Customization of GiD & FEAP for Scientific Applications

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SUMMARY: The visualization of results from FEM calculations is an important step in the analysis of complex problems. Due to the fact that high performance graphic cards where only available to the limited area of workstations and graphic standards changed over long time periods, major development effort was set on the scientific simulation codes. Recent development of computer hardware made adequate computing and visualization power available to everybody and increased the necessity of easy to use pre- and post processing. For scientific use, it is important to provide the full user interface capabilities of the original finite element (FE) code due to code development and debugging reasons. While visualization aspects become important, the FE code has to provide all information to the post processor. The stage of development for an interface of GiD and FEAP will be demonstrated by examples of current research projects such as the process simulation of foam forming, model adaptivity for beams and an adaptive 3D implementation of hanging nodes.

KEYWORDS: visualization of FEM results, software customization.

INTRODUCTION

Visualization of numerical results has been a topic since the invention of sophisticated calculation tools such as the Finite Element Method (FEM). As high performance graphic cards were only available to the "workstation domain", development was mainly focused on the numerical analysis and algorithmic part of these FE codes. This situation changed after introducing consumer computers (PC's) in the early 1980's, although they were still quite expensive. With respect to recent computer hardware development concerning memory and visualization power, an exceptional development has been taking place in that field. On the application side, the awareness of the advantages of FEM solutions established these methods as standard analysis tools. Industrial requirements toward an integrated development process in terms of Computer Aided Engineering (CAE) accelerated the progress of pre- and post processing tools. Due to that coupling of FE codes like FEAP and graphical oriented pre- and post processing tools like GiD, integration of both is required. This process has also consequences for the education and the scientific work at universities. Students have to be trained in the philosophy and practice of such tools and scientists use them to improve their daily work. Another aspect is the direct application of new developments to more complex problems than standard test examples.

Customization requirements

Application of pre- and post processing tools in our context needs flexibility on both sides, visualization and calculation codes. This will be explained by the normal development in terms of the calculation code development process:

1. Significant effort is usually set on the development and implementation of new theories and algorithms into the FE code. This is, unfortunately, still a time consuming work and debugging and classical code development tools are used to solve these problems. Mesh generation capabilities of the FE codes are sufficient at this stage and the post processing capabilities can be used to verify the results. A powerful interface in the FE code provides the data for the post processing.

2. After functionality is guaranteed, the pre-processor interface has to be adjusted to new specifications of the FE code input. Now, standard problems defined by the PPPT from a data bank can be used to perform further tests on the reliability, potential and performance of the development.

3. As industry is often interested in the transfer of new developments, extended pre-processing capabilities are necessary while complex geometries are usually delivered in CAD data formats. Now, geometry and mesh generation combined with an intuitive working surface are important to deliver results in limited time.

Here GiD was linked to the FE code FEAP as meshing and visualization tool. Within that integration process, certain difficulties appear because of different philosophies of the programs. In the case of GiD and FEAP, the interface with regard to geometry like nodal coordinates can be implemented easily whereas the classification of the elements has to be done carefully. The connection between the element classes of FEAP and the geometric objects if GiD depend on the dimension of the problem. This is shown in Fig. 1.

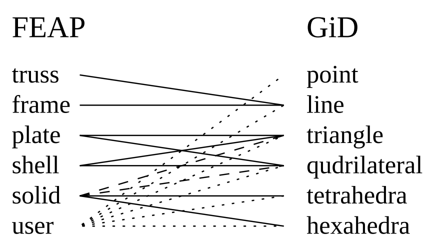

Fig. 1: Element definition connections

Dashed lines indicate connections for 2d cases. For user defined elements, connections can be established directly to all GiD objects as indicated by the dotted lines. For output of e.g. stresses, strains or error indicators, the GiD point visualization option is used to process raw gauss point data from all FEAP elements.

Examples

The selected examples demonstrate particular details for the pre-/post processing process and the interpretation of the results. As the integration process of FEAP and GiD is still going on, the results taken from current research project give an outline of today's functionality.

Model adaptivity

In structural engineering, model adaptivity is an attractive method to improve the accuracy in parts of the structure that are of special interest. This has been realized for structural parts like profiled beams using frame- and shell-elements. To connect the two parts, special transition elements that preserve displacements, internal forces and heat conduction in the transition zone are used. In the example shown in Fig. 2, a uniform

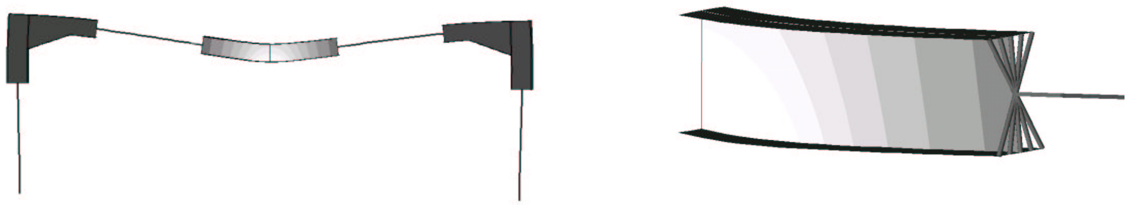

Fig. 2: Temperature distribution, detail of transition elements

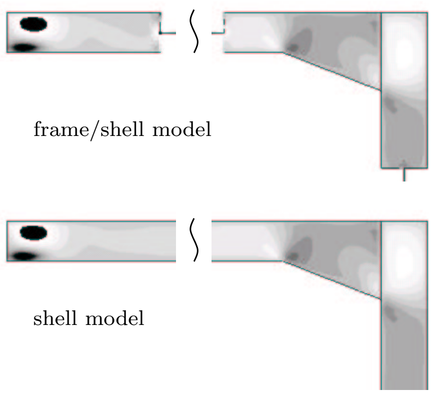

Fig. 3: Comparison of S_{xy} stresses

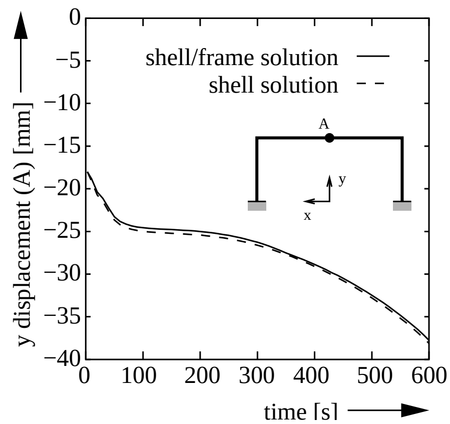

Fig. 4: Displacement in point A

loaded frame is heated in the center (point A, Fig. 4). As a detail, the realization of the transition elements is also described. Good agreement is achieved for the σ_{xy} stresses shown in Fig. 3 and the vertical displacements shown in Fig. 4.

Adaptive 3d meshing using hanging nodes

Adaptive meshing techniques for mesh re- and de-refinement are still under development. One possibility is to use so called "hanging nodes", which are located in faces or on edges of neighboring elements like indicated in Fig. 5. Elements can be easily concentrated by subdividing from a coarse starting grid.

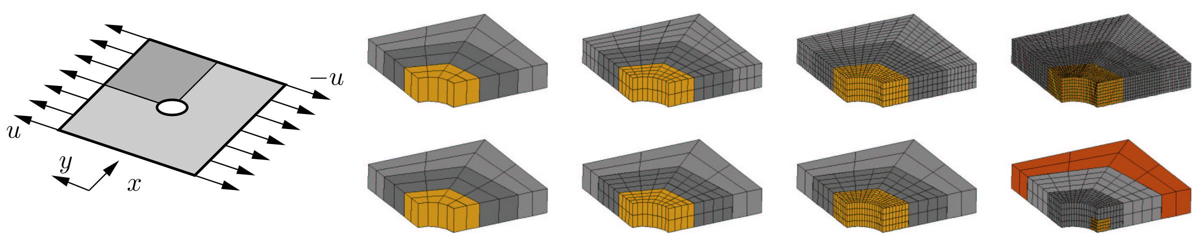

Fig. 5: Problem definition and comparison of uniform / hanging-node adapted meshes

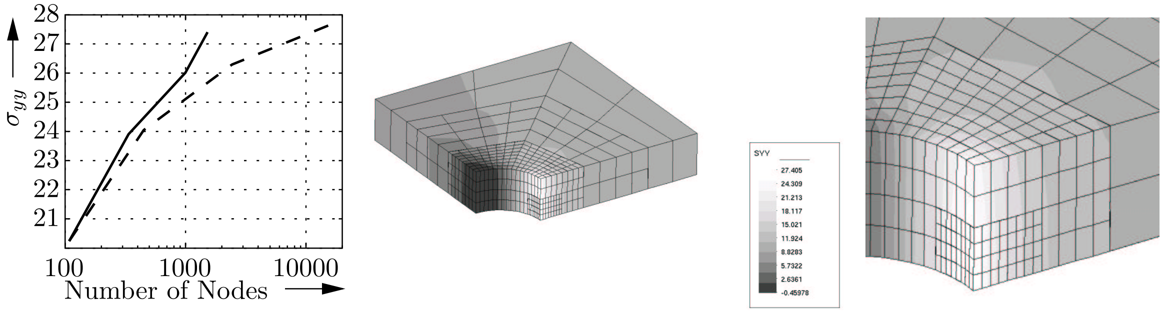

Fig. 6: Quality of calculation (line hanging nodes, dashed uniform adaption) and σ_{yy} stresses [N/mm^2]

A comparison of the quality of the calculation concerning the stresses σ_{yy} is given in Fig. 6. The hanging node calculation was done using approx. 1.600 nodes, where as the uniform refined mesh contained 16.000 nodes which shows the potential of saving computing resources.

Visualization of special computation techniques

Another example is the calculation of particulate materials at finite strains. In these simulations, the particles are described by spheres that are embedded in a matrix. A representative volume element (RVE) is shown in Fig. 7 without the matrix (particles only). This RVE is regularly meshed using hexahedra elements. The particles are introduced by

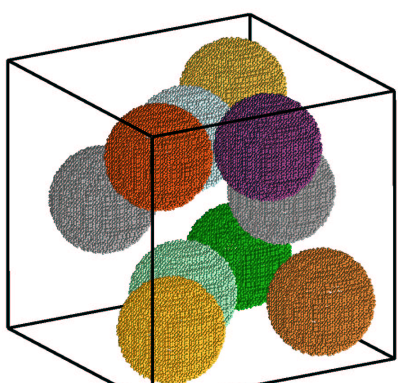

Fig. 7: RVE geometry

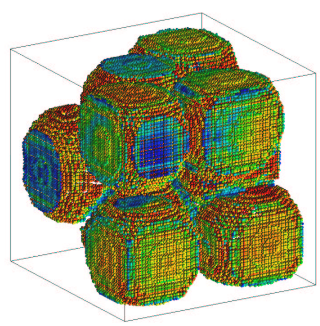

Fig. 8: Main stresses (min. -10 max.-400 N/mm^2)

applying the different material properties on Gauss point level. To improve the geometrical description, the number of Gauss points used in the elements containing both, matrix and particles, is increased. The first main stress computed on discrete Gauss points after homogenious compression (50 % of initial RVE volume) is shown in Fig. 8 (approx. 90.000 Gauss points on the surfaces of the spheres).

Conclusions

Modern engineering has generated powerful FE codes like FEAP and pre- and post processing tools like GiD. The efficient customization of both leads to an integrated tool for many applications in engineering. Scientific development with respect to post processing capabilities is supported and transfer to industrial applications is improved by the use of standard CAD interfaces.