

CONTENTS

1. Complex 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 process13

1.2.2 Modeling the process as an EPC process chart17

1.2.3 Deficits when analyzing the process chart using existing methods .17

1.2.4 Conclusion: Systematic analysis of a process chart20

1.3 The need for systematic analysis in practice21

1.3.1 The problem: Systematic analysis of a process chart21

1.3.2 Basic hypotheses and research questions23

1.3.3 The approach used in this research.....26

1.4 Context of developing complexity metrics.....26

1.4.1 Goals of this research26

1.4.2 Basic requirements of the solution27

1.4.3 Targeted audience28

1.4.4 What this book is not about29

1.4.5 Related fields of science.....30

1.5 Structure of this book30

2. The foundations of complexity metrics **33**

2.1 Structural complexity of a system33

2.1.1 General notions of managing structural complexity.....35

2.1.2 Graph Theory43

2.1.3 Matrix-based methodologies to manage structures45

2.1.4 Network Theory52

2.1.5 Other approaches to managing complex systems56

2.1.6 Summary57

2.2 Structural aspects of process management59

2.2.1 Processes in Engineering Design.....59

2.2.2	Goals of analyzing, improving and managing processes	64
2.2.3	Process models and their structural content	66
2.2.4	Strategies to analyze design processes and models	72
2.2.5	Summary	74
2.3	Metrics to analyze the structure of a process.....	75
2.3.1	Basics and measurement foundation	75
2.3.2	Metrics to describe networks.....	79
2.3.3	Metrics in software engineering	79
2.3.4	Metrics in process management	82
2.3.5	Metrics for engineering design processes.....	85
2.3.6	The limits of using metrics in an organization	87
2.3.7	Summary	89
2.4	Directions from the state of the art.....	91
3.	Concept of an integrated set of complexity metrics	93
3.1	Solution design process.....	93
3.2	Requirements for the solution design.....	94
3.3	Constituents of the solution.....	95
3.4	Overall concept: Analysis procedure	97
4.	Modeling the structure of design processes	101
4.1	Design processes as a multi-layered network	101
4.2	MDM-based modeling of the structure of a process	102
4.3	The Structural Process Architecture model.....	104
4.4	Specific aspects of modeling engineering design processes.....	109
4.4.1	Alignment of the process structure with the product architecture	109
4.4.2	Inclusion of attributes to nodes and edges.....	111
4.4.3	Decision points modeled as Boolean operators	114
4.5	Building the process model	120
4.5.1	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	Conclusion: MDM-based process modeling	132
5.	Complexity Metrics for Design Processes	133
5.1	Assessing 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	Overview of the Structural Measurement System	143
5.2.1	A comprehensive set of complexity metrics	143
5.2.2	Relevance and limits of basic structural metrics	147
5.2.3	Relevance and limits of combined and specific structural metrics	150
5.2.4	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 model	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	Conclusion: Structural metrics	171
6.	The S-QM framework to select metrics	173
6.1	Existing 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	Systematic access to the structure of a process	179
6.2.1	Goals and questions of structural process analysis	180
6.2.2	Allocation of metrics, domains and relationship-types	185
6.2.3	Identifying structural outliers	187
6.2.4	Structural significance of the outliers	187

6.3	Using and adapting the framework	189
6.4	Conclusion: S-GQM framework for structural analysis	190
7.	Industrial application of metrics	191
7.1	Electronic control unit design: General analysis in Automotive Development.....	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	Automotive 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	Conclusions from the case studies.....	225
8.	Conclusions and outlook	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	Outlook.....	233
9.	References	235
10.	Appendix	271
10.1	Structural content of process modeling methodologies.....	272
10.2	Conversion of a process with logic operators.....	288
10.3	Nesting of Boolean operators.....	295
10.4	The complete Structural Process Architecture	297

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

Complexity Metrics in Engineering Design
Managing the Structure of Design Processes

Kreimeyer, M.; Lindemann, U.

2011, XIII, 403 p. With online files/update., Hardcover

ISBN: 978-3-642-20962-8