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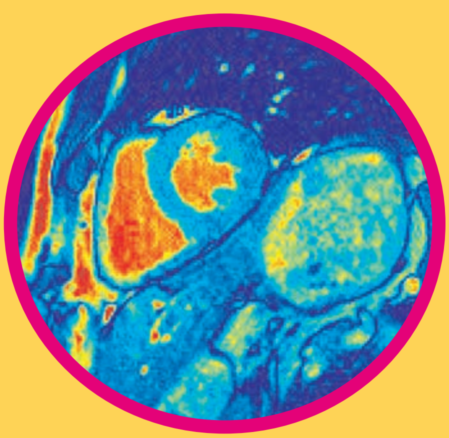
COMPOSE

THE DOE CSGF ANNUAL ESSAY CONTEST JOURNAL

DOE CSGF



MAKING BLURRY IMAGES
A THING OF THE PAST

SPACE HARVEST

THE DOE CSGF ESSAY CONTEST WINNING ESSAYS

2006

The DOE CSGF Annual Essay Contest was launched in 2005 as an exciting opportunity for DOE CSGF Fellows to hone their writing skills. This contest requires Fellows to write a popular science essay on a topic of personal importance written for a non-science audience.

The DOE CSGF is proud to recognize outstanding Computational Science Graduate Fellows who have completed a non-technical writing composition on a topic in computational science. In addition to recognition and a cash prize, the winners received the opportunity to work with a professional science writer to critique and copy-edit their essays.

These copy-edited winning essays are published here, in this issue of Compose Magazine.

FOR MORE INFORMATION ON THE DOE CSGF ANNUAL ESSAY CONTEST, VISIT
http://www.krellinst.org/csgf/compose/index.shtml

This year the essay submissions were judged by a three-person panel consisting of Christine Chalk, David Keyes, and Jacob Berkowitz.

Christine Chalk has been with the U.S. Department of Energy's Office of Science for more than 15 years in a variety of science policy positions. Ms. Chalk has degrees in Economics and Physics and experience on Capitol Hill. She is currently on a long-term detail to the Office of Advanced Scientific Computing Research from the Office of Budget and Planning — Division of Planning and Analysis. In addition, she has served on the screening panels for the American Association for the Advancement of Science's Science Journalism Awards the past two years. This is Ms. Chalk's first year reviewing DOE CSGF essay submissions.

David Keyes is a computational mathematician with primary interests in parallel numerical algorithms and large-scale simulations of transport phenomena – fluids, combustion, and radiation. He is the Acting Director of the Institute for Scientific Computing Research at Lawrence Livermore National Laboratory and is also the Fu Foundation Professor of Applied Mathematics in the Department of Applied Physics and Applied Mathematics at Columbia University. Dr. Keyes is active in SIAM and directs an Integrated Software Infrastructure Center in DOE's Scientific Discovery through Advanced Computing Initiative, called Terascale Optimal PDE Simulations. This is Prof. Keyes' second year as a DOE CSGF essay reviewer.

Jacob Berkowitz is a Canadian writer, journalist and playwright. He popularizes the work of leading scientists at major research-based organizations in Canada and the United States and is a long-standing contributor to DEIXIS, the DOE CSGF annual magazine. Mr. Berkowitz spoke about science writing at the 2006 DOE CSGF Annual Meeting in a talk titled, "Starting from the End: The Power of Turning Science into Story." His first book, "Jurassic Poop: What Dinosaurs and Others Left Behind," was published in 2006 and he's presently at work on a 50th anniversary follow-up to C.P. Snow's classic book on science and society "The Two Cultures." Mr. Berkowitz has been a DOE CSGF essay reviewer for two years.

Julianne Chung – 2006 DOE CSGF Essay Contest Winner

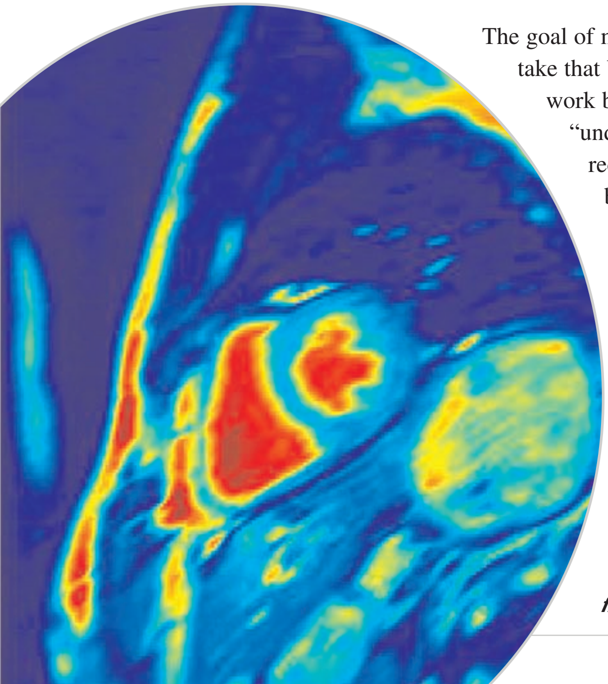
Making Blurry Images A Thing of the Past

My family loves to take pictures. We see stars on Christmas Eve, not from the twinkling night sky, but from the hundreds of flashes coming from my mom's and aunt's 35 mm cameras. When asked why they take so many pictures, they always respond, "Just in case some of them don't turn out."

Nowadays, the convenience of digital cameras allows us to immediately see our picture and take another if we are unsatisfied. But what if it costs $5,000 to take one picture? Would you pay another $5,000 if the picture was blurry or contaminated with specks of dust? Instead, I think you would try to fix the image you already have. With the help of advanced mathematics and high-performance computers, researchers are finding new ways to take the blur out of images.

You may be wondering what kind of picture costs $5,000. One example is a medical image from a device called a PET scan. This particular camera can scan for cancer, detect Alzheimer's disease and diagnose heart disease. But the image will be blurred if the subject fidgets. Performing the scan again is costly, not to mention possibly detrimental to the patient's health. The radiologist, which is just a fancy name for a doctor who interprets medical images, must now face a blurred, degraded image of, say, your heart. She has no hope of a clearer image.

The goal of my research is to take that blurry image and work backwards to "undo" the blur. The reconstruction must be done using a computer. As a computational scientist, I work to develop sophisticated algorithms or instructions for the computer.



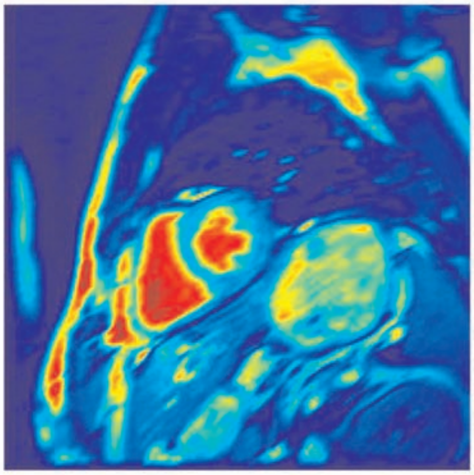
Motion blur makes it difficult for radiologists to image the heart and surrounding organs. The heart beat and natural blood flow could be the culprits, but patient fidgeting also contributes to the problem.

Now, a good detective knows that prior to starting any major operation, we need the proper tools and research. That is, we need some knowledge about our problem. The first line of investigation is determining what caused the blur. There could be many culprits; one example is motion blur. If you take a picture of a fast-moving car, you may see lines and streaks in the image. Many photographers desire this artistic effect, but medical doctors and radiologists want to eliminate it. To alleviate the smearing effects, the radiologist will ask you to lie still during the test. No matter how hard you try, you will breathe, itch, sneeze and/or twitch, thereby causing motion blur in the image.

Once we know the kinds of blur contaminating our image, the next step is to arm ourselves with the tools needed to do the reconstruction. We start with the basics. A digital image is a

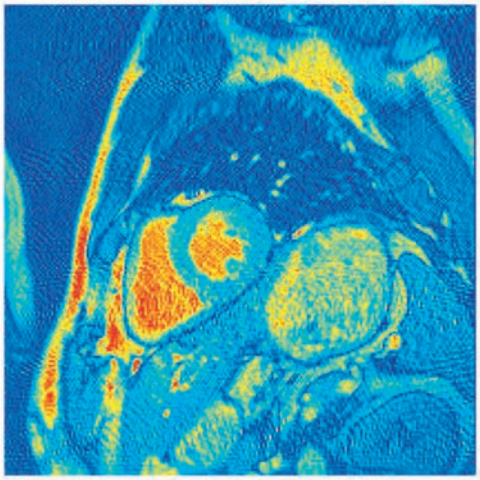
"With my research, maybe one day I will be able to convince my family that one picture is enough."

picture sitting inside a computer. Each image consists of pixels that snap together in a grid-like formation. Each pixel has an associated value, like each tile of a mosaic has its own color. A typical medical image has a grid of 256 pixels by 256 pixels, giving a total of 65,536 pixels in the image. That's equivalent to the seating capacity of a large football stadium. Now imagine we line up all the players and fans into one single-file line and assign each person a number. This is similar to how images are stored in the computer. We organize them by putting all 65,536 pixel values into a very long list, making it easier to access each value individually. Remember that our goal is to "undo" the blur in the image. Thus, it is important to understand what happens during the blur process. We do this through mathematical modeling, which is just a fancy expression for using math to explain real-life phenomena. For example, suppose we want to model



Medical images often are blurry. This one is significantly degraded by motion blur.

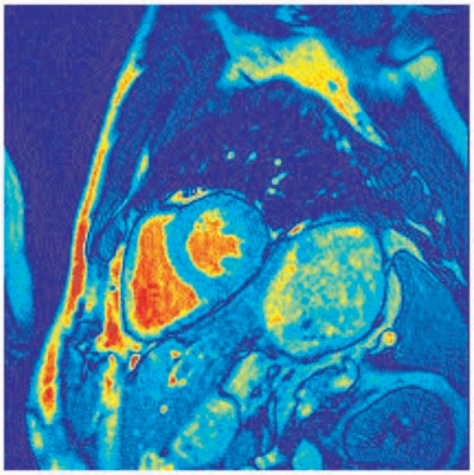
motion blur. Imagine a scenario in which we paint red, yellow and blue stripes side-by-side on the wall. While the paint is still wet, a child runs his fingers straight through all the colors. The mixture of paints causes a rainbow of colors to appear. In the same way that the motion of the kid's hand causes the colors to mix along the wall, motion in an image causes an average (or smearing) of neighboring pixel values. Mathematically, this phenomenon is characterized by a formula we learned in elementary school: to compute an average, sum up the values and divide by the total number of items. Since a typical image has 65,536 pixels, we have to do this "averaging" 65,536 times! That's a lot of values to manage, so computational scientists conveniently store the information in a large table. This is where computers are helpful and important. Not only do we have to store all of these numbers, but massive computing power also is required to execute instructions that work with these huge tables.



Here the image is degraded by undesirable noise.

So far, we seem to have everything needed to perform the reconstruction, but we have overlooked the most notorious villain of all: the "specks of dust" on the image, which scientists call noise. Looking at an image degraded by noise is like trying to see an image behind the black and white static in a bad TV transmission. Due to the random or accidental nature of noise, the chance of us ever getting back to the exact original image now is like finding a pin in a haystack the size of China. I and many other researchers are trying to solve this problem. No definitive answer has been found, but we will NOT give up.

Even though we cannot reconstruct the original image, many computational mathematicians and researchers are investigating ways to get a good approximation. With the advent of novel mathematical techniques and the help of modern computer technologies, we are getting closer and closer to finding a reliable and automated way to "undo" the blur in any image. Clearing up blurry images is important to many aspects of life, whether to clear up the motion blur in your $5,000 PET scan or to avoid taking yet another family photograph. With my research, maybe one day I will be able to convince my family that one picture is enough.



This shows how computers and advanced mathematics allow researchers to suppress noise and reconstruct clearer, more detailed images.

David Potere – 2006 DOE CSGF Essay Contest Honorable Mention

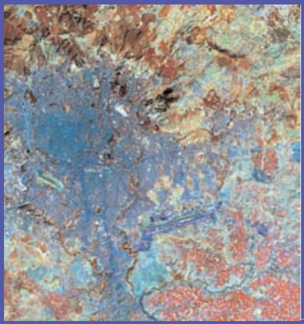
Space Harvest

Each day thousands of engineers in remote locations scattered across the globe are engaged in a carefully choreographed sky-dance. From the soybean fields of Córdoba, Argentina, to the deserts of Alice Springs, Australia, their daily mission is to maintain communications with the hundreds of orbiting sensors that make up our planet's Earth-observing satellite constellation. At the heart of each of these ground-earth stations is a giant white antenna, often more than 100 feet in diameter, which is slewed around in imperceptibly slow arcs, tracing the paths of Earth-observing satellite sensors – satellites, some as big as school buses, that gather views of the Earth while hurtling through space hundreds of miles above us at speeds of more than 15,000 mph.

In a sense, these engineers are farmers, pulling in a daily harvest of new Earth imagery that is changing our understanding of the world. And for these farmers, the new millennium has brought in a bumper crop. The old community of countries with robust Earth-observing satellite programs – the United States, Canada, the European Union, Russia, and Japan – has rapidly expanded to include China, Korea, and India. And in 1999, the launch of the commercially owned IKONOS satellite brought to market the kind of fine-resolution imagery that was once the exclusive property of governments. The constellation of Earth-observing satellites is now so dense that every day, no matter where you stand on the surface of the Earth, you can count on being imaged by as many as half a dozen satellite sensors. Not only are there far more EOS platforms than ever before, but these platforms see the world through some strange new eyes. Like animals that hunt at night, satellite sensors are unbound by the familiar reds, greens, and blues of everyday vision – they peer out into the infrared. Sensors can "see" the temperature of the Earth's surface. Satellites also are on watch in the nighttime sky, building images of moonlit clouds, forest fires, and the lights of our cities. Nor are satellites bound by sunshine or moonshine – new generations of radar imagers and microwave sounders create their own sources of illumination. Transmitting microwave energy that can penetrate the densest clouds, these instruments return images of rain, wind, and the three-dimensional texture of the land surface.

The sheer number and imaging power of all of these satellites means our ground-earth stations are harvesting a lot of data. Anyone who owns a digital camera can appreciate the data storage problems posed by the Earth-observing satellite constellation. A medium-quality digital camera like the one you might use for family photos has a resolution of five megapixels – representing five million individual points of light – and can store a few hundred pictures. The land surface of the Earth spans roughly 58 million square miles. If you want to build a portrait of the Earth's land using your camera, where each camera pixel represents nine square feet (roughly the resolution of much of the imagery displayed by GoogleEarth), you would need to store more than 30 million photographs. Things get much more challenging when you consider that these Earth portraits are gathered every day of the year in a far wider range of "colors" than any digital camera can capture.

Clearly, no Memory Stick can store an Earth portrait. Earth-observing satellites require serious computational power. In 2004, reporting from a ground-earth station in Sioux Falls, S.D., NASA announced that the archive of images from its Earth-observing satellite constellation had just "crossed the petabyte threshold." That's roughly equivalent to the data



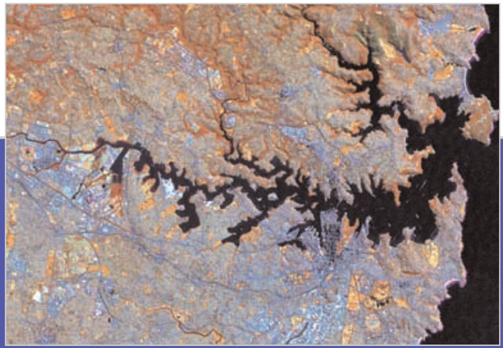
Addis Ababa, Ethiopia, as imaged from the Landsat 7 satellite on December 5, 2000. This capital city is just south of Mount Entoto (upper middle of image), and is home to nearly three million residents. The pink patches in the lower right corner are agricultural fields southeast of the Addis Ababa airport

Havana, Cuba, as imaged from the Landsat 7 satellite on April 3, 2001. Here, the ocean is depicted as black, with Havana harbor clearly visible in the upper right corner.

storage space inside 10,000 entry-level PCs. And of course every other country with an Earth observation system has a similar archive. In a real sense, the expansion of Earth-observing satellites would never have happened without a parallel revolution in computing. There would have been no sense investing billions of dollars in creating a satellite constellation without the ability to store, communicate, and analyze an incredible number of images.

Kinshasa and Brazzaville face each other on the southern and northern banks of the Congo river, respectively. Each city is a national capital; Kinshasa is the capital of the Democratic Republic of the Congo and Congo-Brazzaville is the capital of the Republic of the Congo. This image was taken by the Landsat 7 satellite on April 30, 2001.

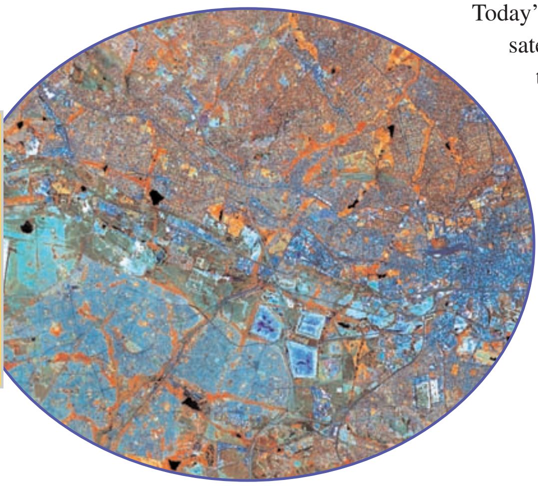
That last requirement – analysis – is crucial. Although the Earth-observing satellite constellation has yielded many iconic Earth images, only careful scientific analysis can turn this harvest of raw satellite imagery into the knowledge we need. From confronting the immediate challenges of natural disasters like Hurricane Katrina and the Indian Ocean tsunami to carefully preparing for the longer-term realities of global climate change, our Earth imagery archives hold many of the answers. Yet the Earth system is complex, and the imagery archives are deep. Finding answers in some of the world's largest data archives demands some of the world's fastest computers.



The famous harbor of Sydney, Australia, as imaged by the Landsat 7 satellite on August 8, 2001. Here deep water is black, and the downtown core is a dark purple agglomerate on the southern shore, just right of center.

Oak Ridge National Laboratory is one place where very large imagery archives have come in contact with very fast computers. As a U.S. Department of Energy Computational Science Graduate Fellow, I spent a summer at the lab, nestled in the Tennessee foothills, collaborating on research with the LandScan project.

The LandScan team works each year to build a detailed global map of the world's human population. To map an entire planet's worth of villages, towns, and cities every year, LandScan relies on traditional census data and Earth-observing satellite imagery from dozens of satellites. In order to tap into some of the deepest global imagery archives available, LandScan scientists have begun training high-performance computers to recognize settlement patterns. Using methods that often approximate the function of human vision, these machines have the potential to perform in a matter of days computations that would require decades of work by a team of humans. This research holds the promise of transforming raw satellite imagery into maps of human population in a matter of hours – building maps that could play a critical role in managing the consequences of our next great natural disaster.



Johannesburg, South Africa, images from the Landsat 7 satellite on January 7, 2002. The downtown is visible as a dark blue grid just right of center. The paler blue blocks in the lower left corner are the community of Soweto. The bright blue blocks that separate the two regions are gold mine dumps.

Today's international community of Earth-observing satellite users is growing even more rapidly than the constellation of satellites. The LandScan team is an example of a new generation of scientists who are grappling with the complexities of the Earth system. With our global human footprint wider than it has ever been, the need for a spaceborne perspective on our planet-wide problems has never been greater.

Science as Story

by Thomas R. O'Donnell
Krell Institute

Science doesn't have to be thick, murky and mysterious. These essays – the latest winners in a competition for Department of Energy Computational Science Graduate Fellows – prove that.

Like a good novel, these pieces connect with readers and draw them in. Julianne Chung's essay on research to refine blurred medical images ties the work to family photos. David Potere uses an effective agricultural analogy to put the daunting task of satellite image analysis in context. The science is unmistakable, understandable, and – thanks to the writers' skill – unforgettable.

The essays published here are substantially the same as they were when submitted. The editing and review process was a collaboration, not a lecture. It was designed to be gentle and to maintain the writers' voices. Through the process, the winners – scientists by training – got a better understanding of how communicators work and how their work can be more clear and concise. The editor learned about the passion driving these students – their deep interest in their research and the difference it can make in people's lives – and about how they think.

Writing, after all, is thinking. It's organizing thoughts into a comprehensible and organized form to share with others. That means the orderly mind of a scientist ought to produce good writing.

Unfortunately, that's unusual. Scientists most often communicate with each other, and necessarily use jargon that is unique to their field. They stick to the facts, because injecting emotion and passion could be seen as hyping the research or as self-promotion. It's difficult for researchers to switch from that mode – appropriate for an academic setting – to a less technical style necessary for a lay audience.

Scientists must overcome that difficulty. Their research must be made understandable if the public and decision makers are to continue supporting it. As these essays show, that does not mean "dumbing down" or vulgarizing science; it means giving readers something to hold onto – such as stories, anecdotes, metaphors and analogies – as they're led through the maze of technical information. Potere's essay is a prime example. The image of satellites "harvesting" data like combines crossing a field is easy for readers to understand, as is the "bumper crop" of information those satellites gather.

Scientists also must overcome any discomfort they have about discussing their own role in the research. Personalizing their work – describing their interest in it, their successes, their failures and their breakthroughs – forges a connection with the reader and draws them into the work. It encourages the reader to share the researcher's passion, tragedies and triumphs. As Chung's essay shows, it can also delight. What reader hasn't taken a priceless photo, only to wish they could correct the blurred result?

Jacob Berkowitz, a professional science writer, author and playwright, stresses the importance of effectively communicating science in his presentation at the 2006 Annual DOE CSGF fellows' meeting in Washington D.C.

Researchers have many opportunities to inform the public through media interviews and articles for the popular press. Each one is a "teachable moment" that can enhance public discourse. Tapping these techniques will not only ensure the reader understands the science, but also remembers it. By entering this essay contest, even those fellows who failed to place have moved toward mastering communication to a lay audience.