A FRAMEWORK FOR SIMULATION PROCESS MANAGEMENT AND DATA MINING

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THEME

SDM, Data Analysis

SUMMARY

More product variants, the increase in government regulations and the use of stochastic and multidisciplinary optimization causes a drastic increase of the number of numerical simulations performed in the car design process. But the availability of the arising numerical data creates the opportunity to compare thousands of simulation variants with the aim to find optimal design variants (even from previous projects) or to evaluate the impact of specific design changes on the functionality of the car. The huge volume of data (large number of simulations and large data-sizes per simulation) and the diverse content of simulation data are major obstacles for the efficient post processing and analysis of such simulation bundles. Here, we propose a methodology that enables suitable processing. In particular, we extend the existing efficient post processing from one simulation to many hundred simulations. We study two types of realistic scenarios for the approach. The first one assumes that the simulation bundle is managed inside a specific SDM and the second one starts without this assumption, that is the information is supposed to be just saved in a repository in a specific simulation data format.
The approach is demonstrated on a simplified frontal car simulation, where a set of geometrical variants is analyzed. A second example shows that the system is able to create a data management capability from simulation data in a specific car design phase.

KEYWORDS

SDM, Data-mining, Post-processing in SDMs

1: Introduction

The use of fast finite element solvers on high performance computers as well as the use of 3D visualization software for engineering analysis of the solutions (simulations) has enabled the rapid modelling of many product variants in car design, resulting in gigantic repositories of simulation bundles. Nowadays, engineers generate several variants of a specific model that need to be simulated. Each simulation can take several hours even with hundreds of processing cores; this design workflow generates thousands of results that have to be saved in very large archives.

Material and geometrical changes or load cases in the finite element models as well as the post-processing quantities derived from them can be managed, provided the information has been imported in a SDM (Simulation Data Management) System. Today the car industry maintains very large repositories of finite element data, but a large percentage of those simulations are stochastic or optimization results and these data are normally not imported in a SDM system.

Data analysis of several thousand very large finite element data sets, even if adequately organized and managed is a challenge. The post-processing using 3D visualization is a time consuming task, since only a few simulations can be loaded and analysed simultaneously.

We propose an integration of a SDM system with modern machine learning methods that do address the above problems and challenges. The system can use information from a SDM system if available or it can organize the information from scratch. A mathematical analysis kernel is able to find a low dimensional parameterization from high dimensional data sets and the post processing is done based on such low dimensional structures. This enables an efficient visualization and exploration of several hundred simulations along a set of automatically identified parameters. Geometrical variants that most significantly affect a design (for example for the deformation) are identified.

The methodology has been used successfully in industrial examples in the areas of vibration analysis as well as vehicle crash simulation. In this paper we present some details of the methodology for the analysis of a simplified set of simulations. First geometrical variations of the model are introduced in an arbitrary way, a frontal crash simulation is performed using those input models and then the output is feed into the system. We show that a parameterization is recovered by the system where geometrical variants and the corresponding simulations get conveniently organized.

2: The SDM System

SDM systems are well known and used in the industry in the fields of FEM analysis. But in our opinion there are still some issues missing in such systems. The main point is the consistence of data in terms how meta data can be saved and, more important, accessed in different phases of development and different stages of calculation. Another topic is the still existing gap between CAD data, which is generated during the design process, and the corresponding FE models. In particular, the FE model cannot be a one to one copy of the CAD model. In this case important meta data easily gets lost, if one does not explicitly take care of this information (i.e. which areas of finite elements belong to one CAD part). Another point, we would like to mention, is that connections between CAD parts to each other and their transformation into the FE model should be documented in such a way, that the properties of these connections are saved along the simulation process. At least there are specific results which must be saved and accorded to the current calculation. This is assuming, that we can provide a methodology to close this gap. The main observation is that there is an increasing amount of information through the calculation process of each simulation. The amount of data can be split between mass- and meta data. Our approach is to provide a method to handle at first the meta, which also includes a closer look on the assembly of parts and which parts are used in a specific calculation. Among these data inspection it is easy to go further and store information about this Meta information and the FE model especially of its parts into a database. The database will be used even to enable the user to request certain things obtaining Meta information and also to provide the access for data mining methods explained later. The architecture of the system is shown in Figure 1.

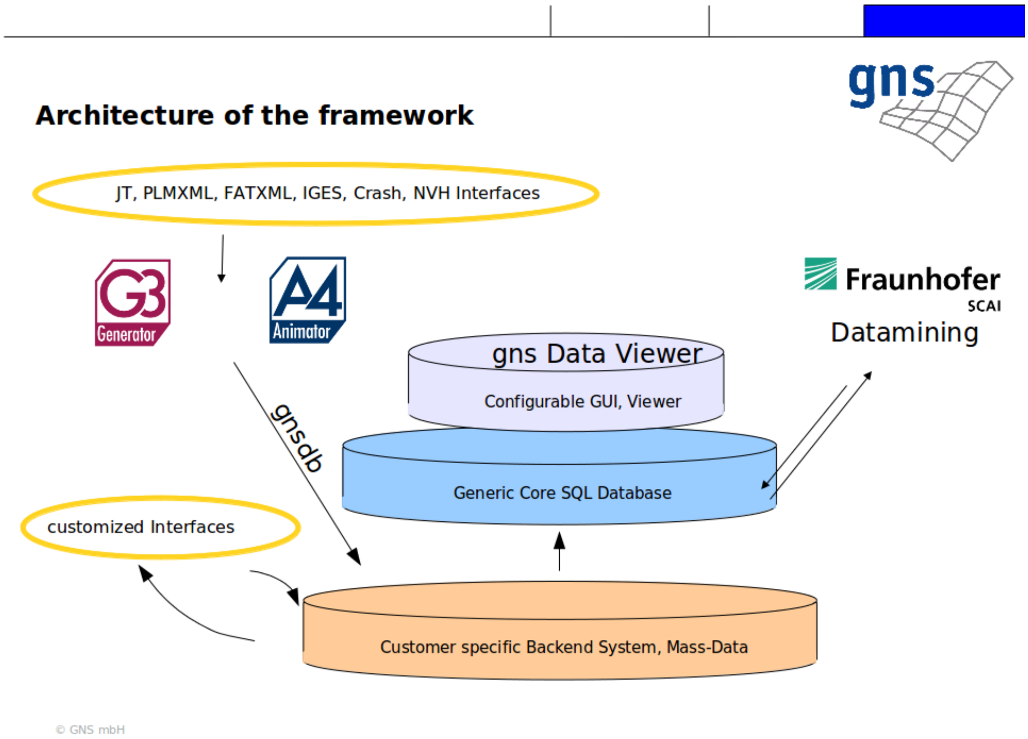

Figure 1: Architecture of the framework

The data is stored on a file system provided by GNS Software such as GENERATOR or ANIMATOR or even customized interfaces uses the HDF5 technology. This assures - if required - a low level access to the data. The database, which contains the meta data, is not specific, that means it is up to the user which kind of meta data will be stored. This assures flexibility from the users point of view. The way, which kind of data should be stored and later accessed, can be decided by the user, including the way the data will be presented on the graphical user interface (GUI). The GUI of the system also enables the user to access and choose data mining technology provided by the FRAUNHOFER SCAI department.

3: The Data Analysis Kernel

An independent Data Analysis Kernel that is coupled with the SDM- System implements data reduction methods that are able to extract a low dimensional representation of a high dimensional bundle from simulations results. The approach consists of a pre-processing and an interactive part, all time consuming calculations are done in the pre-processing so that in the interactive part an efficient visualization and analysis can be done. Specifically we use spectral kernel methods that construct a so called Graph-Laplacian on a lower dimensional manifold, for details see (Coifman & Lafon, 2006), (Hein, 2007).

4: A simplified analysis example

The model has been obtained from the NCAC Model Archive at the University of Washington. A simplified model has been chosen for demonstrating the system. The model has 28127 nodes and 29235 shell elements under frontal crash. Two car parts are modified arbitrary on the frontal part of the structure using the Altair Hypermesh morphing tool (see Figure 2 for the type of geometrical changes introduced). A total of 230 variants are created in this way.

The geometrical modifications were obtained by moving specific nodes in the mesh for those parts.

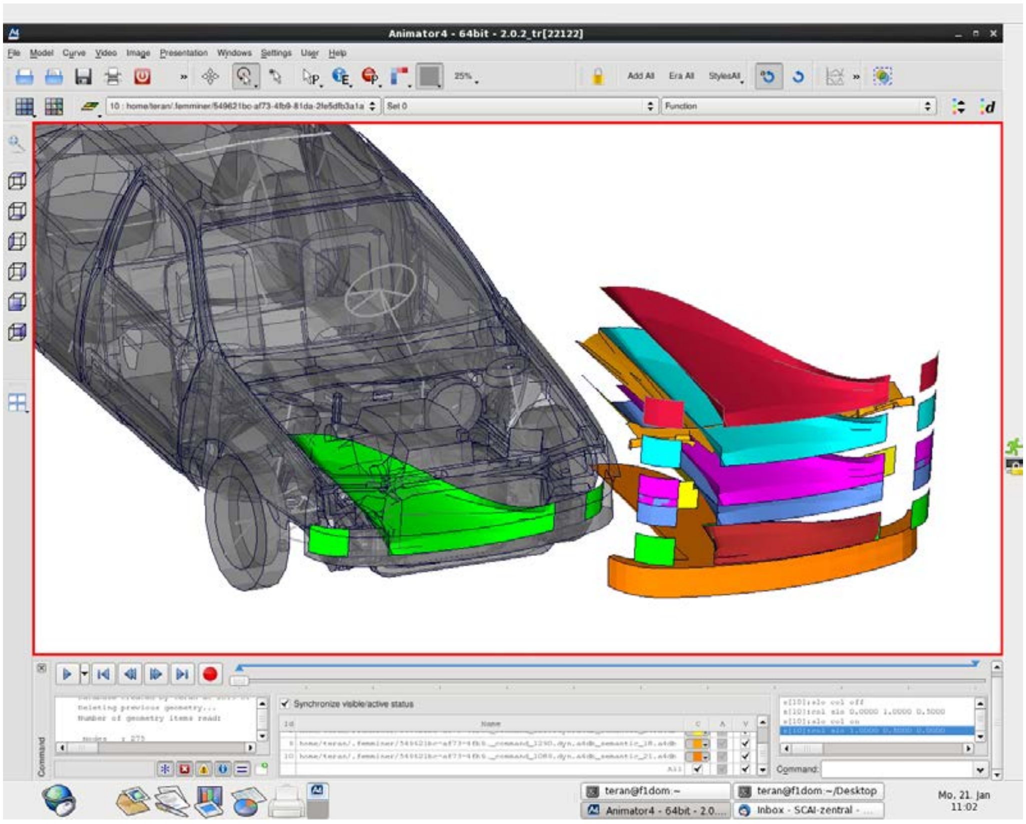

Figure 2: Several model variants obtained by morphing of car parts are shown; the modifications done with the morphing tool are arbitrary.

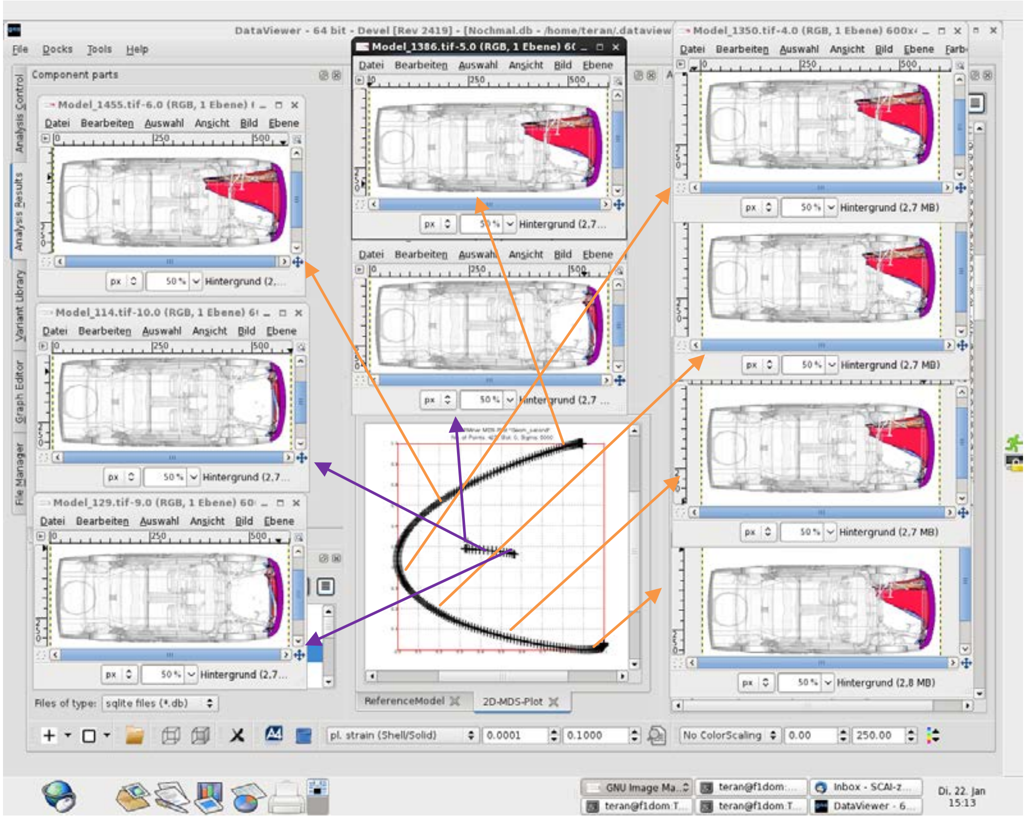

Figure 3: Analysis of the model variants, all geometrical changes are organized along a 2d plot where each point represents a model variant.

Figure 3 shows a screenshot of the result of the geometrical analysis using the proposed system. Each point in the 2D plot represents a specific finite element model. Positioning the mouse over a point updates the visualization to the corresponding model. For this example one can recognize well differentiated areas in the plot. The larger point set is seen to be on a 1D parabola; this curve corresponds to the parametrization (according to the size of the part) of the first modified part. The second cluster of points not in the curve corresponds to the parametrization of the second car part.

The next part of our analysis concentrates on a set of parts at the front of the car. We analyse the behaviour of those parts under frontal crash. With that objective, we perform a frontal crash simulation using LSDYNA for all variants, a specific time step is taken and we consider the total displacement as our analysis variable.

Figure 4 shows that the deformations for 230 simulations are organized according to the total displacement along two completely distinct clusters. By analysing the simulations which are represented in the 2d point plot, one can see that the larger cluster corresponds with the geometrical model changes of the first car part. The second cluster of points is well separated from the first one; the simulations corresponding to these points show a very high deformation in comparison with the first ones.

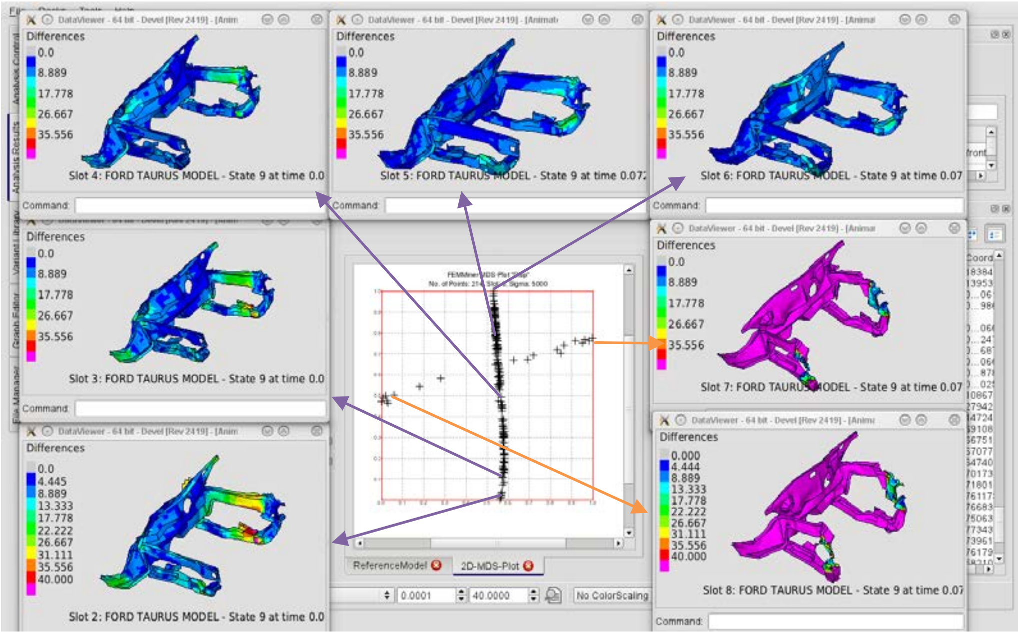

Figure 4: Analysis of simulations of the model variants, all deformations are organized along a 2d plot where each point represent a simulation corresponding to a model variant.

5: Conclusions

A methodology that enables the interactive analysis of several hundred simulations has been presented. The approach combines a SDM system with an analysis kernel and it can analyse simulations that have been processed through a SDM system or it can take the simulation data directly and build an analysis system from scratch. The approach can be very useful for analysis of stochastic simulations, analysing the possible impact of model changes or for learning design practices from simulation data repositories.

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