The Chinese University of Hong Kong
Department of Biomedical Engineering

Engineering Next-Generation Cytometers: Label-free Optical Techniques for Live-cell Analysis in Biomedicine

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Abstract

Cytometers are crucial tools in modern medicine for disease diagnosis and immunotherapies. However, conventional cytometers rely on fluorescence labels that can alter cells, limiting their use in applications where cells must remain viable, such as cell therapy and in situ monitoring. While recent advances in label-free image cytometry have partially addressed these issues, the need to develop next-generation live-cell analysis tools remains high. In this talk, Dr. SHU will share her collective efforts in developing label-free optical cytometry techniques. She will first present the Artificial Intelligence Enabled Reagent-free Imaging Hematology Analyzer (AIRFIHA), which for the first time implemented deep residual networks to classify human white blood cells (WBCs) from quantitative phase images, achieving 90.5% accuracy across granulocytes, monocytes, and B and T lymphocytes without chemical staining. The analysis speed of AIRFIHA was limited by two computational stages: phase retrieval and cell classification. To accelerate phase retrieval, an efficient yet accurate network was identified using Neural Architecture Search, reducing the phase inference time to only 31 ms. To expedite cell classification, optical computing was explored, but a key challenge lay in the simulation-to-reality gap that degrades performance on physical hardware. To address this, a model-free training strategy was developed that achieved high classification accuracy in real-world experiments, successfully classifying WBCs with an inference time of < 1 μs. These advances are expected to pave the way for next-generation cytometers, enabling label-free, real-time, live-cell analysis for clinical diagnostics and therapy.

Biography

Dr. Xin Shu is currently a Postdoctoral Fellow at The Chinese University of Hong Kong. She received her PhD degree in Biomedical Engineering from the same institute in 2023 under the support of the Hong Kong PhD Fellowship Scheme. Her current research focuses on computational optics for biomedical applications by merging optical computing, microscopy, and AI. Dr. Shu has published 12 journal and conference papers, holds 1 granted US patent, and has delivered 10 oral and poster presentations at international conferences. She received the Best Paper Award at the 2024 International Conference on Computational Photography, as well as the Best Oral Presentation Award and Best Poster Presentation Award at the 2023 International Conference on Computational Imaging. Dr. Shu is a member of SPIE and serves as a reviewer for Photonics Research, Optics Express, Journal of the Optical Society of America A, and IEEE Photonics Technology Letters.