Introduction to Molecular Robotics

~Its Perspectives and Motivation

Satoshi Murata[1]

[1] Graduate School of Engineering, Tohoku University, 6-6-1 Aobayama, Sendai, 980-8579, Japan

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The Molecular Robotics is a novel research area aiming at establishing systematic construction methodologies of building systems of chemical devices and nanostructures such as DNA logic gates, DNA nanostructures and molecular motors. In this talk, I would like to introduce the basic concept and research direction of molecular robotics.

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Slime Mold Molecular Robots and Gellular Automata

Masami Hagiya[1]
hagiya@is.s.u-tokyo.ac.jp

[1] Department of Computer Science, Graduate School of Information Science and Technology, University of Tokyo, 7-3-1 Hongo, Bukyo-ku, Tokyo 113-8656, Japan

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The Slime Mold Team of the Molecular Robotics Project [2,3] aims at constructing molecular robots with gels as actuators and bodies of robots. Such molecular robots are called slime mold robots. In the evolution scenario of molecular robots [2], slime mold robots belong to the second generation in which molecular robots are scaled up to millimeter sizes. They are expected to process and amplify molecular and other kinds of signals to drive gel actuators, which make conformational changes to robot bodies and eventually result in motions such as locomotion. In this talk, after explaining the concept of slime mold robots that underlies the research of the team, I briefly introduce research contributions the team has made so far, including some pieces of work on DNA-based hydrogels. I then talk about a mathematical model that is expected to be used to design slime mold robots and analyze their computational power [1]. The model is called "gellular automata", in which solutions are separated into cells by walls made of gels. Reactions occurring in a cell may produce molecules that dissolve or construct gel walls and merge or separate solutions in the neighboring cells. The model is intended to introduce discrete aspects to the gel space for ease of design. It is also expected to overcome the problem of slow diffusion of large molecules such as DNA inside a gel by introducing hybrid of solutions and gels. Cells of solutions will eventually drive surrounding gel walls as actuators.

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Perspectives and objectives of amoeba-type molecular robots

Akihiko Konagaya[1]
kona@dis.titech.ac.jp

[1] Department of Computational Intelligence, Tokyo Institute of Technology,
4259 Nagatsuta-cho, Midori-ku, Yokohama 226-8502, Japan

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The Amoeba Robot team aims at developing an amoeba-like molecular robot with molecular sensors, a molecular controller and molecular actuators enveloped in a molecular container [1]. The amoeba robots are considered the first generation in the scenario of molecular robot evolution [2]. The main challenge for the construction of amoeba-type molecular robots is system integration of molecular components in a molecular container. Giant liposome is one of the most promising molecular containers for amoeba-type molecular robots, although much has been remained in the design of liposome with sensing facilities including photo-reactors and magnetic field reactors as well as DNA channels for small molecules. As for the molecular actuators, a microtubule-kinesin based actuator and an actin filament-myosin based actuator are currently studied. In each actuator, DNA tags or DNA information will play an important role in molecular integration. Integration of advanced molecular sensing systems and molecular control systems is a remaining issue in our future work.

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