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Computing the best high-resolution 3-D tissue images

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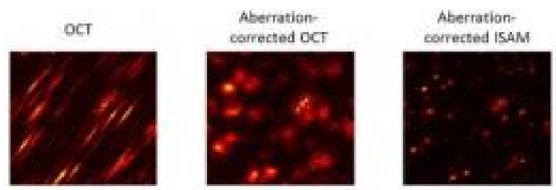


This image shows aberrations in imaging can make points appear as slashes or blurs (left frame). Computational adaptive optics developed by University of Illinois researchers can correct aberrations in high-resolution microscopy (left frames). Credit: Steven G. Adie

Real-time, 3-D microscopic tissue imaging could be a revolution for medical fields such as cancer diagnosis, minimally invasive surgery and ophthalmology. University of Illinois researchers have developed a technique to computationally correct for aberrations in optical tomography, bringing the future of medical imaging into focus.

The computational technique could provide faster, less expensive and higher resolution tissue imaging to a broader population of users. The group describes its technique this week in the online early edition of the Proceedings of the National Academy of Sciences.

"Computational techniques allow you to go beyond what the optical system can do alone, to ultimately get the best quality images and three-dimensional datasets," said Steven Adie, a postdoctoral researcher at the Beckman Institute for Advanced Science and Technology at the U. of I. "This would be very useful for real-time imaging applications such as image-guided surgery."

Aberrations, such as astigmatism or distortion, plague high-resolution imaging. They make objects that should look like fine points appear to be blobs or streaks. The higher the resolution, the worse the problem becomes. It's especially tricky in tissue imaging, when precision is vital to a correct diagnosis.

Adaptive optics can correct aberrations in imaging. It's widely used in astronomy to correct for distortion as starlight filters through the atmosphere. A complex system of mirrors smooth out the scattered light before it enters the lens. Medical scientists have begun applying adaptive optics hardware to microscopes, hoping to improve cell and tissue imaging.

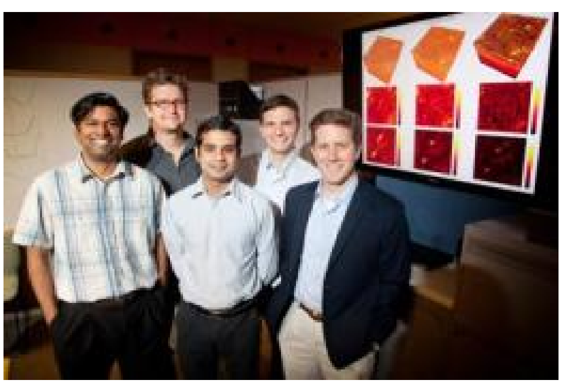
"It's the same challenge, but instead of imaging through the atmosphere, we're imaging through tissue, and instead of imaging a star, we're imaging a cell," said Stephen Boppart, a professor of electrical and computer engineering, of bioengineering and of internal medicine at the U. of I. "But a lot of the optical problems are the same."

Unfortunately, hardware-based adaptive optics are complicated, tedious to align and extremely expensive. They can only focus on one focal plane at a time, so for tomography – 3-D models constructed from sectional images as in a CT scan, for example – the mirrors have to be adjusted and a new image scanned for each focal plane. In addition, complex corrective systems are impractical for handheld or portable devices, such as surgical probes or retinal scanners.

Therefore, instead of using hardware to correct a light profile before it enters the lens, the Illinois team uses computer software to find and correct aberrations after the image is taken. Boppart's group teamed up with with Scott Carney, a professor of electrical and computer engineering and the head of the Optical Science Group at the Beckman Institute, to develop the technique, called computational adaptive optics. They demonstrated the technique in gel-based phantoms laced with microparticles as well as in rat lung tissue. They scan a tissue sample with an interferometric microscope, which is an optical imaging device using two beams of light. The computer collects all of the data and then corrects the images at all depths within the volume. Blurry streaks become sharp points, features emerge from noise, and users can change parameters with the click of a mouse.

"Being able to correct aberrations of the entire volume helps us to get a high-resolution image anywhere in that volume," said Adie. "Now you can see tissue structures that previously were not very clear at all."

Computed adaptive optics can be applied to any type of interferometric imaging, such as optical coherence tomography, and the computations can be performed on an ordinary desktop computer, making it accessible for many hospitals and clinics.



University of Illinois engineers developed a method to computationally correct aberrations in three-dimensional tissue microscopy. From left, postdoctoral researcher Steven Adie, professor P. Scott Carney, graduate students Adeel Ahmad and Benedikt Graf, and professor Stephen Boppart. Credit: L. Brian Stauffer

Next, the researchers are working to refine the algorithms and explore applications. They are combining their computational adaptive optics with graphics processors, looking forward to real-time in-vivo applications for surgery, minimally invasive biopsy and more.

For example, computational adaptive optics could be very useful for ophthalmologists. Boppart's group previously has developed various handheld optical tomography devices for imaging inside the eye, particularly retinal scanning. Aberrations are very common in the human eye, making it difficult to acquire clear images. But adaptive optics hardware is too expensive or too complicated for most practicing ophthalmologists. With a computational solution, many more ophthalmologists could more effectively examine and treat their patients.

"The effectiveness is striking," Boppart said. "Because of the aberrations of the human eye, when you look at the retina without adaptive optics you just see variations of light and dark areas that represent the rods and cones. But when you use adaptive optics, you see the rods and cones as distinct objects."

In addition, the ability to correct data post-acquisition allows the researchers to develop microscope systems that maximize light collection instead of worrying about minimizing aberrations. This could lead to better data for better image rendering.

"We are working to compute the best image possible," said Boppart, who also is affiliated with the Institute for Genomic Biology at the U. of I.

Provided by University of Illinois at Urbana-Champaign