AI-BASED SOLUTION TO THE OPTIMIZATION PROBLEM OF THE MICROFLUIDIC GEOMETRY DESIGN

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This paper outlines a generative design approach for developing a microfluidic single-red blood cell trap for applications in single-cell analysis. A key challenge in single-cell microfluidic traps is achieving the required flow velocities through the trapping slits to capture cells while satisfying implicit design constraints. In this work, the cell-trapping design, validated by experimental data, was developed using a generative design methodology, and an evolutionary algorithm. Without the generative design, the cell-trapping slits exhibited low flow velocities, rendering them incapable of trapping single cells.

A complex integrated system was developed, combining MATLAB, COMSOL Multiphysics, and Python, to implement the evolutionary algorithm, design randomization and sorting, fluid velocity gradient simulation, and a constraint equation framework. After evaluating 28,271 design solutions, the optimal geometry demonstrated a 42.38% improvement in through-slit velocities. Fabricated and tested prototypes successfully trapped cells, and this evolutionary algorithm and design can be applied to several microfluidic optimization problems. The convergence speed of the algorithm could be further enhanced by incorporating expert-generated initial assumptions or pre-existing solutions, and the integration of deep learning and generative adversarial networks may build more effective hybrid algorithms further enhanced by integration of the Lattice Boltzmann based particle tracing.

References

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