Title: Rapid 3D Multiphoton Microscopy with Physics-based Deep Learning for Drosophila Brain

Abstract:

In this talk, first I will present a temporal focusing multiphoton illumination (TFMI) method for achieving selective volume illumination (SVI) (i.e., illuminating only the volume of interest) in light-field microscopy (LFM). The proposed method minimizes the background noise of the LFM images and enhances the contrast, and thus improves the imaging quality. Three-dimensional (3D) volumetric imaging is achieved by reconstructing the LFM images using a phase-space deconvolution algorithm. The experimental results obtained using 100-nm fluorescent beads show that the proposed TFMI-LFM system achieves lateral and axial resolutions of 1.2 μm and 1.1 μm, respectively, at the focal plane. Furthermore, the TFMI-LFM system enables 3D images of the single lobe of the Drosophila mushroom body with GFP biomarker (OK-107) to be reconstructed in a one-snapshot record.

Furthermore, conventional reconstruction algorithms take Richardson-Lucy (RL) deconvolution to solve the complex inverse problem. However, such ill-posed tomographic inverse problems present challenges, including high computational complexity and the generation of reconstruction artifacts. To address these challenges, a novel network architecture based on the RL deconvolution process is introduced. This architecture, informed by established modeling principles, incorporates two phases of RL structures with different sizes, eliminating the number of iterations numbers of the iterative algorithm. By adhering to physical principles, the network and training process remain interpretable and consistent with theoretical foundations. Additionally, LFM is combined with temporal focusing multiphoton illumination, enabling selective volume epi-illumination, which enhances image contrast and simplifies the illumination-collection setup. This setup also facilitates the straightforward acquisition of experimental dataset pairs for further network training, allowing the network to compensate for uncertainties and non-idealities in the system. The proposed physically informed network effectively provides a model to reconstruct a uniform high-resolution volume over a range of 40 μm with high speed LFM.

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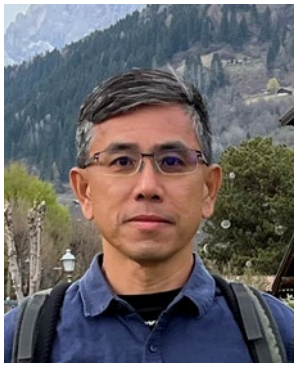

Shean-Jen Chen received his B.S. from National Taiwan University in 1987, his M.S. in Mechanical Engineering from Columbia University in 1991, and his Ph.D. from UCLA in 1996, specializing in adaptive noise cancellation and image restoration. He served as a distinguished professor at NCKU (2012-2016) and Dean of College of Photonics at National Yang Ming Chiao Tung (NYCU) (2018-2021). Currently, he is a distinguished professor at NYCU, focusing on advanced nonlinear optical microscopy for 3D bioimaging and intelligent photonics for agricultural field robots. He has published over 140 SCI journal papers and more than 300 conference papers. He is also a Fellow of both SPIE and OPTICA, with an h-index exceeding 40.

Selected Publications:

1. G.-F. Hong, S. Nair, C.-Y. Lin, C.-S. Kuan, and **S.-J. Chen***, "Deep learning-based detection of green-ripe pineapples via bract wilting rate analysis," ***Smart Agricultural Technology*** 11 (2025) 100949.
2. L.-W. Chen, S.-Y. Lu, F.-C. Hsu, C.-Y. Lin, A.-S. Chiang, and **S.-J. Chen***, "Deep-computer-generated holography with temporal-focusing and digital propagation matrix for rapid 3D multiphoton stimulation," ***Optics Express*** 32 (2024) 2321.
3. Y. Y. Hu, C.-W. Hsu, Y.-H. Tseng, C.-Y. Lin, H.-C. Chiang, A.-S. Chiang, S.-T. Chang, and **S.-J. Chen***, "Temporal focusing multiphoton microscopy with cross-modality multi-stage 3D U-Net for fast and clear bioimaging," ***Biomedical Optics Express***, 14 (2023) 2478.
4. F.-C. Hsu, C.-Y. LIN, Y. Y. Hu, Y.-K. Hwu, A.-S. Chiang, and **S.-J. Chen***, "Light-field microscopy with temporal focusing multiphoton illumination for scanless volumetric bioimaging," ***Biomedical Optics Express*** 13 (2022) 6610.
5. C.-W. Hsu, C.-Y. Lin, Y. Y. Hu, C.-Y. Wang, S.-T. Chang, A.-S. Chiang, and **S.-J. Chen***, "Three-dimensional-generator U-Net for dual-resonant scanning multiphoton microscopy image inpainting and denoising," ***Biomedical Optics Express*** 13 (2022) 6273.