



اقْرَأْ بِاسْمِ رَبِّكَ الَّذِي خَلَقَ (1)

خَلَقَ الْإِنْسَانَ مِنْ عَلَقٍ (2)

اقْرَأْ وَرَبُّكَ الْأَكْرَمُ (3) الَّذِي

عَلَّمَ بِالْقَلَمِ (4) عَلَّمَ الْإِنْسَانَ

مَا لَمْ يَعْلَمْ (5)

□□□□□□ □□□□ □□□

□□□□ □□□□ :□□□□□□ (5 - 1)

Dedication

Dedicated to
My Wife and My Daughter

Acknowledgement

I would like to thank all those who supported me, my mother, my father, my brothers, and my sisters. Special thanks are due to my Supervisor/ Prof. Saad Daoud Sulaiman El-Shamma, for his supporting me. I greatly express my thanks to all persons whom supported me in completing this research

ABSTRACT

The main objective of this thesis is to simulate and implement two dimensional (2-D) tracking systems using two DC motion control system.

In this thesis an introduction has been given to the importance of 2-D tracking systems and its operation. The system component discussed briefly based on motion control system which is the core of the system. It is specified to use DC motor as actuator. DC motor has been modeled by writing differential equations of its circuit, after that the component of motion control system added one by one until it completed. The motion control system simulated and analyzed using .MATLAB/ SIMULINK

In this thesis the Proportional–Derivative (PD) controller preferred because there was integral component in the forward path of the system and it gave acceptable .Simulation results

The analysis results have been compared with the system .specification using MATLAB/SIMULINK software

□□□□□□□□

الهدف الرئيسي من هذه الدراسة هو تصميم نظام تتبع ثنائي الأبعاد باستخدام نظام للتحكم في الحركة يعمل بمحرك التيار المستمر. في هذه الدراسة أوضحت المقدمة أهمية نظام التتبع ثنائي الأبعاد وطريقة عمله. تم شرح مكونات النظام باختصار اعتماداً على نظام التحكم في الحركة والذي يمثل قلب نظام التتبع. تم إيجاد المخطط الكتلي لمحرك التيار المستمر وذلك من المعادلات التفاضلية لدائرة المحرك, بعد ذلك تم إضافة مكونات نظام التحكم في الحركة إلى أن إكتمل النظام. تم محاكاة وتحليل النظام باستخدام برنامج MATLAB/SIMULINK. في هذه الدراسة تم تفضيل استخدام المتحكم التناسبي-التفاضلي على غيره لأنه يوجد مكون تكاملي في المسار الأمامي للنظام. نتائج التحليل تمت مقارنتها مع مواصفات النظام باستخدام برنامج MATLAB/SIMULINK ثم مناقشتها وعرضها.

TABLE OF CONTENTS

| PAGE | DESCRIPTION |
|--|---|
| i | الآية |
| ii | DEDICATION |
| iii | ACKNOWLEDGEMENT |
| iv | ABSTRACT |
| v | المستخلص |
| vi | TABLE OF CONTENTS |
| x | LIST OF FIGURES |
| xiii | LIST OF ABBREVIATIONS |
| xiv | LIST OF SYMBOLS |
| CHAPTER ONE: INTRODUCTION AND LITERATURE REVIEW | |
| 1 | Introduction 1.1 |
| 1 | Problem Statement 1.2 |
| 2 | Objectives 1.3 |
| 2 | Methodology 1.4 |
| 2 | Literature Review 1.5 |
| 4 | Thesis Structure 1.6 |
| CHAPTER TWO: THEORETICAL BACKGROUND | |
| 5 | Introduction 2.1 |
| 6 | Tracking systems 2.2 |
| 6 | Types of Control System Design 2.3 |
| 7 | Classification of control systems 2.4 |
| 7 | Open-Loop and Closed-loop Control Systems 2.5.1 |
| 8 | Analog and Digital Control Systems 2.5.2 |
| 9 | Classification According to Application 2.5.3 |
| 9 | Process Control 2.5.3.1 |
| 9 | Sequentially Controlled Systems 2.5.3.2 |
| 10 | Motion Control Systems 2.5.3.3 |
| 10 | Servomechanisms Systems 2.5.3.4 |

| | |
|---|--|
| 10 | Numerical Control System 2.5.3.5 |
| 11 | Robotics Systems 2.5.3.6 |
| 11 | Control systems design 2.6 |
| 11 | Control System Integration 2.7 |
| 12 | Main component of the tracking system 2.8 |
| 13 | Sensors 2.8.1 |
| 14 | Encoder 2.8.1.1 |
| 15 | Resolver 2.8.1.2 |
| 16 | Actuators 2.8.2 |
| 16 | Motors 2.8.2.1 |
| 21 | Controller 2.8.3 |
| 22 | Proportional control 2.8.3.1 |
| 22 | Integral control 2.8.3.2 |
| 22 | Derivative control 2.8.3.3 |
| 22 | PID control 2.8.3.4 |
| 23 | Fuzzy logic controllers 2.8.3.5 |
| 23 | Tuning PID Controller 2.8.3.6 |
| 24 | Programmable logic controller 2.8.3.7 |
| 25 | Analog-to-Digital and Digital-to-Analog 2.8.4 Converter |
| 26 | Driver 2.8.5 |
| 27 | Slip rings 2.8.6 |
| 27 | Limit switch 2.8.7 |
| 28 | Inductive sensors 2.8.7.1 |
| CHAPTER THREE: MODELING AND SIMULATION | |
| 29 | Introduction 3.1 |
| 29 | System Specification 3.2 |
| 30 | Mathematical Modeling of DC Motor 3.3 |
| 32 | System block diagram 3.4 |
| 32 | System Design 3.5 |
| 32 | Azimuth axis position control system 3.5.1 |
| 33 | Motor 3.5.1.1 |

| | |
|----|--|
| 34 | Reduction ratio 3.5.1.2 |
| 37 | Controller 3.5.1.2 |
| 40 | Encoder 3.5.1.3 |
| 41 | Elevation Axis Position Control System 3.5.2 |
| 41 | Motor 3.5.2.1 |
| 42 | Reduction ratio 3.5.2.2 |
| 44 | Controller 3.5.2.2 |
| 46 | Limiter 3.5.2.4 |
| 48 | Encoder 3.5.2.3 |

| | |
|--|------------------------------|
| CHAPTER FOUR: ANALYSIS | |
| 49 | Introduction 4.1 |
| 49 | Azimuth axis 4.2 |
| 49 | Azimuth Travel Angle 4.2.1 |
| 50 | Disturbance rejection 4.2.2 |
| 51 | Overshoot 4.2.3 |
| 51 | Delay time 4.2.4 |
| 52 | Rise time 4.2.5 |
| 52 | Settling time 4.2.6 |
| 53 | Steady-state error 4.2.7 |
| 53 | Input following 4.2.8 |
| 54 | Elevation axis 4.3 |
| 54 | Elevation Travel Angle 4.3.1 |
| 55 | Disturbance rejection 4.3.2 |
| 55 | Overshoot 4.3.3 |
| 56 | Delay time 4.3.4 |
| 56 | Rise time 4.3.5 |
| 57 | Settling time 3.4.6 |
| 57 | Steady-state error 3.4.7 |
| 58 | Input following 4.3.8 |
| CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS | |
| 59 | Conclusions 5.1 |
| 60 | Recommendations 5.2 |
| 61 | References |

| LIST OF FIGURES | |
|------------------------|--|
| 5 | Figure: 2.1 the axes of movement for El over Az Tracking Pedestal |
| 7 | Figure 2.2 : Open-loop control systems |
| 8 | Figure 2.3: closed-loop control systems |
| 13 | Figure 2.4: tracking system components |
| 16 | Figure 2.5 Internal structure of a resolver |
| 17 | Figure 2.6: DC motor construction |
| 17 | Figure 2.7: simplified model of a DC motor |
| 18 | Figure 2.8: Permanent magnet DC motor equivalent circuit |
| 19 | Figure 2.9: A single phase motor using capacitor and centrifugal switch |
| 22 | Figure 2.10: controller in simple position control system |
| 26 | Figure 2.11: Illustrate usage of ADC and DAC |
| 30 | Figure 3.1 Model of a separately excited dc motor |
| 32 | Figure 3.2 Block diagram of a dc-motor system |
| 33 | Figure 3.3 Assumed box shape |
| 35 | Figure 3.4 Armature-Controlled DC Motor with Gear Block Diagram |
| 36 | Figure 3.5 The Step response of system with velocity feedback |
| 36 | Figure 3.6: Position and velocity feedback model |
| 37 | Figure 3.7: Step response of the position feedback .system |
| 38 | Figure 3.8 the system model with PD controller |
| 39 | Figure 3.9 system step response for first tuning |
| 39 | Figure 3.10: System step response of second tuning |
| 40 | Figure 3.11: System step response of last tuning |
| 41 | Figure 3.12 Assumed box shape for elevation |
| 43 | Figure 3.13 The Step response of system with |

| | |
|----|--|
| | velocity feedback |
| 43 | Figure 3.14 the step response for position feedback system |
| 45 | Figure 3.15 system step response for first tuning |
| 45 | Figure 3.16: System step response after second tuning |
| 46 | Figure 3.17: System step response of last tuning |
| 46 | Figure 3.18: Elevation system with electrical limiter |
| 47 | Figure 3.19: System step response when sets to 120° |
| 47 | Figure 3.20: System step response when sets to -12° |
| 49 | Figure 4.1: System step response when set point = 380° |
| 50 | Figure 4.2: System step response when set point = -80° |
| 50 | Figure 4.3: System step response to test the disturbance rejection |
| 51 | Figure 4.4: System step response when set point = 45° |
| 51 | Figure 4.5: System step response when set point = 45° |
| 52 | Figure 4.6: System step response to find rise time |
| 52 | Figure 4.7: System step response find the settling time |
| 53 | Figure 4.8: System step response to find steady state error |
| 53 | Figure 4.9: Illustrate the output follows the input |
| 54 | Figure 4.10: System step response when set point = 90° |
| 54 | Figure 4.11: System step response when set point = -7° |

| | |
|----|---|
| 55 | Figure 4.12: System step response to test disturbance rejection ability |
| 55 | Figure 4.13: System step response when set point = 30° |
| 56 | Figure 4.14: System step response to find delay time |
| 56 | Figure 4.15: System step response to find rise time |
| 57 | Figure 4.16: System step response to find settling time |
| 57 | Figure 4.17: System step response to find steady state error |
| 58 | Figure 4.18 the output follows the input profile |

LIST OF ABBREVIATIONS

| | |
|---|------|
| Two dimension | D-2 |
| Analog-to-digital converter | ADC |
| Active disturbance-rejection controller | ADRC |
| Brushless direct current motor | BLDC |
| Digital-to-analog converter | DAC |
| Degree of freedom | DOF |
| Digital signal processor | DSP |
| Extended state observer | ESO |
| Light emitting diode | LED |
| A linear variable differential transformer | LVDT |
| Microelectronic mechanical system | MEMS |
| Numerical control | NC |
| Personal computer | PC |
| Proportional- Derivative | PD |
| Proportional integral derivative controller | PID |
| Programmable logic controller | PLC |
| Permanent magnet | PM |
| Permanent magnet direct current | PMDC |
| Process variable | PV |
| Pulse-width modulation | PWM |
| Silicon-controlled rectifiers | SCRs |
| Set point | SP |
| Variable reluctance | VR |

| LIST OF SYMBOLS | |
|---------------------------|------------|
| Rotor angular velocity | ω_m |
| Load angular velocity | |
| rotor displacement | θ_m |
| Load angular acceleration | |
| back-emf constant | |
| back-emf | |
| Proportional gain | K_P |
| Integration gain | K_I |
| Derivative gain | K_D |

| | |
|---|----------|
| Voltage across the coil of the armature | V_a |
| Back emf electrical motion force | E_b |
| Armature current | i_a |
| Armature resistant | R_a |
| Armature inductance | L_a |
| Torque constant | K_t |
| Load torque | T_L |
| Motor torque | T_M |
| moment of inertia of the rotor | J |
| damping (friction) of the mechanical system | B |
| System displacement | θ |
| Efficiency | η |
| magnetic flux in the air gap | Φ |
| Reduction ratio | N |
| Rise time | t_r |
| Settling time | t_s |
| Maximum Overshoot | M_p |
| Delay time | t_d |
| steady-state error | e_{ss} |