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Celebrating invention, inspiring youth

Guy Satat

Massachusetts Institute of Technology

$15,000 "Drive it!" Lemelson-MIT Student Prize Graduate Winner

All Photons Imaging and FemtoPixel

The Challenge: Seeing through obstructions, such as fog, has always been a problem for drivers and pilots, and even for state-of-the-art vehicles, like autonomous cars and drones. In the United States alone, 32% of flight delays and 22% of all vehicle crashes are due to inclement weather[1]. These vehicles require continuous and long-range visibility in order to safely operate. The current systems that are utilized to see through weather obstructions are incomplete solutions, as the existing technology does not provide the contrast and resolution required to guarantee vehicular safety.

Another related problem is the ability to image in challenging parts of the electromagnetic spectrum like terahertz, infrared, and ultraviolet, which is essential for remote sensing in areas such as gas leak detectors, airport security, medical imaging, and artwork analysis. Producing high-quality lenses and a dense array of detectors (or pixels) in these spectra is extremely hard to do. Researchers have tried single-pixel cameras in the past, but they suffer from an exceptionally long measurement time, which limits their applicability for dynamic scenes.

The Solutions: Guy's primary invention is All Photons Imaging, an imaging system that removes fog from the image to produce a clear photo and depth map as if the fog were not there. His device is able to produce images in real time by using information from scattered light.

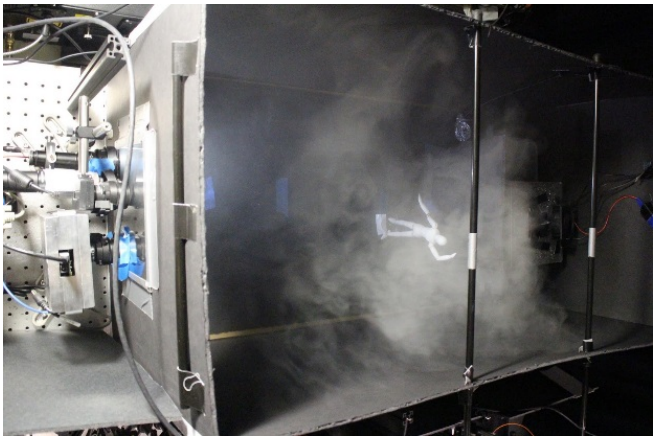

Figure 1: Seeing through fog with All Photons Imaging. At left, SPAD camera and pulsed laser. At right, fog chamber and mannequin target.

Weather conditions like fog cause particles of light (photons) to "scatter" and as a result, far objects cannot be clearly seen. However, these scattered photons carry valuable information about fog levels and hidden objects – all crucial elements for safe driving. Guy's invention processes this information to computationally remove the obstruction and reconstructs a

[1] Bureau of Transportation Statistics (U.S. Department of Transportation).

clear image, using a pulsed laser and an ultrafast Single Photon Avalanche Diode (SPAD) camera.

Seeing through obstructions has multiple transportation-related applications, such as assisting human drivers and enabling self-driving cars to operate in challenging weather. Human drivers could utilize the system on their dashboard, showing a real-time image of the road without the fog. The system would alert drivers to an object on the road, and would enable them to read road signs that would otherwise be impossible to decipher.

For future self-driving cars, the clear fog-less image would be fed into the car's algorithm, instead of using the image from traditional sensors, enabling the cars to drive in difficult weather. Pilots could also benefit from Guy's imaging system, as it would lower the risks associated with reduced visibility. Flight safety would be drastically improved during takeoffs, landings, and low-level flights, and his device would help to decrease costly and inconvenient flight delays due to fog. Other transportation-related applications include allowing drones to navigate and follow targets in inclement weather, and allowing trains to travel faster in low visibility. All Photons Imaging has also been demonstrated as a medical application to see through 1.5cm thick tissue phantom for greatly enhanced medical imaging.

To meet the challenge of sensing in difficult parts of the spectrum, Guy's secondary invention is FemtoPixel, a computational camera based on a single detector that requires no lens. It directly combats the limitations of industrial and scientific measurement in challenging spectra. FemtoPixel utilizes a novel sensor that time-tags photons as they arrive to the detector. This additional information coupled with an algorithm that Guy developed enable a shorter measurement process. His analysis has validated that FemtoPixel is fifty times faster than other existing techniques.

Figure 2: An optical experiment demonstrating FemtoPixel.

Commercialization: Guy recently filed a provisional patent application for All Photons Imaging, and to further maximize impact, he is currently working with several automotive companies affiliated with the MIT Media Lab, on potential paths to commercialization and adoption of the technology. The hardware for All Photons Imaging is compatible with Laser Radars (LIDARs), one of the fundamental sensors for autonomous vehicles. It is expected that by 2030, 15% of all new cars will be fully autonomous and 50% highly autonomous[2], with a market growth to the range of $42-77 billion by 2035[3]. Recently, the cost of LIDAR sensors has decreased significantly, making them cost-effective for deployment in automotive vehicles and paving the way to commercialization for All Photos Imaging. All Photons Imaging also has potential

[2] Advanced Industries Report (McKinsey & Company, 2016).

[3] Revolution in the Driver's Seat Report (Boston Consulting Group).

commercialization options in other transportation markets such as drones, airplanes, and trains, as well as uses in the medical sector.

Guy is simultaneously working on commercial deployment of FemtoPixel. He is currently collaborating with Glasgow University in Scotland on building a high-resolution and high frame-rate infrared camera.