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How to see around corners

Ultra-fast camera can create images of hidden objects using scattered laser light.

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The ability to see objects hidden behind walls could be invaluable in dangerous or inaccessible locations, such as inside machinery with moving parts, or in highly contaminated areas. Now scientists at the Massachusetts Institute of Technology in Cambridge have found a way to do just that.

They fire a pulse of laser light at a wall on the far side of the hidden scene, and record the time at which the scattered light reaches a camera. Photons bounce off the wall onto the hidden object and back to the wall, scattering each time, before a small fraction eventually reaches the camera, each at a slightly different time. It's this time resolution that provides the key to revealing the hidden geometry. The position of the 50-femtosecond (that's 50 quadrillionths of a second) laser pulse is also changed 60 times, to gain multiple perspectives on the hidden scene.

"We are all familiar with sound echoes, but we can also exploit echoes of light," says Ramesh Raskar, head of the Camera Culture Research Group at the MIT Media Lab which carried out the study.

A normal camera can only see objects that are right in front of it. Light that reaches the sensor from beyond the direct line of sight is too diffuse to convey useful information about the hidden scene, having been scattered by multiple reflections. The new set-up, described today in *Nature Communications*[1], overcomes this problem by capturing ultra-fast time-of-flight information — that is, how long each photon has taken to reach the camera. This information is then decoded by a reconstruction algorithm concieved by team member Andreas Velten.

Exploiting scatter

Most ultra-fast imaging technologies aim to mitigate the effects of scattered light, focusing instead on just the first photons to reach the sensor. The difference here, says Raskar, "is that we actually exploit the scattered light".

The camera really earns its ultra-fast label. It can record images every 2 picoseconds, the time it takes light to travel just 0.6 mm. So it can record the distance travelled by each photon with sub-millimetre precision.

One of the big technical challenges was teasing apart the information from photons that have travelled the same distance, and reached the camera at the same position, after hitting different parts of the hidden scene.

The computer overcomes this complication by comparing images generated from different laser positions, allowing likely positions for the object to be estimated. Whereas photons that have hit different parts of the hidden scene from one laser position may be the same, they will have a different total distance for another laser spot. "The overall mathematical technique," explains Raskar, "is similar to the computational tomography that is used in X-ray CAT-scans."

At present, the whole process takes several minutes, but researchers hope that in the future, it will be reduced to less than 10 seconds.

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References

1. Velten, A. *et al*. *Nat. Commun*. http://dx.doi.org/10.1038/ncomms1747 (2012).