

Representations

The Hard Problem for Artificial Life

Harry Halpin

H.Halpin@ed.ac.uk

<http://www.ibiblio.org/hhalpin>

Introduction

Representationalism, the idea that *cognition involves the manipulation of symbolic structures*, originally was at the heart of artificial intelligence and cognitive science. At first it was taken to be a revolutionary force capable of explaining previously inexplicable phenomena. Yet its proponents could not explain much of physical behavior by virtue of representations alone, and artificial life and other disciplines that did not rely on explicit representations have now risen to the forefront. Despite the success of anti-representationalism, there has been recent broad recognition that some problems are “representation hungry,” and that an adequate theory of representations is needed (Clark, 1997).

Representations: Solved?

Several researchers in artificial life have suggested that work in cellular automata (CAs) can either *evolve representations* as explanations (Mitchell, 1998) or provide a simulation of the evolution of physically implemented representations (Rocha and Hordijk, 2005). However, we disagree that these are *genuine representations in the way they are understood by the rest of AI and philosophy*, and instead hold that the goal of simulating representations is still to be achieved. Problems that do not fit within an explanatory framework but that de facto either exist or seem to exist are considered “hard” problems. These problems can be banished by two routes: either an *expansion, refactoring, or revolution of the explanatory framework* such that a solution for the “hard problem” is forthcoming, or *proof that the problem does not exist*. In the case of representations, neither type of solution has been forthcoming.

Defining Representations

A representation “stands-in” for something, so that when that thing is not present it may “be represented; that is, something else can stand in for them, with the power to guide behavior in their stead. That which stands in for something else in this way is a **representation**; that which it stands in for is its **content**; and its standing in for that content is **representing** it.” (Haugeland, 1991). It is this relationship that makes the problem *hard*. In physics, as commonly conceived, for one thing to **effect** another thing (change the “physical configuration” of), both things must be physically concrete and in direct contact with each other. So

properties that are effective are also *local*, such that there is “no action at a distance” (Smith, 1996).

The Problem with Particles

Particles are just “localized boundaries” between “simple to describe” domains (Mitchell, 1998). The content of a particle is not non-local, since the particle is said to represent the boundary between one group of CAs and another, and this boundary is precisely where the particle is to be found. The particle is a description of the boundary, not a physical representation of it, since the particle *is* the boundary. The particle do not have a *non-local* “stand-in” relationship with the boundary.

Requirements

In characterizing a representation, Rocha and Hordijk develop the three following requirements (Rocha and Hordijk 2005):

1. **Dynamically incoherent memory:** Material representations demand inert physical structures which can effectively be seen as dynamically incoherent regarding the overall machinery in which they are utilized as representations. The role of these physical structures is not defined by their dynamic characteristics but rather by their informational value.
2. **Construction Code.** There needs to exist machinery to construct arrangements of building blocks (which subsequently self-organize to produce some dynamic behavior) from the representations of Requirement 1 - an arbitrary construction code.
3. **Self-organization and selection.** The encoded building blocks, after construction via the code of Requirement 2, self-organize at different levels.

We add a **correspondence condition** which is the dynamic behavior caused by operation of the construction code that corresponds to a non-local process.

By **non-local** we assert that the dynamic behavior caused by the representation in memory must be dynamically incoherent in terms of the current state of the non-local dynamic process.

Second, by **correspondence** we mean the dynamic behavior caused by the construction code should have some covariance with the state of

the non-local dynamic process, likely the state of the non-local dynamic process at the time of its *storage* into memory.

The Representational Cycle

If the representational process is viewed over time, everything can be explained in terms of local cause and effect. This **representational cycle** is in a large part a rephrasing of Brian Smith’s concept of registration (Smith, 1996).

1. **Presentation:** Process *A* is in effective local contact with process *B*.
2. **Input:** The process *A* possesses dynamically incoherent memory M_a . An input procedure of *A* puts M_a in correspondence with process *B*. This is entirely non-spooky since *A* and *B* are in effective local contact.
3. **Separation:** Processes *B* and *A* change in such a way that the processes are non-local.
4. **Output:** Due to some local effect in process *A*, it activates a construction code that uses M_a to initiate the local dynamic behavior.

Representations are physically implemented structures that create local effects that are effective by virtue of their correspondence with non-local parts of the world.

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