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# Early insight in systems design through modeling and simulation

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**Abstract**

In early design stages, system architects mostly rely on estimations to make design decisions. These are based on the available information at hand and their experience. Modeling and simulation is almost exclusively applied in more detailed stages of design. In this paper we present an approach aimed at making better informed design decisions, early in the design process.
Our approach focuses on giving insights in early design through simulations and models that are usually only provided in more detailed design stages. To do so, we propose a framework and address three conflicts that arise when connecting techniques from early and detailed design stages. These are dealing with uncertainty, accommodating multidisciplinary views and accounting for more divergent design space exploration strategies.
The approach has been applied to a medical imaging system, to analyze a possible latency reduction. The goal of this case study was to gain realistic insight in system latency using a highly abstracted system model and a generic simulation model. Insights gained with these models confirmed that a new design reduces system latency and deals better with large variations in latency. The underlying structure of the approach has proven itself to be feasible. Further research is necessary to determine whether the approach can cover a broader range of applications and to evaluate how the full approach can be implemented.



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## 1. Introduction

Nowadays, modeling and simulation are common practices in multidisciplinary complex system design and provide system architects with appropriate insights. However, in previous work[1], we identified that early stages of system design lack modeling and simulation, leading to less insight when making early design decisions.

In this work we aim to support system architects by connecting information and techniques that are available at the start of a new design process to simulations and models used in more detailed design stages. Based on a design problem at hand, a system architect will seek insight in certain key characteristics or behaviors of a system. To gain these insights, we propose an approach that draws on the strengths of both early and detailed design. We have applied this modeling approach in a tool that makes it possible to define a high level system model quickly and effectively. For this, we use the Y-Chart paradigm[2] which connects an application model to a platform model through a mapping. The high level model is supported with simulation models that provide the required insight. This approach was applied in a case study on a medical imaging system.

This paper is structured as follows. In the rest of this section, we discuss the background and define our objective. In section 2, we explain the framework and methods in our approach. Then, section 3 outlines a case study in which we implemented our approach. Finally, section 4 contains the discussion and future work.

### *1.1. Insight in Early System Design*

Every design process starts with a collection of knowledge that is both explicit (design documents, requirements documents, an existing system, etc.) and tacit (knowledge and experience of architects and designers). A method that handles both types of knowledge well is the A3 Architecture Overview method (A3AO)[3]. This method has been developed as a tool for effective documentation and communication of architectural knowledge. By combining various views, it creates a concise and usable overview of information of key system aspects on two sides of an A3 paper (or a set of A3's). It has also been shown that this method can provide a good overview of designs during development[4]. However, when the A3 is utilized in design discussions, many designers have expressed a need for more interactivity. This is because a system architect has various ways to reason about a system under design, for instance using thinking tracks[5]. An example of a thinking track is dynamic thinking, which encompasses thinking about aspects such as how the system changes over time and effects of changes in input and output. These thinking tracks give a framework for the insight system architects seek and explain the need for more interactivity, whereas a static system overview gives little insight in its dynamic behavior.

When an architect explores various solutions to a design problem, the architect will make estimations to gain insight in performance or behavior of possible solutions. These estimations are based on experience and are made through logical reasoning, interpolation and extrapolation or through low-order models. Once an architect comes up with a promising design, it will be detailed to verify whether the design is indeed promising. This elaboration can be done using models or simulations. At these, in our view detailed levels, many simulation frameworks exist[6]. A good example is Metropolis[7]. These simulation and modeling techniques give very good insight in dynamic system behavior or insight in how the system deals with feedback.

### *1.2. Comparing Early and Detailed Design*

To increase the insight of system architects in early design stages, we aim to apply these simulation techniques in early design. However, this is not a straightforward process and several conflicts will need to be addressed.

First of all, there is a large difference in the degree of uncertainty between early and detailed design. In both cases, it is necessary to estimate an input to determine performance. But in early design, parts of the system might still be completely unknown. For example, in early car design, the propulsion method might not be decided yet. This complicates insight in for example driving behavior. In detailed design, using the same car example, the early decision might have been to use an electric drivetrain, but the size of the battery packs is yet unknown. In this case, the general behavior of battery packs is already known, so a model can be established much easier.

Secondly, estimations, happening early in the design, are much more multidisciplinary in nature. This means that the input stems from multiple disciplines, but also that the output of the step has to be communicated to multiple