Development of an Automated Microfluidic Platform Using Deep Learning for Scalable Production of Microgels

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Research Area:	Microfluidics, Applied Machine Learning, Microfabrication
Project Start Date:	Fall 2026

Project Description

Objectives:

This project seeks to develop a parallelized droplet microfluidics platform produces, images, and autonomously tunes monodisperse droplets across multiple microfluidic chips simultaneously. The platform extends recent single-chip demonstrations of ML-based droplet detection and closed-loop control to a scalable, multi-chip array with independent per-chip control and automated fault isolation.

Background & Motivation:

Microgels are increasingly used in applications such as drug delivery, tissue engineering, and cell encapsulation, because they provide precise control over the cellular microenvironment and material properties, creating a growing need for scalable and reproducible manufacturing methods. Microfluidic droplet generation enables the production of highly uniform microgels [1-2]; however, achieving high-throughput production while maintaining consistency requires automated monitoring and control to ensure consistency. Integrating machine learning (ML)-based image analysis with microfluidic platforms can enable automated process monitoring and control, improving reproducibility, throughput, and scalability of microgel manufacturing.

This project focuses on developing a parallelized platform consisting of multiple droplet microfluidic devices (e.g., Fig 1 A-B) that leverages deep learning model to analyze real-time images of microdroplets flowing through a microfluidic chip (e.g., Fig 1 C-D). The images will be captured using a fast camera while running experiments using a microfluidic device to produce droplets/microgels in the lab. The first aim is to explore selected microfabrication techniques, designs, and materials, particularly thermoplastic materials, to make microfluidic devices that can produce droplets/microgels at a large scale. The second aim is to automate the process

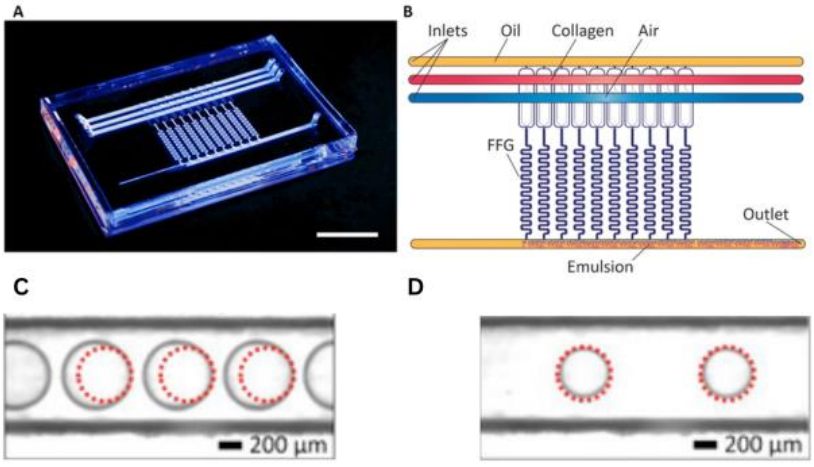

Fig. 1. *(A-B) Image and top view of a parallelized microfluidic device with 10 droplet generators [2]. Scale bar: 2 cm. (C-D) Droplet size detection before (C) and after (D) automated control*

through developing a close-loop feedback platform using automation hardware (that will be acquired and set up) and deep leaning model (that will be built). Integrating these goals, the project aims to establish an automated and scalable microfluidic system that can operate and produce droplets/microgels at large scale in an autonomous manner using a closed-loop flow control system.

Preferred Skills/Experience

- Prior microfluidics or microfabrication experience is a plus, but not required.
- Experience with Python programming is required.
- Familiarity with computer vision concepts is an asset.
- Comfort working in a wet lab environment (training and safety supervision will be provided).

Goals

1. Explore different protocols, designs, and conditions to optimize scalable fabrication of microfluidic devices using thermoplastic elastomers
2. Develop and validate a real-time ML-based model for real-time image analysis
3. Demonstrate closed-loop flow control on a single microfluidic device
4. Benchmark for real-time autonomous operation of a scalable multi-device platform

Additional Information

- Onsite
- This project potentially allows for co-authorship on a journal publication.
- Experimental work will be conducted at the Center for Research and Applications in Fluidic Technologies (CRAFT) [6].

Application Instructions

- Please submit CV and unofficial transcript to Prof. Axel Guenther (axel.guenther@utoronto.ca) and Prof. Afshin Abrishamkar (afshin.abrishamkar@utoronto.ca).

References

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