Interactive Postprocessing Formulations in 3D

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***Abstract*—Nowadays, the postprocessing and visualization of finite element solutions is performed by means of static formulations and methods. Dynamic modifications and interactive exploration of 3D solution data are only possible in a very limited way. In this paper, an interactive postprocessing approach is introduced, allowing for a dynamic modification of finite element solutions, a simplified mesh cutting and data exploring as well as new ways of exploring complex solutions.**

I. Introduction

The exploration and interpretation of a large amount of solution data is the most important part of a typical design process when using the finite element approach. Important decisions are made on basis of solution visualizations and next design steps are planned in dependency of the ongoing understanding of the device under research. Therefore, effective postprocessing algorithms handling large amount of finite element data and the usability of such methods in an interactive way allows a faster and optimized design with finite elements. Today, typical visualizations of finite element solutions are static colorized representations of a field distribution, which map a computed value to a specific color. Additionally, vector fields can be visualized by colorized cones or arrows, indicating the direction of the solution in every element. In this paper, further postprocessing methods and visualization techniques are introduced to enhance the exploration of finite element solutions. These are mainly mathematical modifications of the visualized solutions, simplified placing of cutting geometries like planes or spheres, and dynamic changing of display objects. For all mentioned aspects, examples are given to underline the usage possibilities of the proposed postprocessing formulations.

II. Computer Graphics Software

3D finite element analysis (FEA) leads to a large amount of solution data. In general, developers of electrical devices need to analyze the electromagnetic behavior in certain critical machine parts, such as teeth or teeth heads, or identify local magnetic hot spots. In intuitive method for the evaluation of such simulation data is the interactive exploration in virtual reality [1], which provides a direct visual impression of the field characteristic. This ability supports the machine designer to recognize the points of design interest quickly and allows to perform further interactions and operations on the solution data directly. Therefore, in this paper a software methodology is presented to extend [2] by interactive postprocessing abilities.

The graphical package VTK [3] has been applied to visualize (static) 3D finite element solutions. The Visualization Toolkit (VTK) is an open source, platform independent, software library for 3D computer graphics, image processing and visualization including an interface layer for several interpreted languages, such as Tcl/Tk, Python. The object oriented design of this software is characterized by general, easy to use data structures, whose versatility encourages a modular use of algorithms acting as filter objects. The working principle of VTK is based on visualization pipelines (see fig. 1).

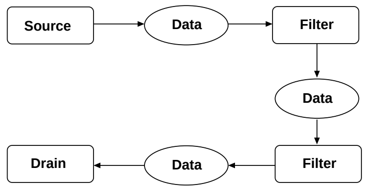
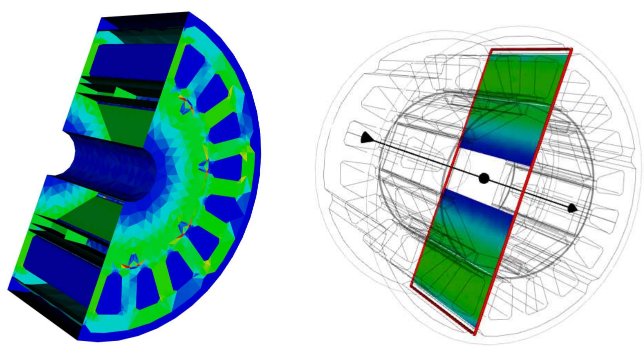


Fig. 1. Visualization pipeline of VTK.

III. Application

A. Interactive Cutting

Due to performance issues, the solution data of meshes is generally mapped to its surface in 3D visualization, so that mesh geometry and colorized solution appear correlated. The corresponding visualization is restricted to the surface mesh of the data object, so that no information of the internal structure is available and cutting methods lead to an opened hollow representation, compare. fig. 2(a). In these situations,



(a) Hollow cutting through a flux density distribution of a PMSM. (b) Interactive cutting of the flux density in a PMSM.

Fig. 2. Different cutting types for the visualization of the flux density distribution.

a cutting filter chain is required, that provides an insight into the electromagnetic behavior within the simulated devices. Since this exploration is data and user depended (direct user interaction), an intuitive cutting method is required which provides an interaction with the model, previewing the cutting surface and the solution.

The necessary filter procedure is shown in fig. 3. First,

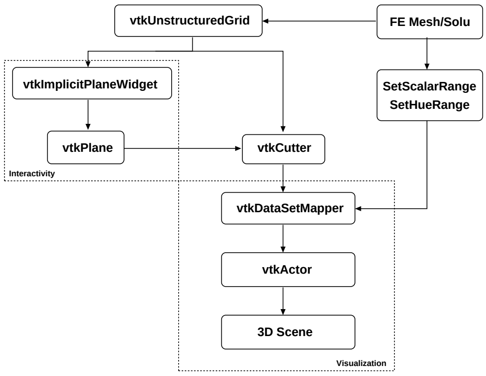


Fig. 3. VTK filter chain for interactive cutting.

the finite element mesh and solution are converted into a vtkUnstructuredGrid data set for each material. A vtkImplicitPlaneWidget, an interactively placeable infinite plane, is bounded to these grids. The mathematical representation of the cutting surface, in this case a vtkPlane, can be obtained from the 3D widget, so that the vtkCutter filter can generate a cutting mesh along that surface. The resulting grid is mapped to graphics primitives by the vtkDataSetMapper, who also maps the scalar range of the finite element solution to a given color range, specified by SetHueRange. The next element of the filter chain is the vtkActor representing an entity of the rendering scene. In particular, vtkActor combines object properties (color, shading type, etc.), geometric definition, and orientation in the world coordinate system. Since visualization, model interaction and cut-mesh generation are separated objects in the filter chain, other widgets types, such as point-, line-, plane-, sphere- and spline-widgets, can be applied for further purposes.

The cutting plane of fig. 3, can be moved, resized or rotated within the model boundaries and is computed in real time. Fig. 2(b) exemplifies this cutting interaction on a permanent magnet synchronous machine (PMSM) to illustrates the flux density distribution inside.

B. Direct Model Interaction

To improve the interactivity in 3D visualizations of finite element data, possibilities for a direct model interaction are required. The idea of a direct model interaction is to give the users an intuitive direct access to the visualized solution data. By this, any kind of operation, e.g. mathematical integration or multiplication, can be performed on the input, so that the modification of the visualization can directly be observed. Since 3D visualizations are scalable on different display systems (from normal desktop pc up to virtual reality systems like cave style systems [2]), an intuitive model interaction, controllable by various 3D input devices that directly operate in the 3D scenes, is required. To fulfill the mentioned criteria, a software methodology is required, that analyses the actual 3D scene to distinguish between different visualization types like a geometry, a mesh or a scalar or vectorial field solution plot. The methodology needs to returns the corresponding original data sets from the FE meshes and solutions. The generalized VTK filter chain for direct model interaction is shown in fig. 4. As mentioned before, the finite element mesh

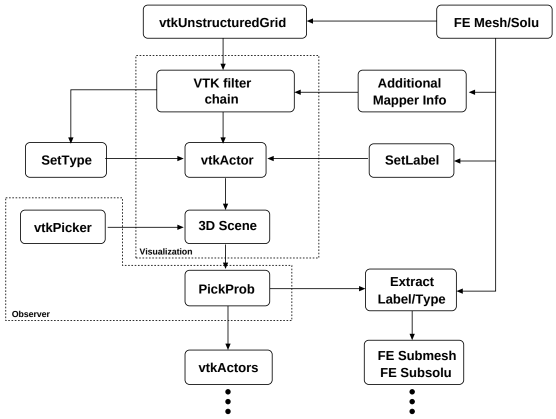


Fig. 4. VTK filter chain for interactive cutting.

and solution are filtered by an arbitrary VTK filter chain and stored in a vtkActor placed in a 3D scene, conf. sec. III-A. To identify the vtkActors in the further processing, each object gets additional information about the visualization type (SetType) and the submesh label identification (SetLabel). In the 3D scene, vtkPicker, controlled by a 3D input device, can be applied to grab vtkActor objects (PickProb). Type and label characteristics of the latter class objects can be used to extract the corresponding input data from the FE solution. These data sets are returned to the user interface. The same control pattern enables a direct access to the properties of single visualization objects.

Therewith, a combination of the interactive cutting geometries (cmp. section III-A) with the direct model interaction presented here is possible, to calculate the flux in various positions in an electrical machine for example.

IV. Conclusion

Efficient methods for the visualization of finite element solutions are essential for the evaluation of electromagnetic devices under research and development. In present, FE data is illustrated by means of static visualization formulations and methods. In this paper, an interactive postprocessing formulation is introduced, that extends the static process to provide dynamic modifications within the visualization and an intuitive 3D data exploration. Generalized techniques for this postprocessing approach are proposed and described by means of visualization patterns for interactive cutting and direct model interaction. A first application example is given to demonstrate the benefit of the presented 3D postprocessing formulation.

Since interactive visualization enables other illustration facilities, further applications, examples and details will be given in the full paper.

References

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