CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

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Project Number

J0103

Project Title

Manhattan Fluidics: On Optimizing Network Geometry by Circuit Analogy for Low-cost 3D Printed Lab-on-a-Chip Devices

Abstract

Objectives/Goals

My research goals are (1) to develop an empirical model for flow in 3D printed channel segments, and (2) to use that model to optimize the flow rate in networks composed of fluidic segments connected in series and parallel.

This work responds to a growing need for rapid point-of-care diagnostics that have the potential to reduce healthcare costs, speedup patient treatment and prevent the spread of global pandemics. Unlike conventional microfluidics, 3D printed millifluidics can be manufactured rapidly and inexpensively. This opens the possibility of widespread adoption of onsite testing in low-income countries that are subject to heavy infectious disease burdens. Since 3D printed fluidics is new, fundamental questions remain open, and my research seeks to close this knowledge gap.

Methods/Materials

I designed and 3D printed a set of discrete millifluidic elements of varying lengths and cross-sectional dimensions ranging from 800 micrometers to 2 millimeters. I built a novel test rig and used a video-based method to determine the flow rate of water/glycerin solutions in these elements as a function of driving pressure (ranging between 100-1000 Pascals) with high accuracy. From this data, I extracted a model of the hydraulic resistance of these components as a function of their interior dimensions. Then, I incorporated this model into a Python program, which utilized the analogy between fluid flow in channels and current flow in circuits, to predict flow rates in complex fluidic networks.

Results

The experimentally measured flow rates in discrete components, as a function of cross-sectional area and length showed trends consistent-though not in full agreement-with the ideal behavior predicted by the Hagen-Poiseuille Law. Using a regression method, I determined empirical coefficients to improve the fit between model equations and the measured data. Using this fitted model, and my program I found sets of geometrical parameters that maximized net flow in hierarchically bifurcating fluidic networks, under fixed interior volume constraints.

Conclusions/Discussion

I designed and printed a set of discrete fluidic elements of varying geometry and measured their hydraulic resistance. Using a model extracted from this data I optimized flow rates in a class of fluidic networks that occur frequently in lab-on-a-chip devices.

Summary Statement

I have demonstrated the feasibility of 3D printing complex millifluidic networks with predictable behavior; my contributions to this emerging research area have potential applications in low-cost blood testing and disease screening.

Help Received

I would like to thank my science teacher Mrs. H. Mackewicz for her helpful discussions. I would like to thank my dad and mom for their encouragement throughout the course of this project.