Case Study.

Lighting Up DreamWorks with High Performance Computing

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DreamWorks Animation SKG, creators of full-length computer graphic (CG) animated films such as Shrek*,* Kung Fu Panda*,* Madagascar *and this summer's block buster* Monster vs. Aliens*, rely on powerful high performance computing (HPC) clusters to make its characters come alive. But when the company's software engineers needed to test new software concepts to significantly improve the capabilities of their proprietary tools, their clusters had neither the available time nor the configuration they needed to experiment. DreamWorks found help through the Department of Energy's Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program—the company was awarded a grant to refine and test its redesigned software on the leadership-class supercomputer at the Oak Ridge National Laboratory. The prototype software was successfully tested and immediately put to use on* Kung Fu Panda*. The knowledge gained from the INCITE grant informed an entirely new rendering architecture and has now become an essential part of the tools used to create all of DreamWorks' animated films.*

People do not actually believe that Shrek walks the face of the earth, but somehow no one has a problem suspending disbelief when wrapped up in the stories and characters brought to life by the talented artists at DreamWorks Animation SKG.

The artists at DreamWorks realize that in order for the magic to work, Shrek and his animated cohorts have to have much of the rich detail that exists in real life. To be believable, the same holds true for the environments and effects in the films as well. As the DreamWorks Animation website explains, the characters and their worlds are created using a "delicate marriage between creativity and technology. Every detail, every leaf, tree, blade of grass, rock and cloud; every shadow and shaft of light; every thread of clothing and lock of hair [or fur]…" is imagined, designed with intention, and brought to life by the studio's creative teams.

To achieve this level of exquisite detail and also produce two, sometimes three, full-length feature films each year, the studio relies on its powerful HPC clusters and proprietary software. But as images become richer in detail, the critical processes continue to grow in complexity and demand for computation. A single DreamWorks film today requires tens of millions of CPU hours for the critical process of adding color, texture and lighting to each frame.

DreamWorks was uncomfortably aware of a growing bottleneck that could hinder their drive to increase the visual sophistication in each of their movie releases. It could also impede the company's competitively advantageous production schedule of releasing two or three films a year.

Tough but Necessary Multiple-Release Schedule

DreamWorks Animation, with 2008 annual revenues of over $650 million and over 1,800 employees, is principally devoted to developing and producing computer generated animated feature films, as well as other forms of family entertainment. With world-class creative talent, a strong and experienced management team, and advanced CG filmmaking technology and techniques, the Company makes high-quality, CG-animated films meant for a broad movie-going audience. DreamWorks Animation has theatrically released a total of 18 animated feature films, the most recent of which was *Monsters vs. Aliens*, and all of its feature films are now being produced in stereoscopic 3D technology.

The *Shrek* and *Madagascar* movies, *Kung Fu Panda*, *Monsters vs. Aliens* and several other CG family features have made the DreamWorks Animation brand a household name. In 2004, the company also became the first to release two computer-generated (CG) animated features in a single year, a feat not even its closest competitor has achieved. Included in the year of releases was *Shrek 2*, the highest-grossing animated movie of all time. Since the release of the 2009 hit movie *Monsters vs. Aliens*, the studio is releasing all of its films in stereoscopic 3D, a move that has effectively doubled the need for processing power since stereoscopic films require both a separate left and right eye image to be created for every frame.

"DreamWorks Animation appreciates the vital link between technology and the goals of our company," says Ed Leonard, DreamWorks Animation CTO. "HPC is critical in achieving both our creative goals—bringing great characters and stories to life, as well as our business goals—releasing two or three high quality feature films every year."

Quality of Light (and Life)

Evan Smyth, principal software engineer at DreamWorks Animation, was the lead engineer on the INCITE project. Smyth explains that 48 frames or images have to be computationally created for every second of stereo animation, a feat that demands HPC capabilities. Every frame requires that the camera's moves be designed and every character, effect or prop on screen to be animated. An animator painstakingly crafts the animation of every character creating only seconds of a single character's animation every week.

While this process requires significant amounts of computation, it is the next step in the film making process called "rendering" that requires the enormous amounts of computing power. Rendering is the process of adding light and color and involves sophisticated algorithms to create the various lighting effects. The rendering artists, called lighters, use HPC to set and control the lighting effects in a scene. These lighting effects can include both direct and indirect lighting, bounce lighting, reflections and shadowing.

Smyth says that a full frame rendered at final quality can take anywhere from two to eight hours to complete on DreamWorks' in-house HPC clusters. A feature film contains more than 200,000 individual frames in the final product and can consume tens of millions of CPU hours of rendering to complete. The company uses their "rendering farm" of several HPC clusters to keep production moving swiftly and smoothly.

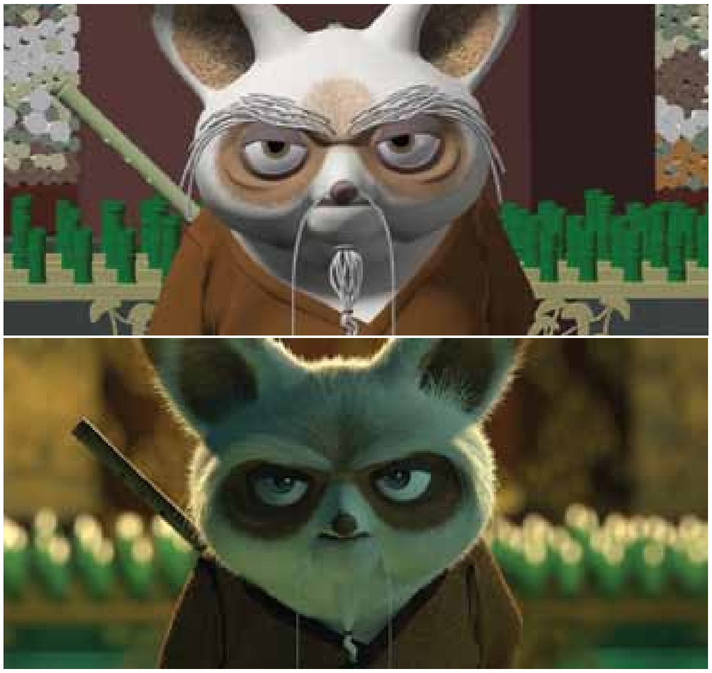
Given the amount of computing time and power needed to render an entire movie, the lighting artists routinely render a number of frames in parallel, switching between an interactive lighting session on an individual workstation and the off-line batch queue of the render farm. However, working in parallel is, at best, a fragmented approach that can hamper both creativity and efficiency, making the artist's job more difficult and also less satisfying. As Smyth says, "Building great tools for artists is not just a quality of lighting issue; it's a quality of life issue for the lighter as well."

Lighters also employ other strategies to accommodate and reduce the long processing times. For example, they often render at a lower resolution, perhaps turning some quality settings down, or only render a sub region of the image. However, mistakes can creep in that are not immediately apparent at these lower resolutions. A lighter may work on a series of frames at one-quarter resolution and then show it to the director, who replies, "Okay, that's great—let's render it at full size." Unfortunately, quite often new, previously hidden problems can show up at the resolution necessary to project in the theater. If the lighter had the ability to work interactively at high resolution, a good deal of rework and frustration could likely be avoided.

"The vision for our next generation lighting tools was to connect the interactivity of our desktop lighting tools with the power of our HPC clusters," says Leonard. "But to do that required significant retooling of our software and access to an HPC cluster that could give us a platform to test out our ideas."

Seeking a New Approach

"We needed a rendering solution that would essentially allow us to dial up or dial down performance depending on what the artist was trying to accomplish," Smyth says. "By re-designing and re-architecting DreamWorks' proprietary rendering software, we were sure we could provide the artists with a much faster turnaround time. If we could substantially reduce or even eliminate the iteration delay, lighters would be able to work on a sequence in near real time rather than wait minutes or even hours to see the results of their work. They could also work at or near full resolution, eliminating mistakes that aren't visible at lower resolutions."



Kung Fu master Shifu before (above) and after (below) final rendering.

Smyth and team had a number of ideas about how to improve the architecture and design of DreamWorks' rendering software, but they had a problem. The DreamWorks' HPC clusters are production systems, dedicated to creating those two or three CG feature films every year. Exploring a new, highly scalable rendering solution in-house would take a substantial amount of their cluster's processing time. And even if time were available on the DreamWorks clusters, they lacked the necessary configuration and raw horsepower to test their ideas. Fortunately the answer to this problem was waiting several thousand miles away in Oak Ridge, Tenn.

Assistance from INCITE and Oak Ridge National Laboratory

The DreamWorks Animation team applied for and was awarded time on a leadership class HPC system at the Oak Ridge National Laboratory (ORNL). The award was made through the Department of Energy's INCITE program. INCITE provides access to computing time and expertise at some of the world's most powerful supercomputers centers at ORNL, Argonne National laboratory, Lawrence Berkeley National Laboratory and the Pacific Northwest National Laboratory. The program supports innovative, large-scale projects that enable scientific advancements. The exploration of the DreamWorks' vision to create dramatically faster, more powerful rendering software met the INCITE criteria, and precious time on the ORNL supercomputer was made available.

In part, the DreamWorks solution relied on creating software that significantly ramped up the rendering process by leveraging the parallel processing taking place in the memory of the company's HPC clusters.

"We had designed a new renderer, and we had some ideas about how to get it to scale across many processors," Smyth recalls. "But we had no real expertise writing complex programs that had to work in parallel across such a large number of distributed memories. Because the HPC system at Oak Ridge was designed to handle highly complex, compute-intensive problems, we felt it would be a huge advantage to explore our ideas there. In the event we found that our software wasn't scaling well, we would be confident that whatever was wrong was a problem with our code, not the HPC cluster. If we had tried to investigate the software's scalability on our DreamWorks' HPC cluster, we would have spent a lot of time separating possible hardware and configuration errors from problems with our prototype software application. The ORNL computer allowed us to quickly eliminate a whole class of variables and focus on the inner workings of the optimized rendering software."

Much to their surprise and delight, the lab's supercomputer confirmed not only that their prototype rendering software worked, but also that it would scale to meet their most optimistic rendering goals. Using the knowledge gained in the experiment, Smyth and his team were able to quickly incorporate the newly verified capabilities into DreamWorks' in-house rendering software–just in time for the rendering of *Kung Fu Panda*.

HPC's Competitive Impact: Catalyst and Catapult

"I'm happy to report that after we got through some initial deployment pains, the lighters working on Kung Fu Panda loved the new software," Smyth says. There were several reasons why it was quickly and enthusiastically adopted. It allowed the lighters to offload the work from their local workstations and run multiple lighting sessions concurrently–something they had not been able to do before. But the biggest win was the raw speed at which they could get back frames. Iterations were sped up by an order of magnitude–a tenfold savings in total processing time. An iteration that once took hours was now accomplished in a matter of seconds.

The faster turnaround time allows the lighters to express more of their creativity in the lighting, ultimately creating a better film. The increased productivity means that DreamWorks can get more of their production costs to show up on screen, which ultimately will help them to maintain their competitive edge.

"I regard the INCITE program as a tremendous catalyst and a catapult into the future," Smyth continues. "I was already trying to develop an advanced rendering system, and everyone saw the potential. The INCITE award allowed us to focus these efforts. Having access to the Oak Ridge HPC system gave us the capacity to test our ideas without taking our critical production system offline. What had been a theoretical problem became an empirical challenge that we were able to investigate and solve very quickly.

"The INCITE program has allowed us to investigate leading edge ideas, validate them on leadership class supercomputers, and then make them practical to our business," said Leonard. "The program has allowed us to advance the state of the art for our business in a way that would not have been practical without the help of the program."

Leonard says both their in-house high performance computing hardware and software are considered strategic assets to DreamWorks. He and his team will continue to investigate ways to provide the film makers at DreamWorks Animation with better and faster tools to do their jobs, a quest that everyone there expects to continue to challenge engineering teams for years to come.

As for Smyth, he and his team continue to chase one of the holy grails of animation, real-time rendering of film quality frames. "Having access to some of the world's biggest and fastest supercomputers is a real advantage when your ideas exceed what is practical," commented Smyth. "We are inventing the future of rendering at DreamWorks Animation, and the INCITE program has been a big part of that."

In Brief

Key Challenges

- Overcome the long rendering time of each frame that slows the artists' productivity, impedes their creativity and ultimately slows time-to-market.
- Prevent mistakes that can be seen only at high resolution and that are not visible when frames are periodically rendered at lower resolution to compensate for the long rendering time.
- Develop and test new rendering software despite the fact that resources on the in-house high performance computing systems were either unavailable or insufficient to conduct the required research.

Solutions

- Applied for and received time on the leadership class high performance computer at the Oak Ridge National Laboratory through the DOE Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program.
- Accessed computational capabilities at Oak Ridge that exceeded in-house HPC capabilities.

Key HPC Benefits

- Validated their prototype rendering software and determined that it could be adapted for use on their current and future in-house HPC systems.
- Achieved a transformational order of magnitude (10x) acceleration in the processing time required for the rendering of each frame, allowing lighters to work more quickly, creatively and with fewer errors.
- Reduces time-to-market for their feature length CG films and ancillary productions (e.g., trailers, shorts, TV specials).
- Allows for future expansion of DreamWorks Animation's production capabilities and positions DreamWorks to create films with even more visual richness.
- Keep DreamWorks on their demanding two to three movie release production schedule and ahead of their competition.

Web Site

- www.dreamworksanimation.com

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