HyperMesh and Custom Export Template Streamline CFD Analysis in Research Projects at Arizona State University

Overview

Integrative Simulations & Computational Fluids Lab researchers from SEMTE (School for Engineering of Matter Transport and Energy) at the Arizona State University (ASU) wanted to use the commercial code HyperMesh as a general preprocessor to mesh complex geometries for use with the spectral element CFD code Nek5000. The challenge was to benefit from the rich functionality of existing meshing tools such as HyperMesh while using the Nek5000 code, since this CFD code requires 3D hexahedral elements. SEMTE researchers set up a project to develop a converter tool with which a HyperMesh mesh could be exported into a format the Nek5000 code could work with. With this export template the overall process is now much more user-friendly and less error-prone. The mesh is generated in HyperMesh and the export template organizes all the data and sorts it so it can be imported in the proper formats into the Nek5000 user template.

Customer Profile

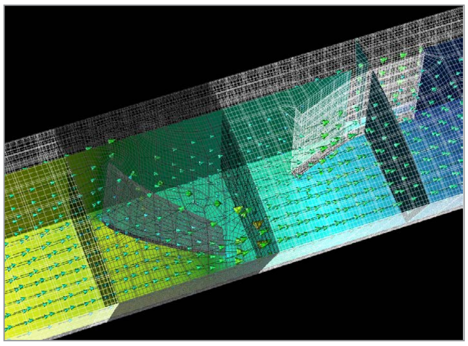
Arizona State University has developed a new model for the American Research University, creating an institution that is committed to excellence, access and impact. ASU pursues research that contributes to the public good, and ASU assumes major responsibility for the economic, social and cultural vitality of the communities that surround it. ASU's SEMTE (School for Engineering of Matter Transport and Energy) encompasses mechanical, aerospace, materials and chemical engineering. For more information please visit: http://semte.engineering.asu.edu/.

Challenge

The Integrative Simulations & Computational Fluids Lab research group is strongly focused on developing and utilizing tools to investigate complex engineering and physical systems on massively parallel machines. They perform their research with the open-source computational fluid dynamics (CFD) solver Nek5000 which is based on the spectral element method and is supported through Argonne National Laboratory. Nek5000 is used in a broad range of applications including thermal hydraulics of reactor cores, transition in vascular flows, atmospheric and ocean modeling, and combustion. SEMTE researchers use the code to explore fundamental physics questions in areas such as heat transfer and turbulence, and their current industrial applications are primarily for the aerospace and wind energy sectors. The department is developing various applications to improve the code's functionality.

Nek5000 employs a spectral element method, combining the geometric flexibility of a finite element solver with the high order accuracy of global spectral methods. The advantage of the code is that it enables exploration of more complex flow types, including geometrically complex and multi-component/multi-physics flows, with a very high level of accuracy. For high-fidelity predictive methodologies for turbulent flows, such as direct numerical simulations, in which Navier-Stokes equations are discretized on fine enough meshes so that all scales of motion are directly resolved and no model is required, this is a superior method due to its minimal dispersion and dissipation errors. One difficulty in using Nek5000 is that it requires 3D hexahedral elements. Typically most CFD tools use tetrahedral meshes because they are easier to generate for conventional geometries. That provided a challenge for the researchers at Arizona State University – how to benefit from the rich functionality of advanced meshing tools, such as HyperMesh, capable of producing high-quality hexahedral meshes, while using the Nek5000 solver code.

SEMTE SCHOOL FOR ENGINEERING OF MATTER, TRANSPORT & ENERGY



The tools are used in a broad range of applications, including thermal hydraulics of reactor cores, transition in vascular flows, atmospheric and ocean modeling, combustion.

"I am very happy with HyperMesh; I consider it the best mesh generation tool I have ever used. It is a very valuable tool for a lot of reasons, including its outstanding documentation that is readily available, which isn't always the case with other commercial tools. HyperMesh allows us to establish a process for any kind of geometry and the geometry can be treated like any other problem for which you have to create a mesh, export it, run it, and check it. If needed, one can also go back to HyperMesh and refine the mesh. We can work on multiple problems very quickly and the meshing process is a lot less difficult when using HyperMesh. Virtually every master's student in our group over the last year and a half has used our HyperMesh custom export template to generate the meshes to explore flows through geometries that would not have been accessible otherwise."

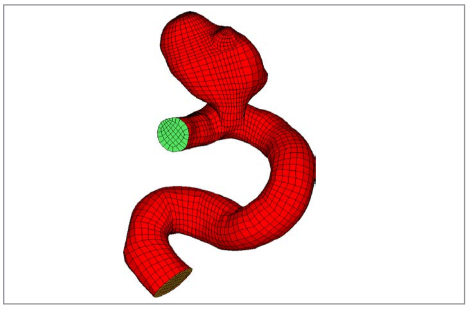
Philip Sakievich, Ph.D. Student and Research Assistant, Aerospace and Mechanical Engineering Department, Arizona State University

Solution

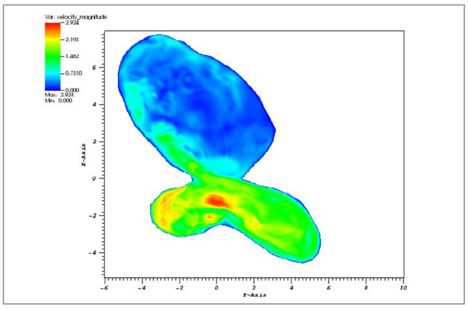
To meet this challenge, Integrative Simulations & Computational Fluids Lab researchers set up a project to develop a converter tool for exporting a mesh from the commercial code HyperMesh (Altair Engineering) into a form that the Nek5000 code can use.
Before the project started, the researchers had no general process for meshing in place. Most of the meshing was handled with custom-made tools that were developed 15-20 years ago and have seen minimal updates since that time. Other users created their own meshing tool for specific problems in software such as MatLab. This cumbersome approach became even more complicated when dealing with irregular geometries. When establishing a standard process, a mature tool such as HyperMesh is advisable, as it allows the user to start with the geometry and then develop the mesh. SEMTE researchers chose HyperMesh because of its solver-neutral functionality, outstanding documentation, and open architecture.

"Using HyperMesh allows us to create high quality grids within our group, and because it can read in all of the common mesh formats we can use it to translate a grid that is supplied by outside parties who may use different software. This dramatically increases our ability to collaborate with other researchers, and it allows us to focus more of our attention on the actual research problem. These are both big wins for our research group," said Philip Sakievich.

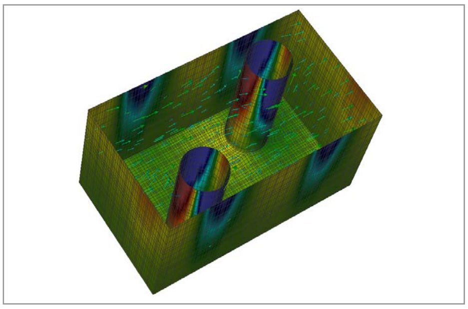
With the tools in place, engineers started with very small problems that did not include more than five to ten elements. In the course of the project they worked through the development and debugging process and subsequently started to test it on larger domains.
After some weeks of intensive researching and coding, the researchers finalized the export template, creating an overall more user-friendly and less error-prone process. After a mesh is generated in HyperMesh, the export template organizes and sorts all the data so it can be imported in the required format into the Nek5000 user template. The converter tool starts by translating the nodal coordinates for each element from the native format within HyperMesh to the Nek5000 data structure. The users also supply the boundary conditions through HyperMesh and this data is converted to the Nek5000 format after the geometric conversion takes place. All of this data is then written to a file that can be fed into the Nek5000 solver. The engineers also added mid-side node support for the meshes to increase geometric flexibility and the converter automatically implements this information based off the element type used in HyperMesh.



Aneurysm mesh in HyperMesh



CFD simulation of the aneurysm in NeK500



HyperMesh to NeK5000 model

Results/Benefits

Researchers and students at the School for Engineering of Matter Transport and Energy at Arizona State University now have a universal approach available with which they can evaluate virtually any application and its complex geometry with the spectral element CFD code Nek5000. Currently there are plans to enhance the converter and rework sections of it to optimize its functionality and make it work even faster.

HyperMesh and the custom export template helped to:

- establish an extremely user-friendly and generally applicable mesh preparation process
- open the way for an advanced and highly integrated engineering workflow
- increase the ability to collaborate with other researchers who use different tools
- speed up the learning curve of all students working on these kind of projects
- achieve better and more precise results for all analyzed tasks
- allow for evaluating flows within complex geometries.

Altair Engineering, Inc., World Headquarters: 1820 E. Big Beaver Rd., Troy, MI 48083-2031 USA
Phone: +1.248.614.2400 • Fax: +1.248.614.2411 • www.altair.com • info@altair.com