PERFORMANCE EVALUATION ON OPTIMIZING PID CONTROLLER USING GREY WOLF OPTIMIZER AND DRAGONFLY ALGORITHM ON DC MOTORS

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ABSTRACT: Optimization is a method to find a balance performance when the design must compromise between a certain factor, which affects fitness and cost. In engineering field, one of the common optimization problems is optimization of PID controller. Optimization is difficult to optimize as there are three parameters that are needed to be tuned, K_p, Integral parameter, K_i, and derivative parameter, K_d. In this work, swarming intelligence is used to solve optimization problem. Grey Wolf Optimizer and Dragonfly Algorithm were chosen. Three plant system were used in this study. First system is based on the ball and hoop system and second system is based on the DC servo motor. Last system is based on the brushed DC motor. Objective function in this research, cost function was chosen. The criteria of the cost function are low peak overshoot, M_p, low steady-state error, e_{ss}, low settling time, T_s, and low rise time, T_r. However, to fully utilize the algorithm, the parameter of the algorithm needs to be set properly. In this case, the right number of the search agents for both algorithms. The stopping criteria also need to be identified. In this study, maximum number of iterations is the stopping criteria. The expected result is the algorithms can optimize the PID controller. However, the performance of system is expected to be different from different algorithm.

KEYWORDS: *Optimization, PID controller, Grey Wolf Optimizer, Dragonfly Algorithm*

1.0 INTRODUCTION

Search algorithm is an algorithm that been used to achieve a certain objective in problem domain [1]. The appropriate search algorithm is chosen depending on the problem domain. The problem can be optimization, classification or satisfaction problem. Optimization problem is the problem of searching the finest solution from all possible solutions. The problems can be split into two categories depending on the variables either it is continuous or discrete. The discrete optimization is searching for an object such as an integer, permutation or graph from a finite while the continuous optimization is usually involving constrained problems and multimodal problems. Essentially, the aim of objective optimization is to minimize or to maximize the value of a function [2].

For this comparative study, meta-heuristic algorithm which is part of stochastic optimization algorithms was studied. The algorithm used in this research was Grey Wolf Optimizer (GWO). It is one of the subclasses of meta-heuristics, Swarm Intelligence (SI) methods [3]. For the example, one of the swarm intelligences is Cat Swarm Optimization. Cat Swarm Optimization (CSO) is an algorithm influenced based on the natural behavior of the cat. Cats is one of the animals that seen to spend their time in resting but they have high alertness and curiosity about their surroundings and moving objects in their environment. This behavior helps cats in tracking and hunting them down. While resting, they conserve their energy. According to Chu and Tsai [4], there are 2 main mode of the cats, which are seeking mode and tracing mode. During seeking mode, the cat is resting while keeping an eye on its environment. They decide to move when they sense a prey or danger. If the cat decides to move, it does that slowly and cautiously. The second mode is tracing mode. The tracing mode simulates the cat chasing a prey. After finding a prey while seeking mode, the cat decides its movement speed and direction based on the prey's position and speed. This algorithm is terminated if the cat hunt down a prey.

The aim of this work is to study the performance of Grey Wolf Optimizer (GWO) for tuning the parameters K_p, K_i and K_d of PID controller. The objectives to be achieved from this study are to optimize PID controller using Grey Wolf Optimizer (GWO) and Dragonfly Algorithm (DA) and compare the performance of Grey Wolf Optimizer and Dragonfly Algorithm.

2.0 OPTIMIZATION ALGORITHM

A. Grey Wolf Optimizer

Grey Wolf Optimizer is a nature-inspired metaheuristic proposed by Mirjalili [5]. Grey Wolf Optimizer is basically an algorithm influenced based on the social behavior of grey wolves, group hunting in addition to the social hierarchy of wolves in the pack. Based on the **Figure 1**, the pack is dominated by alphas, followed by beta, delta and omega. The alpha wolves are the leader and responsible for making decisions for the pack. The betas are subordinate wolves that advice alpha in decision making. The omega plays the role of scapegoat and must submit to all the other dominant wolves. In order to model the social hierarchy of wolves, the fittest solution is considered as alpha followed by beta, delta and omega respectively.

B. Dragonfly Algorithm

Dragonfly algorithm is another algorithm that designed by Mirjalili [6]. Dragonfly is basically an algorithm inspired from the static and dynamic swarming behaviors of dragonflies. The modelling is designed based on the action, finding for the foods and by-passing enemies when swarming dynamically or statically.

3.0 METHODOLOGY

A. System Plant

A plant transfer function is needed to design the closed- loop system. Three different plant transfer function were chosen from research papers. According to Pareek *et al*. [7], G_{p1} (*System A*) was used while one from a research paper, G_{p2} (System *B*) by Wadhwani and Verma [8]. Another one, G_{p3} (System *C*) from a research paper by Zahir *et al*. [9]. The System *A* is based on the ball and hoop system. The System *B* is based on the DC servo motor. The last system, System C is representing the brushed DC motor for cart follower system. The plant transfer functions, System *A*, System *B* and System *C* are depicted as Equation (1), (2) and (3) respectively.

$$G_{p1}(s) = \frac{1}{s^4 + 6s^3 + 11s^2 + 6s} \tag{1}$$

$$G_{p2}(s) = \frac{0.01}{0.005s^3 + 0.06s^2 + 0.1001s} \tag{2}$$

$$G_{p3}(s) = \frac{104.9}{s^3 + 103.5s + 2617} \tag{3}$$

B. Cost Function as Objective Function

This work is focusing on optimizing PID controller by tuning PID parameters. In order to identify whether the PID parameters are optimized or not, certain criteria were observed using cost function. Optimized PID must be able to give minimal cost function.

The cost function is represented by Equation (4). The elements that can be obtained from cost function were peak overshoot, M_p, steady-state error, e_{ss}, rise time, T_r and settling time, T_s. This cost function was chosen because it is well defined what a good PID controller supposed to be. Minimal peak overshoot, minimal steady-state error, short rise time and short settling time [10].

$$F = (1 - e^{-\rho})(M_p + e_{ss}) + (e^{-\rho})(T_s - T_r) \quad (4)$$

Where ρ is the scaling factor of designer's choice

According to Gaing [11], the value of ρ can be set larger than 0.7 for low overshoot and steady-state error while for short rise time and settling time, the value of ϱ can be set less than 0.7. For this study, two values of ϱ were chosen, which are 0.5 and 1.5.

C. Algorithm Parameter

The algorithm has its own specialized control parameters that can be tuned based on the optimization problem. This parameter is like an interface of the algorithm. The control parameters are listed in **Table 1** for GWO, and **Table 2** for Dragonfly Algorithm.

Table 1. Control Parameters GWO for System *A*, *B* and *C*

System	*A*	*B*	*C*
Number of agents	30	30	30
Dimension	3	3	3
Maximum iterations	200	200	200
Upper bound	10	50	1500
Lower bound	0	0	0

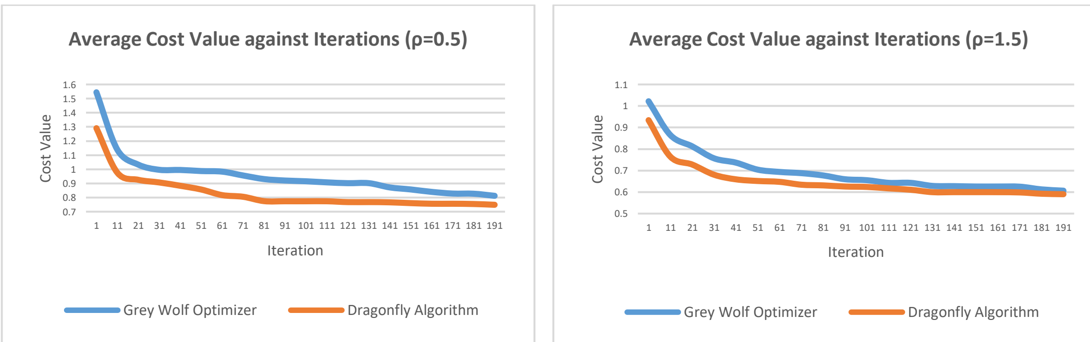
Table 2. Control Parameters DA for System *A*, *B* and *C*

System	*A*	*B*	*C*
Number of agents	50	50	50
Dimension	3	3	3
Maximum iterations	200	200	200
Upper bound	10	50	1500
Lower bound	0	0	0

5.0 RESULTS AND DISCUSSION

A. Average Cost Analysis

Figure 1 (a) and (b) shows the result of System *A*, Dragonfly Algorithm outperformed Grey Wolf Optimizer by having the lowest steady cost value for both cases, ρ=0.5 and ρ=1.5. The rate of convergence for both algorithms are almost the same.



(a) (b)

Figure 1. (a) and (b) show the graph of average cost versus iterations using System *A* with ϱ = 0.5 and ϱ = 1.5.

Figure 2 (a) and (b) show the graph of average cost versus iterations using System *B* with $\rho = 0.5$ and $\rho = 1.5$. Dragonfly Algorithm has a slightly better performance compared Grey Wolf Optimizer for both cases, ρ=0.5 and ρ=1.5. However, the lowest cost value obtained by both algorithms were almost equal for case ρ=0.5. For case ρ=1.5, dragonfly algorithm reached lower steady cost value compared to Grey Wolf Optimizer. However, it can be seen that the GWO reached minimum cost quicker than Dragonfly algorithm for both cases.

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