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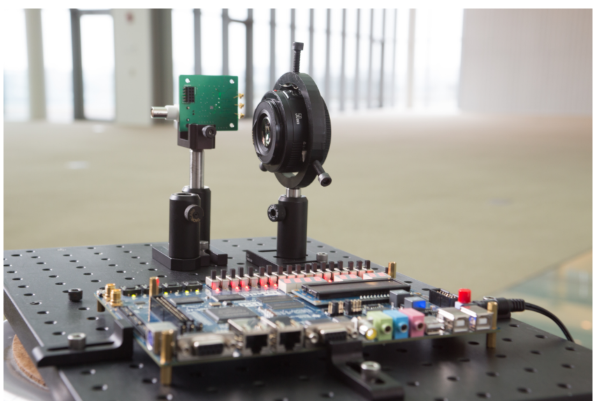
Achuta Kadambi
Massachusetts Institute of Technology (Cambridge, Mass.)
$15,000 Lemelson-MIT "Use it!" Graduate Winner
Superhuman Visual Systems to Capture Light

The Challenge: A slow camera blends all of the light that reaches the sensor, which is often not desirable (a digital single-lens reflex camera or the human eye are examples of a slow camera). On a foggy day, a slow camera blends backscattered light from fog with the light reflecting off of an obstacle (this can cause self-driving cars to crash in fog). A fast camera could select light paths, based on their path length, to separate the scattered light from fog and direct reflections from the obstacle. The ability to unmix optical paths is also relevant to biology, where propagating light encounters a tiny delay when bouncing off of fluorescent cancer cells that can be difficult to see with traditional camera techniques. A camera fast enough to capture light in motion could be used to unmix light, potentially distinguishing tumor cells from healthy cells.

While speed is important, Achuta also believes that digital representations should preserve the richness of our three-dimensional physical world. Today, most of our photographs are two-dimensional. Three-dimensional imagery could be used in applications like 3D printing or virtual teleconferencing. According to Achuta, while 3D imagery is an active problem, the best solutions capture low-precision depth maps of real-world objects.



The Solution: Achuta's first invention, the Nanophotography camera, is a fast camera that can capture light in motion (faster than the human eye). This invention works by rapidly strobing the camera flash in a carefully chosen pattern (inspired by radar codes), and using software to demix optical paths. Since most of the complexity is in software, the invention costs $500 in parts. Expensive and fragile optical components are replaced by the capability of embedded processors that are programmed to emulate optical functionality.

His second invention, the Polarized 3D camera, is a new type of 3D depth sensor that incorporates information about the rotation of light waves (invisible to the human eye). This invention captures three-dimensional photographs in a manner that is, an order of magnitude, more precise than the state-of-the-art Microsoft Kinect. His invention is the first, fully 3D camera to use the polarization of light as an operating principle. In particular, the local surface of an object causes a slight change in the polarization of reflected light. Computer algorithms incorporate information from polarized photographs and a depth skeleton to estimate the precise orientation of the surface facet.

Application and Commercialization: The Nanophotography invention is currently being prototyped in a variety of applications including self-driving cars and biological imaging. Nanophotography is also being investigated for use in manufacturing and construction, by using the fast camera to analyze how light interacts with materials. Achuta, along with New Zealand-based engineers James Schiel and Refael Whyte as well as Media Lab colleagues Ayush Bhandari and Ramesh Raskar, are planning for a public release of Nanophotography as a DIY kit.

Polarized 3D can be used in medicine to assist surgeons with placing incisions. In virtual reality, it can be used for acquiring precise depth of the physical world to allow for photorealistic simulations in the digital world. With Media Lab colleague Vage Taamazyan, Achuta hopes to commercialize Polarized 3D and encourage adoption in a variety of consumer devices (cell phones and AR/VR headsets).

His ongoing work translates ideas from his Nanophotography and Polarized 3D inventions to the domain of medical imaging with collaborator Dr. Rajiv Gupta at the Massachusetts General Hospital. This particular area of experimentation, if successful, could impact the industry of medical scanning, leading to reductions in patient suffering.