Spiral-Sooty Tern Optimization Algorithm for Dynamic Modelling of A Twin Rotor System

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***Abstract*—This paper presents a hybrid Spiral - Sooty Tern Algorithm (SSTA) which is an improved version of the original STOA. A spiral model is incorporated into the Sooty-Tern Optimization Algorithm (STOA) structure. A random switching is utilized to change from random-based to deterministic-based searching operations and vice versa. This is to balance between the exploration and exploitation of all searching agents throughout a feasible search area. For solving a real-world problem, the proposed SSTA algorithm in comparison to STOA is applied to optimize parameters of a linear Autoregressive-Exogenous (ARX) dynamic model for a twin rotor system. The dynamic modelling of the system is challenging in the presence of cross coupling effect between the main and tail rotors. 3000 pairs of captured input-output data from the system are used for the identification and optimization purpose. Result of the test has shown that the SSTA has achieved a better accuracy performance compared to the competing algorithm. For dynamic modelling of the nonlinear system, both SSTA and STOA have acquired a sufficiently good model for the twin rotor system.**

Keywords—Sooty-Tern algorithm, spiral dynamic, Twin rotor system, parametric modelling, ARX.

I. INTRODUCTION

Optimization algorithm is a huge area of research. It can be categorized into gradient-based and free-gradient based. The gradient based algorithm is a conventional type of optimization algorithm. It is commonly found in a local search method or a single solution approach. Examples of this type of algorithms includes Newton Raphson [1] and Steepest-Descent [2] algorithms. In the early stage, the algorithms were popular as an optimization tool for solving many real-world problems. However, the algorithms are not suitable for solving problems with a non-convex search surface. This led to the introduction of a non-gradient based algorithms. The non-gradient based method is a derivative-free optimization algorithm. It is also known as a heuristic type algorithm where the process of finding an optimal solution is based on an experience or a trial-and-error approach. Apart from solving the aforementioned problem, it offers less computational cost for solving many real-world problems. Examples of these algorithms include Nelder-Mead Simplex [3] and Pattern Search [4] algorithms. Due to the single solution approach, the algorithms are not suitable for solving problems with many local optima solutions. For this kind of problems, a population-based method is more promising.

The population-based method is also known as a global optimization algorithm. It can handle problem with a huge search space. With the presence of extra agents in the operation, the computational cost is also huge. However, the convergence speed of the agents towards the optimal location is significantly increased. The algorithm has a faster time to reach the optimal solution. The local and global search methods can complement each other in a way one strategy can reduce computational cost and another strategy can increase convergence speed. This introduces a more interesting type of optimization algorithms known as metaheuristic algorithm.

Mostly, metaheuristic algorithm is a population-based method or a combination of a local and a global search methods. The word 'meta' implies that this technique is an upper level of heuristic approach. It combines a strategy that is inspired from various natural phenomena and heuristic approach. Bacterial Foraging Algorithm (BFA) [5] adopts the concept of foraging strategy of a bacteria population, Spiral Dynamic Algorithm (SDA) [6] is inspired from Spiral phenomena in the universe, Sine Cosine Algorithm (SCA) [7] adopts the mathematical theory and Chemical Reaction Algorithm (CRA) [8] is inspired from chemical process. Metaheuristic algorithm is a commonly used algorithm to solve many complex problems. Since many real-world problems are complex and non-linear in nature, the algorithm offers a more promising solution. In engineering field, application examples of metaheuristic algorithms include optimization of a control algorithm [9] and a dynamic modelling of a complex system [10], [11].

Sooty-Tern Optimization Algorithm (STOA) is a relatively new type of metaheuristic algorithms [12]. The original concept of STOA is inspired from foraging strategy of a Sooty-Tern bird colony. The strategy is unique since it has a combination of random and deterministic based approaches. Although STOA is a promising optimization algorithm in solving many real-world problems [13], [14], like other optimization algorithms, the strategy of STOA can be further improved to achieve a higher accuracy performance. On the other hand, SDA is a deterministic type algorithm that where the development was inspired from various spiral phenomena on earth. It has a simple structure and therefore computation time of the algorithm is relatively low. The strength of SDA lies on its spiral model. It is considered as a good exploitation strategy. However, relying solely on the spiral model, the algorithm suffers a premature convergence and thus has a low accuracy.

This paper proposes a Spiral – Sooty Tern Algorithm (SSTA) where a spiral scheme is incorporated into STOA structure. This is to enhance its exploration and exploitation capabilities and to improve the dynamic behavior of all searching agents throughout the searching process. The

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