GSA–TUNED PID CONTROLLER FOR A NONLINEAR GANTRY CRANE SYSTEM

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A report submitted in partial fulfilment of the requirements for the degree of

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DECLARATION

I declare that this report entitles "GSA–Tuned PID Controller for a Nonlinear Gantry Crane System" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date : 5 JULY 2021

APPROVAL

"I hereby declare that I have read through this report entitle "*GSA–Tuned PID Controller for a Nonlinear Gantry Crane System*" and found out that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering.

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Date : 5 JULY 2021

DEDICATIONS

Specially dedicated to my beloved mother, father, brothers and friends who have encouraged, guided and inspired me throughout my journey of education.

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Firstly, I would like to express my sincere gratitude to my supervisor Ts. Dr. Hazriq Izzuan Bin Jaafar for his guidance, patience, motivation, enthusiasm, immense knowledge, and support throughout my research. His guidance really helped me in all the time of research and completing this project during this pandemic. I could not have imagined having a better supervisor, mentor, and guidance in completion of my final year project in Universiti Teknikal Malaysia Melaka

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ABSTRACT

This project introduces the implementation of an efficient PID+PD controller to control a nonlinear 2D Gantry Crane System (GCS). In order to find the optimal PID+PD parameters for the controller, investigation on the existing Particle Swarm Optimization (PSO), Priority–Fitness Binary PSO (PFBPSO) and Multi–Objective PSO (MOPSO) tuning techniques are used. The combination of PID and PD controllers are utilized for various desired positions and low payload mass oscillation control of the GCS, respectively. The transient responses and behavior of the GCS are observed and analyzed. Simulation is conducted within MATLAB environment to verify the overall performances of the GCS. Based on the investigation, MOPSO is shown to obtain optimal PID+PD parameters and provided the best transient responses of the GCS compared to PSO and PFBPSO. Therefore, the MOPSO is chosen as a benchmarking, and compared with a Multi-Objective Gravitational Search Algorithm (MOGSA) which is used in the investigation to observe the significant of an alternative meta-heuristic optimization for the GCS. Hence, based on the investigation, MOGSA is shown to obtain optimal PID+PD parameters and provided the best transient responses of the GCS compared to MOPSO.

ABSTRAK

Projek ini memperkenalkan pelaksanaan sistem pengawal PID+PD yang cekap untuk mengawal Sistem Kren Gantri (SKG) 2D yang tidak linear. Untuk mencari parameter PID+PD yang optimum untuk pengawal, penyelidikan mengenai teknik penyesuaian Pengoptimuman Kerumunan Zarah (PSO), Fitnes–Keutamaan Binari PSO (PFBPSO) dan Objektif–Pelbagai PSO (MOPSO) digunakan. Kombinasi pengawal PID dan PD digunakan untuk berbagai posisi yang diinginkan dan kawalan ayunan jisim muatan rendah SKG. Tindak balas sementara dan tingkah laku SKG diperhatikan dan dianalisis. Simulasi dilakukan dalam lingkungan Matlab untuk mengesahkan keseluruhan prestasi SKG. Berdasarkan penyelidikan, MOPSO ditunjukkan untuk memperoleh parameter PID+PD yang optimum dan memberikan tindak balas sementara SKG yang terbaik berbanding PSO dan PFBPSO. Oleh itu, MOPSO dipilih sebagai penanda aras, dan dibandingkan dengan Objektif–Pelbagai Algoritma Pencarian Graviti (MOGSA) yang mana ia digunakan dalam penyelidikan untuk melihat siknifikasi pengoptimuman alternatif meta-heuristik untuk SKG. Oleh itu, berdasarkan penyelidikan, MOGSA memperoleh parameter PID+PD yang optimum dan memberikan tindak balas SKG yang terbaik berbanding dengan MOPSO.

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LIST OF ABBREVIATIONS

GCS	-	Gantry Crane System
GSA	-	Gravitational Search Algorithm
MOGSA	-	Multi-Objective Gravitational Search Algorithm
FA	-	Firefly Algorithm
PFS	-	Priority-based Fitness Scheme
PFFA	-	Firefly Algorithm via Priority-based Fitness Scheme
PSO	-	Particle Swarm Optimization
MOPSO`	-	Multi-Objective Particle Swarm Optimization
PFBPSO	-	Particle Swarm Optimization via Priority-based Fitness Scheme
PID	-	Proportional, Integral and Derivative Controller
AI	-	Artificial Intelligent
GA	-	Genetic Algorithm
DFS	-	Delay Feedback Signal
LQR	-	Linear Quadratic Controller
SMC	-	Sliding Mode Controller
SSE	-	Steady-State Error
Ts	-	Settling Time
OS	-	Percent of Overshoot

LIST OF SYMBOLS

x	-	Trolley Position
θ_1	-	Payload Oscillation
m_1	-	Trolley Mass
m_2	-	Payload Mass
L	-	Cable Length
g	-	Gravity Acceleration
F	-	Force Input
kg	-	Kilogram (Mass unit)
m	-	Meter (Distance unit)
V	-	Velocity
T	-	Kinetic Energy
P	-	Potential Energy
K_P	-	Gain of Proportional Controller
K_I	-	Gain of Integral Controller
K_D	-	Gain of Derivative Controller
K_{PS}	-	Gain of Proportional Controller for Payload Oscillation
K_{DS}	-	Gain of Derivative Controller for Payload Oscillation

CHAPTER 1

INTRODUCTION

1.0 Overview

This section provides a brief overview of the project. There are few explanations about the Gantry Crane System (GCS). This chapter explains the problem statement, objectives, scopes, and research outline for the entire research.

1.1 Introduction

A crane is machine and capable of lifting loads by its own weight or by a counterweight to lift an object. Basically, crane is an articulated structure that consist of two or more parallel beams and rotate about their fixed ends. One end is fixed and the other rotates while each beam has one or more pulleys or sheaves arranged around it.

The most basic purpose for using cranes is to lift heavy things in the air by themselves, especially over long distances such as with certain construction projects. Crane is machine or tool that help people migrate payloads from one place to another. The crane is made up of a wire rope, hoist, and sheaves that could be utilized to lift and lower a load horizontally. The hoist is a simple machine that assists people in moving loads that are too heavy for them to carry.

In the year 900BC, Ancient Greeks created the first crane [1]. Cranes were first operated by animals, such as donkeys, and then by humans. As a result, it is thought that the Ancient Greeks used these cranes to construct tall structures for building purposes. In today's world, the ability to move loads such as tools, equipment, and other items to a distant or close location is critical. The majority of loads to be moved are typically large, heavy, and dangerous, and cannot be handled manually by humans.

Cranes are divided into two types, static cranes and mobile cranes. A static crane as shown in Figure 1.1 is a permanent or semi-permanent structure that lifts and transports items along a fixed path and is fixed to the ground or building. As shown in Figure 1.2, a mobile crane is a crane that can be transported from job site to job site and is mounted on treads or wheels. Mobile cranes, unlike static cranes, are not bound to a defined path.

Figure 1.1: Static Crane

Figure 1.2: Mobile Crane

The fundamental aim of a crane is to move huge loads of material from one location to another as quickly as feasible while maintaining the target position, reducing payload oscillation, and meeting safety requirements.

Cranes are divided into three main categories known as gantry cranes, boom cranes, and rotary cranes. Trolley movement across a bridge is part of the GCS support mechanism. In the horizontal plane, this bridge is supported by a second set of orthogonal railings. This design allows for one or two rectilinear translations of the suspension point in the horizontal plane.

The rotary crane consists of a jib that is fixed on the vertical axis and rotates at a fixed speed. The only motions allowed are the suspension point, a rotation, and two horizontal plane motions. The boom crane has a permanent suspension at the end of the boom, as well as two motion patterns, one of which is rotation around two orthogonal axes at the base of the boom.

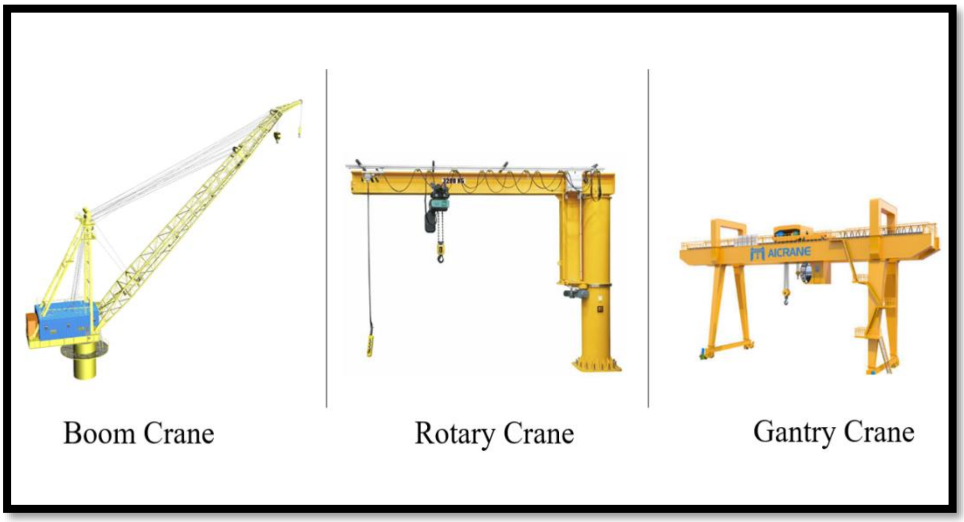

Figure 1.3: Types of Cranes System

Trolley movement across a bridge is part of the GCS support mechanism. In the horizontal plane, this bridge is supported by a second set of orthogonal railings. The suspension point can be moved in the horizontal plane in one or two rectilinear directions with this design. The rotary crane consists of a jib that is fixed on the vertical axis and rotates at a fixed speed. Only the suspension point, two horizontal plane motions, and a rotation are allowed. The boom crane has a permanently suspended end and two motion patterns, one of which is rotation around two orthogonal axes at the boom's base.

In conclusion, a crane is a machine that uses a pair of long horizontal lifting arms and a hook to lift and move objects. They are typically operated by an operator with a control panel or joystick. Some of the important parts that make up the crane's lift capacity is determined by its weight, height above ground, diameter of the cutting edge, lifting speed on one side, and load on the other two. Nevertheless, crane's base must be flat and even before it can operate correctly.