MULTIPHYSICAL SIMULATIONS WITH ELMER FINITE ELEMENT SOFTWARE IN COMBINATION WITH GID

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Abstract. *We present the interface between GiD and the Finite Element software Elmer. GiD can be used in both pre-processing and post-processing of Elmer simulations. Elmer is an open source software capable of simulating a diverse selection of multiphysical phenomena. Examples of GiD usage in combination with Elmer simulations are presented.*

1 INTRODUCTION

This paper introduces the Elmer software and describes the interface which has been developed to import data from GiD into Elmer, and vice versa. The interface has gained popularity among the Elmer users both in academic organizations and among industry.

Elmer is a multiphysical simulation software that is developed by CSC, the governmental funded Finnish IT center for science. Elmer uses Finite Element Method (FEM) to discretize partial differential equations and the resulting matrix equations can be solved with various efficient methods, including direct, iterative and multigrid solvers. Elmer has been developed since 1995 and it includes modules for simulating a large range of physical phenomena, such as fluid dynamics, heat and mass transfer, electromagnetics, acoustics and elasticity[i]. The strength of the software is in its modular structure which allows almost arbitrary coupling between the physical models. This is reflected by the publications on many application areas in which coupling of equations is essential: microsystem modeling[ii], ice-sheet modeling[iii], hemodynamics[iv], acoustics[v], and silicon crystal growth[vi].

Recently, CSC has published Elmer under an open source license, the GNU Public License (GPL). The source code can be downloaded from the Elmer website, http://www.csc.fi/elmer. A public source code gives scientists interested in advanced mathematical modeling a possibility to review the algorithms of the software and to apply own changes to them.

2 ELMER – GID INTERFACE

The interface between GiD and Elmer includes both the transfer of element mesh created in GiD into Elmer and the transfer of simulation results from Elmer into GiD for post-processing. The interface uses the advanced features of GiD that allow smooth linking with other software. Basically, the functionality is achieved by two separate file type conversions. First, the conversion of GiD meshes into Elmer mesh files has been implemented as GiD template. The conversion of Elmer results into GiD post-processing format, on the other hand, has been implemented as a module in Elmer software. Together these tools provide a powerful and efficient method for computational science and engineering.

2.1 Benefits of the GiD – Elmer interface

The emphasis of Elmer development has long been in the inclusion of physical models and in the improvement of numerical methods. Also, a powerful postprocessor, ElmerPost, has been developed. For pre-processing Elmer offers a Delaunay mesh generator for 2D meshes, including adaptive meshing, and structured mesh generator for simple 3D meshes. Elmer has also been made available for most operating systems, such as Windows, Linux, Mac, Solaris, etc. and it can perform parallel simulations on clusters and supercomputers.

The need for advanced 3D pre-processing has been satisfied by implementing interfaces to various academic or commercially available programs, such as Ansys, Gambit, or Comsol multiphysics (previously known as FemLab). There are many reasons why GiD is an excellent addition to the selection of available pre-processors: GiD provides a graphical user interface, includes advanced meshing capabilities, supports importing various CAD formats and is relatively inexpensive. This makes GiD a very attractive choice as a pre-processor for Elmer simulations.

Elmer contains its own post-processor, as stated earlier. There are, nevertheless, certain advantages in using GiD post-processing for Elmer simulation results. Obviously, if one is already familiar with GiD it is convenient that the post-processing can be done with the same software. Also users of ElmerPost may find GiD post-processing attractive in some cases, since, e.g., producing mpeg-animations is more straightforward with GiD than with ElmerPost.

3 EXAMPLES

GiD – Elmer interface has been used in simulations in the fields of hemodynamics and glacier dynamics, for example. In hemodynamics, the blood flow inside a carotid artery with flexible walls has been modeled. The geometry data for this simulation is taken from medical CT (computed tomography) scans of human head. The scans have subsequently been processed with segmentation tools to produce the geometry of the artery and its walls. The geometry has been imported into GiD as STL format for meshing. The simulations were performed with Elmer and, in this case, also post-processed within Elmer software. Figure 1 shows the imported geometry and the generated element mesh in GiD as well as a snapshot of the simulation results in ElmerPost.

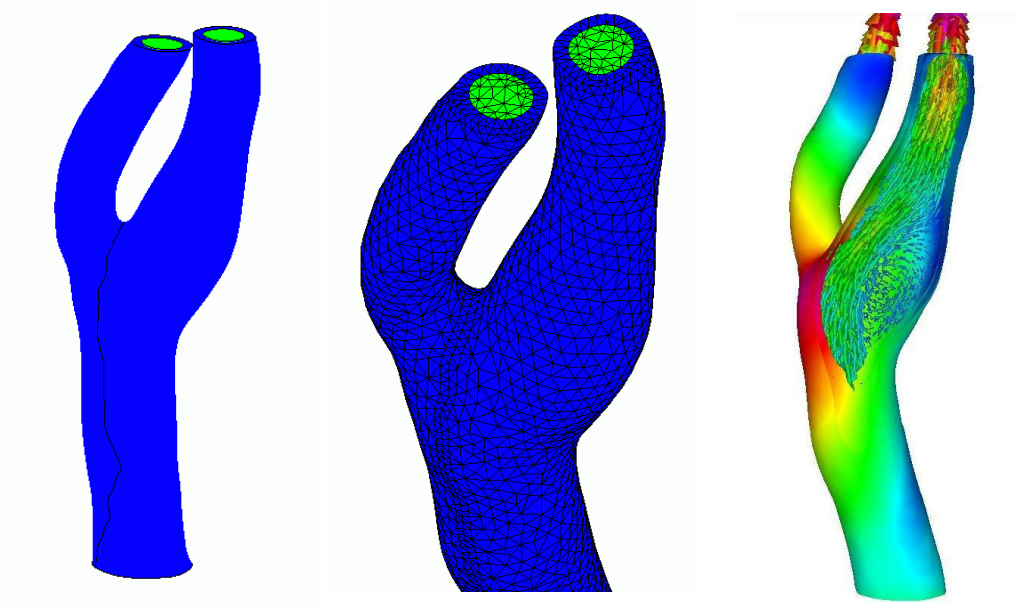

Figure 1: Modeling of blood flow in the bifurcation of carotid artery. Geometry (left), the element mesh (middle), and a snapshot of the simulation results (right). The colors of the artery surface and the vectors indicate the displacements of the artery and the velocity of the blood, respectively. The geometry is meshed in GiD and the results are computed and visualized with Elmer.

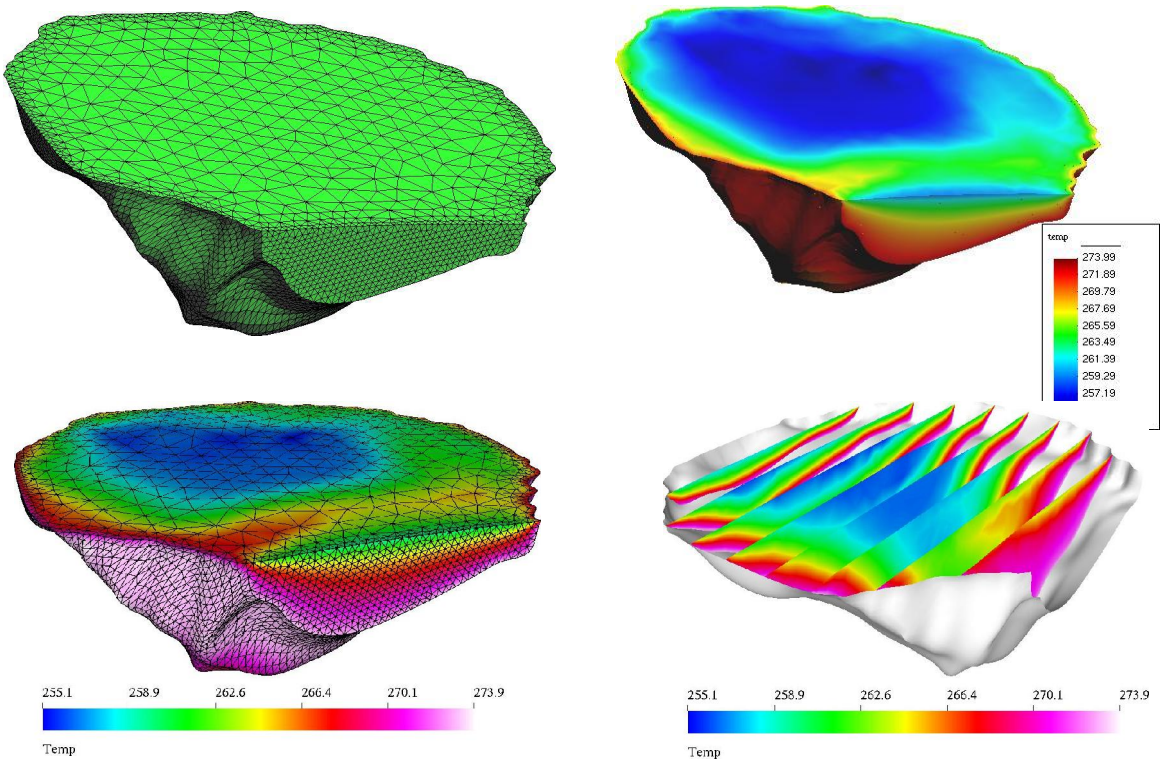

Figure 2: Modeled temperature distributions in a crater glacier. Element mesh in GiD (top left), results in GiD postprocessor (top right), and results in ElmerPost (bottom left and right). The mesh was generated in GiD, the simulations were performed with Elmer and the results have been visualized both with GiD and with ElmerPost. The temperatures above are given in Kelvin.

The interface has been successfully utilized also in modeling of glacier dynamics. As an example the heat transfer inside a crater glacier in the Ushkovsky volcano in Russia is presented. The measured glacier surface extent and bedrock data was converted into an IGES file which was imported into GiD. The tetrahedral element mesh was created with GiD. The simulations were performed with Elmer and the results have been visualized with both GiD and ElmerPost, see Figure 2. The glacier is heated from below by geothermal heating which melts the ice gradually at the bottom. The precipitation, however, gradually accumulates new ice on top of the glacier.

4 CONCLUSIONS

The interface between GiD and Elmer software has been presented. Elmer as an open source software is perfectly suited for academic model development and supports cooperation among computational scientists. There is a clear advantage of using GiD as a pre-processor for Elmer simulations, since the advanced functionality of GiD complement well the features of Elmer package. The interface also increases the target audience of the simulation software by bringing available more pre-processing choices, especially for academic users. Also the post-processor features of GiD may well be applied to Elmer simulations. As demonstrated by the presented examples, the combination of GiD and Elmer forms an advanced simulation package for multiphysical modeling.

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