better solutions exist around good solutions[7].

Diversification: Searching wide region,

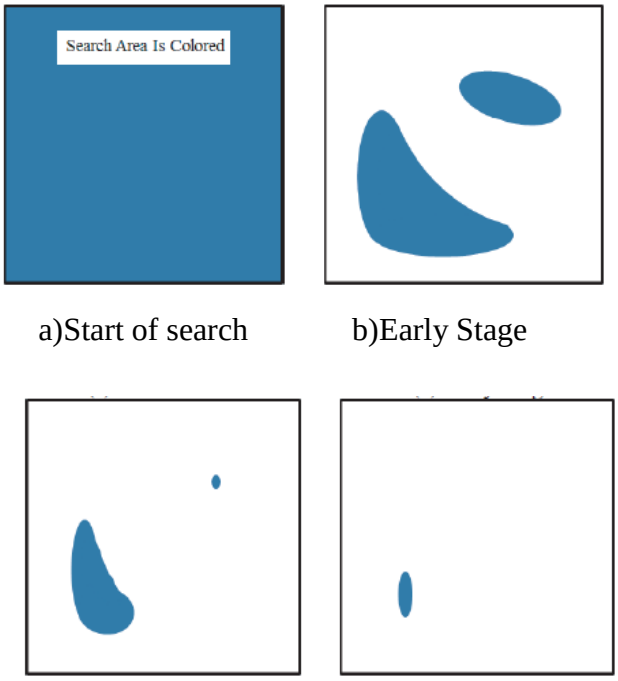
Intensification: Searching limited region.

In general, strategies based on diversification and intensification is carried out as follows:

1) In the beginning, search point moves with the purpose of roughly grasping the tendency of distribution of good solutions by searching wider region in the solution space (Figure 2.3 (a), (b)).

2) In the process of searching, to grasp more concrete tendencies, the search region is narrowed down the region where better region in which better solutions may exist.

Then in the final stage, move search point with the purpose of searching intensively the sufficient of regions to find a better solutions (Figure 2.3 (c), (d)).



a)Start of search b)Early Stage

c)Middle Stage d)Final Stage

Figure 2.3: Search Method [7]

A balance of the diversification and the intensification in the search process is important in searching for better solutions in limited time,which can result to a more accurate solution.

In spiral dynamic algorithm, the two features mentioned above are generated from a important spiral model and its contains two sets of parameter mainly on the speed of the convergence and accuracy of the final solution[2]. The spiral model of spiral dynamic algorithm for *n*-dimension is defined as :

$$x(k+1) = Sn(r,\emptyset)x(k) - (Sn(r,\emptyset) - In)x * \qquad 2.1$$

where x^* is a centre point of spiral, *In* is identity matrix, *x* is a coordinate location of a point, *k* is iteration number and $Sn\ (r,\emptyset) = rR^n(\emptyset_{1,2,}\emptyset_{1.3\ldots}\emptyset_{n,n-1})$. r is a spiral radius, $\emptyset$ is a rotational angle and $R^{(n)}(\emptyset_{1,2}\ \emptyset_{1,3}\ \ldots\ \emptyset_{n,n-1}\ )$is a composition of rotation $n\times n$ matrix. The $R^n(\emptyset_{1,2,}\emptyset_{1.3\ldots}\emptyset_{n,n-1})$ can be represented as:

$$R^n(\emptyset_{1,2,}\emptyset_{1.3\ldots}\emptyset_{n,n-1}) = \prod_{i=1}^{n-1} 1 \left| \prod_{j=1}^{i} R^{(n)}_{n-i,n+1-j}\ (\emptyset_{n-i,n+1-j}) \right| \qquad 2.2$$

Graphical representations of the spiral model with different values of radius, r and angle, θ are shown in Figure 2.4 where represent spiral forms with $r = 0.95$, $\emptyset = pi/4$

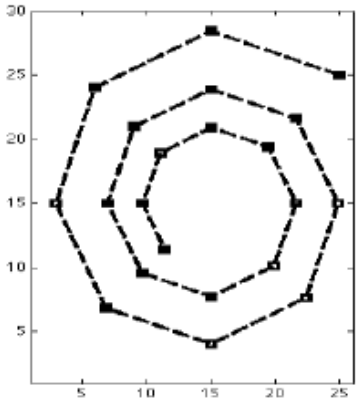


Figure 2.4 : Spiral Forms [5]

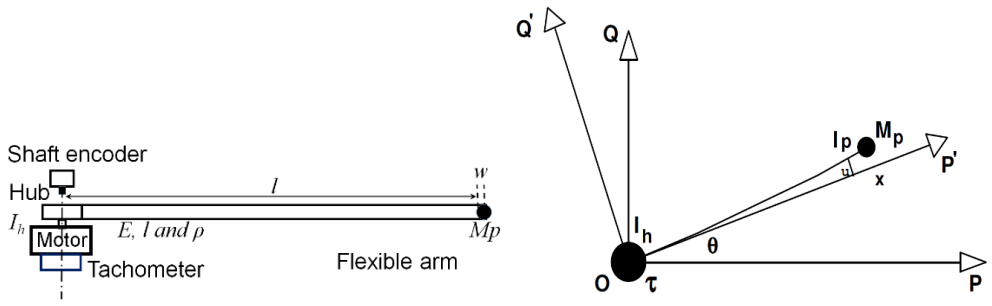
2.2 Theory of Flexible Manipulator System

A schematic diagram of the FMS rig is shown in Figure 2.6 (a) (Azad 1994; Tokhi and Azad, 1997). The system consists of a flexible link made of aluminum beam and attached to an electromechanical motor. The flexible manipulator arm considered in this work is a single-input multi-output system, which is commonly found in the industry [9]. As there are three outputs of interest to be gauged from the system, three different sensor units are incorporated into the system.

An integrated circuit piezoelectric accelerometer is placed at the tip of the beam and used to measure end-point acceleration. The advantages of the sensor are that it is small in size, light in weight, has high voltage sensitivity and low impedance output, which prevent significant amount of signal losses and distortion problems. An encoder with a resolution of 2,048 pulses/revolution and a tachometer are attached to the motor shaft and used to measure hub-angle and hub-velocity respectively. Moreover, a personal computer (PC) embedded with Pentium Celeron 500 MHz processor is connected with PCL818G interfacing unit to the FMS[12].

On the other hand, the schematic representation for the mechanical structure of the FMS is shown in Figure 2.5 (b). The Mp is the payload attached at the tip of the flexible beam, θ is the hub angle or angular displacement , τ is the input torque and u is the elastic deflection of an arbitrary point along the flexible beam. The *POQ* represents the original frame location while the POQ' represents the new frame location when an input torque, τ is applied to the system to rotate with an angle of θ in the X-Y plane.

The input to the system is an analog voltage (motor torque) while the outputs are hub angle, hub velocity and end-point acceleration [12]. Matlab / Simulink software installed in the PC is used as a tool for controlling and manipulation of the system. The physical parameters and specifications of the flexible manipulator system are shown in Table 2.1.



a) Schematic representation of FMS b) Schematic mechanical model

Figure 2.5 : Flexible Manipulator System [8]