## Sirindhorn International Institute of Technology Thammasat University

Thesis ME-PhD-2004-02

ADAPTIVE FUZZY CONTROL OF OPTIMAL AIR CONDITIONS WITH EFFICIENT ENERGY USAGE

Surut Atthajariyakul

## **Table of Contents**

apter	Title	Page
	Signature Page	i
	Acknowledgement	ii
	Abstract	iii
	Table of Contents	· v
	List of Tables	ix
	List of Figures	х
1.	Introduction	
	1.1 Statement of problem	1
	1.2 Literature reviews	4
	1.2.1 Background on the study of control	
	in HVAC system	5
	1.2.2 Background on the study of fluidized	
	bed grain drying	14
	1.2.3 Concluding remarks	17
	1.3 Objectives of the study	18
	1.4 Scope of the study	18
	1.5 Methodology of the study	19
	1.5.1 Study method of real-time determination	
	of optimal air conditions	20
	1.5.2 Implementation of real-time optimization	
	and adaptive fuzzy control	20

2.	Theory of Optimization and Adaptive Fuzzy Logic	
	Control System	21
	2.1 Basic concept of optimization	21
	2.1.1 Introduction	21
	2.1.2 Gradient-descent Method	22
	2.1.3 Steepest descent method	25
	2.1.4 Newton's method	26
	2.2 Basic Theory of Fuzzy Logic Control System	27
	2.2.1 Fuzzy Sets	27
	2.2.2 Fuzzy logic control system	30
	2.2.3 Development of fuzzy logic controller	30
	2.3 Adaptive fuzzy controller	36
	2.4 Real-time implementation of optimization	
	and control with fuzzy adaptive control	38
3.	Determination of Optimal Air Conditions for	
	Efficient Energy Usage of HVAC System	41
	3.1 Parameter index	41
	3.1.1 Thermal comfort index	42
	3.1.2 Indoor-air quality index	50
	3.1.3 Energy consumption index	51
	3.2 Real-time determination of optimal conditions	
	by gradient-based method	52
	3.3 Real-time implementation	56
	3.4 Experimental results and discussion	57
	3.4.1 Field measurement	57
	3.4.2 Performance of existing HVAC control system	58
	3.4.3 Model verification	62
	3.4.4 Real-time implementation	63

4.	Fluidized Bed Paddy Drying in Optimal Air Conditions			
	by Adaptive Fuzzy Logic Control	69		
	4.1 Principle of rice drying	69		
	4.1.1 Introduction	69		
	4.1.2 Drying principle	69		
	4.1.3 Moisture content representation	71		
	4.1.4 Equilibrium moisture content definition	71		
	4.2 Analytical statement of fluidized bed drying	73		
	4.2.1 Rice quality index	73		
	4.2.2 Energy consumption index	77		
	4.3 Real-time determination of optimal conditions	78		
	4.4 Adaptive fuzzy logic control design	80		
	4.4.1 Fuzzy logic control design	80		
	4.4.2 Adaptive fuzzy logic control with sensitivity			
	learning rules	85		
	4.4.3 Real-time implementation of optimization and control	ol 86		
	4.5 Results and discussion	88		
	4.5.1 Model verification	88		
	4.5.2 Real-time implementation of optimization and contr	ol 89		
5.	Conclusion	94		
	References	96		
	Appendix A: Metabolic rate and clothing insulation values	101		
	Appendix B: Neural network PMV-model	104		
	B.1 Neural network model	105		
	B.2 Neural network PMV-model	106		
	B.3 MATLAB computer program for calculating neural-PMV	109		
	Appendix C: The study of an alternative neural network			
	PMV-model	110		
	C.1 Introduction	111		

C.2 Field measurement	112		
C.3 Predicted Mean Vote	113		
C.4 Neural computing PMV index	114		
C.5 Result and discussion	116		
C.6 Conclusion	118		
Appendix D: Calculation of water-vapor saturated-pressure			
and calculation of some derivative terms in Chapter 3	121		
D.1 Calculation of water-vapor saturated-pressure	122		
D.2 Calculation of derivative terms in Chapter 3	123		
D.3 MATLAB computer program for calculating			
the differential terms of $\frac{\partial PMV}{\partial T_a}$ , $\frac{\partial PMV}{\partial R_b}$ and $\frac{\partial PMV}{\partial v}$	125		
Appendix E: Property of paddy and moisture equilibrium			
of cereal grains	126		
E.1 Density of paddy	127		
E.2 Specific heat of paddy	128		
E.3 Heat transfer coefficient	129		
E.4 Grain equilibrium moisture content	130		
E.5 Drying rate	131		
E.6 Calculation of derivative term in Chapter 4	132		