Interactive Visual Analysis in Engineering: From an Early Prototype to Commercially Available Applications

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ABSTRACT

We report the results of a long standing ongoing research collaboration with AVL company to develop new exploration and analysis techniques for parameter space exploration and analysis of multiple simulation runs. The results of our collaboration are published in several research papers and are incorporated in AVL’s suite of comprehensive simulation software tools for automotive industry.

1 INTRODUCTION

Modern engineering design, such as car design, depends on simulation. The conventional approach is to define a simulation model, run the simulation, and analyze results. Depending on analysis results additional simulation runs (with different sets of parameters or modified models) might be needed. Advancements in computing and storage technology reduce the simulation time significantly and allow a relatively novel concept of multiple simulation runs. The main idea is to run multiple simulation runs (hundreds, thousands, or even tens of thousands) using a same model with different set of control parameter values. However, novel exploration and analysis methods are needed. Together with domain experts from AVL, we have recognized new possibilities of multiple simulation runs concept and the need for advanced analysis methods. AVL is the world’s largest independent company for the development of powertrain systems with internal combustion engines as well as instrumentation and test systems, and related simulation tools.

We have proposed to use interactive visual analysis and coordinated multiple views as powerful methods to cope with complex data and analysis tasks. We, an interdisciplinary team of engineering, simulation, and visualization experts, started with a first prototype development, improved the prototype and analysis methodology, and, eventually, it became a standard part of AVL’s software suite. This proves that interactive visual analysis was a right choice.

We describe the development of methodology and different case studies done in recent years which led to a commercially available tool. The development started with a simple data model and injection system analysis and then extended the data model to cope with complex data (families of curves and surfaces). We have analyzed common rail and direct injection systems [2, 7], elastohydrodynamic (EHD) lubrication bearing [6], chain drives [1], and hybrid vehicles [3]. We also supported the interactive visual steering [5], including an automatic optimization method [4].

2 THE DEVELOPMENT STORY

The first step in simulation is a simulation model creation. The simulation model consists of various elements and each element has some control parameters and computes different state variables. We vary the control parameters and compute state variables for each simulation run. The control parameters are (in our case) scalars, and state variables computed can be scalars of functions of time. As conventional table data as used in visualization, as well as the most of automatic optimization methods, support only scalar items, different aggregates are computed for each time dependent state variable.

Figure 1a shows one state variable and aggregates computed in order to analyze results. Once all runs are computed the analysis can start. In our case [7] we varied six control parameters and computed 19,440 simulation runs to get six response parameters. We used a coordinated multiple views system in order to analyze results and identify three basic exploration patterns: Finding Invalid Combinations of Control Parameters, Finding Control Parameter Combinations Providing Desired Results, and Exploring Tendencies. Linking and brushing and basic Information Visualization views were used. Figure 1b-c shows a part of the simulation model and view from analysis.

2.1 Families of Curves and Families of Surfaces

Simulation generates different curves which we aggregate prior to analysis. We soon realized that curve shapes play an important role. The domain experts simply did not have tools and methodology to cope directly with complex simulation data. We have proposed a new data model where we allow function graphs or curves to be basic items. For each simulation run we have a record which consists of a set of scalar control variables, set of scalar state or result variables, and a set of function graphs. We call function graphs belonging to a single dimension across all runs a family of function graphs. In order to analyze such complex data we introduced a curve view.

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to the coordinated multiple views system. The curve view depicts all curves at once using a density mapping. We also introduced a line brush to select curves in the curve view. The newly identified analysis patterns [2] include: **Black Box Reconstruction**, line brush to select curves in the curve view. The newly identified all curves at once using a density mapping. We also introduced a to the coordinated multiple views system. The curve view depicts

Figure 2: Simulation steering workflow process loops.

The forthcoming Cruise M uses novel energy flow diagrams in the simulation model and an advanced 3D view combined with conventional Information Visualization views [3]. All these tools, resulted from a long term cooperation between VRVis Research Center and AVL, are used by many car manufacturers.

### 3 Conclusion
Interactive Visual Analysis is crucial for analysis of complex, multiple runs, simulation data. We have developed (with a full support from AVL company) exploration and analysis techniques for parameter space exploration and analysis of multiple simulation runs. We have learned how important it is to have interested and supporting domain experts. Without AVL support and vision this research would not be possible. The joint efforts over several years (our first joint publication was over eight years ago) resulted in a novel, commercial software tools for expert users in automotive industry. Our ongoing collaboration focuses on improving optimization integration and using hierarchical simulation models.

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### References