Department of Biomedical Engineering
The Chinese University of Hong Kong

Graduate Seminar – PhD Oral Defence

Student	**:**	Mr. NGUYEN Dinh Nguyen
Supervisor	**:**	Prof. TONG Kai Yu Raymond
Co-supervisor	**:**	Prof. SHAKIL Sadia
Date	**:**	21 May 2026 (Thursday)
Time	**:**	9:30 am
Venue	**:**	Room 1122, William M W Mong Engineering Building, CUHK

Title: Large Language Model Agents for Microfluidics: Towards Autonomous Design, Scientific Discovery, and Education

Through the utilisation of large language model (LLM) capabilities, LLM agents can autonomously or semi-autonomously implement plans, make decisions, and execute tasks through interaction with online tools and environments. These agents support closed-loop scientific discovery, which includes literature review, hypothesis formulation, design automation, execution in self-driving laboratories, result analysis, new hypothesis generation, and question answering. However, the exploration of LLM agents for microfluidics remains limited. Microfluidics enables precise manipulation of fluids and biological samples at the microscale. Building on this capability, droplet and microwell microfluidics provide high sensitivity, throughput, rapid detection, and cost savings. However, these microfluidic platforms face long-standing limitations. Regarding droplet microfluidics, there is a limited contextual understanding of structured experimental data in current machine-learning approaches for design optimization and a reliance on manual, iterative design processes that require expert input. In addition, assimilating prior knowledge into both droplet microfluidics and machine learning remains time-intensive. In microwell microfluidics, there are complex, manual design processes and a lack of automated, interpretable, efficient, scalable image analysis and knowledge extraction frameworks. Handling these challenges requires artificial intelligence frameworks capable of understanding scientific context, reasoning autonomously, and integrating linguistic, numerical, and visual information across diverse datasets. To this end, we propose five LLM-driven frameworks: (1) μ-Fluidic-LLMs, (2) DropMicroFluidAgents (DMFAs), (3) an autonomous LLM-powered microwell design framework, (4) a multimodal large language model (MLLM)-logistic regression framework, and (5) MicrowellMicrofluidicsMiner (M^3). In detail, the first framework, μ-Fluidic-LLMs, transforms tabular experimental data into linguistic representations. Doing so enables LLMs to extract contextual features that improve prediction accuracy in droplet microfluidics. When integrated with models such as LLAMA3.1 and DEEPSEEK-R1, μ-Fluidic-LLMs enhance prediction performance. They reduce mean absolute and root mean squared errors by up to 40% and 26%, respectively, and improve regime classification accuracy by over 3%. Next, the second framework, DMFAs, exploits LLM agents to automate droplet microfluidic design and deliver droplet-based microfluidics knowledge, achieving a question-answer accuracy of 76.15% and a design model coefficient of determination of 0.96. The third framework translates natural language prompts into precise computer-aided design (CAD) drawings of various microwell geometries. Surpassing 0.92 for occupancy and 0.99 for shape, the fourth framework demonstrates a high degree of robustness in microwell image classification. In addition, the fifth framework, M^3, leverages a mixture of LLM agents to autonomously extract microwell microfluidics knowledge. Because of this multi-agent configuration, M^3 achieves an accuracy of about 78%, exceeding by more than twice the around 38% accuracy achieved by a single LLM. Taken together, these innovations mark the emergence of a new paradigm in LLM-enabled microfluidics for automated and data-driven discovery.

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

For enquiries, please contact Ms. Joyce Chan, Department of Biomedical Engineering at 3943 8278