**PROJECT TOPIC (TIMES NEW ROMAN 18 – BLOCK CAPITALS - CENTER)**

**A thesis by**

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Author’s Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any University or equivalent institution, and that to the best of my knowledge and belief, contains no material previously submitted or written by any other person , except where due reference is made in the text of this thesis.

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Abstract

Optimization is a key component in solving various types of problems, in almost every field of research and in industries. Even though some problems can be solved using conventional algorithms, NP-hard problems are pretty much impossible to be solved in that manner. The Traveling Salesman Problem (TSP) is one such problem, where the time complexity increases exponentially with the increase in the number of cities, making it unsolvable using conventional optimization algorithms using the resources available up to date. Nature-Inspired algorithms can be used to solve this problem, but these algorithms have algorithm-specific parameters and identifying the optimal value for these variables is normally done using trial and error method, where the values are statistically compared against the performance. To automate this process, if we use another algorithms it will create an endless recurring process because the algorithms applied should be optimized. So to overcome this problem, we should design a multi-objective algorithm where the algorithm itself optimizes its variables. One objective of the algorithm will be to optimize the solution while the other objectives will be to optimize the parameters of the algorithm. Such algorithms are called self-tuning (hyper-optimization) algorithms. The aim of this research is to design a self-tuning optimization algorithm using Firefly algorithm to solve the Traveling Salesman Problem. So that, with our solution, the user will be able to find the optimized path for the given Travelling Salesman Problem, without worrying about adjusting the parameters of the Firefly Algorithm. It will be implemented to solve the Traveling Salesman Problem and will be tested using TSPLIB, which is a library of sample instances for the TSP.

**Keywords:** Firefly Algorithm, Nature-Inspired Algorithms, Travelling Salesman Problem

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# Introduction

## Preamble

Optimization is an essential component in solving various types of problems, in almost every field of research and industry. It can be either reducing time complexity, space complexity or both. Since the industrial revolution, people have been interested in making machines that will reduce the workload of humans. Advancement of this area happened at a rapid rate where we have reduced the physical workload, as well as the mental workload of people with the development of computers, where we implement various optimization algorithms, and by using them; the computer will solve the problem for us. Even though some problems can be solved using conventional optimization algorithms, NP-hard problems are pretty much impossible to be solved in this manner. In computational complexity theory, NP-hard (Non-deterministic Polynomial-time hard) is a class of problems which are at least as difficult as the hardest problems in NP (Non-deterministic Polynomial-time). NP is a class of computational decision problems, for which a given solution can be verified in a polynomial time using a non-deterministic Turing machine.

Traveling Salesman Problem (TSP) is one of the most popular NP-hard problems (Applegate et al., 2011). The problem can be simply described as, the salesman has to visit each city one time and return back to the city where he began the tour, using the most optimized path. This may seem easy but as the number of cities increases the time complexity increases exponentially, making it unsolvable using conventional optimization algorithms utilizing the resources available up to date.

## What are Nature-Inspired Algorithms?

Nature is still a mystery to modern day science. It has inspired number of research in a miraculous way, to make advancements in technology. Inspiring of nature has flooded on to our transportation, industries and in many day-to-day activities. Every machine we use and algorithms we use is bridged with the principles, behaviors, functions and structure in nature. Yet, there are many more functions in nature we are still unable to bridge with. Nature -inspired algorithms is one of the most active research areas in today’s world. It is an attempt to bridge more natural scenarios in the form of evolutionary algorithms, in order to solve complicated problems that cannot be solved using conventional algorithms. As a result, nature-inspired algorithms have developed solutions for a number of complex real-world problems. Among these algorithms, there are some algorithms like swarm optimization, cuckoo search and firefly algorithms which are more popular because of their efficiency in solving problems[1].

## TSP

The Traveling Salesman Problem (TSP) which was mathematically formulated in the 1800s by the mathematicians William Rowan Hamilton and Thomas Kirkman[2]. Since then it became one of the most popular NP-hard problems[3] and is commonly used as a benchmark for optimization algorithms. In this problem, there is a set of cities and a salesman has to visit each city and return back to the city that he started. The salesman’s path is known as a Hamiltonian circuit in graph theory where the vertices of the graph represents the cities and every edge represents the path between the two cities connected. Each edge has a non-negative cost and the sum of the whole path is the cost of that tour (i.e. objective function). Minimizing the total distance of the path i.e. finding the optimum path is the challenge of this problem. Even though there are a lot of conventional algorithms that can be used to solve this problem, all those fail as the number of cities increases. The reason behind this is that, with the increase of the number of cities, the time complexity increases exponentially, making it unsolvable using conventional optimization algorithms with the resources available up to date.

The most common approaches to solve this, is by using approximation algorithms and heuristic algorithms such as Nearest neighbour algorithm[4], Interpolation algorithm[5], Probabilistic algorithm, Clark & Wright algorithm, Christofides algorithm, Double spanning tree algorithm and various Hybrid algorithms. Furthermore, TSP has been solved using multi-agent systems and meta-heuristic algorithms which are said to be of a higher level than the heuristic algorithms[1]. Dozens of research have been carried out in order to solve this problem using various Nature-Inspired Meta-heuristic Algorithms including algorithms like Genetic algorithms [6], Ant Colony Optimization Algorithms [7], Firefly algorithm [8] etc.

## Problem in brief

Most of the NP-hard problems have been successfully solved using meta-heuristic algorithms. However, these algorithms have algorithm-specific parameters where the performance of the algorithm is highly dependent on the values of these parameters. Identifying the optimal value for these variables is normally, done using trial and error method, where the values are statistically compared against the performance. It would certainly be better if we could just input the problem and straight away receive the solution. So, in order to achieve this, we should figure out a way to automate the process of optimizing the parameters.

Parameter tuning can be described as a process of optimizing the optimization algorithm. The problem is that, when applying another algorithm (say B) to optimize one algorithm (say A), we will need a third algorithm (say C) to optimize the parameters of the second algorithm (B), not to forget that we are not sure whether C is well-tuned. When this continuously repeats, it creates and endlessly recurring process. This provides us with the idea that there should be an alternate process for this parameter tuning.

## Aim of the research

This thesis proposes a self-tuning firefly algorithm to solve the Travelling Salesman Problem.

## Objectives of the research

As an approach to design and develop a self-tuning firefly algorithm to solve the Travelling Salesman Problem, the following objectives have been formulated.

1. To study the characteristics of Nature-Inspired Algorithms
2. To study the nature of firefly algorithm
3. To learn the behavior of the algorithm-specific parameters
4. To implement firefly algorithm to solve the TSP.
5. Adopt the self-tuning framework to the implemented firefly algorithm.
6. Discuss and compare the performance of the self-tuning firefly algorithm

## Hypothesis

The hypothesis employed in the thesis can be state as the Firefly Algorithm can be self-tuned in order to solve the Travelling Salesman Problem.

## Overview of the thesis

In this chapter, Nature-Inspired Algorithms and Travelling Salesman Problem were briefed. Then, the problem was presented followed by the aim, objectives and the hypothesis of the research.

The second chapter is the literature survey on nature-inspired algorithms, their applications and drawbacks.

## 

## Summary

This chapter describes the background related to the problem i.e. nature-inspired algorithms and the Travelling Salesman Problem. Then the problem addressed in this thesis was stated, followed by the aim, objectives and hypothesis of the research. Finally, the overview of this thesis was presented.

# State of the art

## Introduction

Most of the real-world optimization problems have to deal with NP-hard problems and are, therefore, very challenging to be solved. Optimization tools must be used in order to solve such problems, but there is no guarantee that optimality can be achieved [9]. Because of the inherent solution mechanism of the conventional or classical optimization algorithms, these impose limitations on solving mathematical programming. Furthermore, conventional algorithms are not at all efficient in solving NP-hard problems [10]. But, no matter how complex it becomes, nature finds a way to maintain its equilibrium regardless of the number of external factors disturbing it. So researchers started to explore the nature to gain inspirations, to come up with means to solve these problems. In the current literature, there are dozens of nature-inspired algorithms which are designed with the expectation of overcoming the flaws of the conventional algorithms.

Among those, Genetic Algorithms[11], Artificial Bee Colony[12], Ant Colony Optimization[13], Particle Swarm Optimization[14], Harmony Search[15], Firefly Algorithm[16], Cuckoo Search[17], Bat-Inspired Algorithm[18] etc. have gained popularity over the others [1]. Scientists have always tried to find a universally better algorithm but, the No Free Lunch theorems [19] showed that the average performance of an algorithm cannot be stated because if one algorithm performs better than another for a set of optimization functions, the second algorithm will outperform the first in another set of problems. This showed that the algorithms must be problem-specific [19]. So now, researchers are on exploration to find the best algorithm for a specific set of problems instead of looking for one in general.

The Firefly Algorithm which was originally designed for solving continuous optimization problems [20] [16] is now used by researchers to solve many types of problems including Travelling Salesman Problem (TSP) [21] [22], Scheduling [8] and Clustering [23]. It was developed by Xin-She Yang in 2008 [24], with the inspiration of rhythmic flashes of fireflies where the pattern of flashes is often unique for particular species of fireflies.

Since the original Firefly algorithm has been used to solve continuous optimization problems, it has been adjusted in a way that other classes of problems can be solved. Those variants can be categorized as modifications, where the original firefly algorithm is developed as binary, elitist or based on chaos etc. and hybridizations, where the firefly algorithm is combined with other algorithms or techniques such as genetic algorithm, ant colony, neural network etc. [25]. However, all these algorithms have a unique drawback where the parameters should be tuned in order to optimize the algorithm to obtain better results. So far, those are basically tuned using trial and error method. Researchers are now interested in auto-tuning these parameters. Recently, Xin-She Yang proposed a framework for self-tuning optimization algorithm which is designed to tune parameters in optimization algorithms [26].

## Firefly Algorithm

Firefly algorithm is a nature-inspired metaheuristic algorithm which was developed by Xin-She Yang, originally to solve continuous domain problems. The inspiration from nature that this algorithm is based on is the behavior of fireflies[16]. Fireflies, also called as lighting bugs are well-known for their use of bioluminescence (flashing light). These insects use this light emitted by their extraordinary photogenic organs situated very close to the body surface behind of translucent cuticle to lure mates or prey. This algorithm is built on this flashing or signal mechanism of fireflies. Fireflies use different flashing sequences to send different messages to other fireflies around in its area. Yang formulated this algorithm based on the following assumptions.

1. All fireflies are unisex therefore, one firefly will be attracted to any other firefly regardless of their sex.
2. Attractiveness is directly proportional to their brightness, hence for any two glowing fireflies, the less bright one has to move towards the brighter one. The attractiveness and the brightness, both decrease as the distance between the fireflies increase. If there is no brighter firefly than a particular firefly, it will move randomly.
3. The brightness of a firefly is affected or determined by the landscape of the objective function. For a maximization problem, the brightness can be directly proportional to the value of the objective function. Other forms of brightness can be defined in a similar way to the fitness function in genetic algorithms.

Based on these three assumptions, the basic steps of the firefly algorithm (FA) can be summarized as the pseudo code shown in Figure 1.

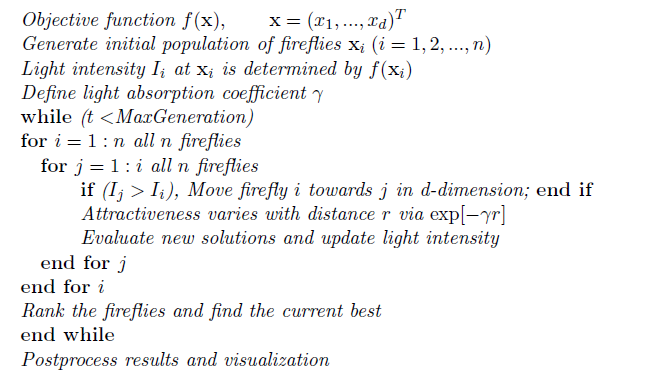


Figure 1: Pseudo code of the original firefly algorithm

Discretization of FA

Firefly algorithm was originally formulated to solve continuous domain optimization problems[16][20].

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## Current Approaches …..

The machine translation approaches can be classified into three categories, namely,

Table 1: Sample Table

|  |  |  |
| --- | --- | --- |
| System | Language pair | Approach & Type |
| Anusaaraka | Among Indian language | Human-Assisted, Application |
| Angalabarath | English to Indian languages | Human-Assisted, Rule-based, Application |
| AngalaHindi | English to Hindi | Machine-aid, Rule-based/ example-based, We based |
| ManTra | English to Hindi | Human-aided, web based |
| English to Urdu MT | English to Urdu | Example based, Application |
| Matra | English to Hindi | Human-aided, transfer-based Application |
| Google TR | Several languages | Statistical, Web-based |
| Bable fish | Several languages | Systran technology, Web based |
| Yahoo TR | Several languages | Statistical, web-based |
| Aprtium | Related languages | Rule-based, Application |
| EDR | English/japaness | Knowladge based, Application |

The sample Figure



Figure 2: Sample Figure

## About References

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## Summary

# Methodology

## Introduction

There are various types of nature-inspired algorithms which have different kinds of input parameters, evolutionary mechanisms and are applied in various areas [27]. These should be studied thoroughly in order to understand the nature of the algorithm. So the initial step is to study the nature of the firefly algorithm. Since these algorithms have algorithm-specific parameters, soon after studying the nature of the firefly algorithm, the behavior of the parameters should be studied. This will help to get an overall idea about the firefly algorithm. With that knowledge, the firefly algorithm can be implemented to solve the TSP. Then, the self-tuning framework introduced by Xin-She Yang will be adopted by the implemented firefly algorithm.

## Summary

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# Appendix A System Figures

This is a sample Appendix.