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Training phase masks for diffractive networks / Emulating quantum computing with optical matrix multiplication

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Training phase masks for diffractive networks

Diffractive optical networks have been shown to be useful in a wide variety of application in the realms of optical computing and information processing, such as modal sorting and multiplexing. These systems utilise repeated phase modulations to transform a set of input states contained within a particular basis into a set of target states contained in some new arbitrary basis. Traditionally, these phase masks are trained iteratively through randomly generated matrices or by optimising for individual pixels using various parameter search methods. In this work, we construct a diffractive network capable of sorting various structured light modes into pre-defined channels using optical aberrations. As such, we leverage phase masks constructed from a superposition of Zernike polynomials, whose component weightings are trained analogously to the weightings within a neural network. In this way, we can solve for the desired transformation by optimising for the weightings of fewer aberrations rather than many individual pixels, considerably reducing the number of variables needing to be solved.

Emulating quantum computing with optical matrix multiplication

Optical computing offers a powerful platform for efficient vector-matrix operations, leveraging the inherent properties of light such as interference and superposition, which also play a crucial role in quantum computation. In this work, we bridge classical structured light with quantum computing principles by reformulating photonic matrix multiplication using quantum mechanical concepts like state superposition. We highlight the tensor product structure embedded in the cartesian transverse degrees of freedom of light, which serves as the foundation for optical vector-matrix multiplication. To demonstrate the versatility of this approach, we implement the Deutsch-Jozsa algorithm, utilising a discrete basis of localized Gaussian modes arranged in a lattice formation. Additionally, we illustrate the operation of a Hadamard gate by harnessing the programmability of spatial light modulators (SLMs) and Fourier transforms through lenses. Our results underscore the adaptability of structured light for quantum information processing, showcasing its potential in emulating quantum algorithms.

Student or Postdoc?

Masters

Email address

2108431@students.wits.ac.za

Co-Authors

CHPC User

CHPC Research Programme

Workshop Duration

Primary authors: BEZUIDENHOUT, Hadrian (University of the Witwatersrand); KONI, Mwezi (University of the Witwatersrand)

Presenters: BEZUIDENHOUT, Hadrian (University of the Witwatersrand); KONI, Mwezi (University of the Witwatersrand)

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