Lecture 01.06 Robot artificiality and artificial life

artificial

We have claimed a necessary quality of a robot is that it is *artificial*, i.e. designed by humans. We include robots designed by robots designed by robots … designed by robots designed by humans. That is, as long as the original robot that begot further generations was designed by humans, these offspring are also considered artificial and therefore robots (if they also meet our other criteria for a robot). Robots designing robots—what does this mean?

artificial life

A field of interest to many roboticists is that of *artificial life*, which is the interdisciplinary (biology, chemistry, computer science, robotics, etc.) study of life itself and its artificial creation. The term "life" has no universally agreed upon definition, but certain features have been suggested as necessary, such as the following.

Appearing life-like is a tacit requirement for many people. Despite its apparent banality, this is perhaps not to be overlooked, for it is plausible that "the meaning of a word is its use in the language" (Wittgenstein and Anscombe, 2001). This has been taken to heart by artists such as Theo Jansen, who has created *strandbeests*: wind-powered kinetic sculptures that walk on the beech and appear life-like. This perspective is limited, however, since it doesn't elucidate the meaning of "life" to say that it is that which appears to be "life."

Self-organization is the process of local interactions of a disordered system yielding global order. Emergence in robotics is a form of self-organization. Examples of self-organization include ant colonies, crystal growth, and lasers.

Self-replication is the process of an entity creating a copy of itself (perfect or not). Of course, these copies would (usually) also be capable of reproducing.

Natural selection is the evolutionary process that requires both variation in self-replication and the natural survival and reproduction of those offspring that are better-adapted to the environment.

Autopoiesis is the (fundamentally cellular) logical loop that posits its own constitutive self-environment boundary as being caused by itself (Varela, 1996). Or, "life emerges when the external limitation (of an entity by its environs) turns into self-limitation" (Žižek, 2012).

Others suggest no such general qualities of life can be established (Wolfram, 2002, 2017) because our definitions are always relative to our own human perspective. One wonders, however, what more one could hope for from any definition.

01.06.1 Cellular automata

Early researchers constructed abstract models of life from small sets of basic rules.

One such model is the *cellular automaton*, which is a set of (abstract) cells in a grid (of any finite dimension) such that each cell has *neighbors*: is adjacent to others. Each cell can be in one of a finite number of states. A set of rules determine the new state of each cell at each (discrete) time step from its previous state and the previous state of its neighbors. Therefore, in non-stochastic models, a given initial state or *initial condition*, together with the set of rules, results in a deterministic process.

cellular automaton

neighbors

initial condition

In *Conway's Game of Life*, a two-dimensional cellular automaton, the two states are taken to be simply "populated" or "empty". The game has the following, simple rules:

Conway's Game of Life

> *For a space that is "populated":*
> *Each cell with one or no neighbors dies, as if by solitude.*
> *Each cell with four or more neighbors dies, as if by overpopulation.*
> *Each cell with two or three neighbors survives.*
> *For a space that is "empty" or "unpopulated":*
> *Each cell with three neighbors becomes populated.*

Somewhat surprisingly, very complex patterns emerge in this simple game. An example of what a game can look like is shown in Figure 01.10. Play it yourself, here

`www.conwaylife.com`.

Or download the app Golly here:

`golly.sourceforge.net`.

One such cellular automaton is *John von Neumann's universal constructor* self-replicating "machine," which works as follows (Von Neumann and Burks, 1966). Consider an automaton system containing the following elements.

John von Neumann's universal constructor

A description ϕ_1 of this system sans the description itself (for it cannot contain both itself and other automatons).

A universal constructor that can read a description of an automaton and construct it.

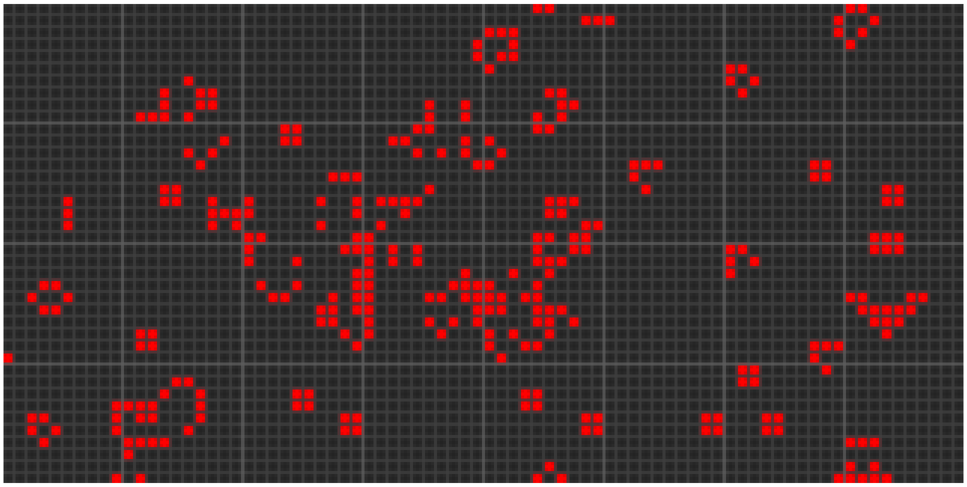

Figure 01.10: a game of life state at one moment in time. Red cells are "populated" and gray are not.

A universal copier that can copy any description of an automaton.
A controller that applies the constructor and copier.

Let the collection of the constructor, copier, and controller be called X_1. Then the original machine is (X_1, ϕ_1). The controller commands as follows. It

1. commands the copier to make two copies ϕ_2 and ϕ_3 of the instructions ϕ_1;
2. commands the constructor to read ϕ_3 (thereby destroying it) and construct a new machine (sans instructions) X_2; and
3. ties together X_2 with the undestroyed copy of the instructions ϕ_2.

Now there are two machines, the original (X_1, ϕ_1) and its descendant (X_2, ϕ_2).

01.06.2 Living robots?

Lest we seem to be too far afield from robotics, let's return to robots, proper, with their mechanical presences. We have examined how a robot might be considered intelligent—but alive? Some researchers not only think it is possible, they plan to make them.

For instance, the "Autonomous Robot Evolution" (ARE) project is designing an ecosystem for robot evolution (Hale et al., 2019). One of the key aspects of natural selection is competitive survival, which requires an arena. This project includes the creation of such an subsystem, along with several others, such as an ecosystem manager, a virtual environment, and a training environment.

This is one among several projects with artificial life as a goal. At this point, few have short-term ambitions to become mechanical, but the foundations are being laid.