Paper Reference

Dynamic control in a coordinated multi-cellular maze solving system – Allen Hsu, Vikram Vijayan, Lawrence Fomundam, Yoram Gerchman, Subhayu Basu, David Karig, Sara Hooshangi, Ron Weiss

Abstract

Cells sense their environment, process information, and continuously react to both internal and external stimuli. Control system theory provides convenient tools and concepts for describing and analyzing complex cell functions. In this paper the authors demonstrates the use of control theory to forward-engineer a complex synthetic gene network constructed from several modular components.

Discussion

Authors present the design and simulation of a synthetic multi-cellular maze-solving system. In this system, bacterial cells are programmed to use artificial cell-to-cell communication and regulatory feedback in order to illuminate the correct path in a user-defined maze of cells arranged on a surface. They carried out experiments with *Escherichia coli* to characterize the diffusion properties of artificial cell-to-cell communication based on bacterial quorum sensing systems.

A recursive algorithm was designed to find a path between two predefined points in a user-generated maze. Colonies were arranged in the shape of a maze, surrounded by a wall of cells. The colonies along the correct path were programmed to illuminate the solution to the maze as a result of executing the algorithm. The algorithm started with an exogenous signal at the entry of the maze. In response, the first maze colony emitted a pulse signal *Signal-1*, which diffused to neighboring colonies. The second maze colony then responded to *Signal 1* by secreting a pulse of *Signal 1*. The process continued until *Signal 1* reached the End colony, which secreted *Signal 2* in response. Signal 2 diffused to all neighboring colonies. Maze colonies that encountered *Signal 2* transformed into *End* colonies, while End colonies encountering *Signal 2* remained *End* colonies. Once this transformation took place, and sufficient degradation of the communication signals had occurred, exogenous *Signal 1* could be re-administered to start another iteration of the algorithm. When the number of iterations equaled the number of colonies between the entry and end of the maze, the maze solving is completed, and the path from start to finish was indicated by the positions of *End* colonies.

In the simulation, the *End/Maze* cells were modeled using a custom application based on MATLAB 7.0 and Simulink 6.0. The components described were designed and analyzed as independent modules with mRNA input/output. Several mazes of varying topologies were simulated with the different set of Hill functions.

Conclusion

This study shows the first iteration of the engineering process: design, simulation and experimentation. Modeling the biological system as an interconnection of control systems has provided a useful method for simulation and analysis of complex synthetic biological systems. The results from simulation and experimentation can be applied to the next iteration of the rational design process to achieve an actual maze solving system.