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Supervisor's Name : En. Hazriq Izzuan bin Jaafar

Date : 1st June 2015

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THE EFFECTIVENESS OF VARIATION WEIGHT SUMMATION APPROACH FOR GANTRY CRANE SYSTEM VIA MULTI OBJECTIVE GRAVITATIONAL SEARCH ALGORITHM (MOGSA)

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A report submitted in partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)

Faculty of Electrical Engineering

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To my beloved father and mother

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ABTRACT

Gantry Crane System (GCS) is known as an object that able to lift heavier load horizontally from one point to another point. It is commonly used in industry for heavy load related in transporting and loading large objects. Moreover, the applications of GCS also are not perfect since that there are always have disturbance when transporting the load. Regarding to this, the probabilities to cause dangerous to the surrounding area are high. Thus, to prevent this, many researchers try to investigate on how to prevent this problem. By using various kind of algorithm, the result shows which kind of algorithm are better to obtain high optimization of GCS. This report focuses the implementation a new algorithm known as Gravitational Search Algorithm (GSA) into GCS. This algorithm gain interest by many researchers since the introduced in 2009. Therefore, the GSA will be implemented with 5 controllers of (PID+PD) into GCS to obtain a good optimization. By using MATLAB R2012a, the simulations of block diagram GCS will be modeled by using mathematical function of Lagrange Equation. This algorithm will be implemented Multi Objective Gravitational Search Algorithm (MOGSA) technique and the result will be compared with another algorithm from previous journal known as Multi Objective Particle Swarm Optimization (MOPSO). The result obtained shows that MOGSA are better in optimization than MOPSO.

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ABSTRAK

Gantri Kren Sistem (GCS) dikenali sebagai satu objek yang mampu mengangkut beban dari satu tempat ke tempat yang lain. Ia biasanya digunakan dalam industri untuk beban berat yang tertumpu dalam pengangkutan objek yang besar. Selain itu, aplikasi GCS juga tidak sempurna kerana terdapat gangguan apabila mengangkut beban. Sehubungan dengan itu, kebarangkalian system ini menyebabkan bahaya kepada kawasan sekitarnya adalah tinggi. Oleh itu, ramai para penyelidik cuba untuk menyiasat mengenai bagaimana untuk mengelakkan masalah ini berlaku. Dengan menggunakan pelbagai jenis algoritma, hasil yang ingin dinyatakan bahawa algorithma yang terbaik adalahan algorithma yang mampu mendapatkan pengoptimuman yang tinggi. Laporan ini memberi tumpuan pelaksanaan algoritma baru yang dikenali sebagai Carian Graviti Algorithma (GSA) ke dalam GCS. Algorithma ini amat dikenali oleh ramai penyelidik semenjak ia diperkenalkan pada tahun 2009. Oleh itu, GSA akan dilaksanakan dengan menggunakan 5 kawalan (PID + PD) ke dalam GCS untuk mendapatkan pengoptimuman yang baik. Dengan menggunakan MATLAB R2012a, simulasi gambarajah blok GCS akan dimodelkan dengan menggunakan fungsi matematik Persamaan Lagrange. Algoritma ini akan menggunakan teknik Multi Objektif Carian Graviti Algorithma (MOGSA) sebagai hasil dimana ianya akan dibandingkan dengan algoritma lain yang dikenali sebagai Multi Objektif Pengoptimunan Kumpulan Zarah (MOPSO).Hasil menunjukkan MOGSA mempunyai pengoptimunan yang baik berbanding MOPSO.

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LIST OF SYMBOLS

x	-	Displacement
θ	-	Oscillation
V	-	Voltage
L	-	Inductance
B	-	Damping Ratio
R	-	Resistance
K_t	-	Torque constant
K_e	-	Electric constant
z	-	Gear ratio
r_p	-	Radius of pulley
g	-	Gravity
i	-	Armature current
m	-	Mass
l	-	Length
θ_m	-	Rotor angle position
T_m	-	Motor torque
T_L	-	Load torque

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LIST OF ABBREVIATIONS

AB	-	Armed Bandit
BGSA	-	Binary Gravitational Search Algorithm
BPSO	-	Binary Particle Swarm Optimization
DGSA	-	Discrete
DFS	-	Depth First Search
FACTS	-	Flexible AC Transmission System
FL	-	Fuzzy Logic
GA	-	Genetic Algorithm
GABSA	-	Gravitational Algorithm Based on Simulated Annealing
GCPSO	-	Guaranteed Coverage Particle Swarm Optimization
GCS	-	Gantry Crane System
GSA	-	Gravitational Search Algorithm
LMI	-	Linear Matrix Inequalities
LMQ	-	Lloyd-Max Quantization
MGSA	-	Memory Gravitational Search Algorithm
MOGSA	-	Multi Objective Gravitational Search Algorithm
MOPSO	-	Multi Objective Particle Swarm Optimization
NOGSA	-	Non-dominated Sorting Gravitational Search Algorithm
MAS	-	Multi Agent System
PCB	-	Printed Circuit Board
PSO	-	Particle Swarm Optimization
UPFC	-	Unified Power Flow Controller
WSN	-	Wireless Sensor Network

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CHAPTER 1

INTRODUCTION

1.1 Gantry Crane System

The Gantry Crane System (GCS) is a lifting object by a hoist which can move horizontally on a rail or pair of rails fitted under a beam. GCS is suited to lift a heavy objects and huge gantry cranes that are mostly used for ship building. GCS is commonly used in industry for heavy load that related with the process of transporting and carrying the load.

Figure 1.1: Gantry Crane System (GCS)

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GCS consists of trolley, which in horizontal plane. The payload is attached to the trolley by a cable vertically, whose length can be varied by a hoisting mechanism. The load with the cable is treated in one-dimensional pendulum and moves in linear direction. The operations of GCS in many industrial are achieved based on the skill of the experienced crane operators. The precise payload positioning is difficult to control due to the fact that the payload is free to swing in a pendulum-like motion. If the payload performance is not concern, it may cause damage to the surrounding environment and personnel. Thus, the controllers are always used to achieve fast and reliable response with reduced cost and high precision positioning.

1.2 Problem Statement

There are several problem statements as listed below:

1. Moving the payload using the crane is not an easy task especially when strict specifications on the swing angle and on the transfer time need to be satisfied.

2. The usage of GCS to transfer the load are not safety due to the natural characteristic such as swing, robustness or error that might be occur and cause incident.

3. Conventional tuning technique of PID controller parameter is a constraint for finding the optimum condition value. Finding the optimal value for PID controller parameter is significantly contributed to the advancement of control system knowledge and fulfills with industrial needs.

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1.3 Objectives

There are three objectives need to be achieved:

- To model the linear and nonlinear of Gantry Crane System (GCS) using Lagrange Equation.
- To analyze the linear weight summation approach for obtaining optimal PID+PD controller parameters and performance in terms of overshoot, settling time and steady-state error.
- To compare the performance of overshoot, settling time and steady-state error response between Multi Objective Gravitational Search Algorithm (MOGSA) and Multi Objective Particle Swarm Optimization (MOPSO).

1.4 Scopes

This research focuses more on:

1. Derivation and modeling the linear and non-linear equation of the GCS via Lagrange equation.

2. Apply the optimal PID+PD controller to control the performance of payload by using PD controller and various desired position of trolley displacement by using PID controller.

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3. Observe the simulation of overshoot, settling time and steady-state error on trolley displacement with different payload oscillation.

4. Implement the Multi Objective Gravitational Search Algorithm (MOGSA) to solve highly optimization problems in GCS.

1.5 Motivation

One of the most priorities when dealing a real work environment is safety. Many cases and accident can occur during handling the crane. On 2nd February 2012, at Port Mann Bridge, Canada, it was reported where 700 tons of Gantry Crane fell down. The distinctive yellow Gantry Crane was holding about 90 tons sections of the bridge deck. Due to this situation, it causes danger to people nearby and employee. Thus, many factors must be considered not only to reduce the accident but also to prevent the loss of innocent life.

1.6 Report Outlines

Chapter 1 is an introduction about GCS in real life environment where the problem statement, objectives, scopes and motivation of projects are stated clearly.

Chapter 2 discusses the review from previous researchers on GSA applications from 2009 until 2015. The advantages of GSA are determined and conclude as a reason to implement this algorithm to GCS.

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Chapter 3 is about methodology that will be used for this project. The mathematical calculation for Lagrange equation for linear and non-linear are derived. GCS is modeled by using MATLAB Simulink software. The GSA technique also will be implemented in GCS

Chapter 4 focuses on the result obtained from the simulation. The block diagram of GCS is modeled and the performance responses from the output are included in the graph. The different output response are discussed and analyzed between linear and non-linear equations for the first phase. At the second phase, the result of GCS with five parameter controller (PID+PD) will be shown. Lastly, the result involves the analysis of the linear weight summation performance by using MOGSA technique and will be compared with MOPSO technique performance.

Chapter 5 is a conclusion from the overall report done and some recommendations for future works also are stated.

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CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter focuses the review from previous research about the system that has been implemented via Gravitational Search Algorithm (GSA). Based on the previous review, this GSA is known as one of the technique in algorithm that suitable to solve optimization problem in engineering system.

2.2 PID Control Systems

PID controller has been widely used in various industries and known as a control feedback mechanism controller. It involves three term parameters which consist of proportional (P), integral (I) and derivative (D). The PID is used to minimize the error by adjusting the process control inputs and improve the error value that occur between a measured process variable and a desired set point.

$$u = K_P e + K_i \int e \, dt + K_d \left(\frac{de}{dt}\right) \quad (2.1)$$

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In PID controller, three parameters need to be tuned. A proportional controller (***K_P***) has the effect of decreasing the rise time and steady state error but the percentage of overshoot in the system was increased. For the integral controller (***K_I***), the rise time also decrease but it will eliminate the steady state error in the system while the percentage of overshoot remains high together with settling time as well. Another parameter known as derivative controller (***K_D***) has the ability to improve the transient response and increase the stability of the system. This characteristic of P, I and D performance can be summarized as Table 2.1 below:

Table 2.1: PID Controller Properties

Controller	**Effect of performance**			
	Rise Time (T_r)	**Steady State Error (SSE)**	**Overshoot (OS)**	**Settling Time (T_s)**
Proportional (P)	Decrease	Decrease	Increase	Small Change
Integral (I)	Decrease	Eliminate	Increase	Increase
Derivative (D)	Small Change	Small Change	Decrease	Decrease

The performances of ***K_P*, *K_I*** and ***K_D*** are dependent on each other. If one of these changes, it might be affecting the other two controller performances as well. Thus, Table 2.1 is used as a reference to obtain high stability and short transient response of the system.

2.3 Gravitational Search Algorithm

Gravitational Search Algorithm (GSA) is one of the latest meta-heuristic algorithms introduced by Rashedi *et al*. in 2009 that inspired by the Newtonian Law of Gravity: "Every particle in the universe attracts each other with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them"

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[1]. The GSA has been applied mostly in complex engineering system such as hole drilling process, simulated annealing, retaining structure, real power loss and voltage deviation optimization, hexagonal honeycomb sandwich plate, discrete optimization problem and etc. Typically, GSA is a standard algorithm that can be applied in various systems. Since the introduction, due to the great interest by lots of researcher around the world, this algorithm has been enhanced to be more specified cases such as Binary Gravitational Search Algorithm (BGSA), Memory Gravitational Search Algorithm (MGSA), Non-dominated Sorting Gravitational Search Algorithm (NOGSA) and Multi Objective Gravitational Search Algorithm (MOGSA). In this project, the MOGSA will be applied to the GCS and compare the performance response result between Multi Objective Particle Swarm Optimization (MOPSO).

2.4 Research on Gravitational Search Algorithm

In order to get a better optimization, Rashedi et al. have introduced a new optimization based on the law of gravity and mass interactions [1]. The agents are considered as objects where their performances are measured by their masses. The agents consist of four specifications: position, inertia mass, active gravitational mass, and passive gravitational mass. In other word, this mass presented as an optimum solution in the search space. The heavier of the mass indicates as a better agent which has higher attractions and walk more slowly. This can cause a faster convergence rate and search the space more locally.

Hassanzadeh et al. proposed a MOGSA that focuses the methods on how close the obtained result are to the global optimum [2]. The optimizations problems are not aimed to single objective but rather to maximize a set of objective exist as MOPSO. By using the MOGSA, the optimization problems can be recognize as this technique are able to set a balance between two important factor by tuning K-parameter.

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For Muneendra Ojha, the GSA has been modified by implementing the Multi Agent System (MAS) to find the optimum strategy in managing demand supply chain management and observes the pattern of product usage [3]. The result of GSA shows functionally useful for optimized solution to a non-linear and dynamic problem domain, where MAS have capability choose to perform the action that of result in the optimal outcome for itself among all feasible actions.

In addition, Sudin et al. modified the GSA known as Discrete Gravitational Search Algorithm (DGSA) for discrete optimization problems based on its direction and velocity [4]. The DGSA shows its advantages as it is superior rather than the existing BGSA in terms of quality of solution found and speed of convergence as well as less likely to trap in local minima.

Other researchers also use this kind of technique to presents an effective optimization method for nonlinear constrained of retaining structures. Khajehadeh et al. applied GSA controls all geotechnical and structured design constraints while reducing the cost of retaining walls [5]. The optimization result shows that the GSA required far fewer iteration and less computational time when compared with Particle Swarm Optimization (PSO) and GA. Thus, it is extremely well for solving the economic design of retaining structure.

To achieve high optimization, Suresh et al. have applied the GSA for real power loss and voltage deviation optimization to solve multi constrained optimal reactive power flow problem in power system [6]. The performance of GSA is tested on standard IEEE-30 bus test system using MATLAB. By using the parameter, the results are compared with other method to prove the effectiveness of the new algorithm like PSO and BBO. The result stated that GSA takes less number of iterations while maintaining the global best result. The GSA also is capable to achieving global optimal solution and good in dealing with power system optimization problems.

Shendi et al. proposed a commitment of hydro thermal generation scheduling of a large power system with cooling-banking constraint by using GSA [7]. Since that the objective is to minimize the total system operating cost, GSA is applied and demonstrated. The result shows

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