

Did Somebody Say Virtual Colonoscopy?

Doctors are saving lives with virtual, 3D exams that are less invasive than a conventional optical colonoscopy.

MOST PEOPLE OVER 50 years old ignore their doctor's advice and forgo the standard, invasive test that screens for colorectal cancer and precancerous growths. Fortunately, a computer-based, noninvasive alternative to the conventional optical colonoscopy, known as virtual colonoscopy, is changing people's attitudes—and could save tens of thousands of lives each year.

A virtual colonoscopy starts with computed tomography (CT), a common diagnostic technology that uses X-rays to record cross-sectional, 2D images of the body's interior. A 3D model is constructed by segmenting the colon and from the rest of the abdomen and using an electronic cleansing algorithm to factor out fecal material. Next, doctors use visualization software to navigate a virtual fly-through of the colon. If a polyp or

suspicious growth is found, doctors can perform a virtual biopsy and investigate further.

The case for a convenient mass-screening method is strong, says Arie Kaufman, chair of the computer science department at New York's Stony Brook University. Colorectal cancer is the third most common cancer and the second leading cause of cancer deaths in the U.S., with more than 140,000 new cases and more than 50,000 deaths a year. "If all patients 50 years of age and older will participate in these screening programs, over 92% of colorectal cancer will be prevented and over 600,000 lives could be saved worldwide every year," Kaufman says.

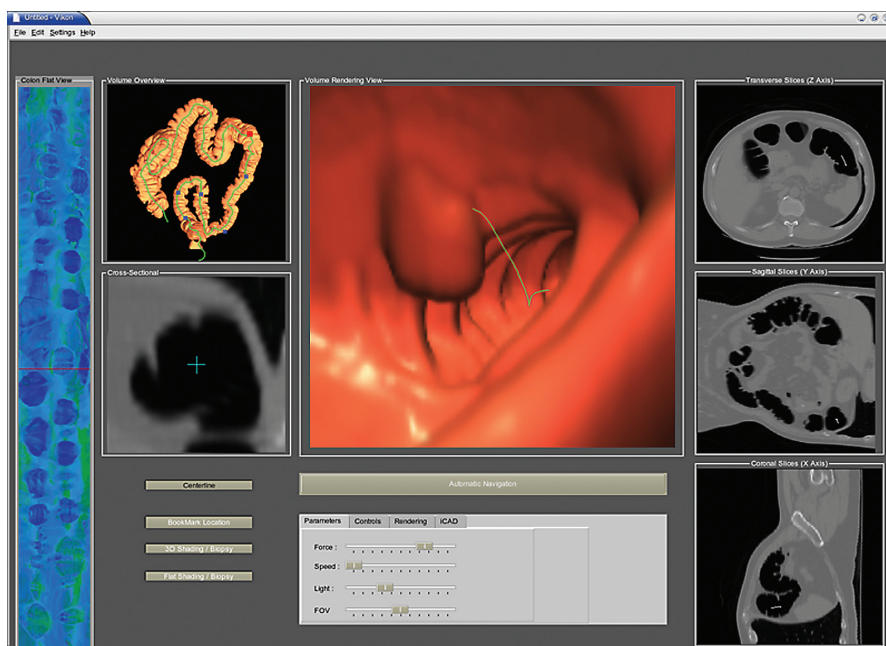
Virtual colonoscopies became possible in the mid-1990s, when Kaufman and others developed volume-rendering techniques that enabled 3D, virtual fly-throughs and associated tools, which were soon commercialized.

Virtual colonoscopies have recently earned the imprimatur of the medical establishment, which prefers the formal term CT colonography. In a study at U.S. military hospitals, 1,233 symptomless subjects underwent a virtual colonoscopy, followed by a conventional optical colonoscopy, on the same day. The virtual colonoscopy results, reported in the *New England Journal of Medicine* in 2003, showed 94% sensitivity (real polyps found) and 96% specificity (false-positive rate) for polyps 8mm and larger—numbers comparable to those of optical colonoscopy, the gold standard among doctors. Subsequently, the U.S. Food and Drug Administration approved virtual colonoscopy for colon cancer screening.

Virtual colonoscopy outperforms optical colonoscopy in certain ways, advocates claim. A University of Wisconsin study, for example, found it better at finding 8mm and 10mm polyps. It also outperforms optical colonoscopy in finding polyps hidden in folds and around corners of the twisting tube of the colon, and in reliably reaching the farthest reaches, called the caecum. It can also do something optical colonoscopy, by its nature, cannot do: spot polyps on the colon's outer walls.

Also, because it is noninvasive, a virtual colonoscopy avoids the risk of the rare but deadly tears or holes that can occur during an optical colonoscopy (and which can require immediate surgery). "The examination is done on the data, rather than the patient," says Dr. C. Daniel Johnson, a principal investigator at the Mayo Clinic in Scottsdale, AZ, and the lead researcher on several studies.

Virtual colonoscopy's only significant health risk is a patient's exposure to radiation. This trade-off



A screenshot of a user interface for virtual colonoscopy and computer-aided detection.

is being addressed in a technique called low dose, which Kaufman's group is researching, with a grant from the National Institutes of Health (NIH). Another drawback of a virtual colonoscopy is it can't remove polyps; patients still need an optical colonoscopy for their surgical excision. However, a virtual colonoscopy study has shown that only about 7% of patients required such follow-up.

Insurers, however, have been slow to catch on. Medicare, for example, announced a tentative decision earlier this year to not pay for virtual colonoscopies. And some insurers have setup the payment codes that healthcare providers need to be reimbursed for the procedure, but the money has yet to materialize. However, Kaufman says the political will to mandate coverage is growing, and patients can pressure their insurer to pay for a virtual colonoscopy by refusing to undergo optical colonoscopy.

Early Detection

Screening is critical because a patient's successful outcome often hinges on the early detection of polyps. A virtual colonoscopy removes many of the uncomfortable hurdles. "Only 15%–19% of individuals eligible for screening currently undergo colon evaluation," says Hiroyuki Yoshida, an associate professor at Harvard Medical School and director of 3D Imaging Research at Massachusetts General Hospital. "The cathartic cleansing required for bowel preparation is the biggest barrier."

A virtual colonoscopy still requires preparation, so developing a laxative-free procedure will be indispensable to its practicality, Yoshida says. One hitch: eliminating laxatives leaves more fecal matter in the colon, which requires improvements in electronic cleansing. What's more, patients still must ingest an oral contrast agent, such as barium or iodine, and air or carbon dioxide must still be used to distend the colon. Yet, a laxative-free virtual colonoscopy could be ready for public use in the near future, Yoshida says.

Many of the challenging issues with virtual colonoscopies involve software applications. Computer-aided detection (CAD), the focus of Yoshida's re-

Virtual colonoscopies could become more available in remote places via telemedicine.

search, brings much-needed automation to electronic cleansing and polyp detection. It holds great promise, says Kaufman. "In mammography, this has been entirely successful," he notes. "Basically, the computer is another set of eyes."

Skill in interpreting diagnostic images varies among radiologists, who can mistake the colon's normal valves and folds for polyps. Yoshida says CAD could make results more objective and consistent, and shorten radiologists' learning curve. It could also be useful in hospitals that lack expertise with virtual colonoscopies.

However, CAD presents its own challenges. "Sometimes CAD's weak spots are comparable to human viewers' weak spots," says Dr. Ronald Summers, a radiologist and senior investigator at NIH. One important challenge is detecting flat lesions, which are more difficult to detect with a virtual or optical colonoscopy, but constitute a higher risk for cancer.

Kaufman has co-developed a novel CAD technique, utilizing colon flattening and volume rendering, which has achieved perfect sensitivity and tolerable specificity, and could function as either a first or second reader.

Another problem is false positives: they require patients to undergo an optical colonoscopy. Of course, false positives aren't as deadly as false negatives, and doctors can dismiss false positives with a second read. Ideally, Kaufman says, CAD should be a first reader for radiologists, who can inspect the regions flagged by it. "I think the second read is the one the radiologist should use, because it has the highest sensitivity, but we're still working that out," Dr. Summers says.

There is also considerable debate

Technology

TechFest 2009

Microsoft Research unveiled more than 100 innovations at its annual TechFest showcase in late February in Redmond, WA. Among the emerging technologies projects were:

SECONDLIGHT

Used with Microsoft Surface, SecondLight can project images and detect gestures in mid-air above Surface's display (in addition to supporting its multitouch capabilities). The magic behind SecondLight involves Surface's LCD screen that can switch between opaque and translucent, alternating 60 times per second. A pair of recessed projectors alternate flickering 30 times per second, with one projector timed to illuminate the screen when it is opaque and the second projector timed to illuminate when it is transparent. When the screen is transparent, any object held above the screen will reveal what is being output by the second projector.

RENLI FANG

When you conduct a Web search for information about a specific person—say, an ex-girlfriend—you still need to examine all of the search results and piece together the information before being able to ascertain the parameters of her social universe. Renlifang is a Web entity-summarization system that automatically creates a biography page of the person; a social-network graph for the person; a shortest relationship path between the person and someone else; titles for the person found on the Web; and all of the structured information that Microsoft possesses on the person in its local database.

REAL-TIME STITCHING OF MOBILE-GENERATED VIDEOS

Microsoft demonstrated a real-time video-stitching system from multiple mobile phones that produces a wide field-of-view experience with high resolution. Possible applications include citizen journalism; virtual attendance of family events and gatherings; and emergencies in which citizens provide a real-time video feed for first responders before they reach the scene of the emergency.

on how to best combine 2D and 3D imagery. “We seem to be moving to a consensus that the sensitivity and specificity of 2D and 3D are comparable,” Dr. Summers says. “The question is which one do you use as your primary.” Yoshida thinks CAD could soon replace 3D visual fly-throughs for first reads, though expert examination of 2D images—what radiologists called “problem solving”—will still be needed.

2D is important in a virtual biopsy, which depends on flattening the images to simulate what pathologists do when dissecting a polyp. “They will slice it along its length and lay it flat and look at it,” Dr. Summers says. “You do the same thing on the computer.” Some experts, he notes, think such 2D dissection provides faster diagnosing than 3D fly-through.

Seeking Improvements

Medical and computer-science researchers are striving to make virtual colonoscopy technology more accurate, affordable, easier to use, and patient friendly.

A technique called dual-energy imaging, for instance, highlights polyps by blending images derived from different radiation doses to increase

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contrast, Yoshida says. And graphics processing unit-based rendering is being touted as a faster method of getting images to radiologists, as Kaufman’s group has done. Also, Dr. Summers says his collaborators and him have figured out how to bolster CAD with wavelets on manifolds to reduce false positives by more precisely characterizing polyps. And machine learning and neural nets are the subject of ongoing research.

To increase virtual colonoscopies’ usability, computer scientists are also focusing attention on the PCs that are used for analyzing images. One possibility is off-site image processing, which Yoshida says Massachusetts General Hospital is ready to implement.

Others hope to democratize virtual colonoscopies by getting the software to run effectively on desktop and laptop computers. For example, the Redmond, WA, company FiatLux Imaging employs the Direct3D technology in video games and in virtual colonoscopies. “It’s usually required to run on very heavy-duty, expensive hardware,” says Rosemary Fisher, FiatLux’s clinical application specialist. “That is prohibitively expensive for small hospitals and clinics.” Many of them lack colonography software and have little financial incentive to invest in it before insurers start uniformly reimbursing for virtual colonoscopies. But as spiral CT scanners become more broadly distributed, affordable volume-rendering software, such as FiatLux’s Visualize, might make virtual colonoscopies more available in remote places via telemedicine.

The takeaway message is that virtual colonoscopies are poised to dramatically increase successful colon screening outcomes. Says Kaufman, “We’re going to save 50,000 lives every year just in the U.S.”

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Computer Graphics

Catmull Wins Second Oscar

ACM Fellow Ed Catmull, a computer scientist, co-founder of Pixar Animation Studios, and president of Walt Disney and Pixar Animation Studios, received the Gordon E. Sawyer Award from the Academy of Motion Picture Arts and Sciences in recognition of his lifetime of technical contributions and leadership in the field of computer graphics for the motion-picture industry. Catmull was presented with an Oscar statuette at the Scientific and Technical Awards Presentations last February at the Beverly Wilshire Hotel.

“Ed is one of the rare individuals who can bridge the space between science and art,” said Academy President Sid Ganis. “His vision, ingenuity, and groundbreaking designs have made the impossible

possible—for filmmakers and movie audiences around the world.”

Catmull, who delivered a keynote address at SIGGRAPH 2008, has described ACM SIGGRAPH as his “home community.” He is regarded as an innovator by the community for his key contributions to fundamental computer graphics concepts like z-buffer and subdivision surfaces, and has held several leadership positions in SIGGRAPH over three decades. In 1995, Catmull became an ACM Fellow, and was cited for “his many and noteworthy advances in computer graphics as an individual researcher, as an inspiring leader in the field, as a director of organizations, and as a mentor for many.”

In the course of his career,

Catmull founded the computer graphics laboratory at the New York Institute of Technology as well as the computer division of Lucasfilm Ltd., and Pixar Animation Studios.

In 2000, Catmull and his team received an Oscar for an Academy Award of Merit for their significant advancements to the field of motion picture rendering as illustrated in Pixar’s *RenderMan*. He previously received two Scientific and Engineering Awards from the Academy. In 1992, he was part of a team recognized for the development of *RenderMan* software. In 1995, he was on a team honored for pioneering inventions in Digital Image Compositing. He also shared a Technical Achievement Award from the Academy in 2005.



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