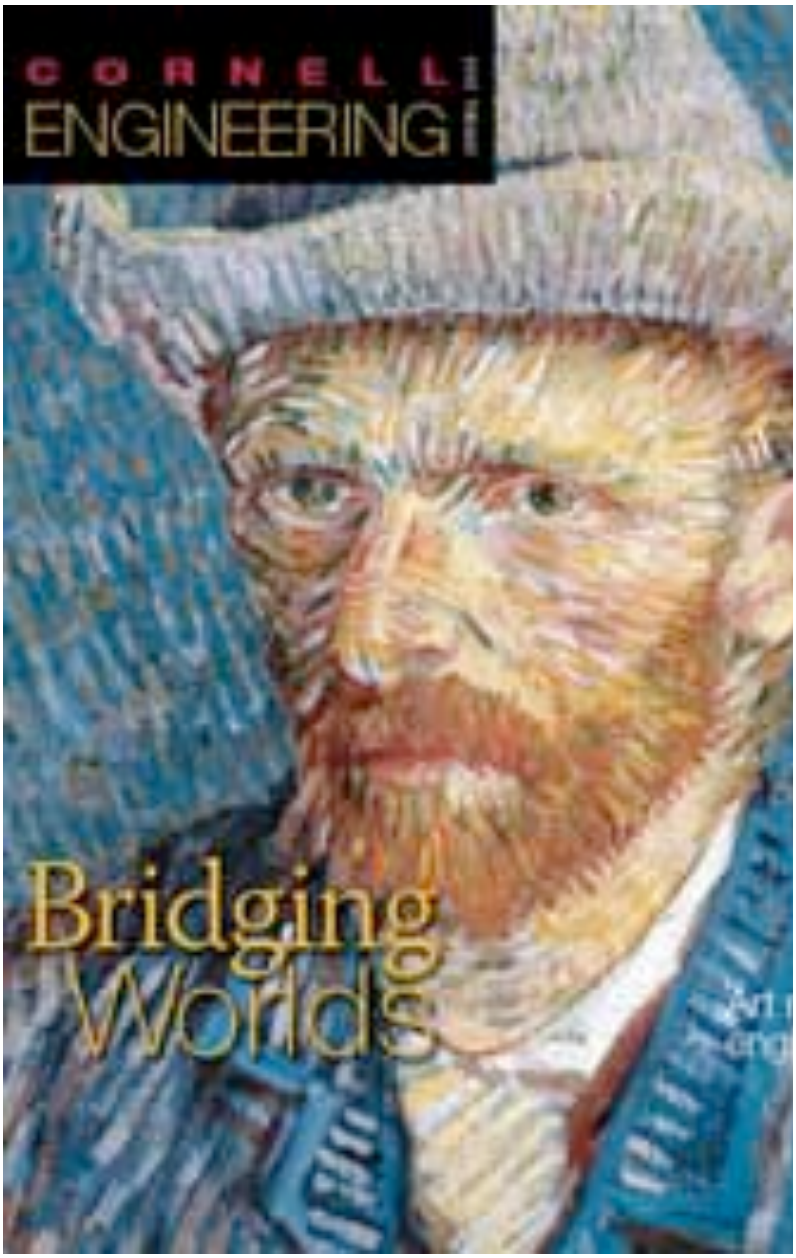
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BRIDGING WORLDS

ECE Prof. Rick Johnson has signal processors and art historians talking about painting authentication

By Robert Emro

Growing up in northwestern Georgia, C. Richard Johnson Jr. never visited an art museum, heard a classical music concert, or attended serious theater. A second grader when the Soviets launched Sputnik I and the ensuing space race, Johnson was channeled into engineering when he exhibited an early aptitude for math and science. Not until he was a student at Georgia Tech did he get his first taste of fine art.

He was in Germany with a study-abroad program. His travels took him to the Gemäldegalerie (Picture Gallery) in Berlin. This collection of old masters was split by the wall when Johnson visited in the early 1970s. Even so, the West German side still held an impressive collection, including The Man With the Golden Helmet, one of Rembrandt's most famous paintings. Seeing it for the first time was a revelation. "I spent several hours in the Rembrandt rooms," says Johnson. "I didn't know why. I just had some kind of response to it."

Self-Portrait in a Gray Felt Hat: Three Quarters to the Left, September 1887–October 1887. Courtesy The Van Gogh

From a working-class family, Johnson didn't even entertain the idea that he could somehow make a career of art. "It never even crossed my mind at that point," he says. "That just wasn't done where I come from."

But he couldn't stay away. As an electrical

engineering grad student at Stanford, Johnson took a course on Rembrandt knowing that if he bombed, the F would not appear in his record. Far from flunking, he was one of the star pupils. During one test, he was the only person to realize that a slide of a Frans Hals painting had been loaded backwards. He could tell because Hals always painted the light falling from the left. One class led to another and by the time Johnson graduated in 1977 he had pioneered Stanford's first Ph.D. minor in art history. The topic of his final report, appropriately enough, was Vermeer's use of the camera obscura. Careful measurement of the angles in his paintings and reconstructions of the rooms he painted them in have led some to argue that Vermeer used this rudimentary optical device in creating his almost photographic paintings.

Museum.
-Van Gogh Museum

"It was a survival technique to get myself through engineering, to some extent," says Johnson. "Art history is something I found a passion for that I see in my students for technical things that I sometimes don't have."

Johnson received an appointment as an assistant professor at Virginia Tech, but he was still drawn to art history and after a couple of years he put together a book proposal on Rembrandt's self-portraits. He knew he was at a major fork in the road of his life, and he was willing to take a different path, but it turned out Kenneth Clark had just written an about-to-be published chapter on the same topic. His proposed collaborator's publisher rejected the proposal.

Lumiere Technology of Paris used its multi-spectral digital camera to capture images of van Gogh's *The Bedroom*.
-Lumiere Technology

So Johnson took a position at Cornell instead, joining the faculty as an associate professor in 1981. He continued a successful academic engineering career in the School of Electrical and Computer Engineering, periodically reinventing himself. First he worked on the theory behind adaptive feedback systems, used to kill the echo you can sometimes hear while talking on the telephone, then he created and analyzed blind equalization algorithms, used in receiving hi-def TV. But he never lost his love of art history, so in 2005, when he was ready to change his research focus once again, he began wondering how his expertise in signal processing could get him a backstage museum pass.

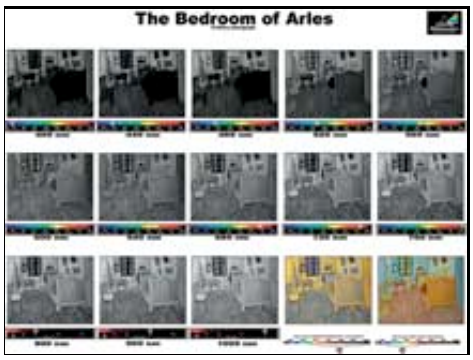
"When I decided to change, I looked for an area where I would have some special talents," he says. "I asked myself, 'How can I leverage something I know into getting behind the scenes?'"

Johnson knew that art historians and curators used a variety of technologies to study paintings, including X-radiography, infra-red photography, and UV fluorescence. While on a Fulbright in Paris, Johnson arranged a lunch meeting with Louis van Tilborgh, a curator at the Van Gogh Museum in Amsterdam. He offered his services as a translator helping the art history experts at the museum communicate with

the technical types doing the image processing. Tilborgh was intrigued and asked Johnson to make a more formal presentation to museum management. While preparing, Johnson discovered that these tools helped de-attribute the very painting that awakened his passion for art in the first place. In 1985, the Rembrandt Research Project determined The Man with the Golden Helmet was not painted by Rembrandt but by an unnamed apprentice.

The museum liked the idea of having an expert in signal processing to help connect them with the computer-based technology used in painting authentication and gave Johnson a five-year appointment as an adjunct research fellow. "I'm a Ph.D. student again, working for the head of conservation at the Van Gogh Museum, doing with her what she does and finding out what we can give to a computer to do—which is mostly signal processing," he says. "Whether the data comes from a CAT scan or a satellite or a painting, it becomes an array of numbers to which the kit of signal processing tools can be applied."

"It's quite a luxury for me to have a student that's so efficient and hardly needs any supervision. He's so enthusiastic," says Ella Hendriks, Johnson's new adviser. "He's willing to spend time for things that are hugely useful."



The Bedroom in 13 spectra, from ultra-violet to infrared, plus false color infrared and visible light.

-Lumiere Technology

While some in the art world balk at the idea that a computer can perform the duties of a human art expert, the Van Gogh Museum has embraced this new technology. "It's not replacing the judgment of the art historian, it's simply an added tool that will assist the art historian in making his judgment," says Hendriks. "It's very important to make a good tool and the best way to do that is to collaborate with the tool maker. If you're involved at the beginning you're going to get the best tool."

One thing Johnson has done in his new role is connect the museum with a company in Paris—Lumiere Technology—that has designed a multi-spectral camera for digitizing works of art. The company used it to reveal the true colors of the Mona Lisa in 2004. He helped convince Lumiere and the Van Gogh Museum to take images of The Bedroom and The Potato Eaters in October. If all goes well, the company will do the rest of the museum's collection, amassing a huge database for engineers and art historians to work with. "It's just been a dream to me because all the doors seemed to open up for the asking," says Johnson.

In a year or so, Johnson envisions teaching a new course at Cornell examining how others have approached using signal processing to authenticate art so students can infer a general approach to the problem. He hopes his interaction with the museum will eventually result in a textbook that combines art history with technical material. "I'm

not an engineering professor just because I want to tinker with cool things," he says. "I'm an academic because I want to teach cool things."

But first Johnson wants to bring together the scattered groups working at this intersection of engineering and fine art. "This is a field that doesn't really exist yet," he says. "There are some people out there doing things, but not as a cohesive field."

Once considered a Van Gogh, *Still Life with Bottle of Wine, Two Glasses, and Plate with Bread and Cheese* is now thought to be by an unknown friend of Vincent's brother Theo.

-Van Gogh Museum

Dan Rockmore, a professor of math and computer science at Dartmouth, has been working with the Metropolitan Museum of Art in New York to authenticate Rembrandts. Professors Jia Li and James Wang at Penn State have identified the creators of Chinese ink paintings from the 15th to 20th centuries. And researchers led by Eric Postma at the University of Maastricht in the Netherlands have developed a program dubbed "Authentic" that can distinguish between the works of Van Gogh, Cézanne, and Gaugin. Although they all use a variation of a technique called stylometry, first developed to identify literary authors, they had never met as a group to share ideas.

Working with the gray scale values of each pixel in a digital image of the painting, signal processors at the workshop were able to use wavelet processing to corroborate the connoisseur's determination.

-Van Gogh Museum

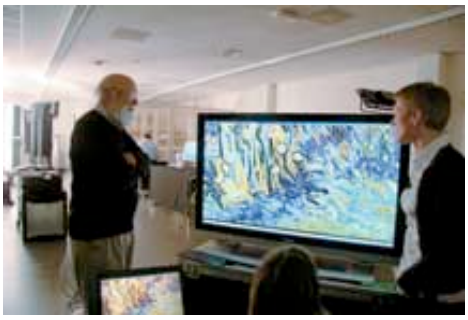
The field is set to flourish. Research on how to best collect and organize data from paintings is mature and recent technological advances have enabled museums to amass huge databases of

images. "The time is certainly right in that people have been thinking about images computationally for a long time. It certainly makes sense as a science problem to compare images and see if you can find some commonality," says Rockmore. "The problem's a totally natural one. Whether it has a nice solution is one that everyone is working on. There are a lot of aspects there and you only discover them when you drill down and treat it as a science."

Beyond determining if a painting is really by a master, or just a clever forgery, forensic signal processing can help art historians determine the sequence of an artist's work, or deconstruct a painter's process by identifying which strokes went on first. "There's a lot of things I think [curators] can think of that would be impossible, but there's a lot of things we should be able to do," says Johnson. "Any time the art historian looks at the image for the information they need, we should be able to help."

To get signal processors and art curators together, Johnson organized the First International Workshop on Image Processing for Artist Identification, held at the Van Gogh Museum May 14. Johnson convinced the Van Gogh Museum and the Kröller-Müller Museum in Otterlo, Netherlands, to make digitized images of 101 of their paintings available for analysis. Most are confirmed Van Goghs, but a few are now attributed to others. This irresistible "goldmine" of data got several groups of academic signal processors on board. To get them talking with the attendees from museums across Europe, the daylong program introduced curators to the capabilities of signal processing and engineers to the techniques of connoisseurship, the traditional method of authenticating paintings. Johnson's unique background helped him get the conversation rolling. "He knows both sides of the story, which is needed," says Hendriks. "He knows the words we use to talk about things."

Six months before the workshop, three teams of computer scientists, mathematicians, electrical engineers, and statisticians from Penn State, Princeton, and Maastricht universities set about to see if mathematical analysis could find similarities in Van Gogh's works not present in the other paintings. They also checked the authentic paintings against a 102nd, a modern copy of a Van Gogh commissioned by WGBH's Nova Science Now. The program taped the researchers at the workshop and is scheduled to air on PBS nationally beginning next June.



ECE Prof. Rick Johnson and Van Gogh Museum Head of Conservation Ella Hendriks observe a false color infrared digital image of Van Gogh's *Tree Trunks in the Grass* captured by Lumiere Technology's multi-spectral camera.

-Lumiere Technology

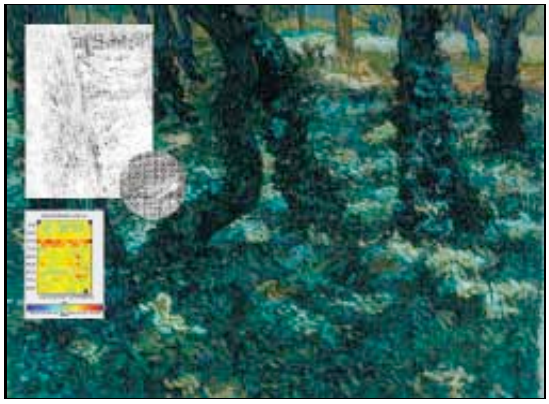
All three teams were successful to some degree at distinguishing real Van Goghs from the copies. The Princeton team found a higher concentration of high spatial frequency content, corresponding to an increased number of small touches in the copies. This jibes with the commonly noted tendency of copyists to use several small brush strokes to duplicate an

image that the original artist may have done in one stroke.

Even more importantly, workshop participants expressed a desire for further interaction. A repeat workshop was held Nov. 9 at the Museum of Modern Art in New York City. Already, art historians and engineers around the world are planning new projects based on the resulting cross-fertilization. "The idea is to amplify this whole thing," says Johnson. "I'm sure there are signal processing research problems in this area that people don't yet know exist, and you can trip over them a bunch of times without noticing them."

A next step to building a cohesive field, says Johnson, is to present problems to beginning engineers so they can start thinking of creative new approaches to solving them, just as in any other field of engineering. So Johnson has been recruiting undergrads and M.Eng. students to work on an automated thread-count project.

Yeounoh Chung got involved because it was a little different from other projects he has worked on. "It seemed like a really interesting project because it has to do with art," says the senior. "As an ECE student, all I've been doing is making something that people don't usually see, but this is more directly related to something people can see and appreciate, so I thought it could be something I could enjoy doing."



Using high-resolution digital images of x-rays, the automated thread count method under development by Johnson and a team of students reveals a strip (in red) of more tightly woven canvas in a corner of Van Gogh's Undergrowth. Such patterns can help art historians better sequence an artist's work or art curators restore paintings that have been cut into pieces.

-Van Gogh Museum/Rick Johnson

Knowing how many threads are in a canvas can reveal a lot to an art historian. Thread counts of the canvases used by Van Gogh and Gauguin during their time together at the Yellow House in Arles, France, in late 1888 helped art historians to construct a timeline for the paintings during this important period. Traditionally, thread counts are estimated using an average of the number of threads hand-counted in five different 2-square-centimeter sections. It's a tedious, time-consuming process and museums would much rather allocate staff time to other work. A computer could do it a lot faster, says Johnson, and by looking at more samples, more thoroughly. Unlike typical hand counts, a computer count is readily repeatable because it can keep an exact record of where it has counted.

Technology alone won't provide all the answers, however. Without knowing that Van Gogh sometimes painted on canvas from a limited number of bolts, thread counts would not have revealed much. "It depends on the artist's practice," says Johnson. "So

it's a mixture of knowing what they did and relating the physical evidence to that."

The project illustrates some of the differences in mind-set among engineers, curators, and conservators. When Johnson first started working on an automated thread-count program, he asked to see the reference book that explains how art historians do such procedures and was told there was no such book. Variations of the process are passed verbally from expert to student. "But this can be broken down into an ordered series of steps. We engineers see this because we're taught to do this in everything we do," says Johnson. "Once we know the steps, we can see where we can help. So, even in this unusual application, we're going to act like regular engineers and come into somebody else's application and use our skills to make their life better."

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