Modular Modeling of an Artificial Organ System

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Summary

Current synthetic biology research is focused on the molecular level, but viable artificial organs require a systematic framework for integration, sustenance, and coordination [1] [2]. While synthetic microbiology and tissue engineering are fundamental components, a higher level view of integration is often non-existent in the literature [2] [3].

A relevant research field is the development of closed-loop combinations of neural tissue and robotics, such as animats and hybrots [4]. As such, a proposed framework for a simple, modular synthetic organism will be evaluated. A closed-loop circulatory system would be used to sustain a "brain" via homeostatic maintenance of a balance of essential nutrients and waste removal. The modular "brains" used would include a cultured neural network [5], a simulated neural network [6], and a hybrid system using a sealed neuronal culture [4]. Research would be initially conducted by simulation and then experimentally.

The implications of the system may be applicable to a number of fields, including hybrots [4], artificial organ design [2], synthetic biology [7], artificial life [8], and automated control systems [9]. While similar simulations have been previously performed [10] [4], none have examined an entire synthetic organ system in the context of modular nodes.

Goals

The initial goals of this research would be to design a mathematical model, a simulation based upon the model, and then a physical system based upon the simulation. The end product should be a model and system with ease of assembly and use, as well as the potential to regulate the desired characteristics of an artificial organ attached to it. The development of an API for such a system and supporting documentation would be a longer term goal.

Methods

The proposed model would be based upon a simple isolated brain scenario, with a set of artificial organs in series along a closed-loop artificial circulatory system [11] [12]. Different parameters for the number of modules may be included, but minimally a "brain," a source of nutrition, and a filtration system for removing metabolic waste products in series around a closed loop should be included [13]. The theoretical model would be based upon metabolically-inspired control systems [5][14] [15] [16] [17] [18]. In addition, although other software can be used for the initial implementation of the system, the development of an Arduino-based implementation and supporting documentation would be a longer term goal.

Intellectual Merit

An important gap within the literature would be closed regarding the development of a modular synthetic organism. The system would be designed to test methods for integrating and controlling artificial organs. At the very least, the system would propose an adaptive facsimile of the circulatory system and the regulation of flow rates. The modular design would enable other types of artificial organs to be added, allowing more complex artificial organ systems, and potentially even a synthetic organism, to be developed [1] [19] [20].

Broader Implications

While artificial organ systems would be the primary field to benefit from this project, the modular approach and system could be adapted for a number of other processes, from educational toys to industrial processes. Complex industrial processes could be regulated in a manner approximating metabolism, allowing for more efficient autonomous control of bioreactors and other systems [14] [15] [16] [17] [18]. By having open documentation and making use of available hardware such as an Arduino, the barriers to entry and adoption would be greatly lowered.

Future Funding

Immediate potential for commercialization exists for research, industry, education, and even recreation. Kits could be used to test the capabilities of artificial organs or regulation of industrial processes. Educational and scientific toys including sets of “starter modules” could be sold to schools and universities. For example, the development of simulated models on Arduino could be a starting point. The ability to make simple organic systems modular could greatly accelerate development by lowering the barriers to entry. Furthermore, the resources required from this research are readily available in many existing labs, potentially lowering the initial cost.

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