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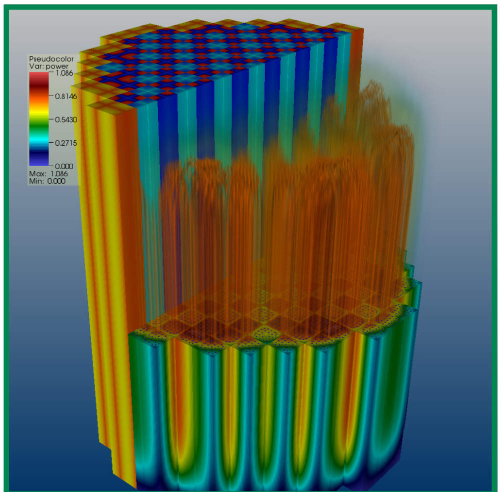
Denovo Scientific Application Code Works to Improve Light-Water Reactors



Denovo radiation transport simulations will help engineers design more efficient and safe nuclear reactors.

Simulating a virtual nuclear reactor gives researchers insight into how to make next-generation nuclear reactors safer, cleaner, and more efficient. By simulating reactor design and how radioactive particles travel, researchers hope to extend the life of nuclear fuel rods.

After a nuclear fuel rod is spent, about 95 percent of its energy value remains. If light-water reactors could safely burn fuel rods longer, nuclear power plants would generate less waste that has to be stored and experience less downtime as old fuel is swapped for new. A scientific application code called Denovo charts radiation transport in a reactor. Run on America's fastest supercomputer at the Department of Energy's first Energy Innovation Hub, it supports research to improve the safety, efficiency, costs, and longevity of nuclear power plants. A multi-institutional computational research endeavor called the Consortium for Advanced Simulation of Light-Water Reactors (CASL), headquartered at Oak Ridge National Laboratory (ORNL), uses Denovo as its computational cornerstone. Running the code allows researchers to simulate a reactor and gain valuable insight into design and operations.

"To match the fidelity of existing 2D industry calculations with consistent 3D codes, we need to solve a minimum of 10,000 times more unknowns than we have achieved to this point," said ORNL computational scientist Tom Evans, lead developer of the Denovo team. "The increased computational power necessary to meet this goal can only be satisfied through efficient utilization of GPU-accelerated hardware."

Denovo pushes the boundaries of Jaguar, the Oak Ridge Leadership Computing Facility's (OLCF's) Cray XK6 supercomputer. The high-performance computer is undergoing a phased upgrade this year and recently received new central processing units (CPUs), increasing its speed from 2.3 to 3.3 petaflops, or a thousand trillion calculations per second. The next phase of the upgrade will add NVIDIA graphics processing units (GPUs), or energy-efficient, high-performance application accelerators, to execute parallel tasks at unprecedented speed. After its full transformation into a CPU/GPU hybrid machine of up to 20 petaflops in autumn of 2012, which will allow greater complexity and realism in simulations, Jaguar will be renamed Titan.

To allow researchers to develop their codes on the new architecture, 10 of Jaguar's 200 cabinets have already gone hybrid; the resulting testbed is called Titandev. CASL partners use Titandev to improve codes needed for next-generation simulations. Current generations of reactor-analysis codes use 2D simulations to generate rough data for input into 3D simulations.

Denovo's most challenging calculation, an algorithm that sweeps through the virtual reactor to track the location of particles, was consuming 80 to 95 percent of the code's runtime. By using Titandev, researchers passed this calculation off to the GPU and saw Denovo's speed increase three and a half times compared to the same calculation using CPUs only on ORNL's 3.3 petaflop Jaguar.

Considering the world gets about 14 percent of its electricity from nuclear power plants, research to improve the longevity of fuel rods would help in producing far less toxic waste over time. Further, this increase in efficiency would save energy customers valuable money by pushing nuclear power plants to greater efficiencies and uptimes.

Due to its ability to run on leadership-class computers, coupled with a compelling need for safer, more efficient nuclear reactors, Denovo is one of five codes under study at the Center for Advanced Application Readiness. Researchers from NVIDIA, Cray, and the OLCF, as well as performance-tool and code developers, formed the center to port leading science applications so they will run effectively on Titan's hybrid architecture from the first day it is operational and to develop a reproducible path for other users to accelerate their codes. *–by Eric Gedenk*

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