Vortex detection with Machine Learning

S. de María-García[*], Ò. Gáribo-i-Orts[*], A. Baeza-Boscá[*],
A. Ferrando[†], J.A. Conejero[*] and M.A. García-March[*]

Phase singularities in complex waves are points where the intensity of the wave is zero and the phase is not defined. Around these points the phase increases by an integer multiple of 2π and this integer is conventionally called the topological charge or vortex charge. Singularities detection is necessary in many fields where singularities play an important role. For many theoretical and experimental studies, it is important to localise and follow during dynamical evolution the phase singularities. Here, we focus in detecting singularities when the evolution of a two-dimensional complex field is dictated by an parabolic partial differential equation (with focus on paraxial optical wave equation and in the Schrödinger equation, but noting that it can be equally applied to e.g. heat equation or diffusion equation). We consider multi-singular initial conditions. The evolution is computed using the scattering-waves method[1].

We consider two cases: detection on the the phase gradient of the field and on the forks patterns resulting from the interference of the field with a plane wave. We create the corresponding training sets for these two cases from generic complex fields containing many singularities located at random positions. Then we use two detectors based in convolutional neural networks (CNNs) are studied: The first one is taken from the field of ultracold atoms[2] and adapted to general complex fields. The second one is the Faster R-CNN[3], a detection network more generic and complex. Both models rely on CNNs for the extraction of images features but each one has a specific inner working, so we will explain in detail how they operates. We analyse the accuracy of the models, as well as their resolution and performance with noisy data (see Fig. 1 for an example of results with second method).

a) b)

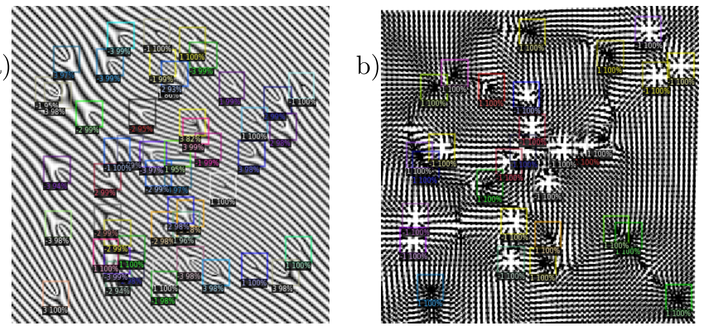

Figure 1: Examples of Faster R-CNN trained models detections. On (a) the predictor trained with forks simulations and, on (b) the one trained on phase gradient simulations.

[*]Instituto Universitario de Matemática Pura y Aplicada, Universitat Politècnica de València, 46022 València, Spain

[†]Department d'Optica, Universitat de València, E-46100 Burjassot (València), Spain

[1]Ferrando and García-March, *J. Opt.* **18**, 064006 (2016)

[2]Metz et al. *Mach. Learn.: Sci. Technol.* **2**, 035019 (2021)

[3]Ren et al. *Adv. Neural Inf. Process Syst. NeurIPS* **28**, 91 (2015)