Agent-based Modeling

Adam Getchell

Nonlinear Physics: Modeling Chaos and Complexity

What is an Agent?

Historically related to the Von Neumann machine, as later improved by Stanislaw Ulam into the first agent-based device – the cellular automata

Agents have:

- Activity
- Autonomy
- Heterogeneity

Agent Activity

- Goal-direction
- Reactivity/Perceptivity to its surroundings (model)
- Mobility: Able to roam the model space independantly
- Bounded Rationality (imperfect information)
- Interacts/exchanges information with other agents, which may in turn cause:
- Adaptation: Change in behavior based on interactions with the model or other agents

What is a Model?

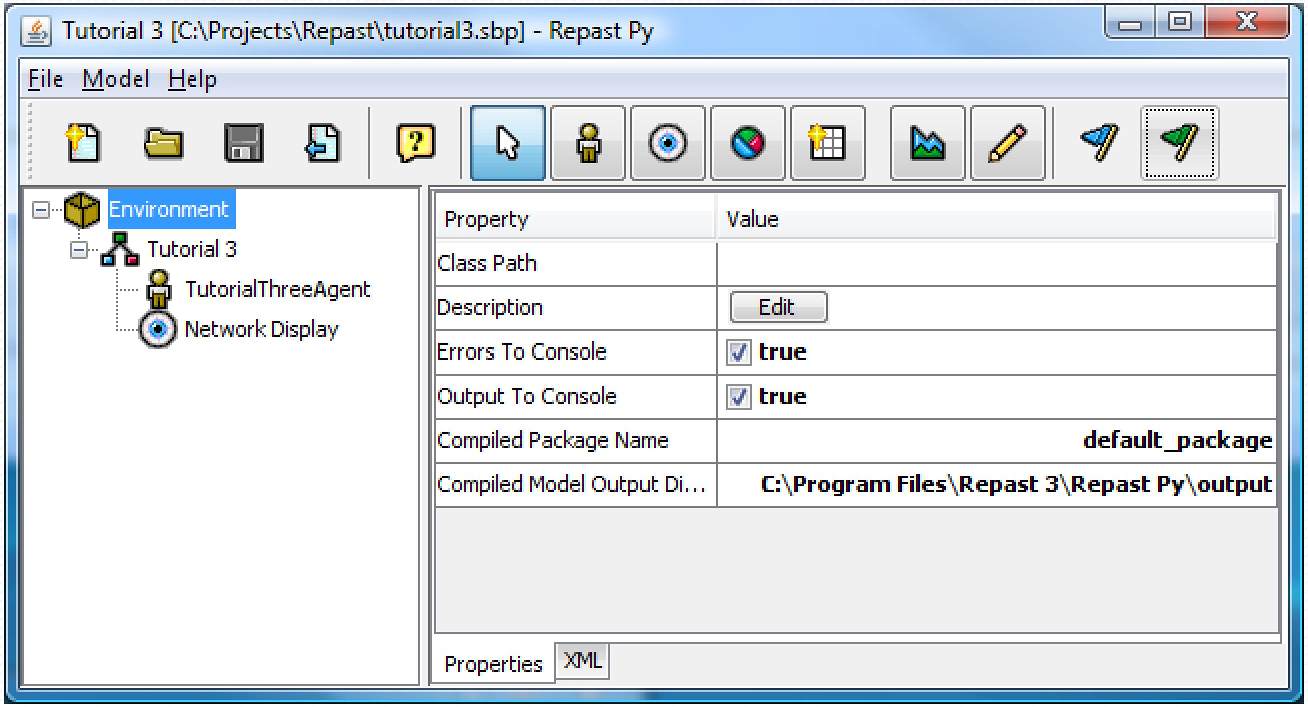
```
import breve

class myControl( breve.Control ):
    def __init__( self ):
            breve.Control.__init__( self )
            self.walkerShape = None
            myControl.init( self )

    def getWalkerShape( self ):
            return self.walkerShape

    def init( self ):
            print '''Setting up the simulation.'''
            self.pointCamera( breve.vector( 0, 0, 0 ), breve.vector( 0, 60, 0 ) )
            self.walkerShape = breve.createInstances( breve.Sphere, 1 ).initWith( 1 )
            breve.createInstances( breve.RandomWalker, 200 )


breve.myControl = myControl
class RandomWalker( breve.Mobile ):
    def __init__( self ):
            breve.Mobile.__init__( self )
            RandomWalker.init( self )

    def init( self ):
            self.setShape( self.controller.getWalkerShape() )
            self.setColor( breve.randomExpression( breve.vector( 1.000000, 1.000000, 1.000000 ) ) )
            self.move( breve.randomExpression( breve.vector( 0.100000, 0.100000, 0.100000 ) ) )

    def iterate( self ):
            self.setVelocity( ( breve.randomExpression( breve.vector( 60, 60, 60 ) ) - breve.vector( 30, 30, 30 ) ) )


breve.RandomWalker = RandomWalker


# Create an instance of our controller object to initialize the simulation

myControl()
```

Tools and Languages in 2008

Program	Language(s)	Description
Swarm	Objective-C, Java	Agent modeling library, dated, last release version 2.2 February 2005
RepastJ	Java	Based on Swarm, written specifically in Java
RepastPy	Python	Friendly GUI, uses Python for scripting, limited
Repast.NET	C#, VB.NET	Leverages .NET framework, doesn’t work with Visual Studio 2008
Repast Simphony	Java	Full-featured, uses Eclipse IDE, can be difficult to setup
MetaABM	Java	Full-featured, uses Eclipse IDE plus own GUI, designed to use standard model file that can work with other tools (Repast, Weka, VisAD, MatLAB), can be difficult to setup
Breve	Steve, Python, Push	Fast, easy to use 3d simulation environment targeted towards physics and artificial life

RepastPy -- Model

- Simple GUI which generates Java classes

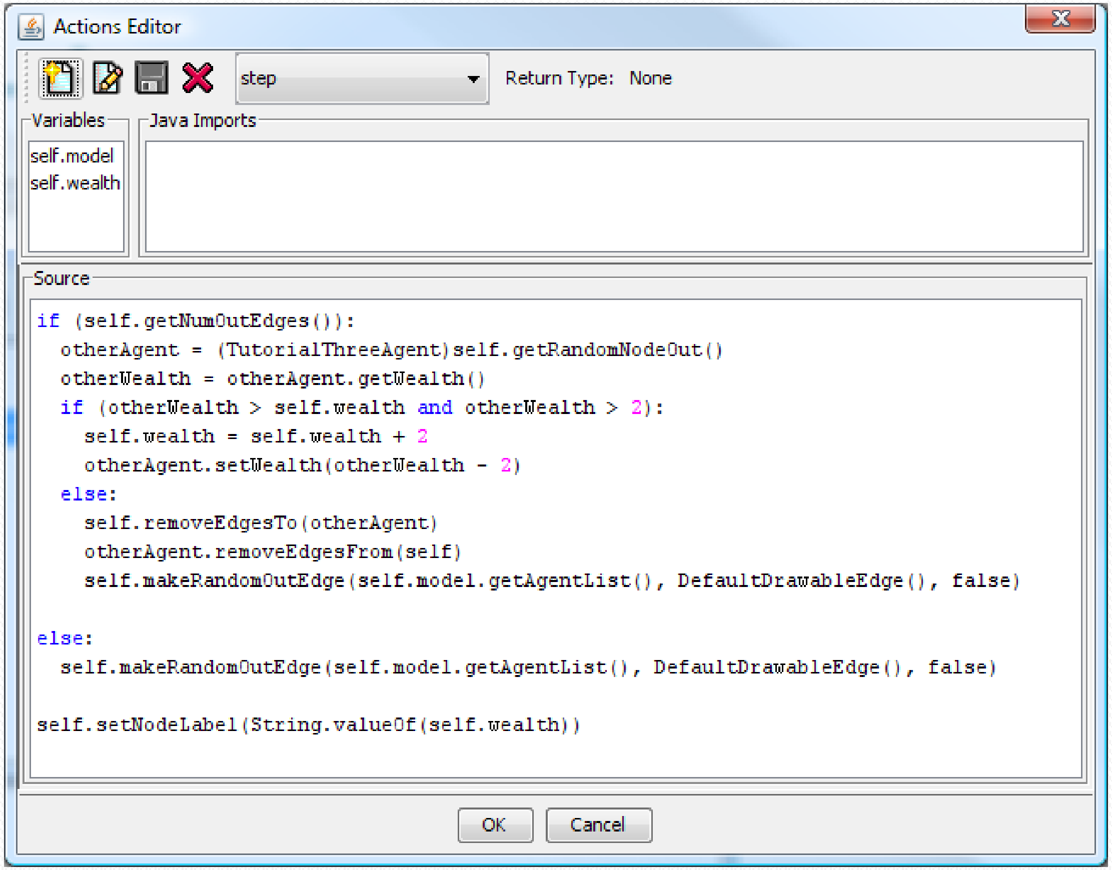


Tutorial 3 [C:\Projects\Repast\tutorial3.sbp] - Repast Py

Property	Value
Class Path	
Description	Edit
Errors To Console	☑ true
Output To Console	☑ true
Compiled Package Name	default_package
Compiled Model Output Di...	C:\Program Files\Repast 3\Repast Py\output

RepastPy – Agent

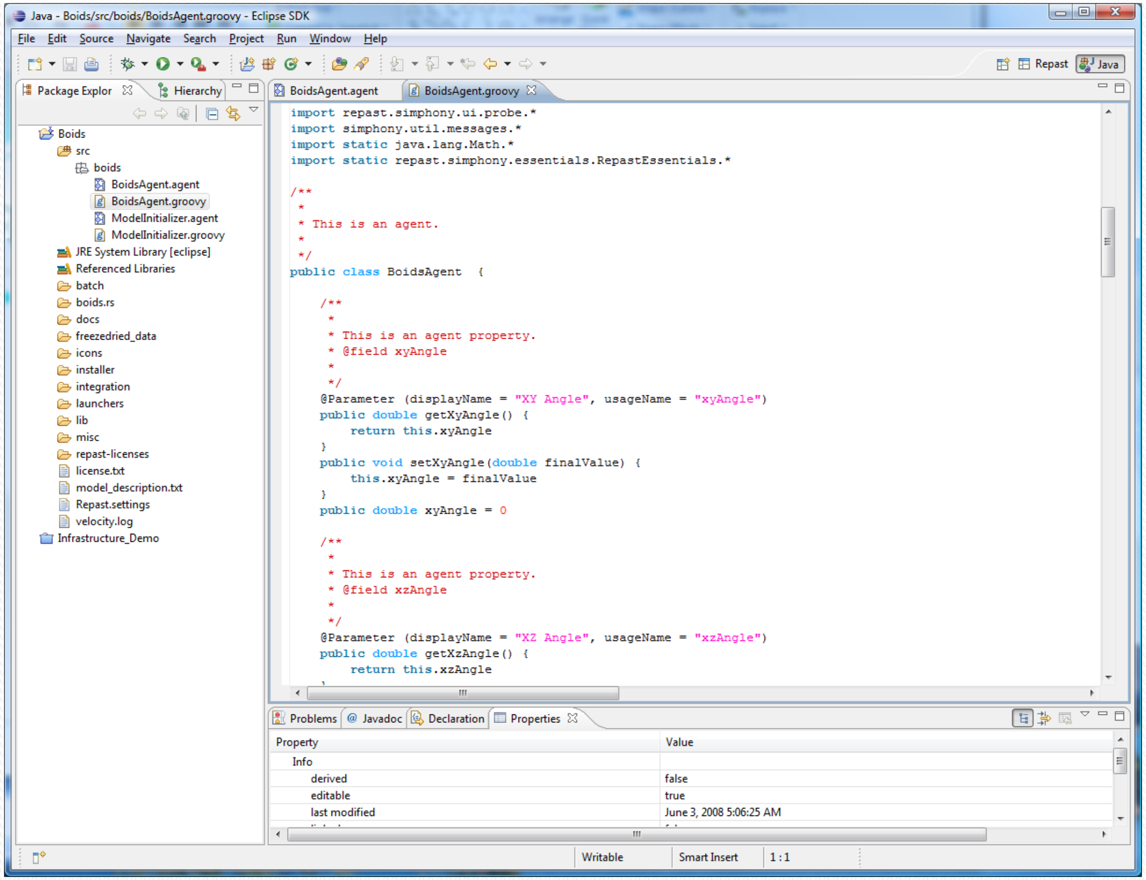
Simple Python scripting for behaviors



```
if (self.getNumOutEdges()):
  otherAgent = (TutorialThreeAgent)self.getRandomNodeOut()
  otherWealth = otherAgent.getWealth()
  if (otherWealth > self.wealth and otherWealth > 2):
    self.wealth = self.wealth + 2
    otherAgent.setWealth(otherWealth - 2)
  else:
    self.removeEdgesTo(otherAgent)
    otherAgent.removeEdgesFrom(self)
    self.makeRandomOutEdge(self.model.getAgentList(), DefaultDrawableEdge(), false)

else:
  self.makeRandomOutEdge(self.model.getAgentList(), DefaultDrawableEdge(), false)

self.setNodeLabel(String.valueOf(self.wealth))
```

Repast Simphony

- Uses Java + Groovy to compile an application



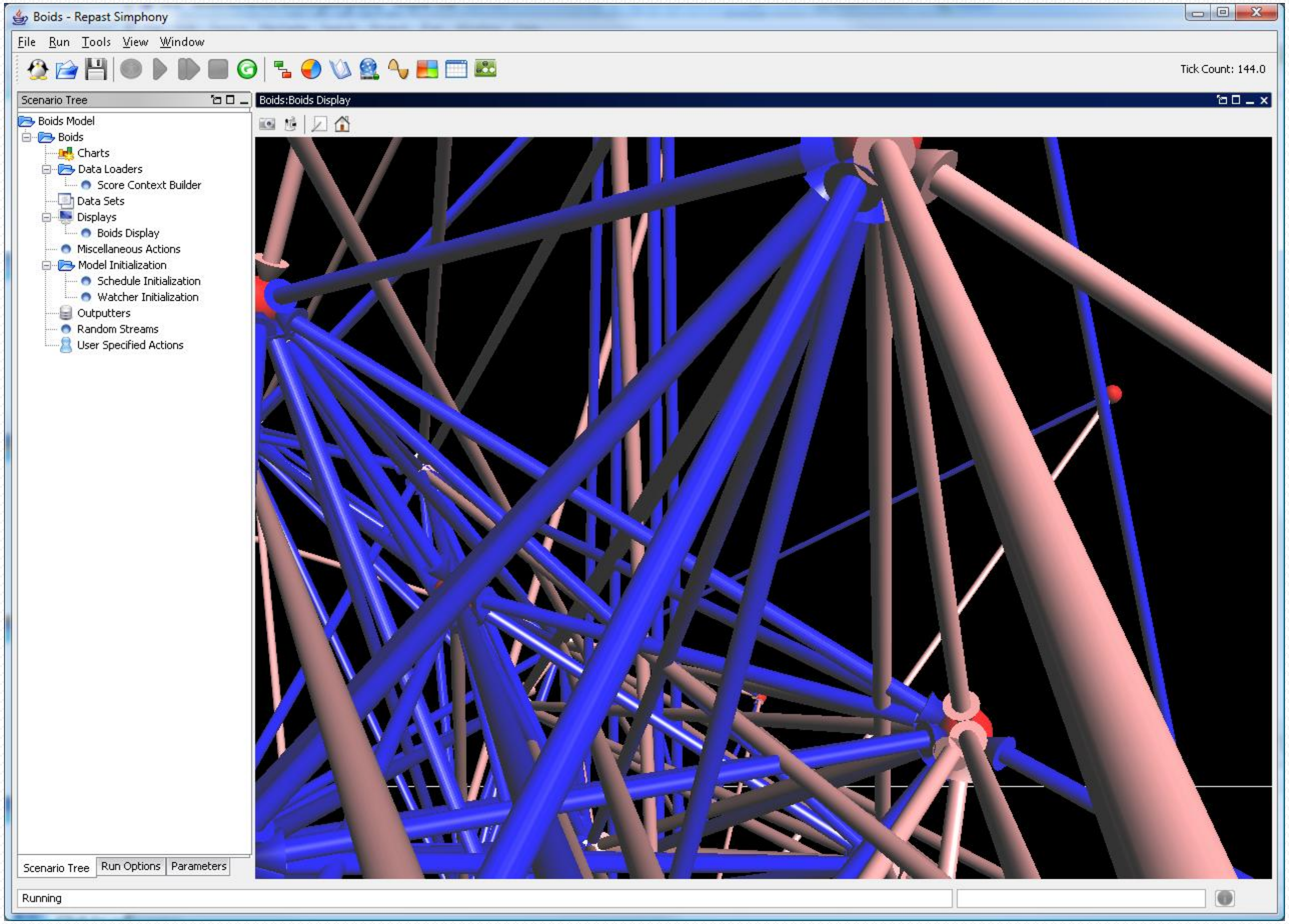
```
import repast.simphony.ui.probe.*
import simphony.util.messages.*
import static java.lang.Math.*
import static repast.simphony.essentials.RepastEssentials.*

/**
 *
 * This is an agent.
 *
 */
public class BoidsAgent  {

    /**
     *
     * This is an agent property.
     * @field xyAngle
     *
     */
    @Parameter (displayName = "XY Angle", usageName = "xyAngle")
    public double getXyAngle() {
        return this.xyAngle
    }
    public void setXyAngle(double finalValue) {
        this.xyAngle = finalValue
    }
    public double xyAngle = 0

    /**
     *
     * This is an agent property.
     * @field xzAngle
     *
     */
    @Parameter (displayName = "XZ Angle", usageName = "xzAngle")
    public double getXzAngle() {
        return this.xzAngle
```

Property	Value
Info	
derived	false
editable	true
last modified	June 3, 2008 5:06:25 AM

Boids

- A kind of 3D Life simulation producing chaotic behavior. The rules are:
  1. Boids try to fly towards the center of mass of neighboring boids (usually, the perceived CoM with respect to that particular boid)
  2. Boids try to keep a small distance away from other objects (including other boids)
  3. Boids try to match velocity with near boids (perceived velocity of neighbors)

A Simphony of Boids



Tick Count: 144.0

Running

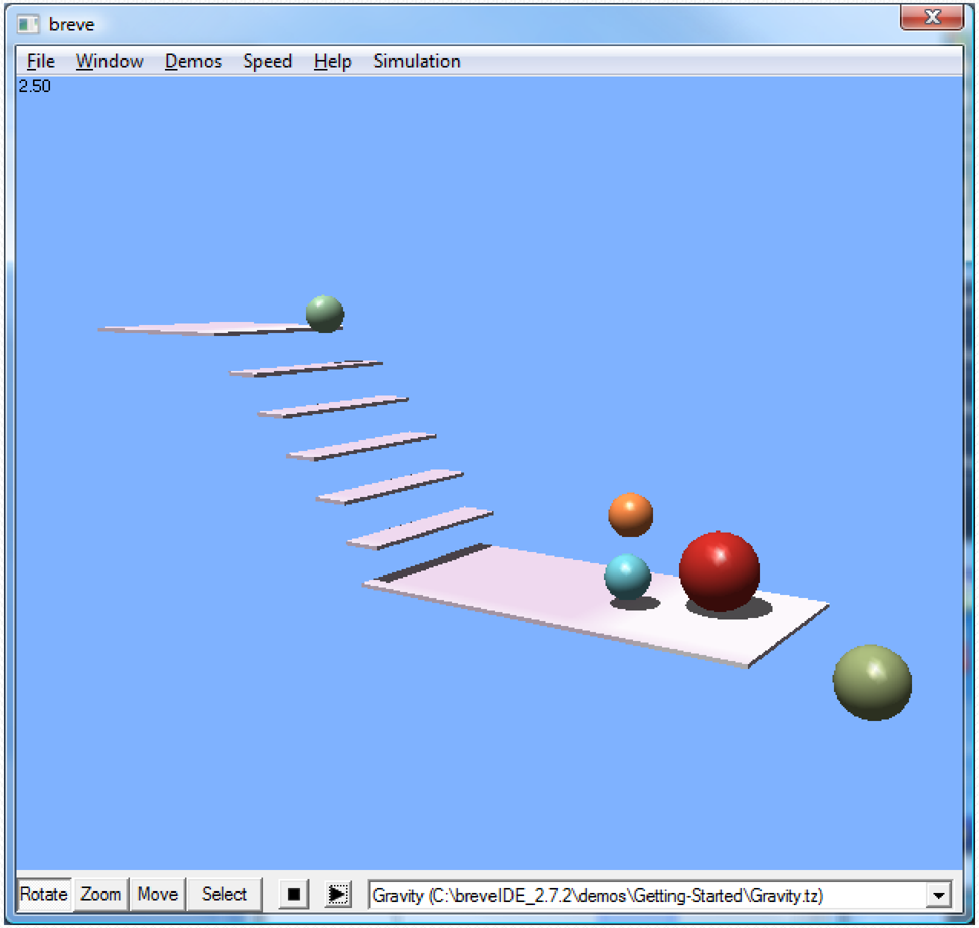
breve – basic Controller/Agent structure (Python)

```
import breve

class HelloWorld( breve.Control ):
    def __init__( self ):
        breve.Control.__init__( self )

    def iterate( self ):
        print "'Hello, world!'"
        breve.Control.iterate( self )


breve.HelloWorld = HelloWorld


# Create an instance of our controller object to initialize the simulation

HelloWorld()
```

breve – basic Controller/Agent structure (steve)

```
@include "Control.tz"

Controller HelloWorld.

Control : HelloWorld {
   + to iterate:
      print "Hello, world!".
  super iterate.
}
```

breve – Gravity & 3D collisions



Gravity (C:\breveIDE_2.7.2\demos\Getting-Started\Gravity.tz)

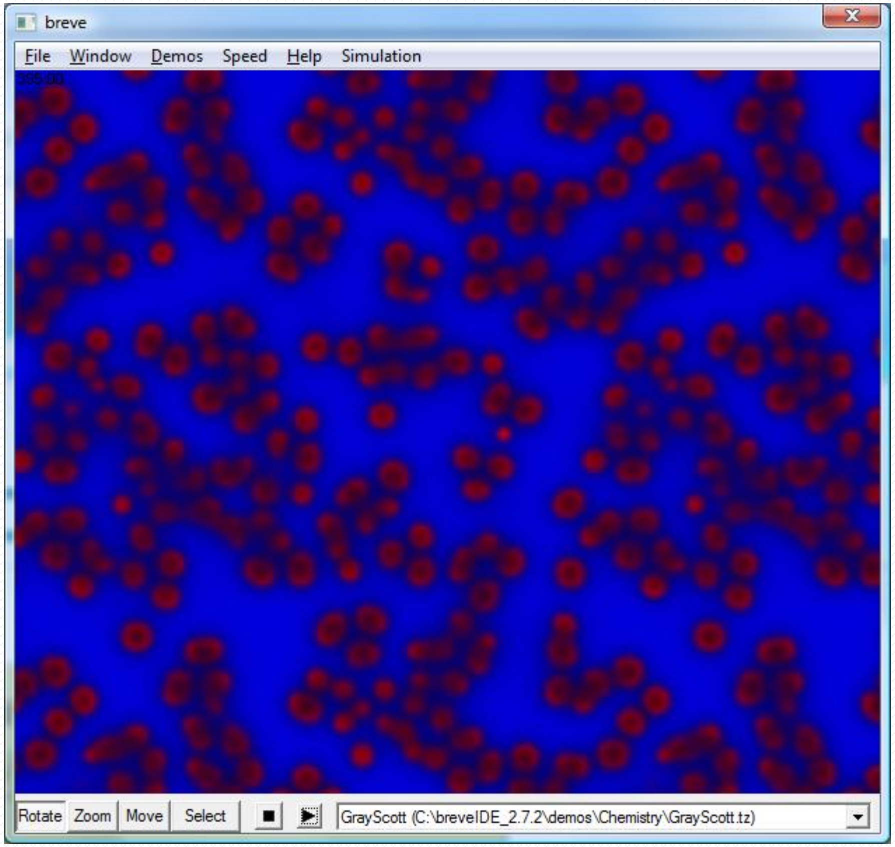
breve – Gray Scott model of reaction diffusion

Equations:

$$\begin{aligned}\frac{\partial u}{\partial t} &= r_u \nabla^2 u - uv^2 + f(1-u)\\ \frac{\partial v}{\partial t} &= r_v \nabla^2 v + uv^2 - (f+k)v\end{aligned}$$

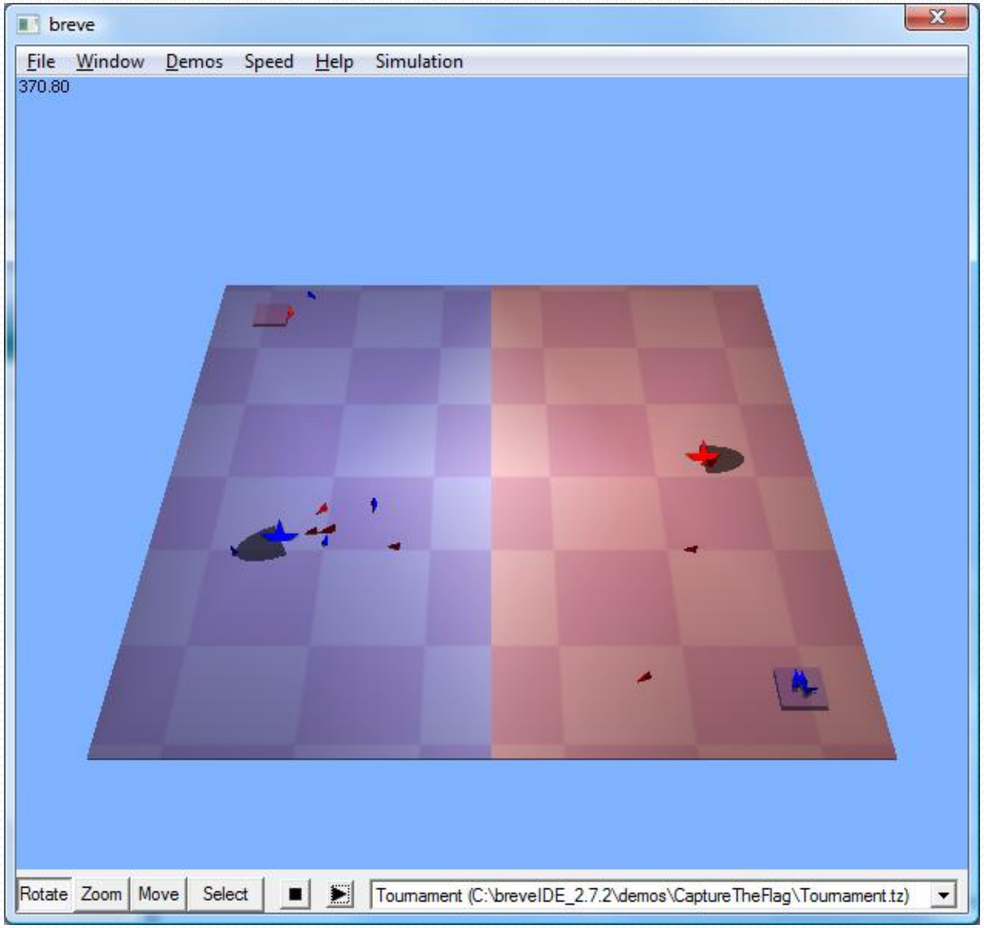
Chemical Reaction:

$$\begin{aligned}U + 2V &\rightarrow 3V\\ V &\rightarrow P\end{aligned}$$

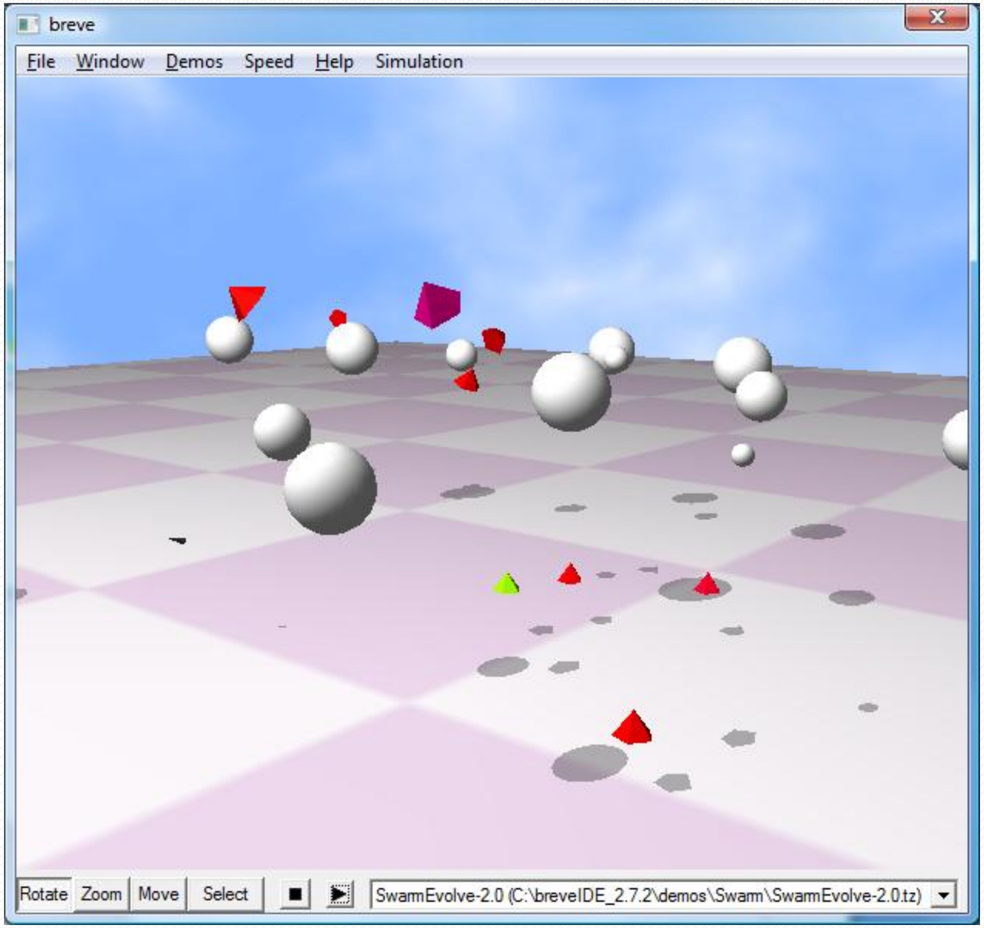


GrayScott (C:\breveIDE_2.7.2\demos\Chemistry\GrayScott.tz)

breve – Capture the Flag


breve
File Window Demos Speed Help Simulation
370.80
Rotate Zoom Move Select
Tournament (C:\breveIDE_2.7.2\demos\CaptureTheFlag\Tournament.tz)

breve – boids to evolving swarms


breve
File Window Demos Speed Help Simulation
Rotate Zoom Move Select
SwarmEvolve-2.0 (C:\breveIDE_2.7.2\demos\Swarm\SwarmEvolve-2.0.tz)

Evolving swarms

In addition to the behaviors of boids, swarm agents:

- Seek out food, which randomly teleports around
- Feed their friends with excess food
- Reproduce when energy (food) hits certain threshold
- Die when they run out of energy, or reach maximum age
- Land on the ground, rest, fly around again
- Mutate in such a way as to improve/reduce reproduction

So how to you mutate code that must be pre-defined?

Push

Genetic programming – random crossover and mutation of computer programs

- Doesn’t work for most computer languages, since they typically have rigid syntax:
- This makes sense:

```
L = [math.exp(val) for val in eigenvalues]
```

- This does not:

```
eigenvalues ] in math.exp(val) = L ] for
```

Push

- Programs made up of: instructions, literals, and sublists
- Push program is an expression, entirely placed on the stack and evaluated recursively according to these rules:
  1. If P is an instruction then execute it
  2. Else if P is a literal then push it on to the stack
  3. Else (P must be a list) sequentially execute each of the Push programs in P

Sample Push program and execution

(2 3 INTEGER. * 4.1 5.2 FLOAT.+ TRUE FALSE BOOLEAN.OR)

- Pushing onto the stack from left to right, we then pop the stack right to left :
- First run is: BOOLEAN.OR FALSE TRUE = (TRUE) (BOOLEAN stack)
- Next we have: FLOAT.+ 5.2 4.1 = (9.3) (FLOAT stack)
- Finally we have INTEGER.* 2 3 = (6) (INTEGER stack)

Note that each stack has its own type, the stack-based typing system puts each instruction on its own type of stack, so that any combination remains semantically valid. We could re-order all of these stacks without issue.

The main trick is to devise programs that actually produce changeable behaviors in the agents, so they can be selected for or against

References

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