A NOVEL WEIGHTED SINE ALGORITHM FOR OPTIMIZING PID CONTROLLER ON DC MOTORS

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ABSTRACT: The Proportional-Integral-Differential (PID) controller is a commonly used method in a feedback system to improve the performance of the system. It has three parameters namely the K_p, K_i and K_d. Each parameter can be tuned to improve certain performance of the system. However, it is not an easy task to determine the best PID's gains for each system. In this work, the Sine-Cosine Algorithm (SCA) is used to run on two different systems and compared its performance with the proposed modified version, the Weighted Sine Algorithm (WSA). These schemes are evaluated on the cost value and the computing time. An objective function is used to determine the cost performance of each algorithms. The result of the simulations showed that the WSA outperform SCA in term of cost.

KEYWORDS: *Weighted Sine Algorithm; PID; Sine-Cosine Algorithm;*

1.0 INTRODUCTION

Compared to past decades, humans had improved the technologies available in the today's world. As the technologies improved, more new systems are being created. Some examples are the mobile robot [1], tree climbing robot [2], reverse osmosis plant [3], ball and hoop system [4], DC servo motor [5], brushed DC motor [6] and single machine infinite-bus system [7]. These systems may function differently and have a separate objective. However, these systems face some problems. One of them would be the stability issue. For example, the power system design for a large capacity of transmission line is facing difficulty in the stability issue [7]. Thus, a certain process control had been implemented to improve the performance of that system.

As part of this work, the Sine Cosine Algorithm (SCA), found in the research paper [8] is studied and modified. The SCA and the proposed modified version, namely Weighted Sine Algorithm (WSA) are tested and evaluated on the ball and hoop system found in [4].

Motivation

Although there are a lot of various kinds of optimizing algorithm available nowadays, there are still researches on going to find new optimizing algorithm. Why is that so? The No Free Lunch (NFL) theorem [8, 9]. This theorem logically proposed that there is no one optimizing algorithm that could be proposed to solve all kind of optimization problems. Therefore, researchers put their effort in exploring for new or improving/modifying the existing optimizing algorithms to solve specific problems for specific fields. Similarly, this has become a part of the motivation of this work to improve and modify the currently available algorithm, namely SCA in tuning the PID controller on the ball and hoop system of [4].

2.0 METHODOLOGY

Sine Cosine Algorithm (SCA)

The Sine Cosine Algorithm is a sine/cosine based mathematical functions proposed by Mirjalili [8]. The SCA had helped the researcher in solving various problems such as the unit commitment problems, feature selection, structural damage recognition and various other biomedical and mechanical engineering problems [10].

Weighted Sine Algorithm (WSA)

Weighted Sine Algorithm (WSA) is a modified version of the SCA. It uses a slightly different function to computes. It does not have any cosine component in it but an additional sine component instead. Besides that, it includes weightage scheme in the function. Moreover, the exploration and exploitation concept in WSA is slightly different that its original, SCA.

WSA works slightly different than SCA. WSA uses only one trigonometric function which the sine function. However, WSA utilized two of this function instead of one in its equations. Besides that, weightages calculation is involved in the WSA computation. Unlike its original, for each iteration, WSA will map each of its solution to the best *n*-th solution obtained so far. Then, the WSA will assign a weightage to the result of each mapping depending on the fitness index of the best *n*-th solution mapped.

Furthermore, WSA uses exploration and exploitation searches. Comparing to SCA, the concept is much simpler. It is done by just adding a negative sign just to the r_1 variable. Therefore, the overall equation is now as shown in (eq. 1).

$$X_i^{t+1} = X_i^t + \begin{cases} \dfrac{\sum_{m=1}^{n} r_1 \times \sin^2(r_2) \times \left(rr_3 P_{i,m}^t - X_i^t\right) \times w_m}{\sum_{m=1}^{n} w_m}, & r_4 < 0.5 \\ \dfrac{\sum_{m=1}^{n} -r_1 \times \sin^2(r_2) \times \left(rr_3 P_{i,m}^t - X_i^t\right) \times w_m}{\sum_{m=1}^{n} w_m}, & r_4 \geq 0.5 \end{cases} \quad \text{(Eq. 1)}$$

Performance Evaluation

Based on the research works in [11, 12], a numerical optimization function is found to be used for evaluating the PID controller. The objective function found is as seen in equation (2). The β is the weighting factor, M_p is the overshoot, E_{ss} is the steady-state error, t_s is the settling time and t_r is the rise time.

$$W(K) = \left(1 - e^{-\beta}\right) \cdot \left(M_p + E_{ss}\right) + e^{-\beta} \cdot (t_s - t_r) \quad \text{(Eq. 2)}$$

From [11], it states that the weighting factor, β can influences the resulting peak overshoot, steady-state error, settling time and rise time. If the β s set to bigger than 0.7, the overshoot and the steady-state error would reduce. Whereas if the β is set smaller than 0.7, the rise time and settling time will reduce. In this work, β is set to 0.5 and 1.5 to verify the claimed by [11].

Types of systems

The optimizing algorithms (SCA & WCA) are evaluated on a ball and hoop system found in [4], namely ***System A***. The transfer function for this system is of the fourth-order model as given in equation (3) below.

$$G(S) = \frac{1}{S^4 + 6S^3 + 11S^2 + 6S} \quad \text{(Eq. 3)}$$

3.0 RESULT & DISCUSSION

Performance Evaluation

The best fitness plots for each system and for each β value after optimized using SCA and WSA are plotted. The fitness plots for *System A* using β = 0.5 and β = 1.5 are show in **Fig. 1** and **Fig. 2**. From the plots for *System A*, the fitness obtained by from both SCA and WSA would quickly fall to a lower cost and remain for several iterations before it drops further to an even lower cost. Taking an example from **Fig. 1**, the plot would start at large value around 32 and quickly drop to 15 in a few iterations. Then it gradually falls for the next iterations and later would retain at the same value until around 130 iterations for WSA and 420 iterations for SCA. Finally, it falls to a very low fitness value and retain or slightly drop to a lower cost.

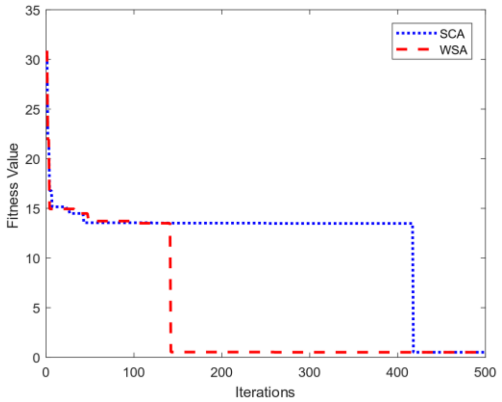

Figure 1. Fitness Plot of SCA and WSA for System A (β = 0.5)

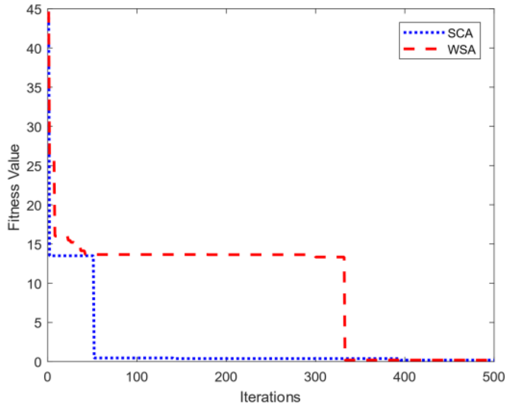

Figure 2. Fitness Plot of SCA and WSA for System A (β = 1.5)

In conclusion, SCA and WSA can be used to optimize the K_p, K_i and K_d value of the PID controller. Lower settling time and overshoot are obtained at post-optimizations. To compare the performance the SCA and WSA, it is found that WSA would performs better in obtaining the best fitness value for both *System A* and *B* for both β value. In the aspect of computing time, SCA outperform in this aspect for *System B* but WSA completes faster for *System A*. As for the effect of β value, it seems to be true for all cases.

4.0 DECLARATION

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