Laser comb system maps 3-D surfaces remotely for manufacturing, forensics

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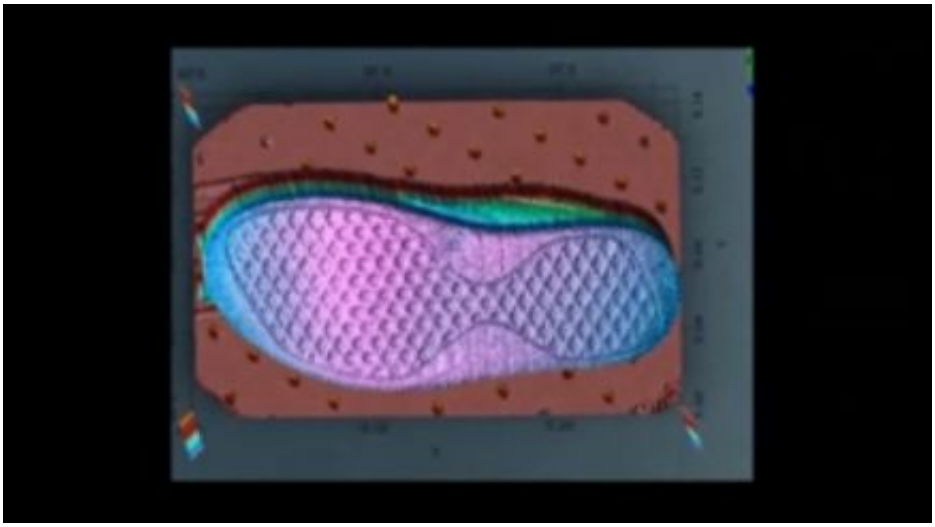

Researchers at the National Institute of Standards and Technology have demonstrated a laser-based imaging system that creates high-definition 3D maps of surfaces from as far away as 10.5 meters. The method may be useful in diverse fields, including precision machining and assembly, as well as in forensics.

NIST's 3D mapping system combines a form of laser detection and ranging (LADAR), which is sensitive enough to detect weak reflected light, with the ranging accuracy made possible by frequency combs, as previously demonstrated at NIST. The frequency comb, a tool for

precisely measuring different frequencies of light, is used to continuously calibrate the laser in the imaging system.

Operating with laser power of just 9 milliwatts—which is safe for the eyes at the instrument's infrared wavelength—NIST's 3D mapping system scans a target object point by point across a grid, measuring the distance to each point. The system uses the distance data to make a 3D image of about 1 million pixels in less than 8.5 minutes at the current scanning rate. Distances to points on a rough surface that reflects light in many directions can be determined to within 10 micrometers in half a millisecond, with an accuracy that is traceable to a frequency standard.

The system has wide dynamic range, enabling precise 3D mapping of targets with varied surface types and reflective properties. NIST researchers demonstrated the range by scanning footprints in soil, vegetation such as cactus (imaging individual spines), and complex mechanical devices such as a piston for a motorcycle.

The new NIST method offers a unique set of capabilities compared to conventional 3D mapping techniques. The NIST system is similar to optical coherence tomography, for example, but can operate much farther away from the target and is inherently accurate because of the frequency comb. The NIST system does not need a reference artifact to be placed next to the target, something typically required for interferometry-based systems.

LADAR typically measures distance based on the round-trip flight time of laser light, which reflects off the target and is detected by a sensor. In the NIST LADAR system, the laser sweeps continuously across a band of frequencies. The initial laser output is combined with the reflected light and the resulting "beat" signals are converted to voltage and analyzed by digital signal processing to generate time delay data, which is used to calculate the distance. (The difference in frequency between

the transmitted and received signals increases with distance.)

This basic technique is well established. However, by including a frequency comb to continuously calibrate the swept laser, the NIST system can operate much more rapidly, yielding one measurement point every half a millisecond and simultaneously maintain sub-micrometer accuracy traceable to a frequency standard. Finally, the system uses real-time, fast processing digital electronics to produce fully calibrated, 3D megapixel images.

As an example application, NIST's 3D mapping system could be used to make virtual casts of forensic evidence such as footprints in dirt. Conventional plaster casts that record impression evidence normally require a lot of effort to make and are difficult to compare to each other or to shoes. Furthermore, conventional analysis can destroy the evidence. By contrast, a remotely created 3D image of a footprint can nondestructively reveal more details than a photograph, such as exact measurements of shoe tread. The tread may show individual wear marks from a bicycle pedal, for example, a type of detail that could link a specific shoe to a crime scene.

Several manufacturers already have expressed interest in the NIST system, which is currently about the size of a desktop but suitable for future potential conversion to a portable, chip-scale instrument. The research was funded by NIST and the Defense Advanced Research Projects Agency.

More information: E. Baumann, F.R. Giorgetta, J.D. Deschenes, W.C. Swann, I. Coddington and N.R. Newbury. Comb-calibrated laser ranging for three-dimensional surface profiling with micrometer-level precision at a distance. *Optics Express*. Vol. 22 Issue 21, Oct. 20, 2014. DOI: 10.1364/OE.22.024914