# OPTIMIZATION OF HYBRID FUZZY PROPORTIONAL DERIVATIVE CONTROLLER USING PSO FOR SINGLE AXES GIMBAL SYSTEM

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## DECLARATION

I declare that this project report entitled *"Optimization of Hybrid Fuzzy Proportional Derivative Controller Using PSO for Single Axes Gimbal System"* is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

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| Date | : | 22 SEPTEMBER 2022 |

# DEDICATION

This thesis is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

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# ABSTRACT

A gimbal is a device that can stabilize payload or an object around a single or several axes of rotation. Inertially stabilized platform is another term for a gimbal (ISP). The gimbal mechanism is divided into two categories. The first part is the scanning application. The second group is tracking application. The sensor axis should be accurately focused on target point for a suitable gimbal system. Tuning process for controllers is the critical issues. Since, manual tuning considered as a time consuming and can't achieve the best system performance, Particle Swarm Optimization (PSO) method has been used to optimize the Proportional Integral Derivative (PID) and Fuzzy Logic Controller (FLC). Manual tuning FLC has achieved a better performance than Ziglor Niclos PID controller. The best performance has been achieved I when utilizing the FLC scaling factors with optimized Proportional Derivative (PD) controller. The results were satisfying and the objective of this project has been achieved, where the settling time was equal to 0.2 seconds, zero overshoot and zero steady state error.

# ABSTRAK

Gimbal ialah sebuah alat yang boleh menstabilkan beban bayar ataupun satu objek pada satu ataupun beberapa paksi putaran. Platform terstabil secara inertia ialah satu lagi istilah untuk gimbal (Inertially Stabilised Platform - ISP). Mekanisme gimbal terbahagi kepada dua kategori. Bahagian pertama ialah aplikasi pengimbasan. Kumpulan kedua ialah aplikasi penjejakan. Paksi penderia perlu ditumpukan dengan tepat pada titik sasaran untuk satu sistem gimbal yang sesuai. Proses penalaan untuk alat-alat kawalan ialah isu kritikal. Oleh sebab penalaan manual dianggap memakan masa dan tidak mampu mencapai prestasi sistem yang terbaik, kaedah Pengoptimaan Kawanan Zarah (Particle Swarm Optimisation - PSO) telah digunakan untuk mengoptimumkan pengawal Berkadar-Kamiran-Terbitan (Proportional-Integral-Derivative - PID) dan Logik Kabur (Fuzzy Logic - FLC). Penalaan FLC secara manual telah mencapai prestasi lebih baik berbanding pengawal PID Ziegler-Nichols. Prestasi terbaik dicapai apabila faktor penskalaan FLC digunakan dengan pengawal Berkadar-Terbitan (PD) teroptimum. Hasilnya memuaskan dan matlamat projek ini telah pun tercapai di mana masa penetapan bersamaan 0.2 saat tanpa pelampauan dan tanpa ralat keadaan mantap.

# TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| DOF | - | Degree of Freedom |
| FIS | - | Fuzzy Inference System |
| FLC | - | Fuzzy Logic Controller |
| GA | - | Genetic Algorithm |
| MF | - | Membership Function |
| PSO | - | Particle Swarm Optimization |
| PID | - | Proportional-Integral-Derivative |
| SISO | - | Single Input Single Output |
| SMC | - | Sliding Mode Controller |
| T-S FLC | - | Takagi Sugeno Fuzzy Logic Controller |
| ZN | - | Ziglor Niclos |
| PD | - | Proportional-Derivative |

# LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.1 Background Study

A gimbal is a device that can stabilize payload or an object around a single or several axes of rotation. A sensor, such as a camera, is usually the payload for a gimbal, but it might also be a missile, radar, gun, or laser. A two-axis gimbal can steady a payload along the yaw (azimuth) and pitch (elevation) axes. Inertially stabilized platform is another term for a gimbal (ISP). Many studies have recently been conducted on the modelling and control of gimbal system. [1] The gimbal mechanism is divided into two categories. the first part is the scanning application. The gimbal is set up to point at the desired coordinates. The second group is the tracking application. The sensor axis should be accurately focused on target point for a suitable gimbal system. [2] [3]

Single axis gimbal system consists of a DC motor to rotate the payload of the gimbal and position sensor to measure the angle position of the gimbal. Many controllers have been designed for controlling the gimbal. Linear controllers provide good performance when the mass of payload of the gimbal is not very big. However, if the payload's inertia is big linear controllers don't perform very well for stabilizing the gimbal. Intelligence controllers provide excellence result. However, it lacks of the simplicity of designing. Two axes gimbal system is the most popular kind of gimbals, the two axes gimbal is very similar to the single axes interim of designing and controlling. Basically, a two axes gimbal consists of two single gimbals which are inner and outer gimbal. Some studies consider the coupling relation between the inner and outer loop, for making the designing easier some researchers don't consider any coupling effecting. Figure 1.1 shows the tow axes gimbal. [1] [4] [5]

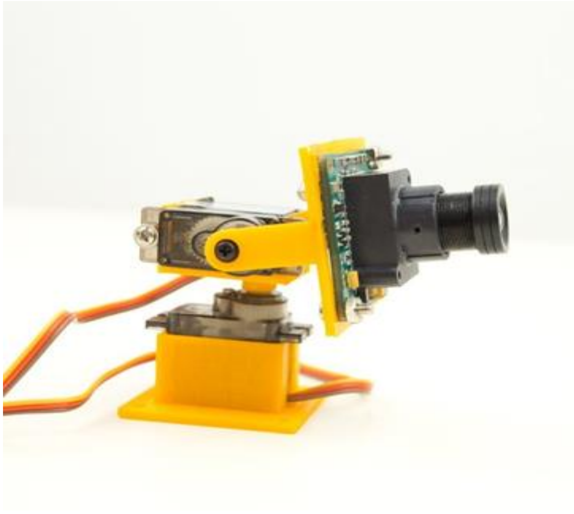

Figure 1.1 Two axes gimbal

## 1.2 Problem Statement

The single-axis gimbaled platform suffers from the slow response and lack of accuracy while remaining stable throughout target tracking. It is well known that the Fuzzy controller used to improve the performance of the system depends upon the tuning of the fuzzy membership functions or rule base of fuzzy system or scaling factors for fuzzy inputs and outputs. However, manual tuning is not sufficient and time consuming. Therefore, using optimization method to tune these parameters is very important to optimize the system performance and overcome all the tuning problems.

## 1.3 Objectives

The project objectives are as follows:

1. To design fuzzy logic controller for single-axis gimbal system.
2. To optimize FLC using particle swarm optimization method.
3. To test the controller performance and compare it with PID controller using MATLAB software.

## 1.4 Scope of Project

The followings describe the scope of the project:

- The controllers are to be designed based on PID and fuzzy logic.

- To develop the controller and test the performance using MATLAB SIMULINK.

- To use PSO method to optimize the system performance.

- To develop PSO code in MATLAB software.

## 1.5 Organization of this Report

The subsequent chapters are organized as follows; Chapter 2 reviews relevant literature in the field of gimbal system as well as some fuzzy and other controllers that have been used. Chapter 3 discusses modelling of the gimbal system and the methodology used in the design of PID and fuzzy logic controllers and particle swarm optimization method to optimize the controllers which are used in this project. This is followed by Chapter 4 which highlights the simulation and experimental results. Finally, chapter 5 will highlight the summary of the project and future work.

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