FIREFLY ALGORITHM WITH APPLICATION TO ENGINEERING PROBLEMS

VONG HUI CHON

BACHELOR OF ELECTRICAL ENGINEERING WITH HONOURS
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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VONG HUI CHON

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DECLARATION

I declare that this thesis entitled "FIREFLY ALGORITHM WITH APPLICATION TO ENGINEERING PROBLEMS 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   :   Vong Hui Chon

Date   :

APPROVAL

I hereby declare that I have checked this report entitled "Firefly Algorithm With Application To Engineering Problems" 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

To my beloved mother and father

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ABSTRACT

In order to solve difficult optimization problems, there are many bio-inspired optimization techniques can be used. Firefly algorithm is a natural inspired algorithm that can solve the optimization problems. Firefly algorithm consists some parameter can be controlled, which this may influence the performance of the algorithm. This research is focus on the variation of parameter setting to know the performance of the algorithm. In order to verify and test the performance of Firefly algorithm, benchmark functions can be used. The parameter settings that been varying is the number of dimension, number of population and number of iterations. When the amount of fireflies increases, it will move toward the optimal point. The algorithm will perform better at lower dimension compare to higher dimension. The flexible manipulator system (FMS) is used as application to know the performance of the algorithm. The Firefly Algorithm is used to tune the PID controller with using the performance criteria. The parameters of the PID controller will affect the performance of the flexible manipulator system (FMS). The analysis method is used to analyse the performance of the hub angle of FMS. There are 3 conditions been set to analyse the performance of the hub angle for each performance criteria. The most suitable performance criteria as the objective function of Firefly Algorithm to tune the PID controller been selected.

ABSTRAK

Untuk menyelesaikan masalah pengoptimuman yang sukar, terdapat banyak teknik pengoptimuman yang diilhami bio boleh digunakan. Algoritma Firefly adalah algoritma semulajadi terinspirasi yang boleh menyelesaikan masalah pengoptimuman. Algoritma Firefly terdiri beberapa parameter yang boleh dikawal, yang ini boleh mempengaruhi prestasi algoritma. Kajian ini memberi tumpuan kepada variasi tetapan parameter untuk mengetahui prestasi algoritma. Untuk mengesahkan dan menguji prestasi algoritma Firefly, fungsi penanda aras boleh digunakan. Seting parameter yang bervariasi adalah bilangan dimensi, bilangan populasi dan bilangan lelaran. Apabila jumlah fireflies bertambah, ia akan bergerak ke arah titik optimum. Algoritma akan melakukan lebih baik pada dimensi yang lebih rendah berbanding dengan dimensi yang lebih tinggi. Sistem manipulator fleksibel (FMS) digunakan sebagai aplikasi untuk mengetahui prestasi algoritma. Algoritma Firefly digunakan untuk menala pengawal PID dengan menggunakan kriteria prestasi. Parameter pengawal PID akan mempengaruhi prestasi sistem manipulator fleksibel (FMS). Kaedah analisis digunakan untuk menganalisis prestasi sudut hub FMS. Terdapat 3 syarat yang ditetapkan untuk menganalisis prestasi sudut hub bagi setiap kriteria prestasi. Kriteria prestasi yang paling sesuai sebagai fungsi objektif Algoritma Firefly untuk menyesuaikan pengawal PID telah dipilih.

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FA   -   Firefly Algorithm

FMS   -   Flexible Manipulator System

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CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter discusses briefly the background of firefly algorithm. It is followed by an introduction of motivation, problem statements and objectives of this project. This chapter also present the scopes of this project.

1.2 Research Background

Nowadays, there are many problems which can be formulated to the optimization problem. The main aim of the optimization method is to determine the best possible solution to solve the mathematical function, called objective or fitness functions. Optimization is a process to obtain or find an optimal result to solve the problems such as improve the performance, efficiency and output of the system. The studies about optimization algorithm have been increasing in the field of applied mathematics, computer science and engineering. In the real world, the optimization problems become more complex and difficult, such as multi-objective, discrete, multimodal, nonlinear and many more.

Deterministic and stochastic methods are the major group of optimization methods. Deterministic method is a method that always produces the same set of solution when it is started under the same initial condition. However, the stochastic method is a method that consists one or more components of randomness. For stochastic method, these algorithms may not generate the same optimal solution when it is started with same initial condition and the same problem. For example, the algorithm, making random walks in the search space. More than half of this method is considered as meta-heuristic.

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The majority of stochastic methods are considered as meta-heuristic. Meta-heuristic are guiding the iterative generation process to find a heuristic that provided an efficiently near-optimal solutions. These algorithms are usually inspired by phenomena or the behavior of nature and animal. The advantage of the meta-heuristic method are easy to develop, convergence rate to the global optimum is faster, larger range of application, and many more.

Firefly Algorithm is a stochastic and meta-heuristic optimization algorithm that introduced by Xin-She Yang in 2008. The abdomen of the firefly produce a light called bioluminescence, which function to attract and communicated with other fireflies. However, Firefly algorithm is inspired by the flashing pattern of the firefly which known as nature inspired algorithm. Firefly Algorithm consist random parameter, which it will make a random movement in the search space. By using random search movement method, the global best values will be easier to achieve, so Firefly algorithm is more efficiency and more accuracy.

1.3 Motivation

Firefly Algorithm is stochastic and meta-heuristic algorithm, which have the random properties. This means the algorithm will not get the same set of optimal solution although the algorithm is starting with the same initial condition. So Firefly Algorithm is very interesting when the selectivity of the optimal solution and know how the algorithm work in order to get the optimal solution.

Firefly Algorithm can used the algorithm to tuning the parameters of the proportional-integral-derivative (PID) controller. By using firefly algorithm, the tuning process will converge faster and speed up the tuning of these parameters. This means the algorithm will get the optimal solution with less number of iteration.

The efficiency to find the optimal solution and others advantage of the Firefly Algorithm, which is the motivation to do this project. This algorithm is bio-inspired algorithm which behaviour will be easier to study.

1.4   Problem Statement

In the era of industry 4.0, there are many problems that required to be solve. In order to solve the problem efficiently, the efficient methods in finding the best possible solution need to be established. There are several methods to find the optimal solution. Some of the method is difficult to use, for example in the tuning PID controller. When the problems become complex and getting bigger (large scale such as national system grid), its more difficult to find the best optimal point. Some of the methods required long processing time. So use optimization to find the best possible solution is more effective.

The process of manual tuning is too hard and it can use an optimization algorithm to tune the PID control. It is much better because algorithm can generate thousands of solution and find the best possible solution automatically.

1.5   Objective

In this project, there are 3 objectives going to be achieved:
- To investigate the performance of firefly algorithm with different parameter setting using different numerical benchmark functions.
- To investigate the performance of firefly algorithm with the control of flexible manipulated system (FMS).
- To analyse the performance criteria (error) that suitable for the flexible manipulated system (FMS).

1.6   Scope

The scope of the project is using Matlab 2016a to simulate this project. The specification of the computer is Intel(R) Core(TM) i5-6200U CPU @ 2.30GHz with 4.00GB RAM. After select the suitable algorithm, the pseudo code of the Firefly algorithm can be find. Editing the pseudo code is required to let the algorithm run automatically though 30 independent runs.

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The initial parameter setting must be set before simulate the algorithm. Firefly Algorithm is started to simulate with different parameters setting. The parameter is set to be varying are the number of iteration, number of dimension and number of population. After the result been simulated, the data must be analysed and simulated the convergence plot.

The simulation for the Flexible Manipulated System is used to know the performance of the algorithms. The Firefly Algorithm will tune the PID controller by using the performance criteria in order to get good response of hug angle of the flexible arm. The analysis method been introduce to analyse the performance of the Flexible Manipulator System (FMS).

1.7   Summary

This chapter is to introduce the project about the background, the problem statement, the scope of the project, the motivation and objective of the project. It is the detail and the work that been done in this project.

The next chapter will discuss the understanding of the project which are the basic concept of the algorithm, the related work that been done about the project and others.

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CHAPTER 2

LITERATURE REVIEW

2.1   Optimization

Optimization is a process to determine the best possible solution to solve the problems. As an example of optimization, travelling salesman problem is a problem to find the shortest possible way that going to each town and come back to the origin town. According to N.F. Johari et al. [1], optimization problem is a computational problem which to find the best solution among all the possible solution. In order to solve the problem, more iteration have to carry out. Throughout every iteration, the solution will move toward the optimal point. One of the major inspiring problem in the field of research is optimization [2].

The optimization problems are classified into few categories, which are continuous, combinatorial, constrained, unconstrained, single and multi-objective problems. The combinatorial optimization problem is a discrete optimization problem where the optimal solution can be determine from a finite set of solutions. However, the continuous optimization problem where the optimal solution is any value within the range of values and normally is a real numbers. The constrained optimization problems are the more constraint on the variables but unconstrained optimization problems does not have limitation on the values of the parameters. Multi-objective optimization problem is finding the optimal solution to achieve more than one objective function simultaneously but single objective optimization problem is concern on finding the solution for an objective function.

The optimization techniques can divide into two types, which are exact and heuristic. The exact optimization technique surely will found the optimal solution and it able doing great for many problems. However, exact optimization techniques needed very high computational costs when solving the complex problems or problems with a very large number of parameters.

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There are many real-world problems are complex problem. In order to solve this complex problem, the heuristic optimization techniques can be used. Heuristic optimization techniques uncertain that can found the optimal solution, but it will get very close to the best solution. For high complexity problems, heuristic techniques it will used.

The heuristic techniques that uncertain will get the optimal solution is because the solution is stuck at the local minimum point which unable to find the desired global minimum. M. Jamil stated that the function will stuck at the local minimum point which the algorithm not search effectively because the poor designed of the exploration process of an algorithm [3].

There are optimization algorithm that can be used to solve the problems such as Firefly Algorithm, Particle Swarm Optimization, Artificial Ant Colony Optimization, Artificial Bee Colony Optimization and many more. According to the No Free Lunch Theorem [4] and [5], for certain classes of problems, some of the algorithm is perform excellent but it will outperformed for others classes of problems. This means the algorithm cannot solve every problem, but suitable for certain problem.

The optimization algorithms can be categories into bio-inspired algorithm and natural inspired algorithm. The natural inspired algorithm is the algorithm that inspired by the natural phenomena or natural material, however bio-inspired algorithm is the algorithm that more related to the fields of biology, mathematics and computer science.

2.2   Firefly Algorithm

R. Francisco, M. Costa and A. Rocha stated that the firefly algorithm has developed by Yang in 2008 which consider as one of the swarm intelligence algorithm stated [6]. Firefly Algorithm is a bio-inspired optimization algorithm, which inspired by the flashing pattern of a group of fireflies in nature. Fireflies are nocturnal which will only active at night. The firefly emits light from their abdomen, which called bioluminescence. Adult firefly is able to emit high and discrete flashes by controlling their bioluminescence. Each firefly has their own flashing pattern where their main

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purpose of flashing is act as a signal to attach other fireflies and to warn the potential predators. The firefly uses flashing pattern to communicate with other fireflies.

Firefly algorithm is able to solve the optimization problems because it is a stochastic, nature-inspired and meta-heuristic algorithm. Stochastic method means it to have one or more components of randomness when searching for a set of solution. This means Firefly Algorithm may not produce the same solutions each time it's run from the same problems.

Majority of stochastic method considers as meta-heuristic. Heuristic means a proceeding to discover or find a solution by trial and error. Meta-heuristic means high level searching process that may generate a sufficiently good solution for the optimization problem where influenced by satisfaction between randomization and local search. This means that the fireflies can make random movement in the search area. The light intensity of the firefly is variation in the search region is related to the encoded objective function.

In order to get the optimum solution, the firefly algorithm basically has three main principles that have to consider:

1. All fireflies are assumed to be unisex and they will attach by each other regardless their sex.
2. The attractiveness of the firefly is determined by their light intensity, which their relation is proportional. The firefly with higher light intensity will attach the firefly with low light intensity. The firefly will move randomly if no other brighter than a particular firefly. When the distance between the fireflies increase, the light intensity will decrease.
3. The light intensity of firefly is depending on the value of the objective function of the optimization problem.

For Firefly Algorithm, the key ideas are the brightness and the attractiveness of the fireflies. The brightness is assumed that it can be define by the objective function. When the light intensity is varying and the change of the attractiveness will be formulated.

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L. Zhang, L. Liu, X. Yang et al mention that the advantage of Firefly Algorithm is it can provide better convergence rate and strong exploration ability [7]. This means this algorithm have more faster convergence the problems to get the optimal solution. However Firefly Algorithm is better in local search but some of the solution may stuck in the local optimal point which do not search globally well. Besides that, Firefly Algorithm is very useful to tune these parameters automatically by the control randomization which can solve the problems effectively in real-world application. Firefly Algorithm is able to solve nonlinear, multimodal and global optimization problems where the complexity or difficulty of the problem does not affect the performance of the algorithm. According to [8], the researcher stated that the execution time for each iteration is higher than other algorithm.

2.3 Basic Understanding of Firefly Algorithm

The fireflies are placed in random position when the algorithm started. The location is determined by the values of parameter for the objective function. By random walk attraction between the fireflies will generated a new solution. The location of the fireflies must be considers after they compare their brightness among each other. When the firefly move toward the brighter firefly encountered, the distance between the fireflies, r must be calculated. The distance between fireflies i and j, r_{ij} can be calculated as Cartesian distance which given as

$$r_{ij} = \sqrt{\sum_{d=1}^{D}(x_{id} - x_{jd})^2}$$

(2-1)

where D is number of dimension, x_i, x_j are the solution position for fireflies i and j and r_{ij} is the distance between fireflies.

After knowing the distance between the fireflies, the light intensity can be calculated. According to the inverse square law, the light intensity is decreasing when the distance between the fireflies i and j, r_{ij} increased. The light intensity $I(r)$ is calculated as

$$I(r) = \frac{Io}{r_{ij}^2}$$

(2-2)

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where I_o is the initial light intensity of the firefly.

The light intensity is the attractiveness between the fireflies. The light intensity coefficient, γ can control the light intensity. Since the brightness is directly related to attractiveness, it can be assume that $I_o=\beta_o$, where β_o is the initial attractiveness. The attractiveness $\beta(r)$ between the firefly i and the firefly j is given as

$$\beta(r) = \beta_o e^{-\gamma r_{ij}^2}$$

(2-3)

The attractiveness $\beta(r)$ and the randomization parameter, $\alpha\epsilon\_i$ can determined the movement of the firefly toward the firefly. The random coefficient, α is a parameter that can control the amount of randomness which normally in range of [0,1]. In order to create a random distance, fireflies can move with a uniform distribution, which the movement can be either forward or backward. The movement from the firefly i at position x_i, to the another more brighter (attractive) firefly j at position x_j which given as

$$x_i = \beta_o e^{-\gamma r_{ij}^2}\left(x_i - x_j\right) + \alpha\varepsilon_i$$

(2-4)

If the $\beta_o=0$, it means that the fireflies can be simple random movement, and $\alpha=0$ corresponds to no randomness.

After a firefly move to a new position, the light intensity and attractiveness are updated by evaluating the objective function in the new position. The new evaluation of brightness is compared with the best found. The firefly will move to the new position if the new position produces higher brightness and attractiveness, which the position will become the new best. If the firefly passes through the location and it not better than any other found, firefly will remain in the current location and the best location is still recorded.