SCALABLE AND RELIABLE DEEP LEARNING FOR COMPUTATIONAL MICROSCOPY IN COMPLEX MEDIA

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Key Words: Deep learning, uncertainty quantification, speckle correlation, computational microscopy.

Emerging deep learning based computational microscopy techniques promise novel imaging capabilities beyond traditional techniques. In this talk, I will discuss two microscopy applications.

First, high space-bandwidth product microscopy typically requires a large number of measurements. I will present a novel physics-assisted deep learning (DL) framework for large space-bandwidth product (SBP) phase imaging [1], enabling significant reduction of the required measurements, opening up real-time applications. In this technique, we design asymmetric coded illumination patterns to encode high-resolution phase information across a wide field-of-view. We then develop a matching DL algorithm to provide large-SBP phase estimation. We demonstrate this technique on both static and dynamic biological samples, and show that it can reliably achieve 5× resolution enhancement across 4× FOVs using only five multiplexed measurements. In addition, we develop an uncertainty learning framework to provide predictive assessment to the reliability of the DL prediction. We show that the predicted uncertainty maps can be used as a surrogate to the true error. We validate the robustness of our technique by analyzing the model uncertainty. We quantify the effect of noise, model errors, incomplete training data, and “out-of-distribution” testing data by assessing the data uncertainty. We further demonstrate that the predicted credibility maps allow identifying spatially and temporally rare biological events. Our technique enables scalable DL-augmented large-SBP phase imaging with reliable predictions and uncertainty quantifications.

Second, I will turn to the pervasive problem of imaging in scattering media. I will discuss a new deep learning-based technique that is highly generalizable and resilient to statistical variations of the scattering media [2]. We develop a statistical ‘one-to-all’ deep learning technique that encapsulates a wide range of statistical variations for the model to be resilient to speckle decorrelations. Specifically, we develop a convolutional neural network (CNN) that is able to learn the statistical information contained in the speckle intensity patterns captured on a set of diffusers having the same macroscopic parameter. We then show that the trained CNN is able to generalize and make high-quality object predictions through an entirely different set of diffusers of the same class. Our work paves the way to a highly scalable deep learning approach for imaging through scattering media.

REFERENCES

[1] Xue, Y., Cheng, S., Li, Y., and Tian, L., “Illumination coding meets uncertainty learning: toward reliable ai-augmented phase imaging,” arXiv:1901.02038 (2019).
[2] Li, Y., Xue, Y., and Tian, L., “Deep speckle correlation: a deep learning approach toward scalable imaging through scattering media,” Optica 5, 1181 (2018).