Software promises more efficient design process

Mechanical engineers at Purdue University have developed software that promises to increase the efficiency of creating parts for everything from cars to computer hardware by making it possible to quickly evaluate and optimize complex designs.

The new approach integrates the design and analysis processes, which are now carried out separately. Currently, the geometry of a part is first created using computer-aided design, or CAD, software. This geometry is then converted into a mesh of simple shapes, such as triangles or rectangles, which, when analyzed using a computer, indicates the part's strength and other characteristics. The painstaking procedure, called finite-element analysis, is extensively used in industry.

"It's like taking a continuous curve and breaking it into pieces," said Ganesh Subbarayan, a professor of mechanical engineering at Purdue. "Otherwise, the form is too complex to analyze."

After the finite-element model of the part is created, the part is analyzed to see how well it will perform. If a portion of the shape is found to need redesigning, the part's entire mesh must be recreated to reflect the change.

"After the designer designs the object, it is thrown over to the analyst, and the analyst says, 'OK, I think, based on my analysis, that your design has to be modified this way,' and then throws it back to the designer, who makes the modification," Subbarayan said. "That is not very integrated and not very efficient, and that's the reason these problems take so much time and computational power to solve.

"We are trying to speed up this process to make it more efficient by rethinking the way analysis is carried out. Instead of waiting until the end of the CAD process to do the analysis, we are trying to unify both the CAD design and analysis so that they are carried out concurrently."

Information about the software tool is detailed in a research paper recently published online and will appear in the May issue of the journal Advances in Engineering Software. The paper was written by doctoral student Xuefeng Zhang and Subbarayan. The software tool is based on theoretical work by another doctoral student, Devendra Natekar. Natekar graduated in 2002 and now works for Intel Corp., and Zhang graduated in 2004 and now works at General Electric's Global Research Center.

The method could be especially important when dealing with the corporate sensitivities of global competition.

"The overall philosophy behind the design approach can be extended to enable one to understand the impact of changes in suppliers' components on the performance of a complex system without revealing details of the components or the system," Subbarayan said. "This will enable suppliers to retain their proprietary design knowledge without revealing each other's intellectual property. Such strategies are critical as products are increasingly designed and produced in a globally distributed manner."

The software application, which was written by Zhang as part of his thesis, contains about 35,000 lines of Java code.

"That is a big and complex code," Subbarayan said. "If you take problems like finding the optimal shape for common automotive and aircraft structures, you have to somehow find the shape that has the least weight but at the same time won't break. We call that process shape optimization or topology optimization. These shapes have holes in them for bolting them in place or to reduce their weight. You have to decide whether to have one hole or two holes or 10 holes in a part, exactly where to put those holes and how to shape the holes."

Finite element modeling is the de facto analysis tool for numerous industries, Subbarayan said.

"When you use finite elements, you convert the complex differential equations that describe the physics of the part's behavior into simpler algebraic equations that the computer can solve," he said. "It's a powerful method because it enables you to take any complex problem and solve it.

"To describe the geometry, you take this complex object and break it into primitive objects like cubes, spheres or cones. With our approach, if I only modify some portion of the part, I only modify the primitives directly associated with that portion I am changing and not all of the primitives. If I only change the shape of a specific hole in the part, for example, the rest of the primitive objects are the same shape, so why should I need to reconstruct the whole geometry and remesh the whole geometry?"

Subbarayan calls the approach a "hierarchical, constructive, meshless procedure" because it enables engineers to analyze the changing design of a part without recreating the complex mesh of elements.

"The way it is now, the same CAD software used to make the shape of the part can't be used to analyze the mesh," Subbarayan said. "But now, the same CAD software or some similar CAD-friendly software will be able to do the analysis, and in a much more efficient manner because there is no remeshing."

Subbarayan began working on the project in 1998.

Purdue researchers are using the software tool to design new materials at the microscopic level, and the method also promises to help engineers create optimized shapes of droplets of solder to ensure longer-lasting circuit boards. A similar application is creating optimized arrangement of particles in "thermal interface materials" as they are inserted into microprocessors for heat dissipation. The material is sandwiched between silicon chips and metal heat sinks to serve as a buffer between the two surfaces so that the expanding and contracting metal does not cause the brittle silicon to crack.

"These are all problems in which a shape needs to be modified," Subbarayan said. "In the case of solder, you are talking about what shape a droplet should take - the boundaries of the droplet are constantly modified until the optimal shape is found."

Source: Purdue University