SOLVING KNIGHT’S TOUR PROBLEM USING PADDY FIELD ALGORITHM

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Bachelor of Electrical Engineering

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SUPERVISOR'S ENDORSEMENT

" I hereby declare that I have read through this report entitle "Solving Knight's Tour Problem Using Paddy Field Algorithm" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)"

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A report submitted in partial fulfilment of the requirement for the Degree of Bachelor in Electrical Engineering (Control, Instrumentation and Automation)

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STUDENT DECLARATION

I declare that this report entitle "Solving Knight's Tour Problem Using Paddy Field Algorithm" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

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ABSTRACT

The main purpose of this project is to solve the knight's tour problems (KTP) by using paddy field algorithm (PFA). KTP is a sub-chess puzzle where the main purpose of the puzzle is to find combination move made by a knight so that it visits every square of the chessboard exactly once. The knight's tour problem is focusing on the mathematical problem of finding a knight's tour moving sequence. In approach with this related application is view from the assembly stability and the number of assembly orientation. KTP is not viewed just from the puzzle it represents, but the concept that can be used in other related fields of engineering application. The objective of this project are to solve the mathematical problem of KTP and design a model using PFA to solve KTP. MATLAB software is used to design the coding to solve the KTP. In this project the size of the chessboard use will be 8x8 as this is to define the moving pattern sequences of the knight. Furthermore, the performance of optimization technique used which is PFA will be evaluate with the performance of Firefly Algorithm (FA). The end result was evaluated in terms of the success rate of finding optimal solution for only 1 locations of the movement made by the knight. There are many method of optimization technique to solve the KTP. The optimization consists of maximizing or minimizing the value to find the optimal best value. There is other several types and method of optimization algorithm can be used to solve the KTP such as the Binary Magnetic Optimization algorithm, Firefly algorithm, Particle Swarm Optimization and many more. The KTP has been solved by many optimization method and the PFA method is new to solve this type of problem. The previous research reveal that the KTP solved with different method produce different output specification such as the accuracy and other.

ABSTRAK

Tujuan utama projek ini adalah untuk menyelesaikan masalah pusingan kesatria atau kuda (KTP) dengan menggunakan kaedah "*Paddy Field Algorithm (PFA)*". KTP adalah masalah matematik untuk permainan catur di mana tujuan utama masalah ini adalah untuk mencari langkah gabungan yang dibuat oleh kuda di dalam catur tersebut supaya ia dapat melakukan pusingan di setiap petak catur dalam satu gerakan. Masalah pusingan kuda ini memberi tumpuan kepada masalah matematik bagi mencari pusingan kuda adalah dalam turutan yang bergerak. Dalam pendekatan kepada permasalahan ini, konsep yang boleh digunakan dalam bidang-bidang lain yang berkaitan dengan aplikasi kejuruteraan boleh diaplikasikan daripada projek ini. Objektif projek ini adalah untuk menyelesaikan masalah matematik KTP dan reka bentuk model menggunakan PFA untuk menyelesaikan KTP. Perisian MATLAB digunakan untuk reka bentuk program untuk menyelesaikan KTP. Dalam projek ini saiz penggunaan papan catur adalah 8x8 kerana ini adalah untuk menentukan urutan corak pergerakan bagi kuda. Tambahan pula, prestasi paling optimum bagi teknik yang digunakan iaitu PFA akan dinilai dengan prestasi bagi kaedah "*Firefly Algorithm (FA)".* Keputusan akhir telah dinilai dari segi kadar kejayaan mencari penyelesaian optimum bagi hanya 1 lokasi gerakan yang dibuat oleh kuda tersebut. Terdapat banyak kaedah atau teknik pengoptimuman yang telah dikaji untuk menyelesaikan KTP. Pengoptimuman ini terdiri daripada memaksimumkan atau meminimumkan nilai untuk mencari nilai terbaik yang paling optimum bagi masalah matematik seperti ini. Terdapat beberapa jenis lain dan kaedah pengoptimuman algorithm yang boleh digunakan untuk menyelesaikan KTP seperti "*Binary Magnetic Optimization algorithm*, *Firefly algorithm*, *Particle Swarm Optimization*" dan banyak lagi. Kajian sebelum ini menunjukkan bahawa KTP yang diselesaikan dengan kaedah yang berbeza menghasilkan spesifikasi output yang berbeza seperti ketepatan dan lain-lain.

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KTP	-	Knight's Tour Problem
PFA	-	Paddy Field Algorithm
FA	-	Firefly Algorithm
PSO	-	Particle Swarm Optimization
CSA	-	Cuckoo Search Algorithm
BMOA	-	Binary Magnetic Optimization Algorithm
ACOA	-	Ant Colony Optimization Algorithm

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CHAPTER 1

INTRODUCTION

1.1 Project Background

The knight's tour problem (KTP) is a sub-chess puzzle where the main purpose of the puzzle is to find combination move made by a knight so that it visits every square of the chessboard exactly once. The KTP is focusing on the mathematical problem of finding a knight's tour moving sequence. Creating a program to find a knight's tour is the problem which needs to be solve. There are variations of the knight's tour problem involve chessboards of different sizes. An example of engineering application of KTP is the assembly sequence planning. Basically the project's attempt is to research and experiment the Paddy Field Algorithm (PFA) in solving the KTP.

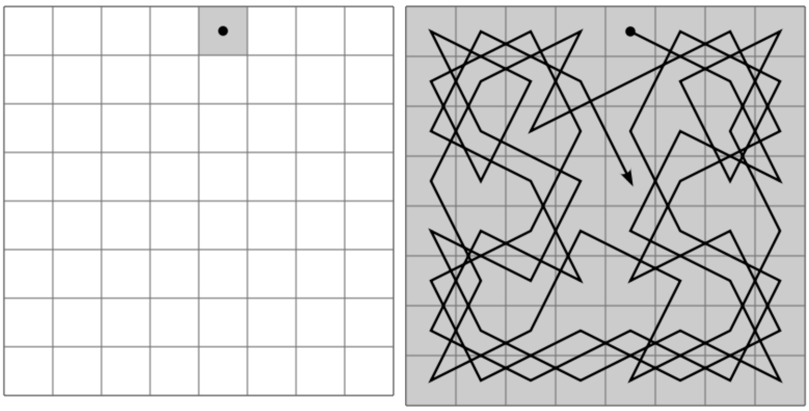

Figure 1.1: Example of an open knight's tour of a chessboard and the visited squares shaded [4]

1.1.1. Optimization

Optimization in this project are mostly entitle on solving mathematical problem which is finding the complexity of the dimensional move made by the knight. It is affected by the roots of dimensionality. Basically when dealing with the term optimization itself, different types of algorithm have a different chances of solving the solutions. In order to discover the best global optimum solution of the problem is by using the method which has great percentage of success rate. This is referring to an exhaustive search. However, this method of exhaustive search will cost in terms of the computational power and time which is normally high. Therefore, most of the regularly used optimization algorithms does not explore the entire parameter space of the problem. Thus, this has led to the high probability of the optimization algorithm thinking that a local optimum is actually the best solution in order to solve the knight's tour problem (KTP).

1.1.2. The Paddy Field Algorithm

The Paddy Field Algorithm (PFA) is an optimization algorithm developed by Upeka Premaratne and Jagath Samarabandu in 2009. The optimization algorithm was inspired by a new biologically inspiration in the field of algorithm. Basically the new biologically inspired algorithm which is known as Paddy Field Algorithm works by initially scattering a seeds at a random parameter space. The PFA concept was the function of the plant that is closer to the optimum solution in which it will produce the most seeds. Thus, this can be applied for various optimization problems. Basically the concept is that when seed are scattered into an uneven field, the seeds which drop into places with the most favourable or in other words the most positive places (in this situation, refers to most fertile soil, best drainage, soil moisture and more of the same type of the subject). From here, it will be likely to grow to become the best plants. Some of the plants will have a tendency to grow taller and capable of generating more seeds than the less fortunate individuals of the plants. Thus, the tallest plant of the population would match to the location with the optimum conditions. In PFA, the fitness of the plant is determined by the tendency of the plant to grow taller and healthy.

1.2 Problem Statement

The issue that is to be address is to find the right combination moves made by a knight so that it visits every square of the chessboard exactly once. This is to be done by using the Paddy Field Algorithm method. The knight's tour problem has been widely research by many academicians throughout years. Although the main purpose of solving the knight's tour problem is to find the right combination of the moving pattern of the knight moves and the issue needed to address here is to compare different algorithm method towards solving this problem. Basically this whole project aims to solve the knight's tour problem by using the paddy field algorithm. Although there have been many algorithms that have been developed throughout the years, the need to find the best solutions or algorithm methods is still remain as a subjective problem to this issue. One example of engineering application of the knight's tour problem is the assembly sequence planning. In approach with this related application is view from the assembly stability and the number of assembly orientation. These changes of the assembly orientation which are a part from the outcome for the optimization used. The approach also could reduce the working time and economic cost of the assembly sequence planning significantly. Thus it will change the performance of the assembly sequence planning in terms of design and manufacturing process and the production process will become more efficient. Assembly sequence planning plays an important role in the manufacturing industry. It is the sequence of coupling operations or system that is carried out to assemble a set of parts which is constrained by the geometric and mechanical properties of the parts to be assembled. This represents one of the most important conditions to assure the future effectiveness and competitiveness of industrial companies. In summary, the knight's tour problem is not viewed just from the puzzle or problem it represents, but the idea and concept is use in other related fields of engineering application such in this case is the assembly sequence planning.

1.3 Objectives

The main objective of this project is to find the combination moves made by a knight so that it visits every square of the chessboard exactly once. Below are the objectives on what to accomplish based on the research work:

1. To solve the mathematical problem of finding the Knight's Tour moving sequence
2. To design a model using Paddy Field Algorithm into written Matlab source codes to solve the Knight's Tour Problem.
3. To evaluate the performance for the Paddy Field Algorithm with the result of Firefly Algorithm Optimization in terms of the optimal solution for one location of the knight.

1.4 Scope of Research

The scope of research sets a clear boundary towards achieving the objectives of the project. Below are the scope for the project:

1. The algorithm that will be used is only focusing on the Paddy Field Algorithm (PFA).

2. The size of the chessboard use will be 8x8 to define the moving pattern sequences of the knight.

3. Moving pattern used is based on the algorithm applied on previous researched (Firefly and Binary Magnetic Optimization Algorithm) as different algorithm may consist of different moving pattern.

4. The performance is discussed in terms of the success rate of finding the optimal solution for one initial locations of the movement made by the knight.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Throughout the project, a feasibility study was performed in order to acquire as much information regarding the project of solving knight's tour problem (KTP) by using paddy field algorithm. In accomplishment of feasibility study, all the necessary information is needed from several of source. This chapter will provide the review from previous research that is related to this final year project. There are previous research on solving the knight's tour problem based on different optimization and algorithm method. From literature's point of view, it can be seen that numerous researches that is related to KTP had been done. Basically optimization is tools or procedure which is to make a system or design as effective or functional as possible applied with the mathematical technique involved. In other words, optimization is to find the 'best available' values for functions which is given by many defined domain. Optimization problem can also be categorized into many other categories such as the Metaheuristic and the combinatorial optimization technique. Metaheuristic optimization technique is among the commonly used as it is easier to implement compared with the other technique approach. This is because metaheuristic optimization technique provide a better result in which it is more attractive than the other optimization technique. In metaheuristic algorithm, there are some types of commonly used algorithm such as the Particle Swarm Optimization algorithm (PSO), the Firefly algorithm (FA), the Cuckoo Search algorithm (CSA), the Paddy Field Algorithm and many more types of algorithm that has been developed previously.

2.2 Previous Research On Solving The Knight's Tour Problem (KTP)

The knight's tour problem (KTP) is a sub chess puzzle where the main key is to find the combination made by a knight so that it visits every square of the chessboard exactly once. Mohd Muzafar Ismail has made a preliminary study on using Binary Magnetic Optimization Algorithm (BMOA) to solve the problem [1]. The authors approach is scalable for a standard of 8x8 chessboard setup. The Magnetic Optimization Algorithm was inspired by the attraction of the magnetic force between two magnetic particles. Basically this optimization method has a similar updating particle position to Binary Particle Swarm Optimization (BPSO). The concept use in this optimization is the particles with higher mass will have a greater magnetic force that attracts other particles with smaller mass to move towards it. This is thus applied only in the magnetic field area. Basically other nature-inspired optimization techniques consist of three major parts which is the initialization process, fitness evaluation and improvement agents. Based on the article, the authors use a standard 8x8 chessboard setup to describe the possible moving pattern of the knights. The moving concept here refers that the knight has 8 possible moves from the square of its initial position of the knight. The result of this optimization techniques is altered from other nature–inspired optimization. In this case the improvement agents which is the change in position is no longer linear to the change in velocity of the particle, but it has become linearly proportional to a sigmoid or tanh function.

The BMOA only found a single optimal solution of the movement made by the knight. The research model here is not too sensitive to the number of computation done. However the research approach used here has a potential solution for further improvement by studying the sensitivity of the parameters towards solving the Knight's Tour Problem. Table 2.1 shows the result obtained by using the BMOA.

Table 2.1: Result obtained for Knight's Tour Problem using Binary Magnetic Optimization Algorithm [1]

Location	Best value of best found		Average fitness of best found		Standard deviation of fitness of best found	
	Sigmoid	Tanh	Sigmoid	Tanh	Sigmoid	Tanh
1	63	62	61.40	60.00	1.140	1.581
2	62	61	60.40	60.20	1.140	0.447
3	63	60	61.00	59.40	1.224	0.548
4	61	62	61.00	60.60	0.000	0.894
5	63	60	62.25	59.20	0.500	0.837
6	62	61	61.40	60.00	0.547	0.707
7	62	62	61.80	60.80	0.447	0.837
8	64	62	62.00	60.20	1.224	1.095
9	62	61	61.80	60.40	0.447	1.140
10	63	62	61.25	60.20	1.258	1.304
11	62	61	61.60	60.60	0.548	0.548
12	61	62	60.50	60.40	0.577	1.140
13	63	62	61.40	59.60	0.894	1.342
14	63	62	61.20	60.40	1.483	1.140
15	62	62	61.20	61.20	0.837	0.837
16	61	61	60.20	60.60	0.447	0.548

From Table 2.1, it can be seen that the best value for sigmoid function is better than tanh function in most cases. The similar can be understood for the average fitness of best found for sigmoid function relative to tanh function. Meanwhile, the standard deviation of sigmoid function is smaller than the tanh function at most cases except for locations of 2, 3, 8 and 14. Based on the proposed model here, it is not too sensitive to the number of computation done due to a small standard deviation in average fitness. The highlighted value in the table refers to the only optimal solution found by the BMOA at location 8 using sigmoid function. The value 64 is the optimal number of movement that the knight visit every square on the chessboard. The author has mentioned that this result can be further improved or enhance depends on the parameters to be tuned.

There has been a more extensive studies in solving the knight's tour problem. Mohd Muzafar Ismail has also developed another algorithm method in solving the knight's tour problem by using the Firefly Algorithm (FA) [2]. The author has proposed a model by using FA to solve the problem. The FA was inspired based on the mating behaviour of fireflies. The concept use in this optimization is that each firefly represents a possible solution of the problem. Each dimensions of the search space represents n^{th} move taken by the knight. The fitness of a firefly is calculated by the number of moves that the knight has taken. The authors approach is scalable for a standard of 8x8 chessboard setup. Based on the article, the authors use a standard 8x8 chessboard setup to describe the possible moving pattern of the knights. The moving concept here refers that the knight has 8 possible moves from the square of its initial position of the knight. Basically the concept of fitness formulation of this firefly algorithm is that each dimension of the firefly position represents n move made by the knights. Such equation is as follows:

$$\boldsymbol{s}_m = [1st\ move,\ 2nd\ move, \ldots,\ nth\ move]^T \tag{2.1}$$

In this equation, n is the total number of squares in the chess boards. For the case of 8x8 chess board, $n = 8 \times 8 = 64$. Therefore the equation will be as follows:

$$\boldsymbol{s}_m = [1st\ move\ ,\ 2nd\ move, \ldots,\ 64th\ move]^T \tag{2.2}$$

The FA has found 11 optimal solution of the movement made by the knight. The success rate of finding the optimal solution for all 16 locations is 75%. By this result, the success rate is impressive. Table 2.2 shows the result obtained by using the Firefly Algorithm.