A Study in Inorganic Life

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The Problem: People, even from a very young age, have little problem distinguishing between artifact and animal, or recognizing that an entity possesses some "essence" of life [3]. However, when prompted as to the basis of this distinction, we find that our definition of life is somewhat oblique. Popular sentiment attributes processes of reproduction, metabolism, and growth, but nature offers living examples that are seemingly exempt from these requirements. Our science still cannot account for what makes something alive.

The problem is to address this issue from an engineering standpoint. We propose to build robots that have some of the canonical properties and engage in some of the putative functions of biological organisms.

Motivation: Questions about the essence of life have long been central to fields such as biology and organic chemistry. But not until recently have we had the technology, materials, and computational power to apply robotics to the pursuit of such inquiry. Clearly, no artificial intelligence laboratory has yet to engineer an entity that could even be mistaken for living. What could a self-sustaining robot that metabolizes its own food or one that has self-assembled from more elemental modules lend to our definition of life? What about a robot that adapts its neural architecture in response to its habitat? These questions are the motivation for this work.

Approach: Our approach is to design, build, and investigate a number of experimental robots, each embodying one or more of the characteristic traits of living systems. Most of the robots will inhabit an aqueous environment which responds amenably to external perturbations and into which appropriate forms of "food solutions" can be introduced. Prokaryotic cells and protozoa (Figure 1) will serve as templates for the robot architectures which may also include neural circuitry and actuation mechanisms based on higher order plants and marine life. Many materials such as electroactive polymers (EAP) [1], biodegradable shape memory polymers, conductive greases, fiber optic sensors, flexible film circuits, and semiconductor laminate solar cells are being investigated as alternatives to the silicon and metal that comprise the power, actuation, structural, and control systems of most modern robots.

Figure 1: An arcella amoeba could be a template for a robot. Image ©Wim van Egmond.

For instance, one proposed morphology consists of an external EAP membrane (Figure 2) doped on either side by a compliant electrode pattern that, when activated, allows for slight deformation of the membrane akin to the pseudopods which amoebae use to capture prey and locomote over surfaces. In other places, the membrane would also act as the dielectric insulator between other doped conductors forming a capacitor. The membrane would envelope a liquid or gel "cytosol" in which hermetic compartments containing circuit elements, such as processors, are suspended. Variations between the pH of the robot's internal suspension and that of the external environment would provide the voltage differences necessary to excite the polymer as well as to drive other processes. The resulting motion of the robot would be in direct response to changes in its surroundings, analogous to the feeding responses of simple bacteria.

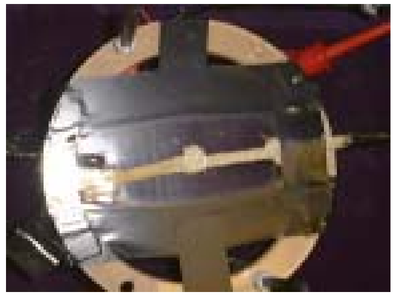

Figure 2: A test setup of EAP actuation.

Impact: The goal of this work is to investigate our definitions and perceptions of life. Granted, these are grand and provocative definitions that have been deliberated upon by many great thinkers [5, 4, 6, 2]. We do not intend to resolve these issues. Instead we hope to draw some conclusions as well as elicit other questions that will relate to both life and to robots. We may find we cannot distill out any requisite for life, suggesting life may rely on an irreducible level of complexity. Maybe the complexity is due to the mandatory inclusion of the environment in the definition of a living organism, taking us further from the notion of the individual life form. On the other hand, we may find that a simple combination of functions and components engenders very life-like behaviors.

And what if it is possible for a human to create an inorganic organism that is ostensibly alive? Are we willing to accept that human intervention can beget life in a way associated with how the earth's prebiotic environment stirred life from the primordial soup? Or must the physics of the world be responsible for such creation, a physics from which we are then saying life itself is exempt? Does a protracted natural evolution satisfy a requirement for life that an engineered, forced evolution cannot?

From an engineering standpoint, would such a robot require an amendment to the definition or concept of "robot" itself? Is a robot that engages in interactions with its environment for the sole purpose of self-preservation, and possibly reproduction, of the same status as an industrial robot?

If this work cannot answer some of these questions, it will at least have expanded upon the metaphor of organism as machine and advanced the use of AI as tool for looking at life.

Future Work: This work is still in the early stages of experimentation and design. Future work will involve the synthesis of material, mechanism, architecture, and environment into complete robotic systems. The first step is the implementation of biologically inspired actuation systems (e.g., flagella, cilia, cytoplasmic movement, mucilage secretion) that may be simulated in the robots.

References:

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