# Table of Contents

Certificate ii  
Acknowledgement iii  
List of Figures viii  
List of Tables x  
Abstract

## Chapter 1. Overview 1  

## Chapter 2. Background 12  

### 2.1. Conventional Methods 12  
#### 2.1.1. Gain Scheduling 13  
#### 2.1.2. Feedback Linearization 13  
#### 2.1.3. Variable Structure Control techniques 14  
#### 2.1.4. Sliding Mode Control 14  
#### 2.1.5. Back-stepping Approach 15

### 2.2. Intelligent Methods 15  
#### 2.2.1. Expert Systems 16  
#### 2.2.2. Fuzzy Control 17  
#### 2.2.3. Neural Control 18  
#### 2.2.4. Neuro-Fuzzy Control 19  
#### 2.2.5. Evolutionary Computation 20

### 2.3. Design of Fuzzy Systems 22  
#### 2.3.1. Fuzzy Controller Design 23  
#### 2.3.2. Adaptive Robust Fuzzy Control of Nonlinear Systems 24  
#### 2.3.3. Integrating membership functions and fuzzy rule sets from multiple knowledge sources 26  
#### 2.3.4. Analysis and Design of Fuzzy Controller Based on Observer 27  
#### 2.3.5. Fuzzy Observer-Based Control of Nonlinear Systems 27  
#### 2.3.6. Design and analysis of a fuzzy logic controller 28
2.3.6.1 Design of Simple Fuzzy Controller
2.3.6.2 Choosing Fuzzy Controller Inputs and Outputs
2.3.6.3 Putting Control Knowledge into Rule-Bases
2.3.6.4 Fuzzy Quantification of Knowledge
2.3.6.5 Matching: Determining Which Rules to Use
2.3.6.6 Inference Step: Determining Conclusions
2.3.6.7 Converting Decisions into Actions
2.3.6.8 MATLAB Simulation of Fuzzy Controller for Inverted Pendulum

2.3.7 Sliding Mode Observers for Takagi–Sugeno Fuzzy Systems
2.3.8 LMI-Based Design of T-S Fuzzy Estimator based Controllers
2.3.9 Fuzzy Regulators and Fuzzy Observers: Relax stability conditions and LMI-based designs
2.3.10 Separation principle: for the analysis & design of fuzzy controller & observer
2.3.11 Design of Fuzzy Controller – Stability concerns
  2.3.11.1 TSK Fuzzy Plant Model, Fuzzy Controller and Fuzzy Control System
  2.3.11.2 Stability Analysis
2.3.12 Fuzzy Controller - Real Time Implementation Issues

Chapter 3. Evolutionary Computations
3.1 Evolutionary Algorithms
3.2 Why Evolutionary Algorithms?
3.3 Basics of Evolutionary Algorithms
3.4 Terminology of Evolutionary computation
3.5 Encoding, Mutation and Crossover
  3.5.1 Numeric Search domains
  3.5.2 Function Search domains
3.6 Population Initialization
3.7 Selection Operators
  3.7.1 Tournament selection
3.7.2. Proportional selection or Roulette wheel selection
3.7.3. Ranking Selection
3.7.4. Steady State Selection
3.7.5. Manual Selection

3.8. Use of EA for Design of Intelligent controllers
3.8.1. Fuzzy Controllers
3.8.2. Neural Controllers

3.9. Stability and Optimality in GA based control
3.9.1. Convergence of the GA controller Population
3.9.2. Stability of GA controllers
3.9.3. Optimality of the GA controllers

3.10. Simulation of PID Controller using GA

3.11. Summary

Chapter 4. Evolutionary Computational Techniques
4.1. Real Time constraints in Intelligent Control
4.1.1. Intelligent control
4.1.2. Real Time Control
4.2. Structure and Parameter Tuning of Neural Network
4.3. Fuzzy Tuned Neural Network
4.4. Design of Fuzzy Controller – A Genetic Algorithm Approach
4.5. GA based methods for Constructing TSK Fuzzy Rules
4.6. Self Learning Fuzzy Logic Controllers using GA with reinforcement
4.7. Evolutionary design of Fuzzy Rule Base
4.8. Hierarchical Evolutionary approach to Design Fuzzy Systems
4.9. Evolutionary fuzzy Systems
4.10. Summary

Chapter 5. Real time Applications of Evolutionary Computational Techniques
5.1. GA based Fuzzy Logic controller – GAFLC for nonlinear systems
5.2. Genetic Reinforcement Fuzzy Logic Controller – GRFLC
5.3. Multi-objective Fuzzy Genetic Algorithm for control system design

vi
5.4. Optimal Fuzzy control using Genetic Algorithm for Spindle Motor 114
5.5. Evolutionary Design for Robust Flight Control 116
5.6. Self Tuning Neuro-Fuzzy Controller by GA (NFCGA) 118
   for Coupled Tank level control
5.7. Genetic Programming based Design of Fuzzy logic controller 122
   for Mobile Robot Path Tracking

Chapter 6.  Real time Control of Ship & Aircrafts – Historical perspective 126
6.1. Ship Steering Problem 126
   6.1.1. Artificial Neural Network 127
   6.1.2. Fuzzy Controller 129
6.2. Aircrafts maneuvering & control 132
   6.2.1. Fuzzy Control 133
   6.2.2. Genetic Algorithm based approach 135
   6.2.3. Adaptive Critic Network 136
6.3. Summary 137

Chapter 7.  Preliminary Analysis 138
7.1. Fuzzy Model Reference Learning Controller (FMRLC) 138
   7.1.1. The Fuzzy Controller 140
   7.1.2. The Reference Model 143
   7.1.3. Learning Mechanism 144
7.2. Ship Dynamics 147
7.3. Aircraft Dynamics 150
7.4. Helicopter Dynamics 154

Chapter 8.  Implementation 157
8.1. Cargo Ship Steering Application 157
8.2. Simulation 160
8.3. Fault Tolerant Aircraft Application 177
8.4. Simulation 181
8.5. Helicopter Application 183

Chapter 9.  Conclusion and Future Scope of work 186

Chapter 10.  Bibliography 187