Speckle correlation imaging beyond memory the effect using deep learning

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Imaging through scattering obstacles is a challenging problem, which has attracted much attention in recent years because of its obvious applications in biology, medicine, defence and other areas. There are several techniques, which rely on ballistic (unscattered) light detection. However, in many cases the ballistic component is unavailable e.g. due to the thickness of the scattering medium and its exponential attenuation. Nevertheless, in some cases it is still possible to retrieve the image from the scattered light passing through the sample. The techniques analysing this scattered light can be split into two categories: the first category requires careful characterization of the scattering sample prior to imaging, which allows to retrieve the image even behind a thick scattering layer by applying the inverse of the medium transmission matrix. This technique can only be applied under the condition that the scattering material remains perfectly static. The second approach relies on the memory effect, which allows fully non-invasive imaging within certain limits, such as thin scattering layer, narrow field of view and minimal distance from the layer to the object. Memory effect-imaging has the very important advantage of not requiring a static scattering layer or the need to always image the same point on it.

Regardless of the specific details of the techniques used, to date all approaches essentially rely on one of the two methods above, therefore requiring either knowledge of the transmission matrix or presence in one form or another of the memory effect. Recently machine-learning-based methods have been demonstrated for scattering configurations similar to those in which the memory effect-imaging is possible and therefore allowed to reconstruct images through a changing scattering layer.

In this work, we extend the experimental conditions to the case when no memory effect is present and the continuously changing scattering process does not allow access to the transmission matrix. In this scenario there is no currently known underlying physical principle that would guide us in building an imaging capability. Nevertheless, we explicitly show that a deep learning method based on a U-net artificial neural network is still able to pick up non-memory effect signatures in the transmitted signal and therefore provide imaging capability. The implications of this discovery are that there are previously unidentified features in the transmission matrix that are sufficiently robust that they maintain sufficient information for imaging even through thick dynamic scattering media.