Non-Line-of-Sight Optical Communication with Structured Light

RESEARCHERS

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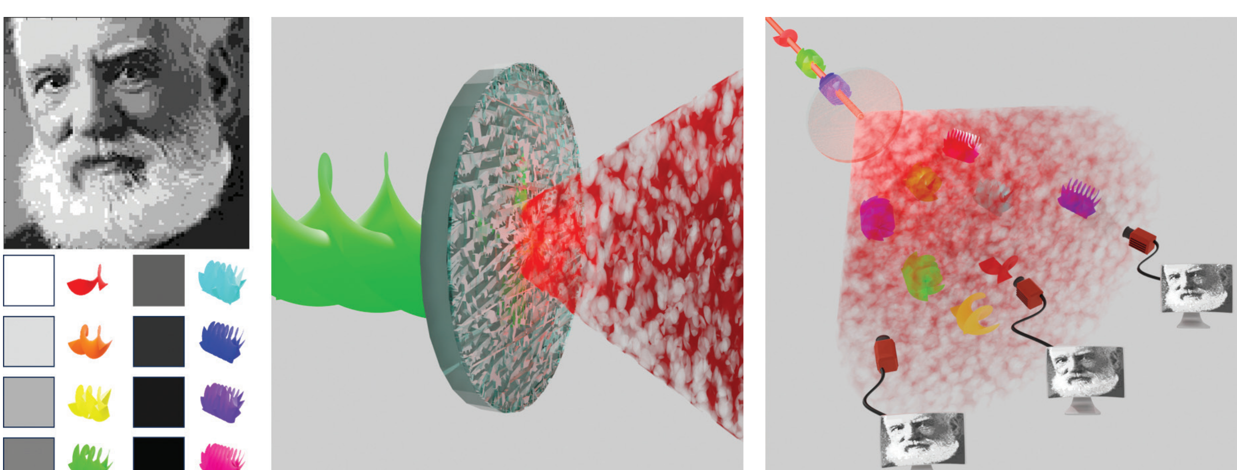
In an era of massive digital data resources, data transmission rates and fidelity are of utmost importance. Structured light beams—such as Laguerre-Gaussian (LG) and Hermite-Gaussian (HG) beams—that possess the spatial degree of freedom have emerged as potential candidates for increasing the spectral efficiency of optical communication links. Due to the high directionality and low diffractive nature of the optical laser beams, communication has been restricted to line-of-sight.[1] In recently published work, by leveraging the power of deep learning and structured-light speckle patterns, we demonstrated—for the first time to our knowledge—non-line-of-sight (NLOS) free-space optical (FSO) communication using structured light.[2]

We have shown that the AI-powered speckle-based model we used is noise-and alignment-free. It recognizes structured light through a small region of captured speckle pattern.[3,4] In addition, to demonstrate the broadcasting capability, we have experimentally demonstrated a "one-to-three" NLOS–FSO communication model by employing structured-light shift-keying.[2] The speckle patterns corresponding to LG or HG beams were generated by passing them through a diffuser, and were captured at three different positions [$C_0(0°)$, $C_{15}(15°)$ and $C_{-15}(-15°)$] in the horizontal beam axis plane, maintaining the radial distance of 26 cm from the diffuser.

The features from the speckle patterns, extracted using a wavelet scattering network (WSN), were then fed to a 1D convolutional neural network (1D–CNN) for training. We encoded a three-bit grayscale image of 100×100 pixels in eight LG (or HG) beams and reconstructed the image simultaneously at three different receiver positions by decoding captured speckle patterns using the trained 1D–CNN. The images were reconstructed with an accuracy of more than 96% at the on-axis (C_0) channel and more than 93% at the off-axis ($C_{\pm 15}$) channel.[2] The proposed NLOS optical communication can be easily extended to one-to-many communication channels.

In addition, the encoded information can be decoded using only a 1D array of speckle patterns taken in random orientations. This drastically reduces the computational cost and enhances the data transmission rate, qualifying the approach for real-time communication systems. We believe that the demonstrated scheme, which can be realized in the near-infrared and microwave-to-radio spectrum, can significantly improve the broadcasting capability of structured light for free-space communication. OPN



Left: Structured-light shift-keying encoding scheme. Middle: Structured-light speckle pattern generation using a diffuser. Right: Non-line-of-sight optical communication using structured light.

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