An Integrated Design Environment for Early Stage Conceptual Design

Jingyan Zuo*

Semiconductor Product Sector, Motorola Inc.

Austin, Texas 78729, USA

Stephen W. Director*

College of Engineering, University of Michigan

Ann Arbor, Michigan 48109, USA

Abstract

Conceptual design, the preliminary phase of design in which both well-defined problem specifications and high level design solutions are developed, is becoming increasingly important as design complexity increases. In spite of the importance of this activity, few tools exist to support this phase of design. In this paper we present a systematic and flexible model of cocneptual design and describe how this model has been employed to realize a prototype conceptual design process management environment, called Clio II.

1. Introduction

Up to 85% of the life-cycle costs of a product are determined during the early stages of design, often referred to as the conceptual design phase, while at that point only about 5% of the life-cycle costs have been spent. Improvements made at the conceptual design stage, rather than at the detailed design stage, can significantly reduce the time-to-market of high-quality products and overall costs. A poor, hasty decision made during the conceptual design phase may be impossible to overcome during the detailed design phase that follows. Therefore it is becoming increasingly important to carefully and thoroughly consider important design trade-offs at the conceptual design phase.

Since conceptual design tends to be highly unpredictable as it is an evolving process in which both the understanding of the problem and design concept are iteratively refined, it is hard to automate and very few CAD tools have been developed to support it.

2. Conceptual Design

Our approach to managing and coordinating the conceptual design process is based on the model of conceptual design shown in Figure 1. The model features three interleaved design cycles: problem definition, issue resolution and concept formation. The dual-directional transition links within each cycle, as well as between each pair of cycles, indicate design iterations.

Problem definition yields a design problem statement that may include a problem description (i.e. a specification of the desired behavior), a set of requirements (i.e. the performance that the object under design must meet by the time the design is completed), and/or a set of design restrictions (i.e. the conditions with which the designer must comply).

Issue resolution is a decision-making process that involves choosing one or more options for each open design issue. Design knowledge is crucial for making sound decisions

during this phase; oftentimes new knowledge is gained during this exploratory stage.
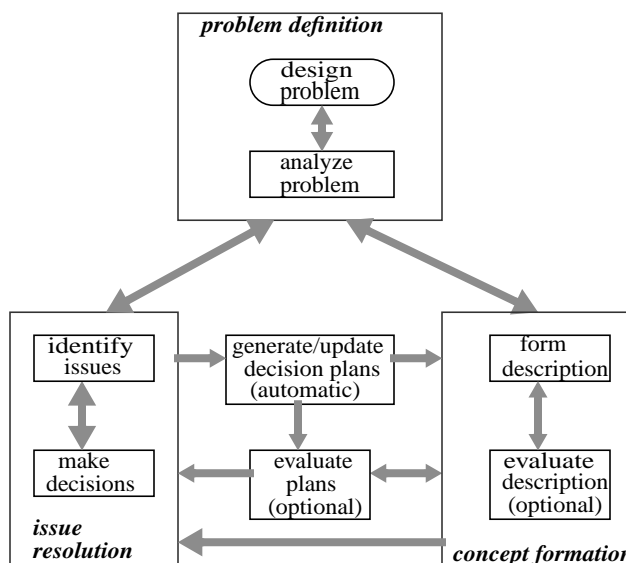

Figure 1. A Model for Conceptual Design Process

Concept formation results in either a pseudo VHDL description or a schematic diagram at a specified abstraction level (e.g. register transfer level), but it does not have to be as detailed as a formal design specification. During concept formation, the designer may go back to the problem definition cycle to modify/review the problem specification, or back to the issue resolution cycle to solve previously deferred issues, identify additional issues, or change previous decisions. Afterwards, an automatic program can be invoked to update the decision plans based on current decisions. The designer can then continue his/her previous concept formation work until a satisfactory conceptual design description is determined.

Design of complex objects requires decomposition into two or more sub-objects, each of which must undergo the same conceptual design cycle as their parent object. After conceptual designs of the sub-objects are completed, the designer can recompose the descriptions of the sub-objects into a coherent description for the parent object.

This framework for the conceptual design process has led to the implementation of a prototype conceptual design environment called Clio II. Preliminary experiments with Clio II has produced encouraging results and valuable insights for further work.

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*Both authors were previously with Carnegie Mellon University.