Opposition-Sooty Tern Algorithm for Fuzzy Control Optimization of an Inverted Pendulum System

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***Abstract*—This paper presents a novel Opposition-Sooty Tern Algorithm (OSTA) which is an improved version of the original Sooty-Tern Optimization Algorithm (STOA). An opposition scheme is incorporated into the STOA structure. This is to enhance the exploration and exploitation of all searching agents throughout a feasible search area. In solving a real-world problem, the algorithm is applied to optimize parameters of a fuzzy logic model for controlling cart's position and pendulum's angle of an inverted pendulum system. Result of the optimization test shows the OSTA has a better accuracy performance compared to its predecessor algorithm. For controlling the inverted pendulum, both OSTA and STOA acquired sufficiently good control performance for the system. However, the fuzzy control scheme optimized by OSTA has resulted in a better tracking and control performance for both cart's position and pendulum's angle.**

Keywords—Sooty-Tern algorithm, inverted pendulum system, Opposition based learning, OSTA.

I. INTRODUCTION

Optimization algorithm is a fast-growing research area. It has been widely applied to solve real-world problems in various areas. Metaheuristic and heuristic algorithms are two common terms found in optimization algorithm. Heuristic algorithm is known as a local search method. It is generally applied for a non-complex problem such that it has only a few local optima points. Combination of heuristic and nature-inspired strategies leads to the metaheuristic algorithm. It is generally known as a global search method and does not involve any gradient approach in its operation. Metaheuristic algorithm offers high accuracy as well as reliable solution. Due to its global approach and non-gradient-based method, it is widely applied to solve nonlinear and complex problems.

Metaheuristic is mainly categorized as biological-inspired and non-biological inspired. Bacterial Foraging Algorithm (BFA) is an example of biological inspired. Its strategy is inspired from foraging strategy of bacteria in human body [1]. Spiral Dynamic Algorithm (SDA) is an example of non-biological inspired algorithm [2]. Its strategy is inspired from the concept of spiral phenomena on earth such spiral of torpedo, nautilus shell and spider web. There are common features of these algorithms. Generally, their strategy involves group-based method where an agent solution is compared with other agents solution. Each agent interacts with other agents in the population and in most algorithms, it leads to a swarming behavior towards the best agent. Different algorithms present different strategies on how the agents move around within a feasible search region.

Sooty-Tern Optimization Algorithm (STOA) is relatively a new type of metaheuristic algorithm [3]. Its development is inspired from the strategy of a colony of Sooty-Tern birds in finding prey location. Sooty-Tern bird colony migrates from one location to another location in order to search for a prey location. A more aggressive movement is adopted if they spotted the location of a prey. This movement is called an attacking behavior. In literature, STOA has been applied to solve various engineering problems. In renewable energy area, the algorithm was applied to optimize parameters of model predictive control for a deregulated load frequency control of a power system [4]. Result of the work showed that the STOA outperformed stain bower braid, differential evolution, firefly algorithm and intelligent water drops algorithms. In machine learning, STOA was applied to optimize parameters of support vector machine [5]. The authors combined Differential Evolutionary algorithm with the STOA to solve stagnation and convergence rate problems of STOA. Result of the work showed the proposed hybrid algorithm improved data classification accuracy compared to its predecessor algorithms.

On the other hand, opposition scheme is a concept of positioning a point in the opposite side of its current position [6]. It offers an alternative approach to many metaheuristic algorithms. Exact location of an optimal solution is unknown and it can be anywhere in a feasible region. Opposition scheme is widely applied into metaheuristic algorithm. Nasir et al. applied opposition scheme into SDA [7]. The proposed algorithm was tested on various CEC14 benchmark functions and also applied to solve an intelligent control structure for a 2-DOF control problem. Result of the work showed that the proposed algorithm significantly improved the controller performance. Azwan et al. incorporated opposition scheme into Manta Ray Foraging Algorithm [8]. The algorithm was tested on various CEC14 benchmark function. Result of the test showed the algorithm outperformed its parent algorithm in finding theoretical optima solution.

This paper proposes an Opposition-Sooty Tern Algorithm (OSTA). An opposition scheme is adopted into the original STOA structure with the aim to enhance exploration and exploitation strategies of the predecessor algorithm. The algorithm is applied to optimize fuzzy control structure for controlling cart's position and pendulum's angle of an inverted pendulum system. The paper is organized as follows. Section II explains about the opposition scheme, STOA and the proposed OSTA. Section III describes the physical structure, schematic diagram, physical parameters and dynamic model derivation of an inverted pendulum system used in the work. Section IV explains about the intelligent OSTA-fuzzy control strategy for tracking the cart position. Section V present result and discussion. Conclusion of the work is presented in Section VI.

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