Clustering Algorithms for Parallel Car-Crash Simulation Analysis

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Summary. Buckling and certain contact situations cause scattering results of numerical crash simulation: For a BMW model differences between the position of a node in two simulation runs of up to 10 cm were observed, just as a result of round-off differences in the case of parallel computing. An engineer has to measure this scatter, to check whether important parts of the car show such indeterministic behavior and to find the origins. The tool DIFF-CRASH compares simulation results and uses data mining technology to cluster those nodes of the car model, which show similar scatter among the simulation runs. For the BMW model the indeterministic behavior could be traced back to a certain part of the motor carrier and was removed by a redesign. DIFF-CRASH is the only activity using data mining technology for crash simulation stability analysis. In this paper we present the clustering algorithm and illustrate its usage in car crash simulation analysis.

Key words: Crash Simulation, Data Mining, Cluster Analysis

1 Introduction

Nowadays the car manufacturing industry relies heavily on simulation results. By simulation the number of real prototypes is reduced, the insight into the features of the actual design is increased and the turn-around time between model changes is much shorter than in the case of real tests. Numerical crash simulation is the most computer-time consuming simulation task in car design. Therefore it is obvious that crash simulation codes were among the first industrial simulation codes, which were ported onto parallel distributed memory architectures during the EUROPORT project\textsuperscript{1} [10] (1994-96).

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Using the mpp-versions of industrial crash simulation codes the engineers made a surprising discovery for certain models: The result of numerical simulation changed from one parallel execution to the next by more than 10 cm for the node positions, although the input decks and the simulation parameters were identical. Figure 1 shows a model provided by BMW consisting of about 60,000 shell elements and maximal and average differences between several simulation runs. Actually this observation has stopped car manufacturing companies from using mpp-system for crash simulation for more than 5 years.

As part of the PROMENVIR project\textsuperscript{2} [8] (1996-97) a stochastic analysis tool was developed (now named STORM), which automatically changes certain parameters of input deck, performs simulations, extracts a set of parameters of the results and analyses the dependency between input parameters and result parameters. Using PROMENVIR it was possible to show that small changes in the input deck may result in substantial changes of the simulation results and no correlation between changes and results may be available.

Geometric scatter analysis is performed in weather forecast, and stability analysis is usually performed by stochastic variation of some design parameters and correlation analysis for some key measures like the intrusion. As part of the AUTOBENCH Project\textsuperscript{3} [14] (1998-01) and the AUTO-OPT Project\textsuperscript{4}(2002-05), the reasons for the scatter of the results were investigated in detail. It turned out that numerical properties of the simulation codes as well as certain features of the car design may be responsible for the "butterfly effects". Typical sources of instabilities are buckling and contact of different parts under an angle of 90°. During the investigation an analysis tool named DIFF-CRASH\textsuperscript{TM} was developed.

2 DIFF-CRASH\textsuperscript{TM} Overview

DIFF-CRASH\textsuperscript{TM} is a tool for the detailed analysis of the scatter of simulation results. Currently it supports PAM-CRASH, one of four leading commercial simulation codes. The preprocessing module of DIFF-CRASH modifies node positions in an input deck in order to generate a set of simulation results. The postprocessing module takes the output files of several PAM-CRASH runs, performs a detailed analysis, computes values for each node and reported time step and adds these functions to one result file (see Figure 2). Standard postprocessing tools can be used for the visualisation of DIFF-CRASH results. Typical result functions of DIFF-CRASH are:

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