Generative adversarial networks for sub-diffraction-limit analysis of confocal images

Catherine Bouchard[12], Theresa Wiesner[12], Andréanne Deschênes[12], Flavie Lavoie-Cardinal[12], Christian Gagné[23]

[1] Centre de recherche CERVO brain research center
[2] Institut Intelligence et Données
[3] Canada-CIFAR AI Chair

OBJECTIVE

Understanding the dynamics of molecular processes in living neurons is highly dependent on the possibility to visualize them. In super-resoltuion microscopy, acquiring multiple images of the same region of interest in living cells is challenging due to phototoxicity and photobleaching effects. The project aims at developing a method where super-resolved information is extracted from diffraction-limited confocal acquisitions thereby limiting the invasiveness of the approach while maximizing the spatiotemporal resolution.

METHODS

A generative adversarial network (GAN) is used to transform a confocal image into its stimulated emission depletion (STED) counterpart. To compel the generator to not only translate the confocal features into realistic STED features but also to generate accurately the sub-diffraction details of interest, an additional network is trained parallely to the generator. This network uses the real STED images to learn a task that is impossible to perform on confocal images, like the segmentation of F-actin rings, and applies corrections on the generator to make this task solvable on the synthetic generations. Once trained, the network is included directly in the imaging workflow to generate a synthetic STED from a confocal acquisition. Stochasticity included in the generator also informs about which regions are worth imaging in super-resolution to gain the most information at a minimal imaging cost; all in real-time and without external user intervention.

RESULTS

The automated approach reduces photobleaching enough to enable the visualisation of the dynamic remodelling of F-actin rings into elongated fibers in living cultured hippocampal neurons. With this technique, the nanoscale organization of F-actin can be monitored for more than 30 minutes, which was impossible using a standard STED imaging protocol. It allows for the first time to observe the dynamic remodeling of F-actin in living neurons, which has only been observed and documented in fixed cells.

CONCLUSION

The method developed shows promising results for F-actin in live cells, and is not limited to this specific application; its flexibility and function simplicity makes it applicable to an extensive number of tasks and modalities. The method improves super-resolution systems by limiting the undesirable effects, like photo-bleaching and photo-toxicity, without compromising on the quality of the information acquired.