A Simulation Environment for Emergent Properties

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Abstract: We propose a *multi-layer* architecture for simulating emergent properties. This is implemented as a form of cellular automaton at the lowest layer, with *mobile processes* to represent objects at multiple upper layers. This architecture supports *multiple levels of emergence.*

1 Introduction

Many definitions of emergence share the theme of existence of distinct *levels*, between which the emergence occurs. They might correspond to, for example, a change of spatial or temporal scale, be used only to simplify a description of behaviour, or they may be essential in *identifying* emergent properties. Regardless of the form of the emergence, levels always seem to be present, and can lead to a hierarchical structure of emergence.

Researchers tend to focus on the generation of emergence in a particular environment, or on simulating a particular natural behaviour. We provide a broader simulation architecture to study emergence, and emergence hierarchies as phenomena in general, whilst also permitting specific, constrained, simulations.

2 Overview of Architecture

The architecture is based on a series of communicating layers of abstraction. The lowest layer is implemented as a variant cellular automata (VCA), that need not be strictly finite, regular, and/or deterministic. This layer encodes environmental information, and captures absolute spatial reference. It forms the substrate of the emergent architecture. In keeping with similar work by Capcarrere [1], we call this the *environmental layer.*

The next layer is constructed from *mobile processes*, communicating with other processes in the same layer, the layer below, and the layer above, via mobile channels. We implement these mobile processes using features of the occam-π language [2]. This *primary mobile layer* uses rules without explicit spatial reference; it relies on *relative* spatial information transmitted from the lower layer. Additional layers of mobile processes can be added, either corresponding to levels in the emergence hierarchy, or purely for implementation convenience.

In their most basic form, the mobile processes simply *tag and track* emergent features at the lower levels, allowing the emergent features to be treated as objects in their own right at the higher level. But they may additonally encompass some of the logic of the simulation, providing information and instruction to lower level processes.

This use of higher level structuring allows us to engineer *specific* emergent behaviour. The system is designed with higher level objects, then rules are systematically *migrated* down to lower level objects. By migrating rules to the lowest VCA layer, we can remove the higher layers and achieve a primitive mono-layer system for implementation.

3 Case Studies

We are now using our occam-π simulation environment to study some simple models: a basic 1D model of platelet flow and blood clot formation [3]; emergent properties in a 2D environment, incorporating rule combination and migration [4]; unbounded growth of diffusion limited aggregation.

References

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