Accelerating Life Sciences by Robotic Biology

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The Robotic Biology Project is a research initiative that aims to explore the potential of using robotics and artificial intelligence (AI) to better understand biological systems and apply them to biomedical and other applications[1]. In this presentation, we will first present an overview of the Robotic Biology Project, including the development of LabDroid, a general-purpose humanoid robot with two arms that performs experiments using the same tools as humans[1], a formal experimental protocol description language LabCode, and an optimal scheduling algorithm for experimental procedures and its implementation[2].

We will then describe two application projects in the field of mammalian cell culture. Cell culture is a fundamental experimental technique in cell biology and medicine. However, culturing high quality cells with high reproducibility relies heavily on expert skills and tacit knowledge, and it is not easy to scale up the production process due to the training bottleneck. Although many automated culture systems have been developed, and a few have been successful in mass production environments, very few robots are capable of the frequent protocol changes that are often required in basic research environments. By combining our newly developed AI software with LabDroid, we have developed a variable scheduling system that continuously produces subcultures of cell lines without human intervention[2]. The system periodically observes cells on plates under a microscope, predicts the cell growth curve by processing cell images, and decides the best times for passage. We have developed a system that can maintain the cultures of two HEK293A cell plates for 192 hours without human intervention.

The second application project we present involves an AI system with a batch Bayesian optimization algorithm that autonomously induces the differentiation of induced pluripotent stem cell-derived retinal pigment epithelial (iPSC-RPE) cells[3]. Induced differentiation is one of the most experience- and skill-dependent experimental processes in regenerative medicine, and establishing optimal conditions often takes years. From 200 million possible parameter combinations, the system performed cell culture under 143 different conditions in 111 days, resulting in 88% better iPSC-RPE production than the pre-optimised culture in terms of pigmentation scores. Our work demonstrates that the use of autonomous robotic AI systems dramatically accelerates the systematic and unbiased exploration of the experimental search space, suggesting immense applications in medicine and research.

We will also discuss the levels of autonomy of AI scientists for experimental sciences and the Nobel-Turing Challenge Initiative[5].

1. Yachie et al., Robotic crowd biology with Maholo LabDroids. Nature Biotech 35(4). (2017).
2. Itoh et al., Optimal scheduling for laboratory automation of life science experiments with time constraints. SLAS Tech 26(6) (2021).
3. Ochiai et al. "A variable scheduling maintenance culture platform for mammalian cells", SLAS Tech 26 (2) (2020).
4. Kanda et al. “Robotic search for optimal cell culture in regenerative medicine.” eLife vol. 11 e77007 (2022).
5. Kitano, “Nobel Turing Challenge: creating the engine for scientific discovery”, npj Syst Biol and Appl 7, 29 (2021).