Chapter 86
Tool and Information Centric Design Process Modeling: Three Case Studies

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ABSTRACT

A new design process modeling approach focused on the information flow through design tools is discussed in this chapter. This approach is applied to three long term mechanical engineering design projects spanning 24 months, 12 months, and 4 months. These projects are used to explore the development of the new modeling approach. This is a first step in a broader effort in 1) modeling of design processes, 2) establishing case study research as a formal approach to design research, and 3) developing new design process tools. The ability of engineers to understand the dynamic nature of information throughout the design processes is critical to their ability to complete these tasks. Such understanding promotes learning and further exploration of the design process allowing the improvement of process models, the establishment of new research approaches, and the development of new tools. Thus, enhancing this understanding is the goal of this research effort.

INTRODUCTION

This chapter begins with a general discussion on the design process and approaches to capturing and modeling the design activities. It is not intended to be a comprehensive review of the literature, but to provide a frame of reference with respect to the critical issues associated with design processes. This is followed by a discussion of case study research in engineering design. Again, this section is used to provide the reader with a broad understanding of how current case study research has been undertaken in engineering design and how it can contribute to our understanding of the

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design process. Next, the reader is introduced to the relevant issues associated with representing the information flow through the tools used throughout the design process. Finally, three industry focused case studies are used to illustrate the application of this tool, demonstrating how it can be used to highlight issues such as iteration, information dead-ends, and tool function duality.

THE DESIGN PROCESS

The design process is a flexible, high level, logical network of activities to be performed and/or design tools to be used for the entire act of designing an artifact, formed by choosing desirable candidate(s) from a set of viable activities/design tools based on certain objectives (Hazelrigg, 1998). The design process is the collaboration of scientific "know how" with mental and physical steps being taken toward the goal of arriving at a satisfying solution (Simon, Kotovsky, & Cagan, 2001). It is a social activity which allows the generation of physical and intellectual property from mental organization and physical tasks (Leifer & Tang, 1988). Engineers perform design processes often with varying degrees of success. The goal of the research presented here is to enhance the ability of designers to understand and therefore complete design processes.

Design Process Modeling

Several approaches have been proposed in the literature for modeling design processes and activities. This section is not intended to review exhaustively the different approaches to modeling engineering design processes, but to highlight a fundamental limitation that appears to be common in most approaches. This limitation is their inability to easily capture the activities executed by the engineering designers in larger design projects outside of artificial academic environments. The goal of this research is to overcome this limitation by focusing on the actual engineering design tools that are used and to model the flow of information through these tools. This modeling approach will be discussed in the following sections.

One example of a design process modeling scheme is to view engineering design as a series of transformative steps that can be modeled as state transitions (Reymen, et al., 2006). In this approach, each state of the design, captured as the complete collection of the description of the design product, is modeled with a transition activity linking the initial and final state. A limitation of this approach is that the granularity of defining the transition activities is extremely coarse and there is no clear demarcation between states, as these are an artifact of the process modeler, rather than the design process itself.

Ullman presents a different approach to modeling the design process based on his empirical studies in the early 1980's (Ullman, Dietterich, & Stauffer, 1988). This approach seeks to define the task episode accumulation (TEA) model as a sequence of tasks that are essential information processing activities. The different activities are classified to include such actions as gather, synthesize, and decide. In this manner, the TEA model looks at sequencing the actual actions taken by individual designers as opposed to capturing the transition states between the entire collection of design product information. This model has been used to capture designer thought processes in controlled environments, but not in larger design projects as it would quickly become too unwieldy to process each task.

Another transformation based modeling approach to engineering design is that of the Function-Behavior-Structure model (Gero, 1990). In this model, there are eight basic steps that transform a function objective into a structure to realize that objective. While this model suggests that there is a distinction between different types of information and defines different design activities as formulation, synthesis, analysis, evaluation, documentation, and three types of reformulation,