Diffractive Neural Networks for Computer Vision Applications

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Imaging under low-light conditions is fundamentally limited by *shot noise*, which arises from the discrete and random nature of photon detection. Such conditions are common in a variety of applications, including astronomical observations of binary stars and exoplanets, nighttime scene analysis for autonomous vehicles, and fluorescence microscopy constrained by phototoxicity or photobleaching. In many of these scenarios, the primary objective is not to reconstruct a full image but to estimate specific parameters of interest.

A case in point was offered by Tsang *et al.*, who considered the problem of measuring the separation of two point light sources that are closer to each other than the diffraction (Rayleigh) limit imposed by the objective lens. They showed that the Cramér-Rao bound (CRB) associated with direct imaging significantly exceeds the fundamental limit established by the per-photon quantum Fisher information (quantum CRB) for this physical setting, with the ratio tending to infinity for small separations [1]. Further, they discovered a measurement that can saturate the quantum CRB: decomposing the incoming field into the orthonormal Hermite-Gaussian (HG) basis of spatial modes and measuring the intensity of each mode. This method has been dubbed *spatial demultiplexing*, or *SpaDe*, giving rise to a new approach to achieving sub-diffraction resolution.

The physical device required to perform SpaDe is a spatial mode sorter. The best known to date principle for building it requires multiplane light conversion setup (MPLC), which is the same type of hardware that is used for diffractive-optical network (DONN). We show that designing mode sorter via DONN training offers significant improvements and results in a parameter estimation. More broadly, we demonstrate how DONN measurement can be beneficial for a wider range of computer vision problems.

References

[1] M Tsang, R Nair and X-M Lu, Phys. Rev. X **6**, 031033 (2016)