Popular science summary of the PhD thesis

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Title of the PhD thesis	A Modular Design Approach For Programmable Cyber-Fluidic Systems
PhD school/Department	DTU Compute & DTU Bioengineering

Science summary

Digital microfluidic biochips have emerged as a technology for miniaturizing and automating the traditional biochemical laboratory processes. The technology allows for direct programmatic control of droplets without the need for pumps, valves, or defined channels, which makes the digital microfluidic biochips highly programmable and reconfigurable devices. Although the technology has already been in the research spotlight for over two decades, the digital microfluidic biochips face significant difficulties in achieving wide-adoption and living up to the expectations for extensive miniaturization and automation of biomedical applications. Among the most significant challenges is that digital microfluidic is an interdisciplinary field where the research is often focused on technology and component level rather than on a complete future proof system.

Taking the digital microfluidics past the step of technology demonstrators required bridging the gap between digital biochips presented in the context of application-specific short term research goals and a programmable application-agnostic digital microfluidics system. This dissertation embarked on the mission to efficiently connect the fluidic and control domains and proposes a cyber-fluidic architecture consisting of three loosely coupled parts; fluidic, instrumentation, and virtual. The cyber-fluidic architecture was developed into a modular platform-based design, which allowed for holistically addressing the spectrum of accompanying challenges on a conceptual and technological level.

The engineering research of the fluidic system led to the development of a digital biochip with a large array of individually addressable electrodes, a novel design of reconfigurable embedded heaters, and an innovative low-cost coating method. This dissertation also discusses the design and implementation of the modular instrumentation system that embraces reconfigurability to provide an evolvable and scalable model for digital biochip instrumentation. We also conceptualized a software stack for programmable microfluidics, including a fluidic instruction set architecture, text and graphical-based programming methods, and an execution model.

The capabilities of the proposed cyber-fluidic architecture and the constructed platform are demonstrated with several real-life protocols, namely performing a gene amplification by a polymerase chain reaction and magnetic beads-based enzymatic immunoassays targeting the detection of MRSA and SARS-CoV-2 spiked protein.

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