# Seeing Errors: Model Driven Simulation Trace Visualization

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**Abstract.** Powerful theoretical frameworks exist for model validation and verification, yet their use in concrete projects is limited. This is partially due to the fact that the results of model verification and simulation are difficult to exploit. This paper reports on a model driven approach that supports the user during the error diagnosis phases, by allowing customizable simulation trace visualization. Our thesis is that we can use models to significantly improve the information visualization during the diagnosis phase. This thesis is supported by Metaviz - a model-driven framework for simulation trace visualization. Metaviz uses the IFx-OMEGA model validation platform and a state-of-the-art information visualization reference model together with a well-defined development process guiding the user into building custom visualizations,essentially by defining model transformations. This approach has the potential to improve the practical usage of modeling techniques and to increase the usability and attractiveness of model validation tools.

**Keywords:** Software visualization, trace exploration, embedded systems, model based validation, model dynamic analysis.

## 1 Introduction

Important efforts were deployed by research and industry in order to develop powerful verification and validation techniques for the design models used in the early phases of development of real-time embedded systems (RTES) [7,1]. In spite of the fact that a lot of interesting results were obtained, formal verification and validation are used on a very few concrete projects. This is partially due to the fact that the results of the formal verification are difficult to exploit Our thesis is that we can use models to significantly improve the information visualization during the diagnosis phase. To support this thesis, we have built *Metaviz* - a model-driven framework for simulation trace visualization. Metaviz aims to *support the user during the error diagnosis phases*, by allowing flexible simulation trace visualization. It is built on top of IFx-OMEGA [34] a simulation and verification toolbox for UML and SysML RTES models.

The goal of the simulation step in the validation process of a System Under Diagnosis (SUD) model is either the *interactive detection of design errors*, or

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the *understanding of the nature of errors detected by automatic verification*. Therefore, the purpose of performing interactive simulation is *diagnosis*, which is essentially a *cognitive* task: the user has to understand the overall behaviour of the system using a scenario exploring interface, and to discover errors in the scenario.

For the type of complex RTES design models that are targeted by IFx-OMEGA, it turns out that the diagnosis generally involves examining *multiple non-contiguous steps of a scenario*, and multiple *entities in the system (blocks, ports, message queues, etc.)*. While supporting some simple forms of view customization, the traditional simulation interface cannot define visualizations computed from different steps in the simulation scenario, and thus it is hard for a user to infer the cause of an inter-process communication error from the simulation of an error scenario.

It is a commonly accepted fact that the human working memory is limited to a few items [42], while dealing with a simulation trace usually implies watching values and relationships of tens or hundreds of elements at multiple steps in the trace. Therefore, what we need is a way to boost the user perception and cognition so that it can gather the right information for finding an error pattern. This kind of problem is addressed by many works in the field of information visualization [46]. The synergy between research in information visualization and software visualization is a promising research area [23] that we exploit in our approach, by defining new visualization facilities. As Larkin and Simsons [29], we believe that using a well designed visualization framework can make the exploration of the simulation traces more effective.

This paper illustrates a new application domain of modelling techniques: the visualisation customization. We apply it to simulation trace visualisation in order to assist the error detection during model validation and verification. The work was triggered by feed-backs we received from industrial partners on the use of traditional model validation and verification frameworks.

The rest of this paper is organized as follows: section 2 overviews the simulation and diagnosis features used in validation tools and the diagnosis process using them. Section 3 presents an extension to this process that includes the creation of customized visualisations. Section 4 presents Metaviz – the model-driven implementation of our approach, that is evaluated in Section 5 using the SysML model of the Solar Generation System (SGS) of the Automated Transfer Vehicle (ATV), designed by Astrium Space Transportation. Section 6 overviews related work.

## 2 Model Simulation and Diagnosis: Process, Toolset, Limits

In this section we present an overview of the simulation and diagnosis features currently used in our tools, which are representative of what is available in other model simulation and validation tools. We also outline some of the limits of currently used approaches, which motivate our work.