OTTO VON GUERICKE UNIVERSITÄT MAGDEBURG

INF FAKULTÄT FÜR INFORMATIK

Agent-Based Modelling and Simulation in AnyLogic

Cells and Birds

Agents in AnyLogic

Types of agents in Anylogic

- Population of agents → "real" ABMS
- A single agent → a "normal" model element
- Agent type → a type / Java class

Agent Elements

- Speed, position, rotation
- Custom Parameters
- Animation Shape
- Functions, variables, etc.

Agents Environment & Connections in AnyLogic

Discrete Environment

- Grid & Dimensions: columns, rows, width, height
- Neighborhood type: Moore/Euclidean
- Layout: Random, Arranged
- Network: Random, Ring lattice, Small world, Scale–free, User–defined

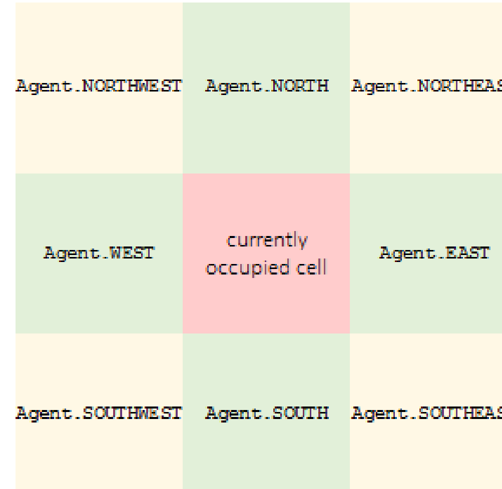
Continuous Environment

- Dimensions: width, height, z–height
- Layout: Random, Arranged, Ring, Spring mass, User–defined
- Network: Random, Distance–based, Ring lattice, Small world, Scale–free, User–defined

GIS Environment

- maps, routes, ...

Agents Movements in AnyLogic



Discrete Space

- Current position: row / column
- Moving in specific direction
- Jumping to target cell / random cell
- Swapping with other agent / cell

Continuous Space

- Current position (x,y,z) and target location (x,y,z)
- Move towards specific coordinates (x,y,z)
- Move towards nearest / specific agent
- Move to node / attractor
- Speed or trip time are explicitly set

Agents Interactions in AnyLogic

General (Discrete & Continuous)

- Network determines connected agents, on startup or dynamically
- Connections can be explicitly established and cut
- *Agent[] getConnections()* – returns list of all connected agents

Discrete Space

- Neighborhood also determines connected agents
- *Agent[] getNeighbors()* – returns list of all agents in chosen neighborhood (Moore/Euclidean)

Communication

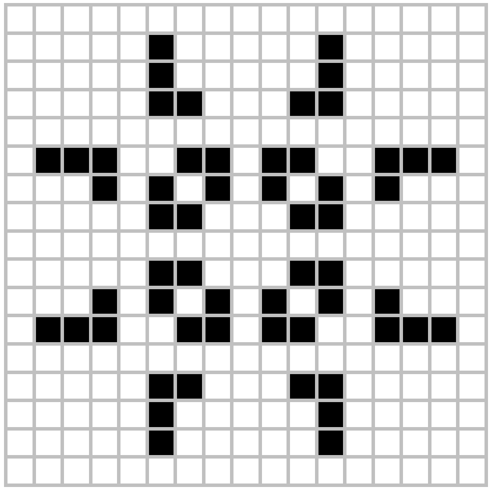
- Connected agents can access each others properties
- Agents can send messages to connected or other agents

Agents (inter–)actions can be synchronized by using steps

- Specific code fragments for: on before step, on step, on after step

Game of Life

Simple Examples



Game of Life

- Cellular automaton
- Each cell can be either alive or dead
- Next generation state depends on Moore–neighborhood

Rules

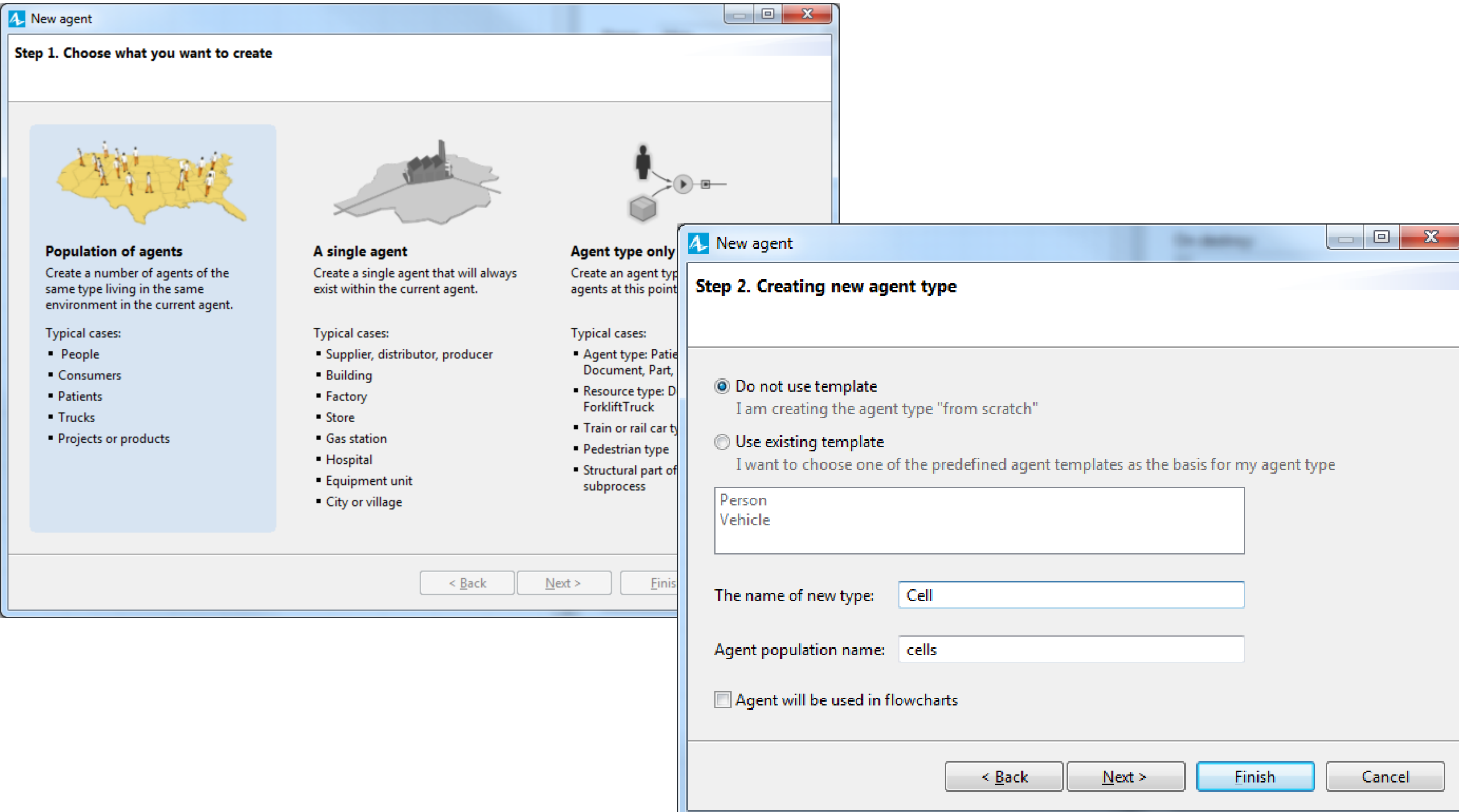
1. A dead cell with 3 live neighbors comes alive
2. A living cell with less than 2 live neighbors dies
3. A living cell with 2 or 3 live neighbors stays alive
4. A living cell with more than 3 live neighbors dies

Specifics

- Grid 50x50 → 2500 Cells

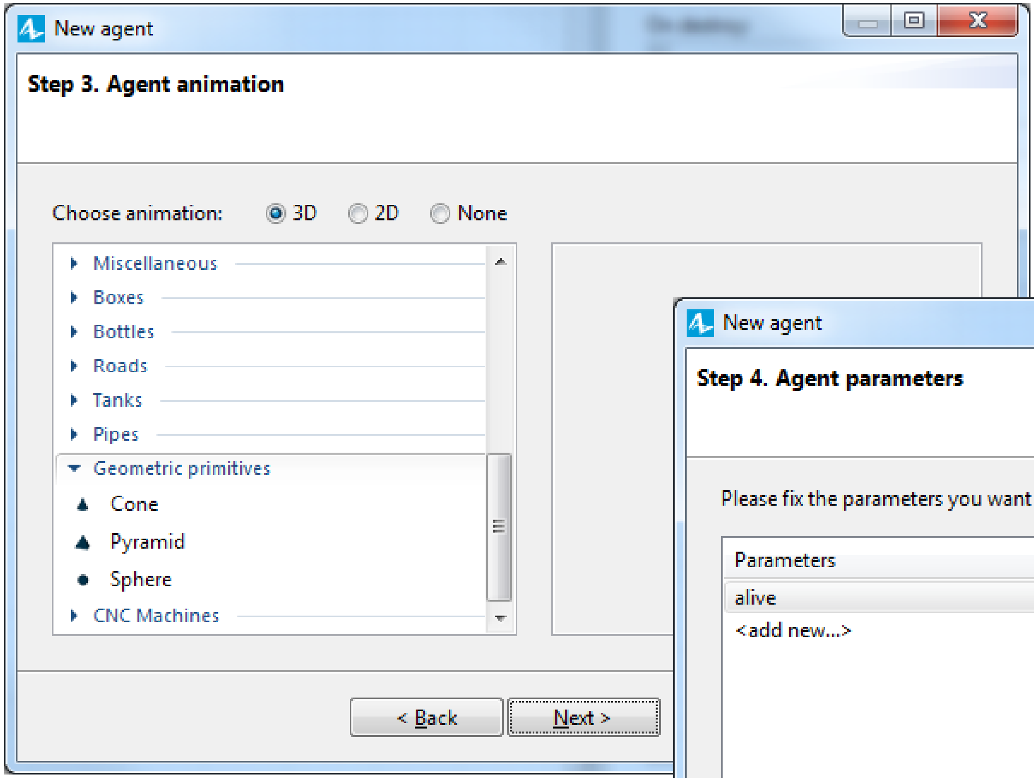
Game Of Life

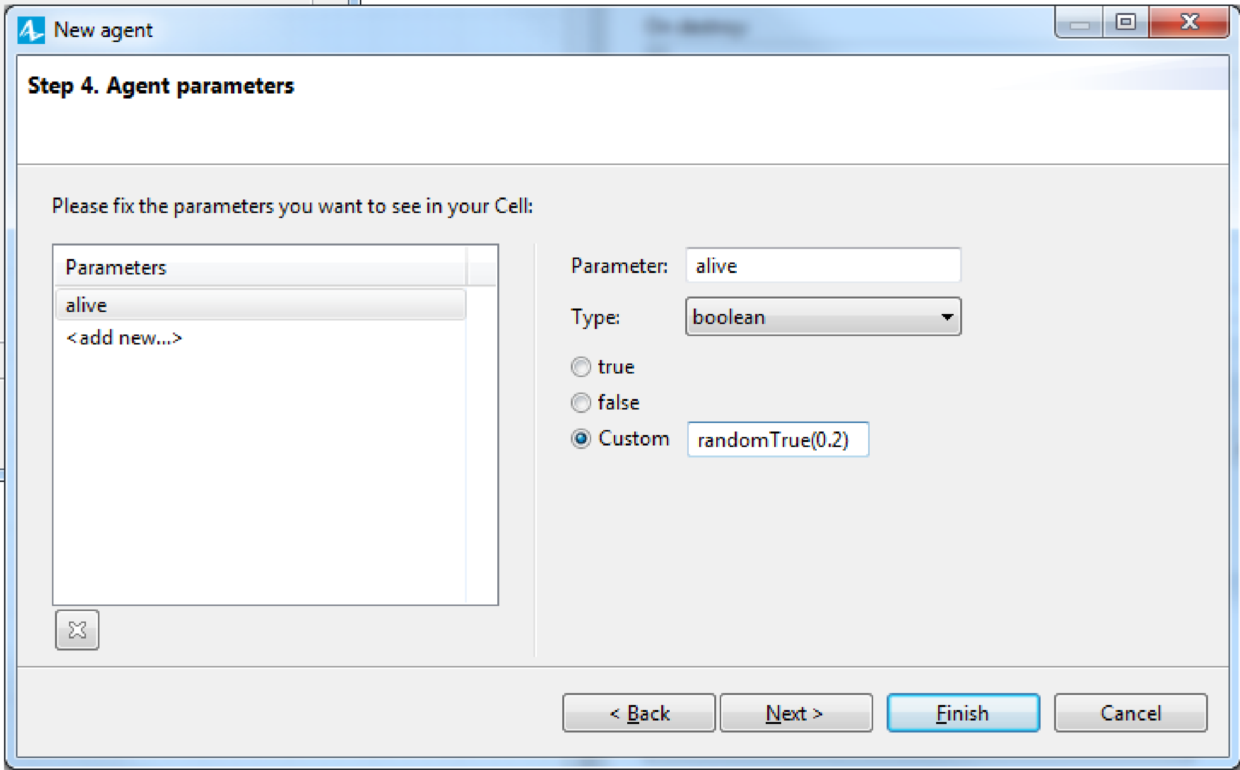
Agent Type & Name



Game Of Life

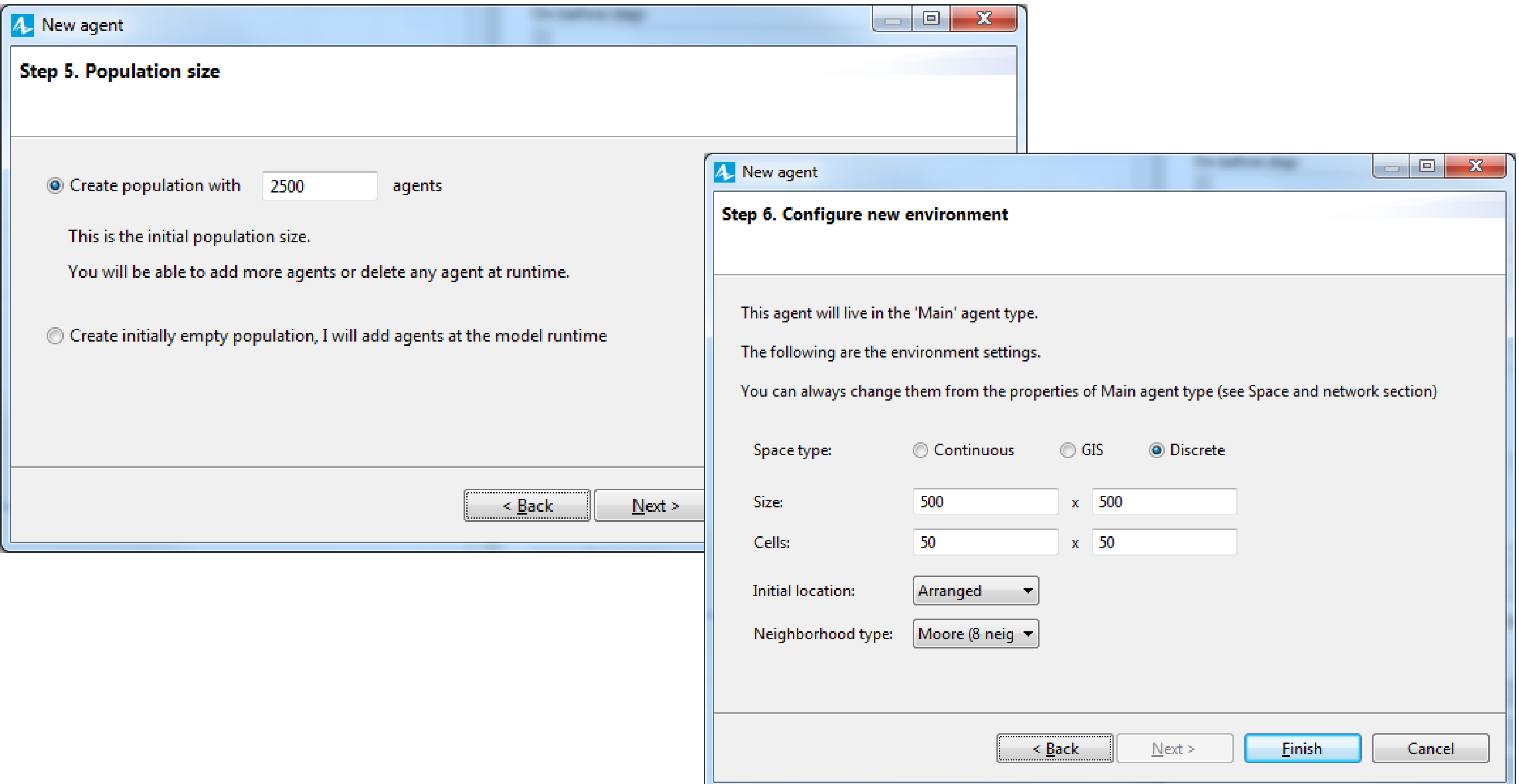
Animation & Properties





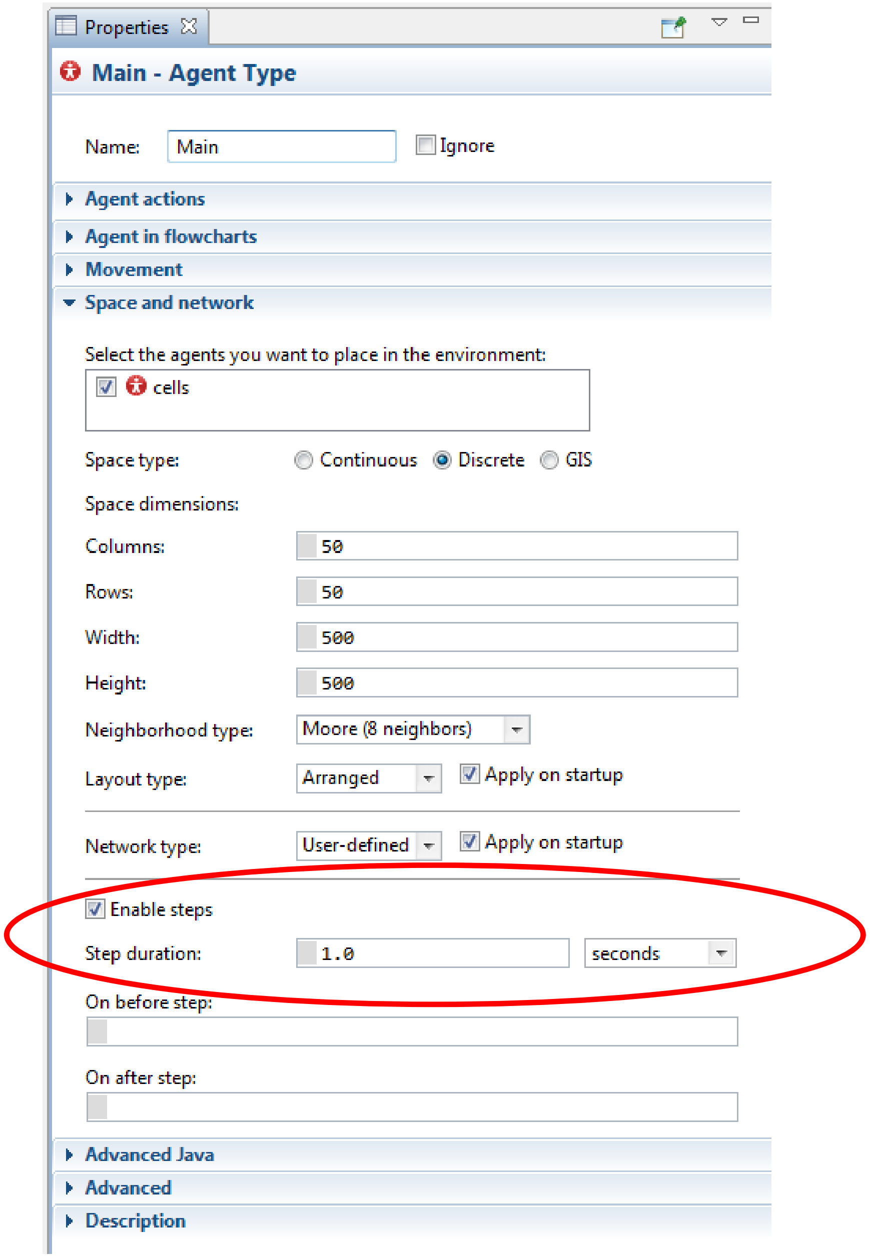
Game Of Life

Population Size and Environment



Game Of Life

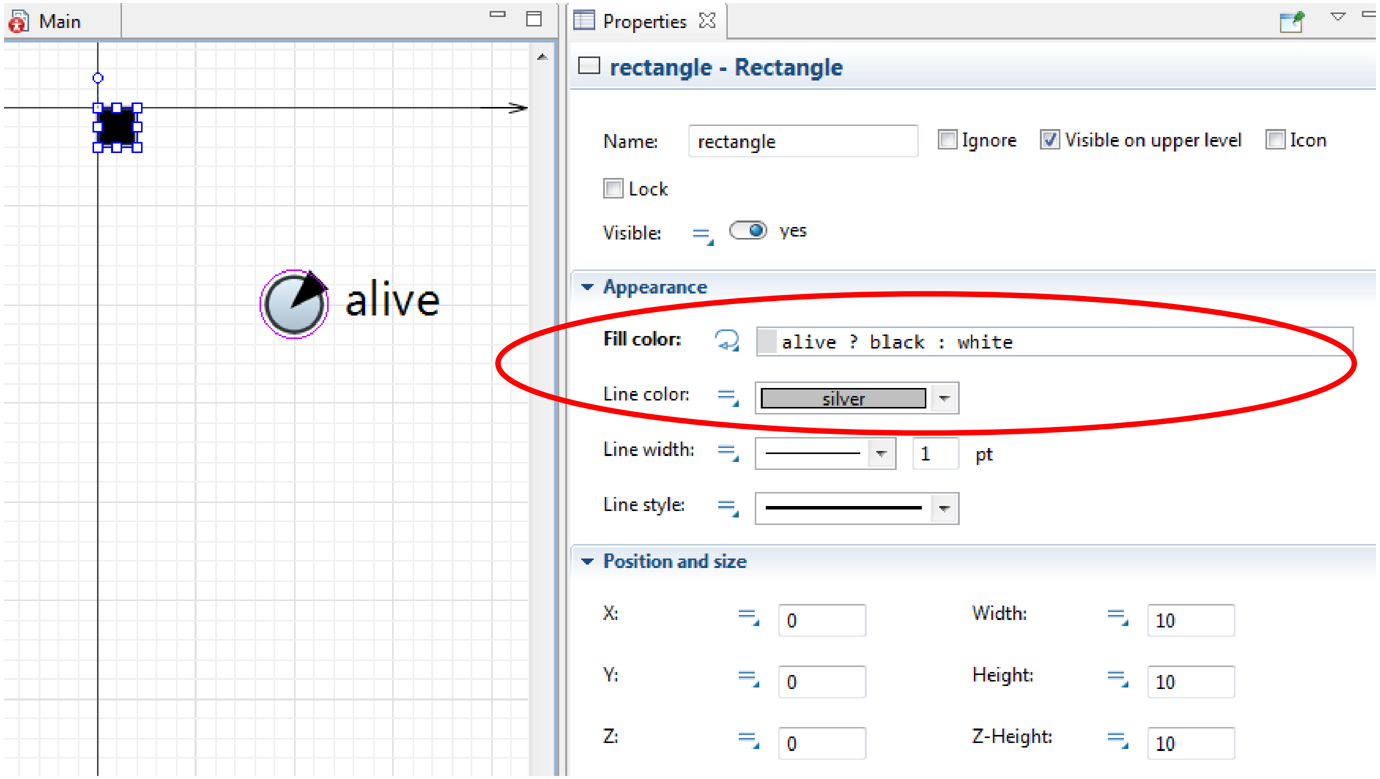
Synchronize cell generations



Game Of Life

Agents graphical representation

- Rectangle with dynamic fill color 10x10 pixels
- Line color results in regular grid



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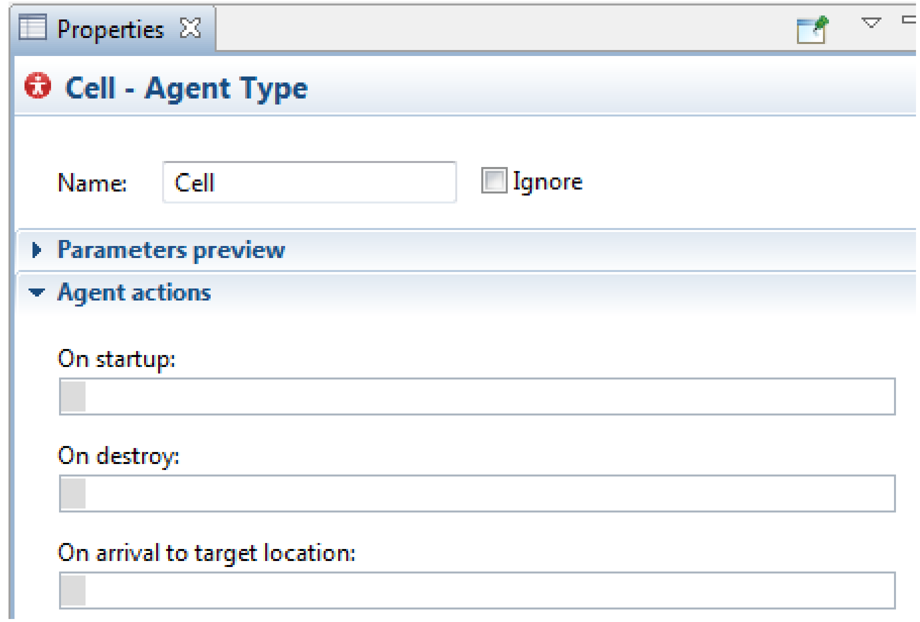
Game Of Life

Dynamic behavior

1. A dead cell with 3 live neighbors comes alive
2. A living cell with less than 2 live neighbors dies
3. A living cell with 2 or 3 live neighbors stays alive
4. A living cell with more than 3 live neighbors dies



On step:

```
//count live neighbors
int liveNeighbors = 0;
for(Agent a : getNeighbors())
    if(((Cell)a).alive) liveNeighbors++;
//rule 1
if(!alive && liveNeighbors == 3)
    alive = true;
//rule 2 & 4
if(alive && (liveNeighbors < 2 || liveNeighbors > 3))
    alive = false;
```

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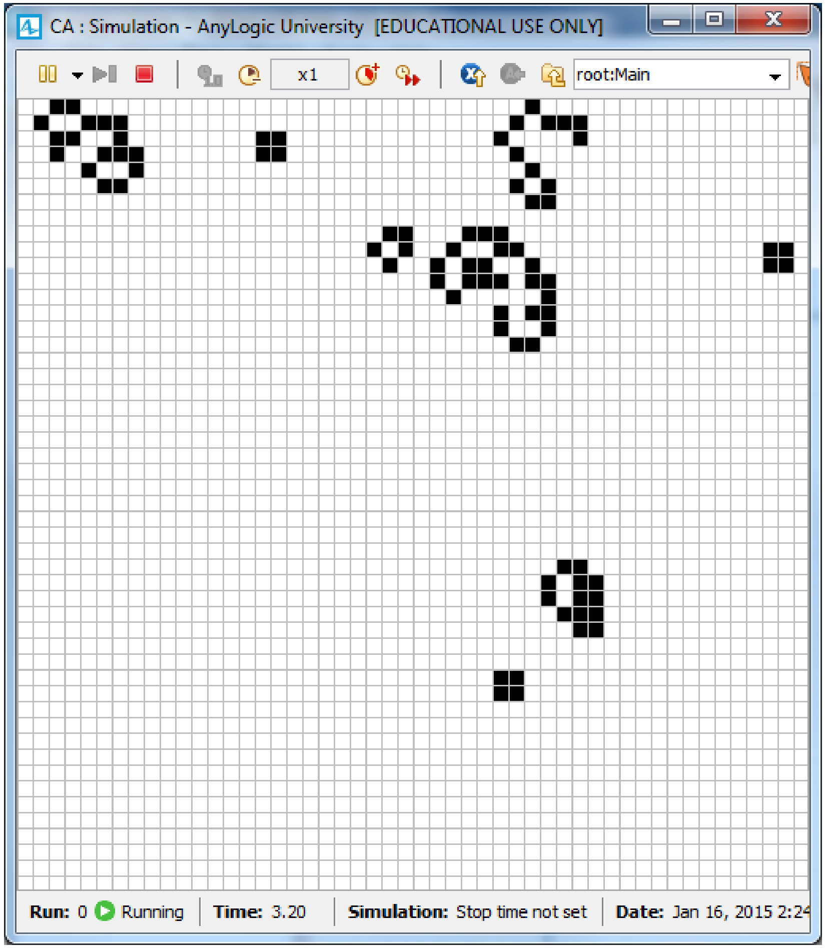
Game Of Life

Resulting dynamic behavior



Game Of Life

Possible questions to solve at home …

- Parameterize initial number of living cells
- Display development of number of living cells per generation
- Enable manual toggling of cells

Modeling a Bird Flocking Behavior

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Simple Examples

Flocking behavior of birds

- Continuous space and movement
- Birds adapt their flight pattern to other birds in their vicinity
- Results in complex, seemingly coordinated flight patterns → flocks

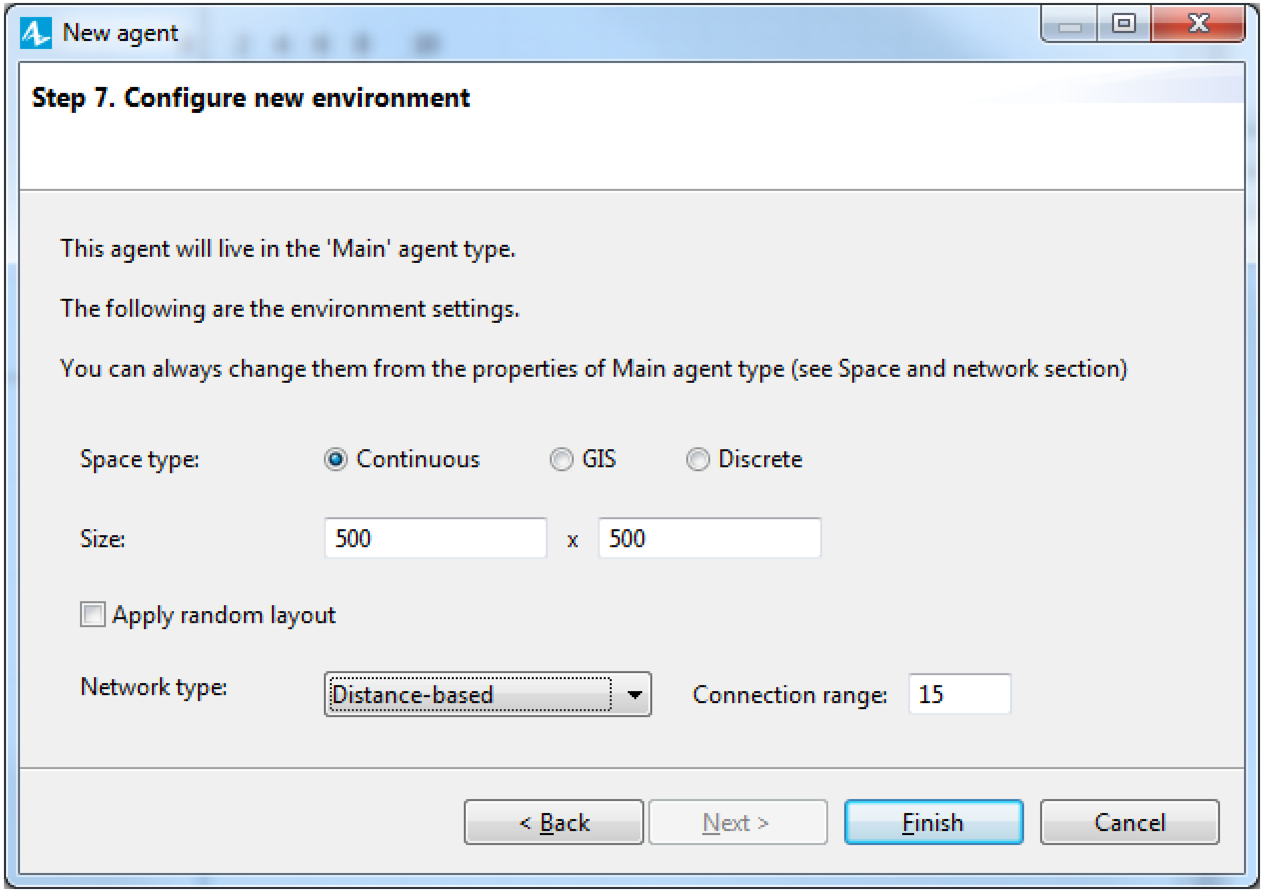
Rules

1. Separation – avoid crowding neighbors (short range repulsion)
2. Alignment – steer towards average heading of neighbors
3. Cohesion – steer towards average position of neighbors (long range attraction)

Flocking Birds

Initial properties

- Continuous environment, random layout, distance based network



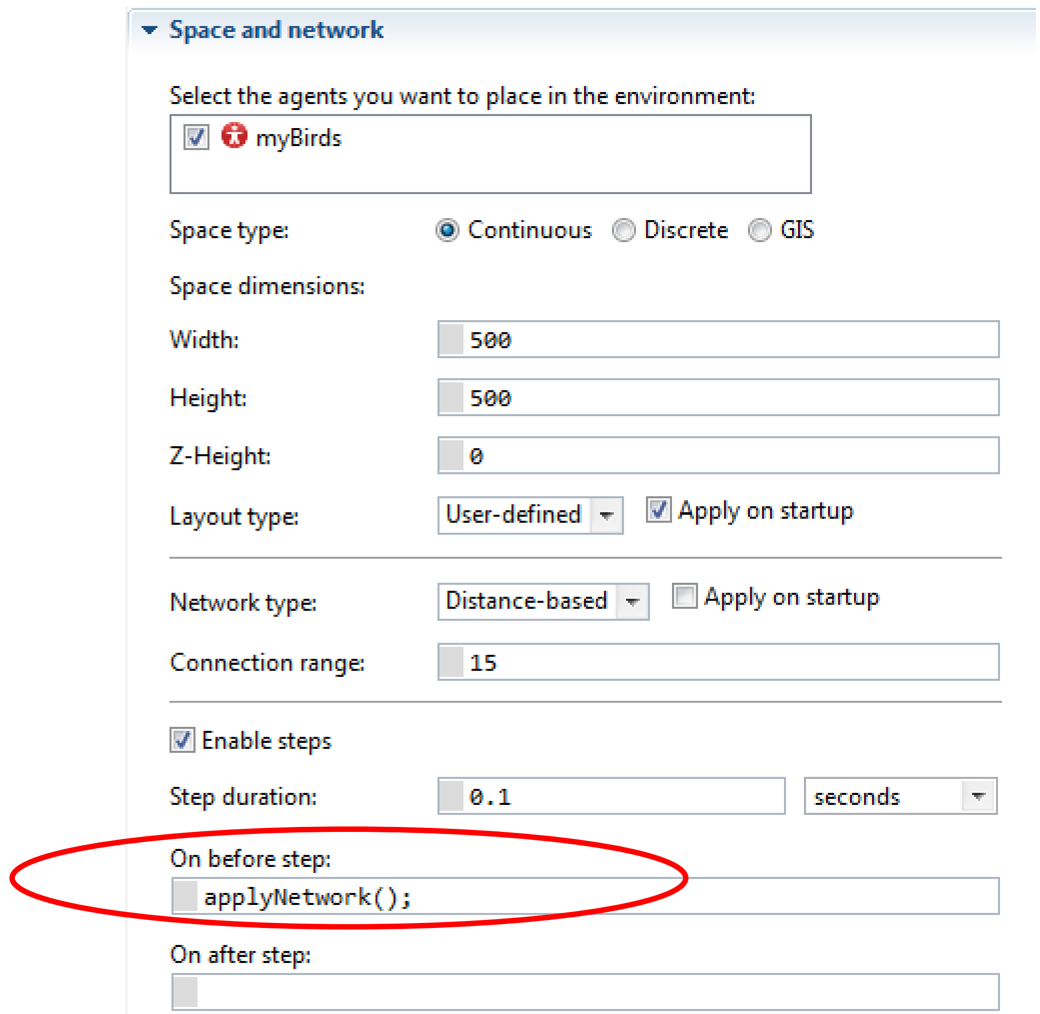
Flocking Birds

Layout

- User defined

Network

- Distance based
- Applied in every step



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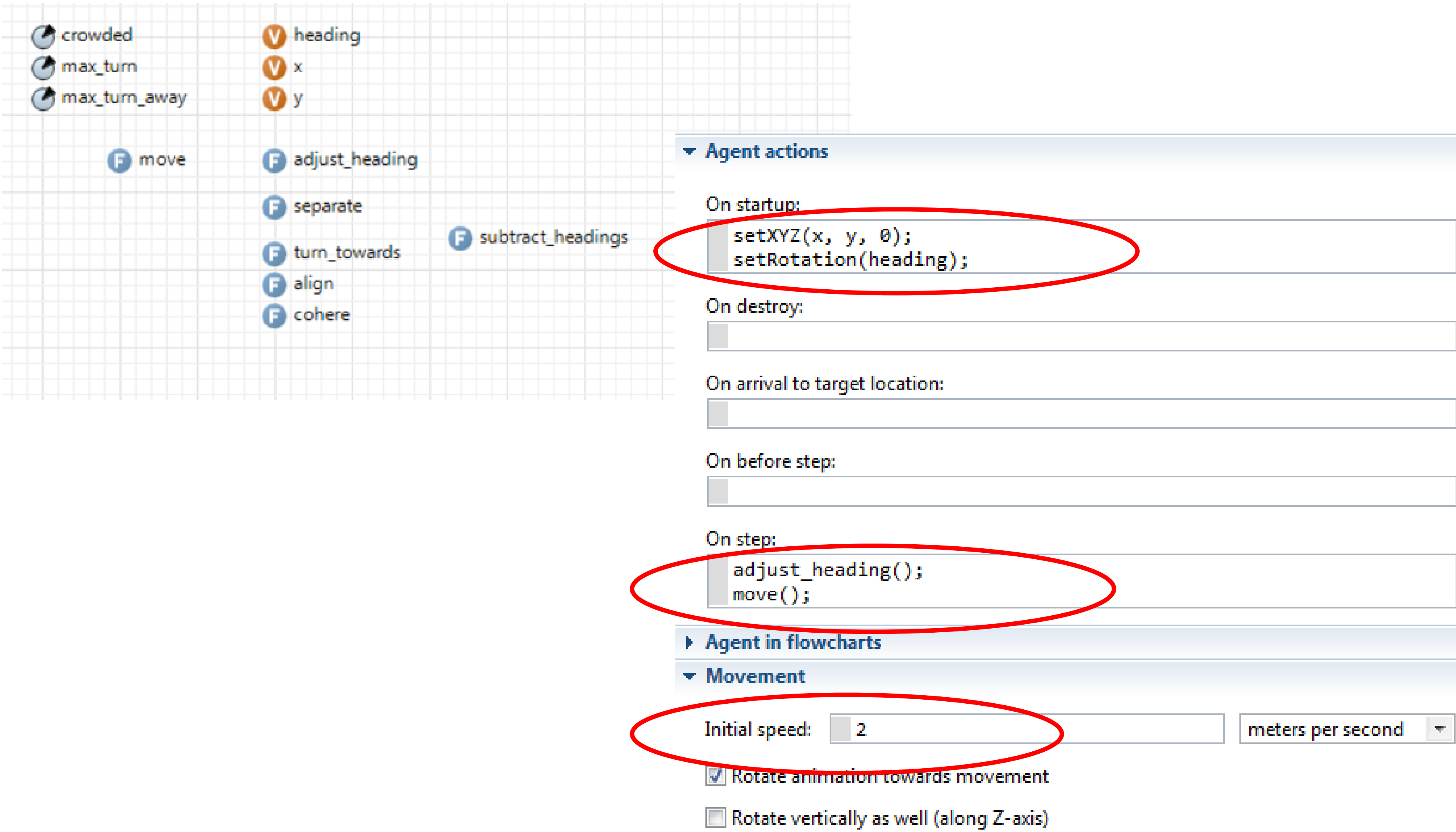
Flocking Birds

Agent Properties and Dynamics



Flocking Birds

Variables – initialized randomly

- heading – current direction in radian (0…2π)

```
heading = uniform() * 2 * Math.PI
```

- x & y – current position

```
x = uniform() * main.spaceWidth()
y = uniform() * main.spaceHeight()
```

Parameters

- minimum distance between birds

```
crowded = 5
```

- max possible turn

```
max_turn = 0.05
max_turn_away = 0.02
```

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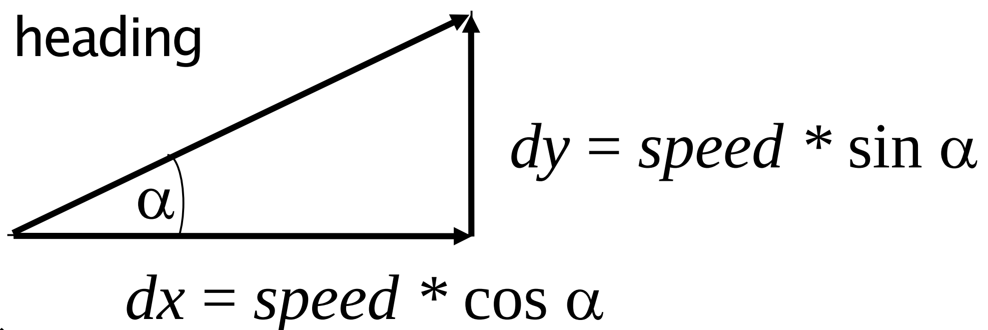
Flocking Birds

Move bird to new position: `void move()`

- Calculate new position
- Make environment into torus
- Modify agents position and heading




```
x += getSpeed() * cos(heading);
y += getSpeed() * sin(heading);
if (x > main.spaceWidth())  x -= main.spaceWidth();
else if (x < 0)  x += main.spaceWidth();
if (y > main.spaceHeight())  y -= main.spaceHeight();
else if (y < 0)  y += main.spaceHeight();
setXYZ(x, y, 0);
setRotation(heading);
```

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Flocking Birds

Modify heading according to rules 1–3: `void adjust_heading()`

- Detect nearest agent; if that one is too close, turn away
- Otherwise align and cohere with surrounding flock mates

```
if(getConnectionsNumber() == 0) return;
double closest_head = heading, double dist = 100, new_dist;
for(Agent a : getConnections()){
       new_dist = distanceTo(a);
       if(new_dist < dist){
              dist = new_dist;
              closest_head = ((Birds) a).heading;
       }
}
if(dist < crowded){ //short range repulsion
       separate(closest_head);
}else{ //long range attraction
       align();
       cohere();
}
```

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Flocking Birds

Turn away from crowding flock mate

void separate(double others_heading)

- Determine difference in headings (direction & size)
- Turn further away from flock mates heading

```
double diff = subtract_headings(heading, others_heading);
if(diff == 0) return;
if(diff > 0) heading -= min(diff,max_turn_away);
else heading -= max(diff, -max_turn_away);
if(heading < 0) heading += 2*PI;
if(heading > 2*PI) heading -= 2*PI;
```

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Flocking Birds

Determine difference between two headings

double subtract_heading(double heading1,double heading2)

- Determine difference
- Normalize between –π and π

```
double diff = heading2-heading1;
if(diff <= -PI) diff += 2*PI;
if(diff > PI) diff -= 2*PI;
return diff;
```

Flocking Birds

Turn towards flock mates heading and position

void align()

- Determine average heading of surrounding flock mates
- Adjust heading in that direction

```
double avg_head = 0, avg_x = cos(heading),
avg_y = sin(heading);
for(Agent a : getConnections()){
        avg_x += cos(((Bird)a).heading);
        avg_y += sin(((Bird)a).heading);
}
avg_x /= getConnectionsNumber()+1;
avg_y /= getConnectionsNumber()+1;
avg_head = atan2(avg_y, avg_x);
turn_towards(avg_head);
```

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Flocking Birds

Turn towards position of flock mates

void cohere()

- Determine average position of flock mates
- Adjust heading to fly there

```
double avg_pos_x = x, avg_pos_y = y;
for(Agent a : getConnections()){
       avg_pos_x += a.getX();
       avg_pos_y += a.getY();
}
avg_pos_x /= getConnectionsNumber()+1;
avg_pos_y /= getConnectionsNumber()+1;
double pos_head = atan2(y-avg_pos_y,x-avg_pos_x);
turn_towards(pos_head);
```

Flocking Birds

Align heading with others heading

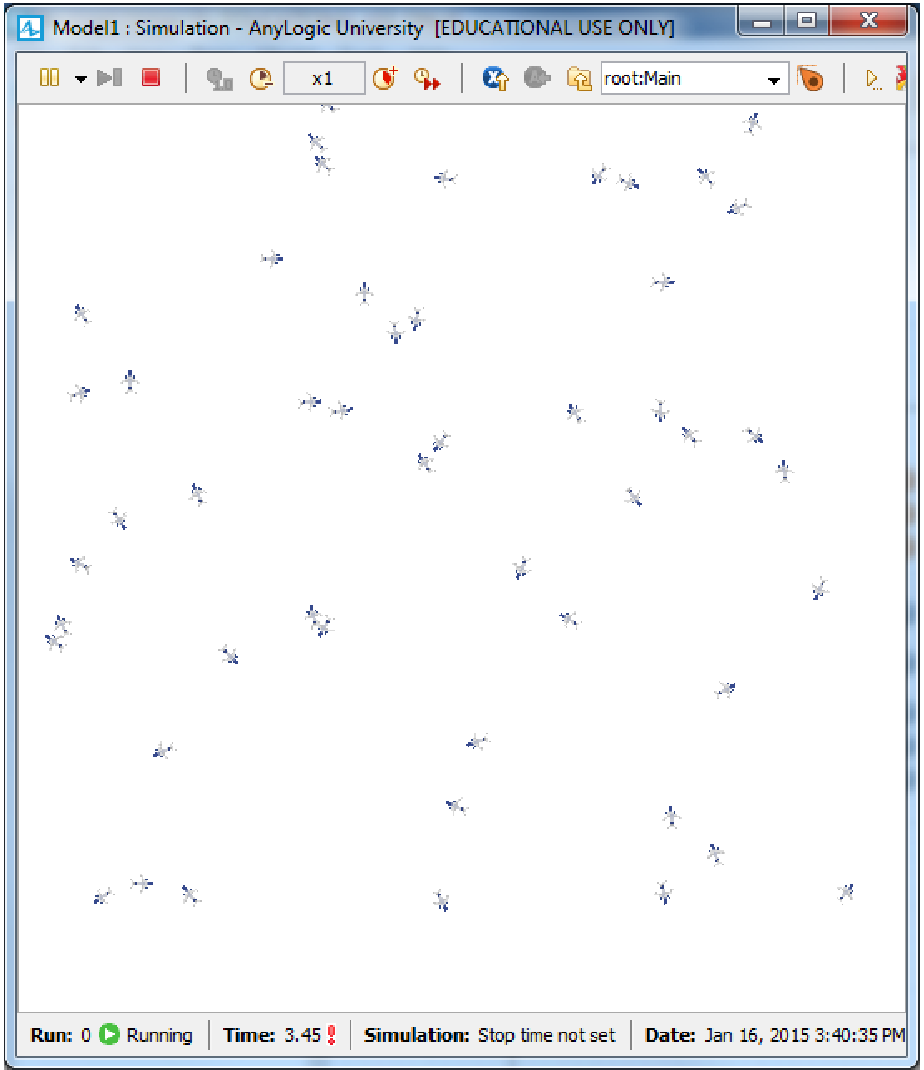
`void turn_towards(double others_heading)`

- Determine difference in headings (direction & size)
- Turn towards flock mates heading

```
double diff = subtract_headings(heading, others_heading);
if(diff == 0) return;
if(diff > 0) heading += min(diff,max_turn);
else heading += max(diff,-max_turn);
if(heading < 0) heading += 2*PI;
if(heading >= 2*PI) heading -= 2*PI;
```

Flocking Birds

Resulting dynamic behavior



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Flocking Birds

Possible questions to solve at home …

- Divide the birds into two groups
- Create and avoid an obstacle
- Parameterize initial number of birds
- Display development of average birds heading over time
- Do replications to find patterns in the flock heading development