Researchers eye papermaking improvements through high-performance computing

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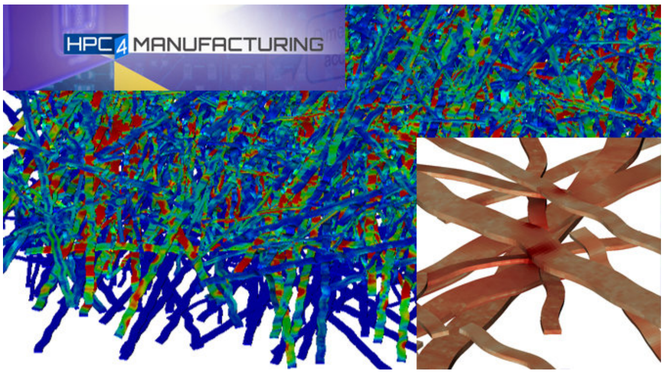

Lawrence Livermore National Lab researchers are developing a parallel program called p-fiber to help Procter and Gamble simulate the way in which paper fibers contact each other. Credit: Lawrence Livermore National Laboratory

With the naked eye, a roll of paper towels doesn't seem too complicated. But look closely enough, and you'll see it's made up of layers of fibers with thousands of intricate structures and contact points. These fluffy fibers are squeezed together before they are printed in patterns, and this resulting texture is key to the paper's performance.

For a large paper product manufacturer like Procter and Gamble , which regularly uses high-performance computing to develop its products, simulating this behavior—the way in which those paper fibers contact each other— is complicated and expensive. The preprocessing stage of generating the necessary computational geometry and simulation mesh can be a major bottleneck in product design, wasting time, money and energy.

To help the company speed up the development process, Lawrence Livermore National Laboratory (LLNL) researcher Will Elmer and his team of programmers focused their efforts on developing a parallel program called p-fiber. Written in Python, the program prepares the fiber geometry and meshing input needed for simulating thousands of fibers, relying on a meshing tool called Cubit, created at Sandia National Laboratories, to generate the mesh for each individual fiber. The p-fiber code has been tested on parallel machines developed at Livermore for mission-critical applications. P-fiber prepares the input for ParaDyn, the parallel-computing version of DYNA3D, a code for modeling and predicting thermomechanical behavior.

The ensuing research, performed for an HPC4Manufacturing (HPC4Mfg) project with the papermaking giant, resulted in the largest multi-scale model of paper products to date, simulating thousands of fibers in ParaDyn with resolution down to the micron scale.

"The problem is larger than the industry is comfortable with, but we have machines with 300,000 cores, so it's small in comparison to some of the things we run," Elmer said. "We found that you can save on design cycle time. Instead of having to wait almost a day (19 hours), you can do the mesh generation step in five minutes. You can then run through many different designs quicker."

Elmer said each individual paper fiber might consist of as many as 3,000 "bricks" or finite elements (components that calculate stress and strain), meaning millions of finite elements had to be accounted for. Elmer and his team generated up to 20 million finite elements, and modeled the most paper fibers in a simulation to date—15,000. More importantly, they verified that the p-fiber code could scale up to a supercomputer, and, using Lab HPC systems Vulcan and Syrah, they found they could study the scaling behavior of the ParaDyn simulations up to 225 times faster than meshing the fibers one after another.

"Procter and Gamble hasn't been able to get this kind of simulation, with this many fibers, to run on their system," Elmer said. "We were able to show there's a path to get to a representational size of a paper product. Questions like, 'How much force do you need to tear it?' can be answered on a supercomputer of the size we're using. That was a valuable finding, so maybe years down the road, they could be doing these simulations for this kind of work in-house. That's what HPC4Manufacturing is all about, showing these power players what can be possible in five years."

Procter and Gamble began using the code on the Lab's supercomputers in June, providing them with a way to use Paradyn remotely, and to determine if it would improve their design process. The company has the option to license p-fiber.

LLNL benefited from the collaboration as well by learning about how Paradyn scales with massive contact problems, Elmer said, and by creating benchmarks for helping to improve the code. The researchers located and fixed bugs in the code and doubled the speed of Paradyn on Vulcan, which could help with mission-critical applications.

"There's still a lot of work to be done, but I'm happy with the way this worked," Elmer said. "I think it's gotten a lot of visibility and it's a good example of working with a sophisticated user like Procter and Gamble. It filled out the portfolio of HPC4Manufacturing at that high level. It was a good way to get the Lab engaged in U.S. manufacturing competitiveness."

More information: For more information, seee HPC4Mfg: hpc4mfg.llnl.gov/

Provided by Lawrence Livermore National Laboratory