

FOREWORD BY THE AUTHORS

To manage and improve engineering design processes in a methodical and systematic manner, an important issue that needs tackling is their analysis, interpretation and goal-oriented improvement. Although approaches for managing complex processes exist, a systematical, method-based analysis and improvement is still highly difficult.

To support the systematic and holistic analysis and improvement of an engineering design process, this book presents a measurement system that makes use of complexity metrics to embody various patterns of the interplay of a process' entities (e.g. tasks, documents, organizational units, etc.). These metrics are used to draw inferences about the process' behavior (e.g. timeliness, need for communication, forming of opinions, etc.). This way, knowledge about a process can be extracted from existing process models, or new process models can be structured systematically by addressing desirable patterns. This supports management in reducing the risks in process planning through better understanding how the structure of a process impacts the behavior of a process. Generating such a means of process analysis and management provides a major contribution both for academia and industry, especially for the improvement of large and complex engineering design processes. The metrics embody the foundations of network theory and the management of structural complexity to generate a practice-oriented application.

The metrics are supported by a meta-model for process modeling. The meta-model uses multiple-domain matrices, integrating existing process models across common domains and relationship types. The modeling method is enhanced with additional constructs of modeling that act as a bridging between existing dependency models and established process models.

Furthermore, the analysis approach is operationalized by a framework to select the metrics in accordance with the goals of the process analysis. To this end, the metrics are classified and allocated to the common goals of process analysis with regard to the structure of a process, producing eight different guidelines. To enable a flexible application, a modular set-up consisting of three steps is chosen: As a starting point, the strategic level is addressed using common goals of process analysis. Then, these goals are concretized by typical questions that can be posed in their context. Finally, these questions are answered using the metrics and parts of the meta-model.

The overall approach is detailed using three case studies from automotive development; on the one hand, the modeling and goal-oriented analysis of the body-in-white design of a premium class mid-size sedan is shown and, on the other hand, the detailed analysis and extraction of possible weak spots within the concept design, programming, and testing of electronic control units for an SUV is regarded. A third case study on general automotive design is used to illustrate all

individual metrics. Results from the case studies point e.g. to particularly robust parts of the process, to critical structural bottle-necks, to the core drivers for iterations or rework, and, more generally, to potential weak spots in the overall structure of a process.

The book is based on a rigorous scientific approach to illustrate the origin of the presented results as well as the limits of their applicability. At the same time, much attention was put to illustrating all details in their industrial relevance to bridge the scientific approach and its industrial application.

Therefore, the book provides both academia and industry with new insights, above all a comprehensive collection of complexity metrics and their interpretation towards common problems in process management. It expands literature in structural complexity management into this field without limitation to its significance to other areas of application, as e.g. the design and management of complex product architectures.

At the same time, the research in this book was motivated to come “full circle”, i.e. it was created in a way that both the modeling scheme, the analysis approach and the overall guidance about how both modeling and analysis work together were integrated in a more general framework. This endeavor thus guides the overall outline of the book. Nevertheless, none of these constituents to the solution are designed to be exclusive, so that, for example, the complexity metrics can also be based on models other than the multiple-domain matrices that are used here.

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THE RELEVANCE OF COMPLEXITY METRICS

Industry and scientific research require methods to support management of complex engineering development processes in a way that recognises and exploits the characteristics of their structural complexity. In particular, there is a pressing need to find ways to exploit the structural knowledge represented in process models in support of process management.

This research addresses this need through development of a systematic and scientifically rigorous yet practical approach to modelling and analysing processes. The approach is clearly demonstrated by application to different case studies of automotive design. It thereby presents a significant contribution to practitioners wishing to understand and improve their complex processes. It also fills a major gap in the scientific literature by further developing and systematising the emerging area of structural complexity management in engineering design.

The empirical background of this research highlights the complexity of engineering design and clearly outlines the problem that, even when models of the activities, information flows, resources etc. are available, such models are sufficiently complex that problem areas cannot be identified by inspection. The concept of structural analysis serves here as a promising means to address this by identifying potential ‘problem areas’ within a complex process.

The main body of this research considers a comprehensive state of the art drawn from the fields of system theory, graph-theory, matrix-based methods for structural complexity management, network theory, process management and software engineering. Contributions from these disciplines are combined, using an established approach of system analysis, enhanced with a clear goal-orientation. The solution is therefore based on three constituents:

An enhanced method of process modelling is first introduced that encompasses a means of combining existing process models. This modelling scheme is, above all, constructed in a way that it serves as a means of making the use of complexity metrics compatible with existing models that, similarly, represent dependencies in a system.

Based thereon, 52 complexity metrics are explained to analyze a process. The metrics address the clear and pressing need for a rigorous approach to formalise and prepare the large volumes of data required for process analysis in many practical situations, as it is often the case with complex systems. At the same time, the abstract approach is illustrated with extensive tables to support the interpretation of any findings. Above all, however, the substantial set of 52 metrics should form a major resource for further research in structural complexity management for engineering design.

Third, both modeling and analysis approach are combined offering a goal-oriented conduction of process analysis. This completes the description of the new

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