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Nonlinear Phase Wrapping for Linear Information Forwarding

Glitta Rosalia Cheeran [*a,b], **Bennet Fischer**[*a], [b] **Mario Chemnitz** [a,b]

[a] *Smart Photonics, Leibniz Institute of Photonic Technology, Jena, Germany*
[b] *Institute of Applied Optics and Biophysics, Friedrich-Schiller-University, Jena, Germany*
[*] *glittarosalia.cheeran@leibniz-ipht.de*

1. Abstract

The study of nonlinear dynamics in optical fibers has attracted significant attention due to their applications in multi-frequency laser engineering [1] and nonlinear imaging [2]. Recently, it has been demonstrated as a powerful optical system that mimics multi-layer neuromorphic computing [3]. The accuracies of this system in classification tasks outperform other optical approaches, but some tasks remain difficult, such as the classification of the MNIST dataset. In the MNIST task, which involves classifying images of handwritten digits (0 through 9), the system achieves only moderate accuracies ($<$90%). Other demonstrations have achieved higher accuracies ($>$90%) with purely linear digital or mildly nonlinear optical networks [3]. We hypothesized that the strong nonlinear mixing of information by the system could be detrimental in the case of MNIST, as the dataset may require significantly less nonlinearity to become separable. Our objective is to study the phenomenon of nonlinear phase wrapping [4], where the phase-encoded in the input pulse of the system is mapped onto the intensity profile of the output supercontinuum. The aim is to comprehend this linear behavior through numerical methods. We'll study the mapping at different input pulse powers to see where the linear information breaks down, utilizing statistical scores such as Pearson correlation to quantify linearity. The Pearson correlation coefficient is a statistical measure that quantifies the strength and direction of the linear relationship between two variables. Then, we'll utilize these dynamics to define encoding regimes for tasks of varying complexity, including operational regimes tailored for tasks requiring linear information alongside the complex nonlinear mappings in optical neuromorphic systems. The next step is to experimentally see if the linear regime gives a better classification for the MNIST task. The results may pave the way for nonlinear wave processors that preserve input information alongside with their nonlinear activation for brain-inspired computing.

2. References

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