## CONTENTS

1.	Comp	lex processes in engineering design	9
	1.1	Preface	9
	1.2	A practical application: A design process at Audi AG	13
	1.2	1 Description of the process	13
	1.2.	2 Modeling the process as an EPC process chart	17
	1.2	3 Deficits when analyzing the process chart using existing a	methods.17
	1.2	4 Conclusion: Systematic analysis of a process chart	20
	1.3	The need for systematic analysis in practice	21
	1.3	1 The problem: Systematic analysis of a process chart	21
	1.3	2 Basic hypotheses and research questions	23
	1.3	3 The approach used in this research	26
	1.4	Context of developing complexity metrics	26
	1.4.	1 Goals of this research	26
	1.4	2 Basic requirements of the solution	27
	1.4.	3 Targeted audience	28
	1.4	4 What this book is not about	29
	1.4.	5 Related fields of science	30
	1.5	Structure of this book	30
2.	The fo	undations of complexity metrics	33
	2.1	Structural complexity of a system	
	2.1.	1 General notions of managing structural complexity	35
	2.1.	2 Graph Theory	43
	2.1.	3 Matrix-based methodologies to manage structures	45
	2.1.	4 Network Theory	52
	2.1.	5 Other approaches to managing complex systems	56
	2.1.	6 Summary	57
	2.2	Structural aspects of process management	59
	2.2.	1 Processes in Engineering Design	59
			1



	2.2	2.2	Goals of analyzing, improving and managing processes	64
	2.2	2.3	Process models and their structural content	66
	2.2	2.4	Strategies to analyze design processes and models	72
	2.2	2.5	Summary	74
	2.3	Met	rics to analyze the structure of a process	75
	2.3	3.1	Basics and measurement foundation	75
	2.3	3.2	Metrics to describe networks	79
	2.3	3.3	Metrics in software engineering	79
	2.3	3.4	Metrics in process management	82
	2.3	3.5	Metrics for engineering design processes	85
	2.3	3.6	The limits of using metrics in an organization	87
	2.3	3.7	Summary	89
	2.4	Dire	ections from the state of the art	91
3.	Conc	ept o	of an integrated set of complexity metrics	93
	3.1	Solu	ation design process	93
	3.2	Req	uirements for the solution design	94
	3.3	Con	stituents of the solution	95
	3.4	Ove	rall concept: Analysis procedure	97
4.	Mode	eling	the structure of design processes	101
	4.1	Des	ign processes as a multi-layered network	101
	4.2	MD	M-based modeling of the structure of a process	102
	4.3 The		Structural Process Architecture model	104
	4.4	Spe	cific aspects of modeling engineering design processes	109
	4.4	<b>4</b> .1	Alignment of the process structure with the product architectu	re.109
	4.4	4.2	Inclusion of attributes to nodes and edges	111
	4.4	4.3	Decision points modeled as Boolean operators	114
	4.5	Buil	ding the process model	120
	4.5	5.1	Generating a process model	121
	4.:	5.2	Aggregate views recombining domains and relationship types	123
	4.	5.3	Example of a process model for engineering release management	130

	4.6	Con	clusion: MDM-based process modeling	132
5.	Com	plexi	ity Metrics for Design Processes	133
	5.1	Ass	essing structural characteristics using metrics	135
	5.	1.1	Basic and combined structural characteristics	135
	5.	1.2	Solution principles for structural metrics	137
	5.	1.3	Evaluation of structural characteristics using structural metrics	138
	5.	1.4	Structural outliers	142
	5.2	Ove	erview of the Structural Measurement System	143
	5.:	2.1	A comprehensive set of complexity metrics	143
	5.2	2.2	Relevance and limits of basic structural metrics	147
	5.2	2.3	Relevance and limits of combined and specific structural metric	:s150
	5.2	2.4	Classification of available metrics	157
	5.3	An	example application of the Structural Measurement System	159
	5.	3.1	The process in focus	159
	5.:	3.2	Overview of the analyses using structural complexity metrics	161
	5.	3.3	Analyses using complexity metrics for the overall process mode	el 162
	5.:	3.4	Analyses using complexity metrics for each task	163
	5.	3.5	Analyses using complexity metrics for each module	167
	5.	3.6	Conclusions for the regarded process	169
	5.4	Con	clusion: Structural metrics	171
6.	The S	S-GQ	2M framework to select metrics	173
	6.1	Exis	sting frameworks to facilitate the analysis of a system	173
	6.	1.1	Quality Function Deployment and the House of Quality	174
	6.	1.2	Goal-Question-Metric	175
	6.	1.3	Balanced Scorecard	176
	6.	1.4	Directions and requirements	178
	6.2	Syst	tematic access to the structure of a process	179
	6.2	2.1	Goals and questions of structural process analysis	180
	6.2	2.2	Allocation of metrics, domains and relationship-types	185
	6.2	2.3	Identifying structural outliers	187
	6.2	2.4	Structural significance of the outliers	187

	6.3	Usi	Using and adapting the framework		
	6.4	Cor	nclusion: S-GQM framework for structural analysis	190	
7.	Indu	ıstria	al application of metrics	191	
	7.1	Eleo Dev	ctronic control unit design: General analysis in Automotive relopment	191	
	7.	.1.1	Goals and focus of the project	192	
	7.	.1.2	The process model used	192	
	7.1.3		Analysis and findings	195	
	7.	1.4	Implications and validation	208	
	7.	.1.5	Reflection	210	
	7.2	Aut	tomotive design process at Audi AG: Analysis of interfaces	211	
	7.	.2.1	Goals and focus of the project	212	
	7.	.2.2	The process model used	213	
	7.	.2.3	Analysis and findings	218	
	7.	2.4	Implications and validation	223	
	7.	2.5	Reflection	224	
	7.3	Cor	nclusions from the case studies	225	
8.	3. Conclusions and outlook 22			227	
	8.1 Summary of results			227	
	8.2 Reflection			228	
	8.	2.1	Strengths and weaknesses	228	
	8.2.2		Implications for industry	231	
	8.	2.3	Implications for Research	233	
	8.3	Out	tlook	233	
9.	Refe	rence	es	235	
10	. Ap	pend	ix	271	
	10.1	Stru	uctural content of process modeling methodologies	272	
	10.2	Cor	version of a process with logic operators	288	
	10.3	Nes	sting of Boolean operators	295	

10.5	List of structural metrics	298
10.6	Computability of metrics	.390
10.7	Classification of metrics	.392
10.8	GQM-Framework for metrics	396
10.9	Complete results of case study 7.2	.398

## 11. Keyword index

401