Deep learning based structured illumination microscopy (DL-SIM) accelerates cell imaging with low light dose and high resolution

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Abstract: Structured illumination microscopy (SIM) is one of the most broadly used super resolution (SR) techniques [1], but it needs special illumination patterns and a dedicated computational algorithm to retrieve SR information from nine or fifteen sequentially acquired images, for 2D or 3D imaging respectively. The primary limitation of SIM is the need to obtain a series of high-quality images for each reconstructed high-resolution SIM image, which routinely induce photobleaching with prolonged light exposure and ultimately hinders its application. U-Net is one of the most popular and convenient convolutional neural network architectures [2] and previous work has shown its great promise in denoising, enhancing signal to noise-ratio, and isotropic imaging [3]. Here, we developed a Deep Learning based structured illumination microscopy (DL-SIM) that permits super-resolution imaging with 1/5 the number of SIM raw images. Using skip-connection U-Nets, we could restore high quality, high resolution images from image sequences acquired under extreme low light dose conditions (100X fewer photons). We validated the performance of our neural networks with different cellular structures, including microtubules, mitochondria, adhesion and actin filaments. We demonstrated its application in multi-color, live-cell super resolution imaging with minimum photobleaching. Our results show that deep learning can substantially push this speed limit using home-built SIM systems or faster commercial systems. We anticipate that our developed DL-SIM method will have vast applications in super-resolution imaging of the dynamics in live cells.

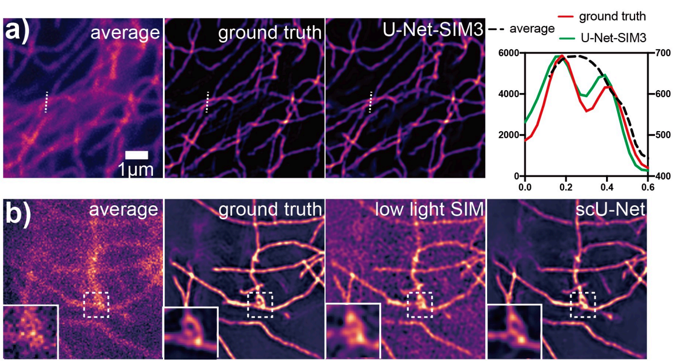

Figure 1 Super resolution imaging of microtubules in MEF cells. a) Under conventional imaging conditions, DL-SIM reached comparable spatial resolution to traditional SIM. b) Under low light imaging conditions, DL-SIM produced better restoration quality compared to traditional SIM reconstruction.

References

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