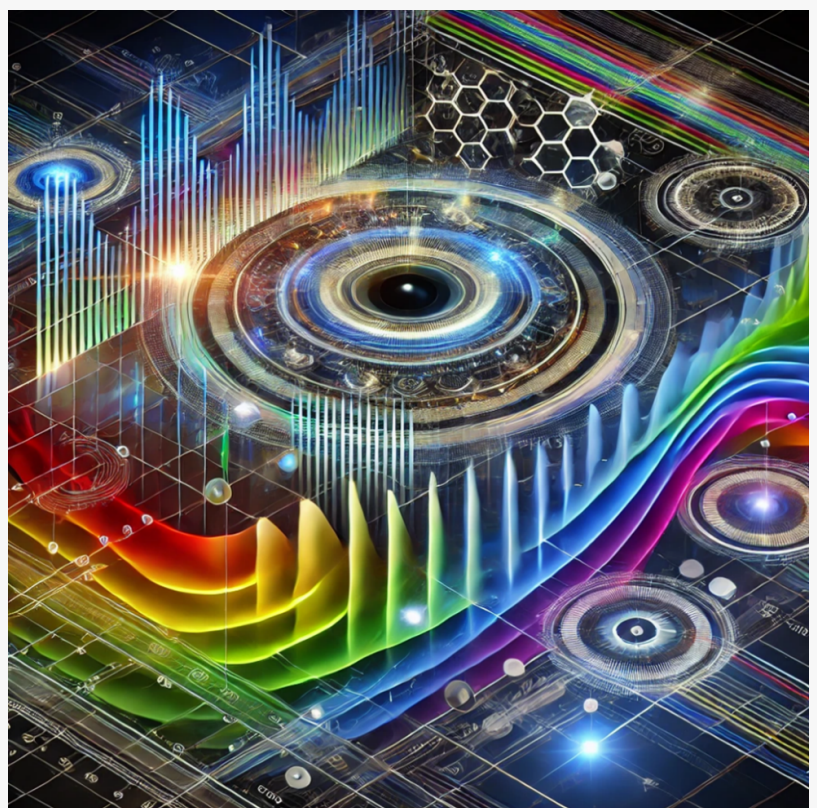# Nonlinear Encoding in Diffractive Optical Processors Based on Linear Materials

USA, July 23, 2024 /EINPresswire.com/ -- Researchers explored nonlinear information encoding in diffractive processors based on [linear materials](#). They revealed that simpler-to-implement phase encoding matches the accuracy of data repetition strategies across various test datasets. While data repetition-based diffractive blocks cannot provide optical analogs to fully-connected or convolutional layers employed in digital neural networks, they are effective in enhancing inference accuracy. This research provides insights into the interplay between linear material-based diffractive systems and nonlinear encoding strategies in visual information processors.

Artistic depiction of diffractive information processing.

UCLA researchers have conducted an in-depth analysis of nonlinear information encoding strategies for diffractive optical processors, offering new insights into their performance and utility. Their study (https://doi.org/10.1038/s41377-024-01529-8), published in Light: Science & Applications, compared simpler-to-implement nonlinear encoding strategies that involve, e.g., phase encoding, with the performance of data repetition-based nonlinear information encoding methods, shedding light on their advantages and limitations in the optical processing of visual information.

Diffractive optical processors, built using linear materials, perform computational tasks through the manipulation of light using structured surfaces. Nonlinear encoding of optical information can enhance these processors' performance, enabling them to better handle complex tasks such as image classification, quantitative phase imaging, and encryption.

The UCLA research team, led by Professor Aydogan Ozcan, evaluated various nonlinear encoding strategies using different datasets to assess their statistical inference performance. Their findings revealed that data repetition within a diffractive volume, while enhancing inference accuracy, compromises the universal linear transformation capability of diffractive optical processors. As a result, data repetition-based diffractive blocks cannot serve as optical analogs to fully-connected or convolutional layers commonly used in digital neural networks. More generally, data-repetition-based diffractive processors can be perceived as a simplified optical analog of the dynamic convolution kernel concept used in some neural network architectures. Despite its different features, data repetition architecture within a diffractive optical processor is still effective for inference tasks and offers advantages in terms of noise resilience.

As an alternative, phase encoding of input information, without data repetition, offers a simpler-to-implement nonlinear encoding strategy with statistically comparable inference accuracy. Implemented through spatial light modulators or phase-only objects, directly, phase encoding is a practical alternative due to its simplicity and effectiveness. Furthermore, diffractive processors without data repetition do not need pre-processing of input information through a digital system, which is required for visual data repetition. Therefore, data repetition can be time-consuming, especially for phase-only input objects, due to the need for digital phase recovery and pre-processing before visual data repetition can occur.

The research team's findings provide valuable insights into the push-pull relationship between linear material-based diffractive optical systems and nonlinear information encoding strategies. These results hold potential for a wide range of applications, including optical communications, surveillance, and computational imaging. The ability to enhance inference accuracy through nonlinear encoding strategies can improve the performance of optical processors in various fields, leading to more advanced and efficient visual information processing systems.

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