Digital-Microfluidic Biochips

Mohamed Ibrahim and Krishnendu Chakrabarty, Duke University

This installment of Computer's series highlighting the work published in IEEE Computer Society journals comes from IEEE Transactions on Multi-Scale Computing Systems.

Digital-microfluidic biochips (DMFBs) are revolutionizing laboratory procedures for point-of-care clinical diagnostics, environmental monitoring, and drug discovery. DMFBs allow bioassay protocols to be scaled down to droplet size. They're executed by enabling precise control of discrete droplets using a patterned array of electrodes.

Biochemistry's inherent complexity means that operational errors due to unbalanced splitting or protein fouling might arise during bioassay execution (see Figure 1a). Therefore, a core challenge in operating DMFBs is to verify the correctness of fluidic interactions; thus, an efficient DMFB design will require careful consideration of error recovery. In "Efficient Error Recovery in Cyberphysical Digital-Microfluidic Biochips" (*IEEE Trans. Multi-Scale Computing Systems*, vol. 1, no. 1, 2015, pp. 46–58), we propose an online synthesis framework that supports error recovery in pin-constrained DMFBs and provide a comprehensive analysis of error recoverability.

Given a general-purpose pin-constrained DMFB configuration connected to a real-time charge-coupled device camera system, we employed a dynamic adaptation technique to generate new schedules, placements, and droplet routes in response to errors (see Figure 1b).

The use of our framework avoids faulty components and, thus, ensures the reliability of DMFB operation. Error-recoverability analysis determines the amount of chip

0018-9162/16/$33.00

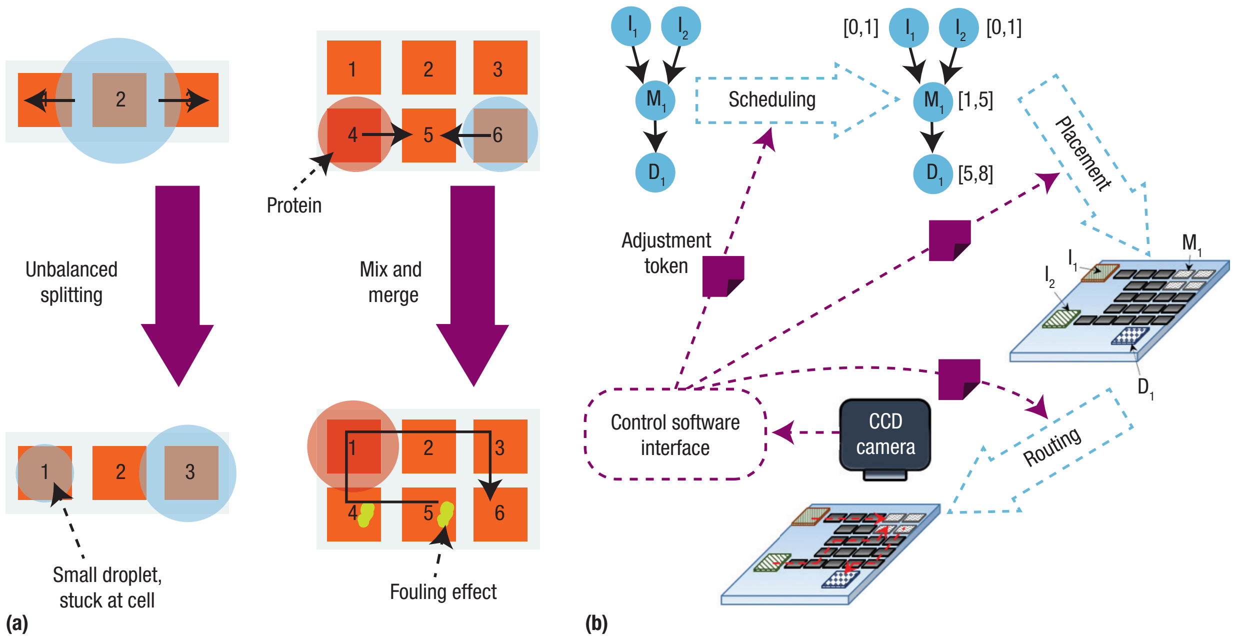

Figure 1. Online synthesis framework to support error recovery in pin-constrained digital-microfluidic biochips. (a) Operational-error mechanisms. (b) Proposed workflow: the control software keeps track of the status of each bioassay operation and reacts to errors by feeding the online synthesis algorithm with required "tokens" for adaptation. CCD: charge-coupled device.

resources required for error recovery given completion-time constraints. Such analysis can help determine how large a biochip should be for a target application.

MOHAMED IBRAHIM is a PhD student in the Department of Electrical and Computer Engineering at Duke University. Contact him at mohamed.s.ibrahim@duke.edu.

KRISHNENDU CHAKRABARTY is the William H. Younger Distinguished Professor of Engineering in the Department of Electrical and Computer Engineering and a professor of computer science at Duke University. Contact him at krish@ee.duke.edu.