ESPCI PARIS — Institut Langevin ONDES ET IMAGES

Master 2 Internship Proposal

Seeing through Optical Scattering Media using Artificial Neural Networks

Contacts

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Context et motivations

Scattering media tends to randomize the propagation of waves. It is in particular what happens for light going through thick biological tissues. However, the response of such a system is not stochastic as long as the medium does not change, it is deterministic and can be learned. By measuring for the first time the transmission matrix [1], we demonstrated that we can actaully *see through* a scattering medium [2]. Nevertheless, this technique requires to have access to both sides of the medium, limiting applications for non-invasive imaging.

We recently discovered at the Langevin Institute that there exist subtle correlations between intensity patterns transmitted through and reflected off a scattering medium [3, 4]. Such an effect allows us to obtain information about the transmitted photons by only measuring the reflected ones, opening new roads for non-invasive imaging procedures. However, the imaging resolution scales as the thickness of the scattering medium, similar to diffuse tomography approaches, which is typically much larger than the wavelength.

Ideally, one wants to obtain information about the details of the transmitted field with a resolution of the order of the wavelength by only measuring reflected photons.

The novel approach consists in using *Artificial Neural Networks* to identify the relevant information hidden inside the reflected field about a target behind a scattering medium.

Scientific project

In the context of a very active research field in the domain of *coherent control of waves in complex media*, we propose to take advantage of numerical approaches from *Deep Learning*. The use of artificial neural networks for complex media applications is still in its infancy. We recently acquired at the Langevin Institute a calculation server dedicated to GPU computation (32 core Xeon with 4 RTX 2080Ti graphic cards). We will use numerical tools developed at the Langevin Institute to estimate transmission and reflection matrices over a large number of realizations of the disorder. This data will then be used to train deep neural networks to learn the link between reflection and transmission.

The goal is first to gather enough information from the reflection to learn how to focus light through the scattering medium and to image small objects. We will then analyze the trained network to identify how the algorithm finds the relevant information in order to highlight and study the underlying correlation effects.

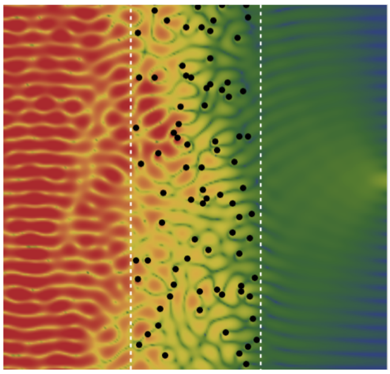

FIGURE 1 – Simulation of an incident wavefront engineered to focus light through a scattering medium.

Applicant profile

The applicant is expected to have a taste for wave physics and numerical simulations. A previous experience with machine learning or neural network is appreciated but not required.

References

[1] S. Popoff, G. Lerosey, R. Carminati, M. Fink, A. Boccara, and S. Gigan, Phys. Rev. Lett. **104**, 100601 (2010).

[2] S. Popoff, G. Lerosey, M. Fink, A. Boccara, and S. Gigan, Nature Commun. **1**, 81 (2010).

[3] N. Fayard, A. Goetschy, R. Pierrat, and R. Carminati, Physical Review Letters **120**(7) (2018).

[4] I. Starshynov, A. Paniagua-Diaz, N. Fayard, A. Goetschy, R. Pierrat, R. Carminati, and J. Bertolotti, Physical Review X **8**(2) (2018).