Algorithmic assembly in soft-matter: Merging chemistry and computation

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Whitepaper for NSF Workshop on Biologically enabled wireless networks design and modeling

Research Interests

Starting from genetic blueprints, biological materials turn into complex, multi-compartmental living things with algorithmic precision. A fundamental difference between biological and physical materials is their inherent computational ability. One of our long-term research goals is to achieve algorithmic means of organizing and manipulating soft-matter in engineered systems, bridging this complexity gap in biological and engineered systems.

For the last 100 years, computation has only been about information processing. Even though physical laws enforce a necessary association of bits of information with physical entities (e.g. electrons in a microprocessor or pieces of chalk on a board), computation has not been developed as a paradigm for material processing. As a first step towards achieving this goal, we have invented a new paradigm in computation where bits can simultaneously transport and manipulate both materials and information, similar to how integrated circuits allow us to control flow of electrons.

In our current work, we have invented a new digital logic family [1] ("microfluidic bubble logic") purely implemented in fluids that allows for simultaneous manipulation of both materials and information in an integrated manner. We have demonstrated cascadability, feedback, bistability and gain; hallmarks of scalable computational substrates. This merging of chemistry and computation opens many doors for scale-free algorithmic manipulation and assembly of entities at a mesoscale (1-100 microns).

Current state of the art and future directions

We are currently exploring applications of this technology platform in ultra-high speed (100kHz) sub-nanoliter chemistry for screening technologies and algorithmic assembly of biological materials.

Another effort in the group is focusing on developing open source design tools for automated synthesis of logic systems from substrates to higher-order programming paradigms. The challenge in developing these tools is to embed the physical nature of the substrate

References

1. Microfluidic Bubble Logic, M. Prakash and N. Gershenfeld, Science, Vol 217, Feb 2007
2. The Physical Nature of Information, Rolf Landauer, Physical Letters A 1996
3. It from Bit, John Wheeler, Proceedings of Foundations of Quantum Mechanics 1989
4. Ultimate physical limits of computation, Seth Lloyd, Nature 2000