The Chinese University of Hong Kong
Department of Biomedical Engineering

Transforming Nucleic Acid Diagnostics Through AI-Enhanced Optofluidics

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Abstract

The global surge in infectious diseases demands digital nucleic acid testing (dNAAT) platforms that combine ultra-sensitivity, scalability, and interpretability. While digital PCR (dPCR) enables absolute quantification by isolating single DNA copies, traditional analysis methods relying on fluorescence imaging or flow cytometry struggle with throughput-speed tradeoffs, platform dependency, and opaque decision-making. Addressing these challenges, we present two AI-driven breakthroughs in optofluidic diagnostics. First, SAM-dPCR utilizes Meta's Segment Anything Model (SAM)—pre-trained on 11 million natural images—to achieve zero-shot droplet quantification across formats (0.154–3.629×10^3 copies/μL) at 97.10% accuracy, processing 600 droplets/frame in <4 seconds without fine-tuning. This outperforms supervised counterparts (Deep-qGFP: 206 labeled images for 96.23%; Mask R-CNN: 60 images for 97.56%) while ensuring cross-platform robustness. Second, I^2dPCR integrates CNN-based classification (99.05% accuracy for >300 droplets/image) with GPT-4o's multimodal reasoning to bridge technical precision and clinical utility. It detects ultralow targets (90.32 copies/μL, AUC=0.98) and generates diagnostic narratives—e.g., correlating merged droplet patterns with surfactant deficiency and recommending protocol refinements. By unifying visual foundation models with explainable AI, our work redefines dNAAT's role in precision medicine, transforming raw data into actionable biomedical insights.

Biography

Yuanyuan Wei is currently a Postdoctoral Scholar in the Neurology Department, at David Geffen School of Medicine, University of California, Los Angeles (UCLA). Before that, she was a Research Associate in Prof. Scott Wu Yuan's lab at the Department of Biomedical Engineering (BME), The Chinese University of Hong Kong (CUHK). She received her B.E. degree in Precision Instrument from Tsinghua University in 2018. She earned her Ph.D. degree in BME from CUHK in 2023 under the supervision of Prof. Aaron Ho-Pui Ho with the honor of the Talent Development Scholarship 2022/23 issued by the Hong Kong Administrative Region Government. Her research encompasses computational bio-analysis, droplet-based microfluidics, neurodegenerative disease diagnosis, and integrative systems for biochemical assays. To date, she has received 6 academic honors and awards. She has published 17 peer-reviewed research papers, including 9 first-author journal (5) / conference (4) papers.

***** ALL ARE WELCOME *****

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