Computer-assisted Design of Microfluidics

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Introduction: Since the emergence of the first lab-on-a-chip devices in the late 1970s, microfluidic chips have found a variety of applications in biomedical engineering and clinics. But while the range of possible applications for microfluidics has blossomed, the process of designing microfluidic chips has remained relatively unchanged since the 1970s. Researchers still draw new microfluidic chips designs by hand, fabricate and test them, and repeat this process until a functional device design is found. This trial-and-error process is expensive and inefficient, and it slows the spread of microfluidic technologies to new fields. In this presentation, we will share our recent work developing computer algorithms and software tools that enable users to design microfluidic chips much more efficiently.

Materials and Methods: In our work, we were motivated by the question, *is it possible to create functional microfluidic devices without actually designing them?* We answered this question in two different ways: Random design of microfluidics: We wrote a custom MATLAB program that generated thousands of random microfluidic chip designs, simulated the behavior of each design using COMSOL Multiphysics, and stored the results in a publicly-accessible database (http://random.groverlab.org). Users can query this database to find a chip design suitable for a given application. As a proof of concept, we created a library of 10,513 fluid mixer chips that can generate any three arbitrary concentrations at the same time. Sixteen of these designs were etched in glass, anodically bonded to silicon, and tested using food coloring and cell growth media to confirm that the designs function as predicted [1]. Microfluidics-optimized particle simulation algorithm (MOPSA): Many microfluidic chips that we would like to design algorithmically will contain particles like cells and microbeads, but the particle simulation tools in existing commercial software are largely not suitable for predicting the behavior of particles microfluidic chips. To address this need, we developed a microfluidics-optimized particle simulation algorithm (MOPSA) that simulates particle trajectories with greater accuracy than existing commercial software. MOPSA treats particles as two- or three-dimensional objects (not single points) and uses an empirical correction to make particle-wall interactions more lifelike. MOPSA is implemented in MATLAB and uses a fluid velocity profile solved by COMSOL Multiphysics.

Results and Discussion: Figure 1 shows one of the 10,513 different random microfluidic mixers that we generated and simulated. The chip was fabricated, tested, and found to generate the expected fluid concentration. Figure 2 shows the predicted trajectories of three different-sized cells flowing through a typical triangle-post deterministic lateral displacement (DLD) sorter chip. MOPSA correctly predicted the paths of the different cells while the commercial software COMSOL Multiphysics failed.

Translational Impact: As libraries of random chip designs proliferate in the future, even complex lab on a chip devices like cell sorters could be created in seconds by users with no experience in microfluidics.

Disclosure Statement: No conflicts of interest to disclose.