Scientific Visualization:
ANALYZING AND UNDERSTANDING COMPLEX DATA

Since the dawn of computing, the world has undergone an information explosion. As the amount of available information increases exponentially, the problem of understanding and effectively using the data becomes more challenging.

Scientific visualization, also referred to as visual data analysis, is the transformation of scientific data into graphical images. It is especially useful when studying massive amounts of complex data in order to gain visual understanding and insight into the information.

Charles Hansen, professor in the School of Computing, focuses his research on developing novel algorithms and building tools and systems that assist in the comprehension of large quantities of scientific data. Hansen is also associate director of the Scientific Computing and Imaging (SCI) Institute at the University of Utah. SCI is an internationally recognized leader in visualization, scientific computing and image analysis.

"Interactive techniques provide better cues when trying to understand spatial and temporal relationships between data," says Hansen. "Therefore, the main focus of my research is on developing better methods for visualization and rendering at interactive rates."

For the past 20 years, Hansen's research has involved employing parallel rendering techniques for visualization, utilizing innovative data structures for faster access to information, and developing visualization algorithms.

"With the advent of the programmable GPU [graphics processing unit], my background in parallel algorithms is providing unique opportunities to develop new methods using the GPU hardware," says Hansen. "We're also able to generate imagery very fast."

VISUALIZING SIMULATED FLUID FLOW

Hansen is using interactive methods to analyze behavior of fluids (liquid, vapor or gas) and applying them to computational fluid dynamics. Hansen and his team have developed software tools for the University of Utah's Center for the Simulation of Accidental Fires and Explosions, or C-SAFE, a large interdisciplinary team from computer science, chemical engineering, mechanical engineering, physics, chemistry, and other departments, that produces cutting-edge research in simulating and visualizing complex physical phenomena including reacting flows, material properties, multi-material interactions, and atomic-level chemistry.

C-SAFE was established through the U.S. Department of Energy's Advanced Simulation and Computing Program.

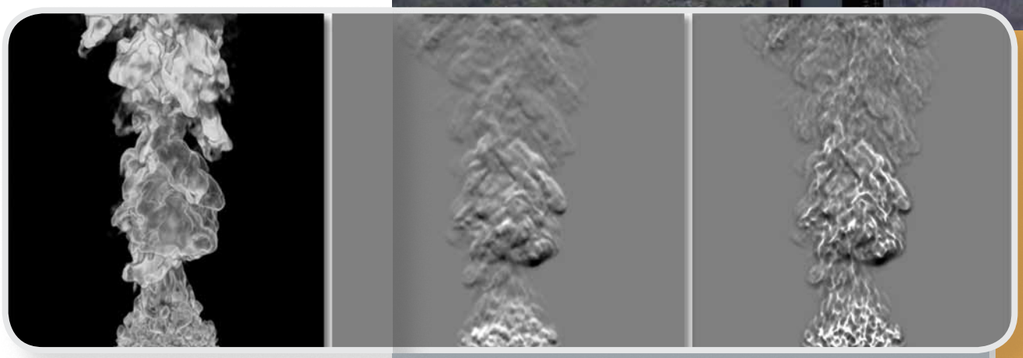
Through unique 3-D computer simulations, C-SAFE researchers can model the "flow" or behavior of fluid when, for example, fuels or explosives ignite accidentally or intentionally. With Hansen's visualization tools, researchers can analyze real fires and conditions that affect them. "Understanding fluid flow is a difficult problem and of increasing importance because computational fluid dynamics produces a huge amount of simulation data," says Hansen.

Hansen's work at C-SAFE is connected to simulation research done by his colleague Philip Smith, professor of chemical engineering, who is also featured in this report. Smith conducts the fire simulations and experiments that Hansen visualizes through graphical images. Read more about Smith's research on page 4.

Hansen and his team have recently developed a novel computational method to analyze fluid flow based on an experimental technique. Their method simulates the refraction of light to generate synthetic flow visualization images derived from computational fluid dynamics data. They use both shadowgraphs (where flow is shown through its shadow) and schlieren images (where flow is shown through light refraction). The group's method uses a combination of GPU programming, acceleration methods, and schlieren techniques to achieve interactive, physically accurate images.

"If we can simulate schlieren imagery to analyze computational fires, we can apply the same analysis methods to computational data that people do to experimental data," says Hansen. "We can link experimental and computational data to try out new and different ideas."

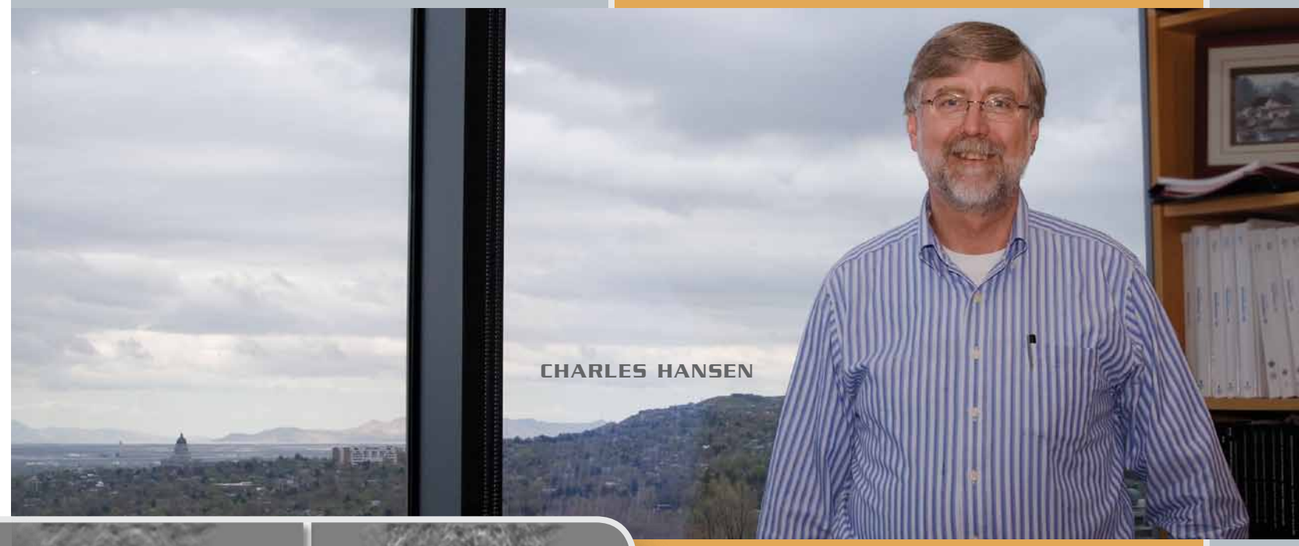
Although shadowgraph and schlieren techniques have been around for a long time, Hansen says, "We've improved upon previous work by tracing curved light paths rather than relying on line-of-sight approximations."



ABOVE: A helium plume is depicted using **(LEFT)** a traditional volume rendering technique, **(CENTER)** a shadowgraph image, **(RIGHT)** a computational schlieren method developed by Charles Hansen's group that achieves an interactive, physically accurate image.

Hansen's team won the Best Paper Award for their research at the 2010 Institute of Electrical and Electronics Engineers (IEEE) Pacific Visualization Symposium.

Although scientific visualization is his main research focus, Hansen is also working on improving computer graphics and rendering models. He plans to develop faster algorithms for visualization techniques, better methods for volume rendering, and improved methods for using GPUs in visualization.



A LEADER IN DIGITAL MEDIA

The University of Utah has long been at the forefront of computer graphics and animation. In the late 1960s, David Evans and Ivan Sutherland took the lead in creating the field of computer graphics and establishing the U's world-renowned computer science program. In addition to their own fundamental contributions, their legacy includes a remarkable group of graduates who pioneered personal computing and computer graphics, including Alan Ashton, Ed Catmull, Jim Clark, Alan Kay and John Warnock.

Computer science professor Charles Hansen is part of a search committee seeking to build a team of experts in digital media at the University of Utah. The Digital Media Institute is being organized as part of the USTAR (Utah Science, Technology and Research) initiative—a long-term, state-funded effort to strengthen technological research and stimulate economic development in Utah. With an emphasis in computer game technology, the institute will be a research center for the university's colleges of engineering, fine arts and architecture. The institute will also collaborate with Utah computer gaming studios to promote entrepreneurship by licensing university technology to spin-off companies.

The search team has already recruited Craig Caldwell, a professor in film studies, and is looking for other experts in computer science and fine arts.

"I think this effort is good for the School of Computing, the College of Engineering, and the state of Utah," Hansen says. "I believe it's where a lot of the future education and research in computer science is moving. It will be a great platform for teaching students in an engaging environment."