Treating Agent-Interactions in ABMs As Algebraic Structures

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# Introduction

# The nature of the MODULE

To be a module an algebraic structure must contain a primary set that is an additive group, G, satisfying four group axioms: closure, associativity, identity and invertibility. There is an operator ⊕ which takes two elements of the group and yields a third element and its operation satisfies these axioms.

In addition, a module contains a secondary set, R, a ring of coefficients, with a second operation, ⊗, which takes an element of R and an element of G and produces and element of G.

## An Analysis of a Generic ABM Interaction as a Module

### Elements: Following Whitehead (2014), we call the elements of our group *prehensions*. A prehension can be roughly understood as a state of affairs in the world *as seen from a particular point of view*. (In this case the world is the world of our model [see Morgan 2012], but Whitehead views this as a useful metaphysics for the actual world.)

### The operation ⊕, which we will call “prehend”, accepts two prehensions as arguments and produces a third prehension.

#### Axioms:

##### **Closure:** Every prehending involving two prehensions will produce a prehension.

##### **Associativity:** (a ⊕ b) ⊕ c = a ⊕ (b ⊕ c) In a typical agent model, this will mean that we must ensure that, say, a neighborhood can interact with a neighborhood (b ⊕ c), and then with an agent (a ⊕ (b ⊕ c)). Furthermore, this must produce an identical prehension to that produced by an agent interacting with one neighborhood and then another one ((a ⊕ b) ⊕ c).

##### **Identity:** Any prehension prehending the null prehension produces itself.

##### **Invertibility:** For any prehension, there is another prehension that combines with it to produce the null prehension.

### The operation ⊗, which we will call “intensify” (although it may also de-intensify) accepts an element of R and an element of G (a prehension), and produces an element of G.

#### Axioms:

##### a, b ∈ G:

###### (a ⊕ b)x = ax ⊕ bx

###### a(x ⊕ y) = ax ⊕ ay

### Meaning:

#### An agent’s prehension of itself is its view of its own internal state.

#### An agent’s prehension of its environment is its view of its surroundings.

#### But from the point of view of the prehension module, these prehensions are interchangeable.

#### A null prehension could arise, e.g., from the environment when an agent has no neighbors. It could arise internally when an agent has “no opinion” on the relevant parameters, e.g., a color-blind agent in our fashion model.

#### Invertibility may occur, for instance, when an agent has some internal tendency to act in some way (e.g., to move to a new neighborhood or switch fashions) but some force in the environment exactly offsets that tendency (e.g., that “authorities” establish come penalty for so acting).

#### An intensification of a prehension leaves the elements of the prehension in the same internal relationship, but they are scaled up or down relative to other prehensions. This is useful for capturing situations like the gradual dissipation of an attitude, or increasing fanaticism over time.

# The advantages of employing this abstraction

## Why bother?

### We achieve a uniform template for all models as far as how agents interact with their environment.

Programming new models becomes much easier. We have, in fact, been achieving code reductions on the order of 30-40% for models we have converted to the new paradigm.

### We will have taken a huge step towards enabling “fill-in-the-template” style programming of ABMs.

A non-programming user ultimately should be able to build his model by choosing from a palette of possible module operations, setting parameters for each, and chaining them together.

### We open up the possibility of using known properties of modules to identify properties of our ABM.

This has not been achieved yet, but the possibility always remains open.

# a sketch of the usual action pattern

An agent gathers together a prehension of its environment, and then combines that with how it views its own state (its self-prehension) to produce a new prehension. The new prehension may simply be adopted, or it may trigger some further step, such as a movement in space on the part of the agent. And each agent may prehend not only a local slice of the overall environment, but a different sized slice as well.

The combination of very generic processing in treating the prehensions with individual agent flexibility in responding to that outcome allows us to combine some of the best features of older-style simulations with ABMs.

## Some examples:

### Fashion model

The prehension returned from the environment will be a vector representing the mix of fashions being worn in the agent’s neighborhood. The agent will modify her own preferred fashion based on that vector and the sort of agent she is. (Fashion followers will incline toward the prevailing fashion, while trend-setters will move away from it.)

### Financial market model

The prehension returned from the environment will be a vector representing the buy/sell sentiment prevailing around the agent. The agent will modify her own market stance based on that vector and the sort of agent she is. (Chart followers will incline toward the prevailing sentiment, while value investors will move away from it.)

### Schelling’s segregation model

In this model, the agent prehends the color mix of his neighborhood. We normalize the vector we get back, and project it onto the axis representing his own color. His self-prehension represents his minimum percentage “like him” he will tolerate in his neighborhood. If the normalized, projected vector representing the neighborhood Falls below that amount, the agent jumps to a random cell.

However, while the above may be typical, our system allows for the reverse: in some models (e.g., Forest Fire), it may be the environment that adopts the new prehension. Furthermore, environmental prehensions may interact directly with each other as well.

# Implementation details

The following are the main modules implementing this paradigm. They have been written up for maximum readability, in both the comments and especially the code itself. (See Knuth, 1992.)

## prehension.py

## prehension\_agent.py

## two\_population\_model.py

## segregation\_model.py

## fashion\_model.py

## fmarket\_model.py

# Bibliography

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