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Optimization of PID Controller's parameters for Gantry Crane Application using Glowworm Swarm Optimization Algorithm

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ABSTRACT – This paper investigates the implementation of Glowworm Swarm Optimization in tuning parameters of PID Controllers for the gantry crane application. Each glowworm location in the search space represents five parameter values of PID controllers. Then, the paper implements the generic Glowworm Swarm Optimization Algorithm using sum of absolute error of the trolley displacement as fitness for evaluating agent fitness. Result obtained shows the potential of the algorithm in tuning parameters of controller for gantry crane application.

1. INTRODUCTION

Gantry crane is always used for lifting and moving heavy load system from one location to another location [1]. In gantry crane modelling there are two outputs from a gantry crane heavily considered in designing and implementing a control strategy: trolley displacement and payload displacement [2]. The objective is to minimize the error between the desire and actual value for trolley displacement and payload displacement.

Many literatures had attempt in achieving the minimal error as stated in the paragraph earlier. H. I. Jaafar *et al.* had proposed the priority-based fitness scheme using Binary Particle Swarm Optimization algorithm in tuning PID parameters in year 2013 [2]. In the same year also, the same authors had proposed the use of Particle Swarm Optimization with priorty-based scheme in solving the gantry crane problem [3]. A year later, implementation of Firefly Algorithm in tuning the parameters of PID in gantry crane was proposed [4]

Glowworm Swarm Optimization (GSO) is one of the Swarm Intelligence (SI) algorithms which mimic the natural behaviour of Glowworm in searching for food [5]. GSO shows promising result when being compared to the benchmark dataset in evaluating of an SI algorithm [5]. The original algorithm adapted from [5], thus this paper excluded the flowchart of the algorithm due page limitation. The modelling of the algorithm will be explained in details in the methodology section.

2. METHODOLOGY

The model of gantry crane for this study is taken from previous literature in order to fairly compared result obtained with past literatures [1]. Figure 1 shows the model used in this study, where the parameters is defined as in Table 1.

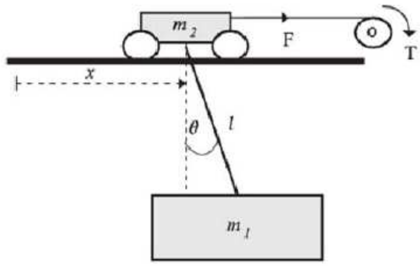

Figure 1 Schematic diagram of a gantry crane [1]

Table 1 Parameters of the system [1]

Payload mass (m_1)	1 kg
Trolley mass (m_2)	5 kg
Cable length (l)	0.75 m
Gravitational (g)	9.81 ms^{-2}
Dumping Coefficient (β)	12.32 Nsm^{-1}
Resistance (R)	2.6 Ω
Gear ratio (z)	15
Torque constant (K_T)	0.007 NmA^{-1}
Electrical constant (K_E)	0.007 Vsrad^{-1}
Radius of pulley (r_p)	0.02 m

The modelling had been explained extensively in [1] and [2] where the control strategy implemented is using two PID controller one PID controller for controlling trolley position and another PD controller to control the payload oscillation. This can be illustrated as in Figure 2. Thus in obtaining optimal control result, there are five parameters of that need to be tuned: K_{P1} is the proportional gain for trolley displacement's PID controller, K_{I1} is integral gain for trolley displacement's PID controller, K_{D1} is the derivative gain for trolley displacement's PID controller, K_{P2} is the proportional gain for payload oscillation's PID controller, and K_{D2} is the derivative gain for payload oscillation's PID controller.

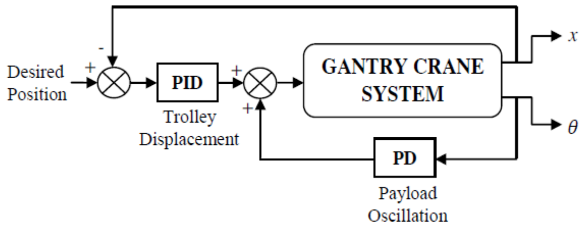

Figure 2 Block diagram of proposed approach

The proposed modelling of the PID's parameters using GSO as in (1) where x_i is the *i*-th agent position for *t*-th iteration.

$$\vec{x_i}(t) = [K_{P1}, K_{I1}, K_{D1}, K_{P2}, K_{D2}]^T \quad (1)$$

The algorithm used as proposed in the original GSO paper [5] where the values of parameters of GSO used as shown in Table 2 where most of the parameters values taken from original literature [5]. The values of γ and r_0 are varied from 0 to 1.

Table 2 Parameters of proposed GSO

Number of run (z)	10
Number of agent (n)	50
Sensor range (r_s)	5
Iteration (t_{max})	250
Threshold decision range (r_{min})	0
Lucifer enhancement constant (γ)	[0, 1]
Lucifer decay constant (r_0)	[0, 1]
Number of neighbour (n_t)	5
Step size (s)	0.3
Decision range gain (β)	0.08

The fitness to evaluate the agent of GSO is as shown in (2) where J is the objective function of an agent which is is based on Sum of Absolute Error (SAE). SAE for this application is using simulation time of 20 seconds, and sampling time of 0.1 second. Thus, number of sampling is 200 times. x_a is the actual trolley displacement and x_d is the desire trolley displacement.

$$J(x) = SAE = \sum_{k=0}^{200} |x_a(k) - x_d(k)| \quad (2)$$

3. RESULTS AND DISCUSSION

Figure 3 shows the average of 10 computations of SAE obtained by GSO for different combination of γ (represented using g) and r_0 (represented using r) are varied from 0 to 1. The circle represents the mean of the 10 computations while the end of top and bottom arrow represented maximum and minimum values of SAE, respectively. Combination of $\gamma = r_0 = 0.5$ provides the best result where the mean SAE is minimal. It can be also seen that for $\gamma = 0.7$ and $r_0 = 0.3$, the result obtained is poor compared to other combination of γ and r_0.

Figure 3 shows the best result obtained whereby the desired trolley displacement is set at 1m, the actual output takes less than 2 second to settle. While the oscillation occurred by the payload is less than 0.25 rad.

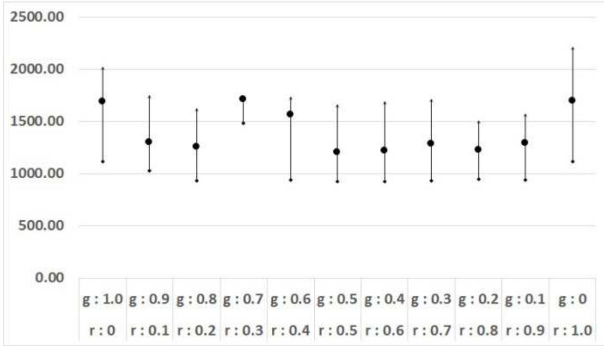

Figure 3 Result for different combination of γ and r_0

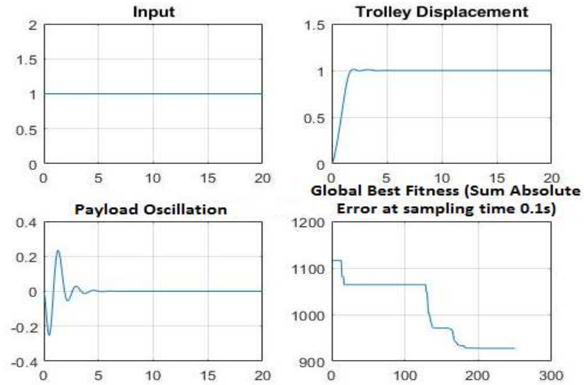

Figure 4 Result of the best found solution by GSO

4. CONCLUSION

This paper presented the result obtained from implementing GSO in tuning PID's parameters in gantry crane system. The result obtained shows that GSO able to tune the parameters for the application. Further analysis is required in order to find the relationship between the GSO parameters with the outcome of the tuned PID parameters.

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