Engineers Take Page Out of Nature's Playbook

Amazing how they make such a simple thing sound a wonderful step forward. This is nothing new just a bigger computer.

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Using their genetic algorithm optimization tool, a takeoff of the natural selection process, Louis Qualls and colleagues can quickly perform searches of huge numbers of potential solutions to an engineering problem and identify the best options. An algorithm is a procedure for solving a mathematical problem. Advances in supercomputing and advanced optimization technologies are making it possible to sift through an enormous number of possibilities even for complex problems such as nuclear reactor design.

"Designing space reactor power systems, nuclear reactors or safer automobiles is a long process that involves making perhaps thousands of choices," said Qualls, a nuclear systems integration specialist. "It can take months or years to perform all of the necessary calculations using traditional methods.

"With genetic algorithms, however, we can perform those calculations and end up with a short list of potential solutions in a matter of just minutes or days, depending on the problem."

As in nature and the survival of the fittest, the genetic algorithm approach evolves by removing poor solutions or designs that do not perform well and repopulates the next generation with only combinations - or mutations - of the better designs. Over time and with successive generations only the best options remain.

Unlike traditional design analysis, which is limited to the specific input of engineers, complete with their biases, design optimization through genetic algorithms has virtually no boundaries. Each answer is created without sequential design information, which results in novel approaches that would likely never be generated with conventional methods.

"Because of our individual education and training, we tend to approach problems with certain preconceptions," Qualls said. "Consequently, we often miss unique solutions to any given design challenge."

Specific areas of interest for the Department of Energy's ORNL are in materials research and development and understanding how various metals and alloys respond to extreme radiation. Qualls noted that these are areas for which ORNL has established a long tradition of excellence and continues to play a key role in the nation's efforts to develop nuclear reactors for the space program and commercial nuclear reactors.

Qualls illustrated the advantage of genetic algorithm-based design methods with a recent example proposed by the Nuclear Science and Technology Division irradiation engineering team. The challenge was to optimize the design of an experiment in which 128 material test specimens were to be irradiated in ORNL's High Flux Isotope Reactor.

The specimens were composed of four different materials that were to be distributed over three different temperatures to obtain the broadest range of evenly spaced irradiation damage levels.

"There are literally billions and billions of possible combinations of temperature and specimen arrangements," Qualls said. "While this is something that can be solved manually given some time, it makes a lot of sense to use genetic algorithms to quickly find the most promising solutions. In just a few minutes we found four solutions that were marginally better than the manually derived solutions."

From the perspective of Sherrell Greene, director of Nuclear Technology Programs at ORNL, the genetics algorithm method is providing new design approaches and innovative designs for terrestrial and space-based reactor power and propulsion systems.

"The tools developed by ORNL researchers have already made valuable contributions to our space power programs by enabling us to rapidly explore new concepts and designs," Greene said. "Now we are beginning to harness the power and flexibility of the genetic algorithm approach to improve the design of irradiation experiments and maximize the value of our R&D facilities to our researchers."