Data Mining and Knowledge Discovery for Process Monitoring and Control

With 121 Figures



CONTENTS

1	Int	roduction	1
	1.1	Current Approaches to Process Monitoring, Diagnosis	
		and Control	2
	1.2	Monitoring Charts for Statistical Quality Control	4
	1.3	The Operating Window	5
	1.4	State Space Based Process Monitoring and Control	6
	1.5	Characteristics of Process Operational Data	8
	1.6	System Requirement and Architecture	9
	1.7	Outline of the Book	11
2		ta Mining and Knowledge Discovery - an erview	13
	2.1	Definition and Development	13
	2.2	The KDD Process	15
	2.3	Data Mining Techniques	17
	2.4	Feature Selection with Data Mining	25
	2.5	Final Remarks and Additional Resources	27

3	Data Pre-processing for Feature Extraction, Dimension Reduction and Concept			
	ro.	rmation	29	
	3.1	Data Pre-processing	29	
	3.2	Use of Principal Component Analysis	30	
	3.3	Wavelet Analysis		
	3.4	Episode Approach	57	
	3.5	Summary	59	
4	Mu	Iltivariate Statistical Analysis for Data		
		alysis and Statistical Control	61	
	4.1	PCA for State Identification and Monitoring	61	
	4.2	Partial Least Squares (PLS)		
	4.3	Variable Contribution Plots		
	4.4	Multiblock PCA and PLS	72	
	4.5	Batch Process Monitoring Using Multiway PCA	72	
	4.6	Nonlinear PCA	74	
	4.7	Operational Strategy Development and Product Design		
		- an Industrial Case Study	76	
	4.8	General Observations		
5	Suj	pervised Learning for Operational		
	-	pport	85	
	5.1	Feedforward Neural Networks	85	
	5.2	Variable Selection and Feature Extraction for		
	2,2	FFNN Inputs	91	
	5.3	Model Validation and Confidence Bounds		
	5.4	Application of FFNN to Process Fault Diagnosis	94	
	5.5	Fuzzy Neural Networks	99	
		5		

XVI

			XVII
	5.6	Fuzzy Set Covering Method	101
	5.7	Fuzzy Signed Digraphs	102
	5.8	Case Studies	
	5.9	General Observations	116
6	Un	supervised Learning for Operational State	e
	Ide	ntification	119
	6.1	Supervised vs. Unsupervised Learning	119
	6.2	Adaptive Resonance Theory	120
	6.3	A Framework for Integrating Wavelet Feature Extracti	on
		and ART2	124
	6.4	Application of ARTnet to the FCC Process	
	6.5	Bayesian Automatic Classification	
	6.6	Application of AutoClass to the FCC Process	142
	6.7	General Comments	147
7	Ind	luctive Learning for Conceptual Clusterin	g
7		luctive Learning for Conceptual Clusterin I Real-time Process Monitoring	149
7		l Real-time Process Monitoring	_
7	anc	I Real-time Process Monitoring	149 150
7	anc 7.1	l Real-time Process Monitoring	149 150
7	and 7.1 7.2	Inductive Learning IL for Knowledge Discovery from Averaged Data IL for Conceptual Clustering and Real-time	149 150 153
7	and 7.1 7.2	Inductive Learning IL for Knowledge Discovery from Averaged Data IL for Conceptual Clustering and Real-time Monitoring	149 150 153 156
7	and 7.1 7.2 7.3	Inductive Learning IL for Knowledge Discovery from Averaged Data IL for Conceptual Clustering and Real-time	149 150 153 156 164
7	 and 7.1 7.2 7.3 7.4 7.5 	I Real-time Process Monitoring Inductive Learning IL for Knowledge Discovery from Averaged Data IL for Conceptual Clustering and Real-time Monitoring Application to the Refinery MTBE Process General Review	149 150 153 156 164
	 and 7.1 7.2 7.3 7.4 7.5 Au 	I Real-time Process Monitoring Inductive Learning IL for Knowledge Discovery from Averaged Data IL for Conceptual Clustering and Real-time Monitoring Application to the Refinery MTBE Process	149 150 153 156 164 172
	 and 7.1 7.2 7.3 7.4 7.5 Au fro 	Inductive Learning Inductive Learning IL for Knowledge Discovery from Averaged Data IL for Conceptual Clustering and Real-time Monitoring Application to the Refinery MTBE Process General Review tomatic Extraction of Knowledge Rules m Process Operational Data	 149 150 153 156 164 172 173
	 and 7.1 7.2 7.3 7.4 7.5 Au 	I Real-time Process Monitoring Inductive Learning IL for Knowledge Discovery from Averaged Data IL for Conceptual Clustering and Real-time Monitoring Application to the Refinery MTBE Process General Review tomatic Extraction of Knowledge Rules	 149 150 153 156 164 172 173 173

	8.3	Rules Generation Using Rough Set Method	178
	8.4	A Fuzzy Neural Network Method for Rules	
		Extraction	180
	8.5	Discussion	
9	Inf	erential Models and Software Sensors	193
	9.1	Feedforward Neural Networks as Software Sensors	193
	9.2	A Method for Selection of Training / Test Data and	
		Model Retraining	194
	9.3	An Industrial Case Study	196
	9.4	Dimension Reduction of Input Variables	204
	9.5	Dynamic Neural Networks as Inferential Models	210
	9.6	Summary	212
		ncluding Remarks	215
Ар	-	dix A The Continuous Stirred Tank	
	Kea	actor (CSTR)	217
Ар	pend	dix B The Residue Fluid Catalytic	
		acking (R-FCC) Process	221
Ap		dix C The Methyl Tertiary Butyl Ether	
	(INT	TBE) Process	227
Ref	ferer	1ces	233
Ind	lex		249

XVIII