Agent Spatial Embedding in 2D Landscapes

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Using Modeling to Prepare for Changing Healthcare Needs
Duke-NUS
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Lecture Outline

- AnyLogic’s Spatial embedding types
  - Overview
  - Reminder of continuous space
  - A glimpse of a discrete space & discrete time model
- Agent Mobility

Agent Spatial Embedding

- Spatial embedding of agents is key to
  - Expressing essential dynamics for problems Locality of influence/Transmission
  - Insight into certain phenomena (spatial concentration, percolation, spatial reference modes)
- Spatial embedding can permit GIS integration

2D Spatial Embedding: Two Options

- Continuous embedding (e.g. Wandering elephants, our built-up model)
  - No physical exclusion: Agents are assumed to be small compared to landscape scale, and exhibit arbitrary spatial density without interfering
  - We have seen this much with distributing agents initially around the space, adding agents in
- Discrete cells (e.g. The Game of Life, Agent-based predator prey, Schelling Segregation)
  - Divided into “Columns” and “Rows”
  - Physical exclusion: Only one agent in a cell at a time

The Locus of Control: Environment

- The Anylogic Environment sets the parameters for the nature of the 2D landscape
  - Width
  - Breadth
  - Continuous vs. Discrete
  - Character of discrete neighbourhoods (cardinal directions vs. Euclidian { N,NE,E,SE,S,SW,W,NW}

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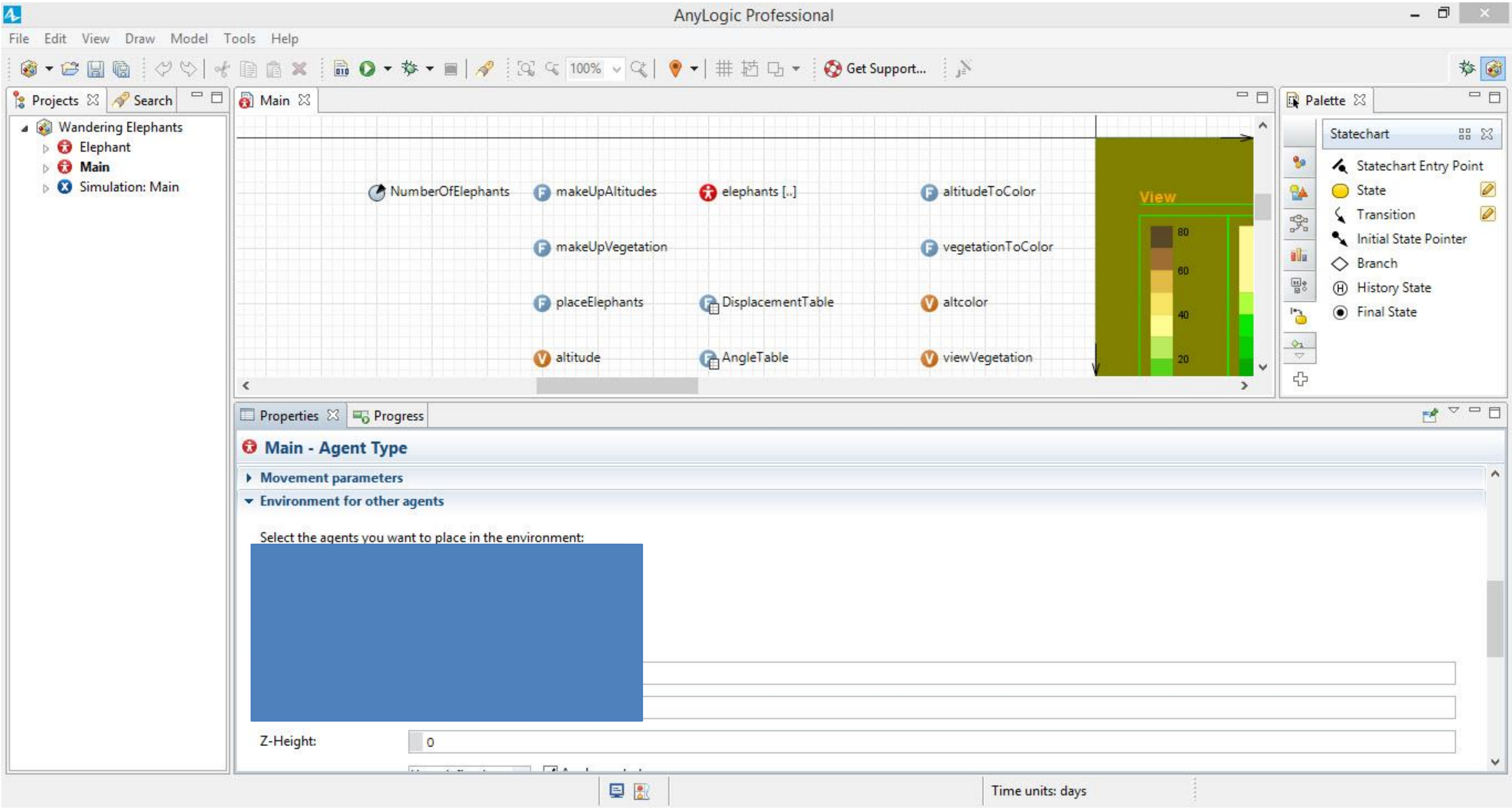
Continuous Environment



Main - Agent Type

Movement parameters

Environment for other agents

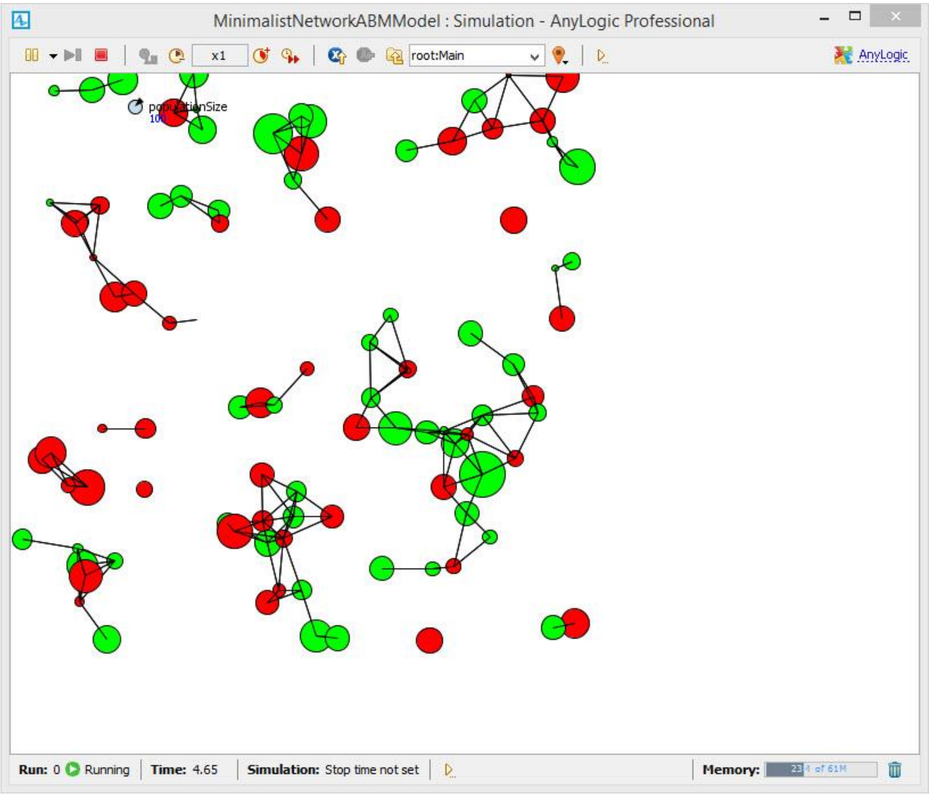
Select the agents you want to place in the environment:

Z-Height: 0

Time units: days

Continuous Environment: Your Model

- We’ve already seen the continuous embedding in our built up model.



MinimalistNetworkABMModel : Simulation - AnyLogic Professional

Run: 0 Running | Time: 4.65 | Simulation: Stop time not set | Memory: 23M of 61M

Lecture Outline

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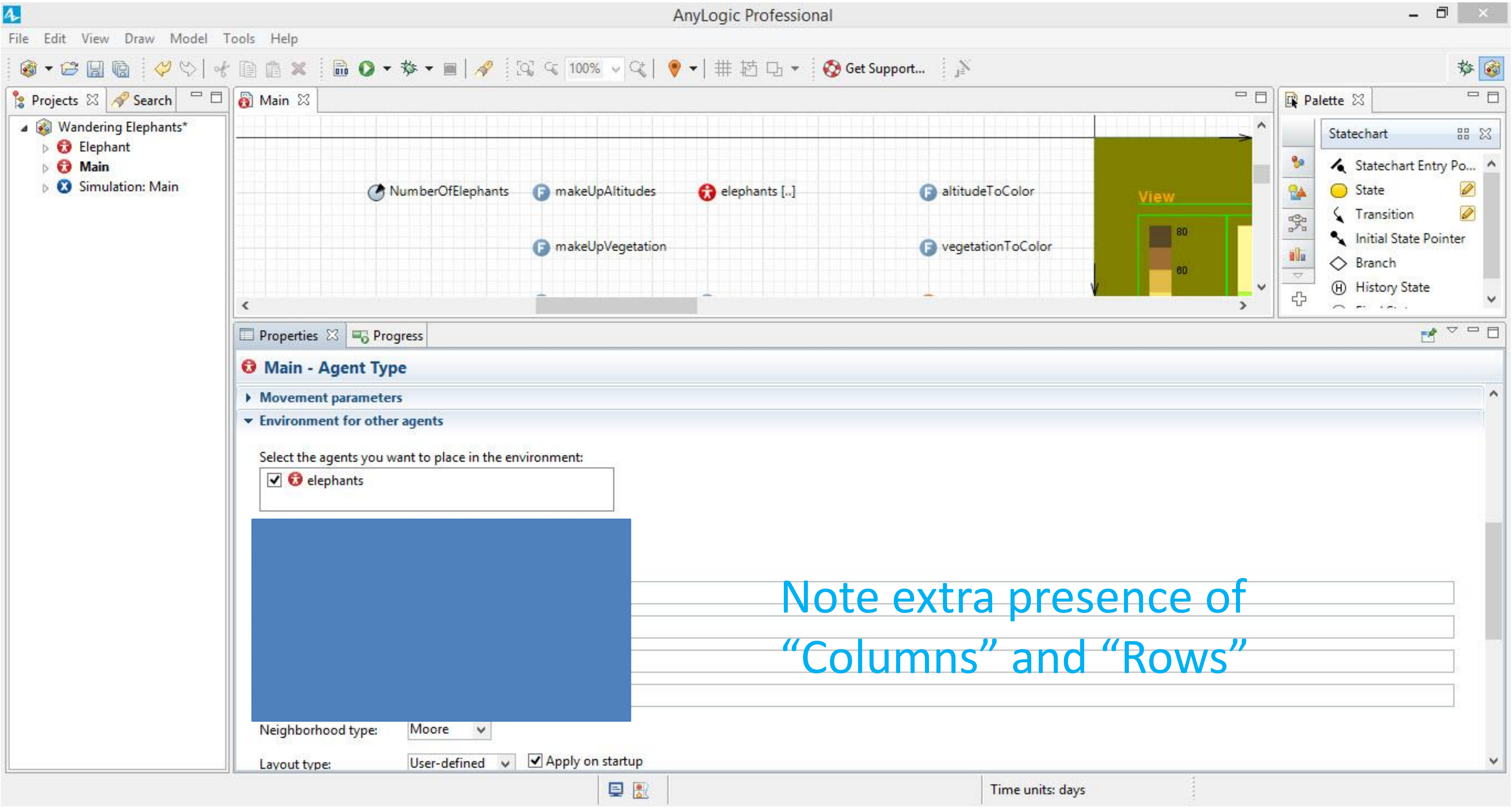
By Comparison: Discrete Environment



Main - Agent Type

Movement parameters

Environment for other agents

Select the agents you want to place in the environment:

☑ elephants

Neighborhood type: Moore

Layout type: User-defined ☑ Apply on startup

Note extra presence of "Columns" and "Rows"

Hands on Model Use Ahead

Load AnyLogic Sample Model: The Game of Life

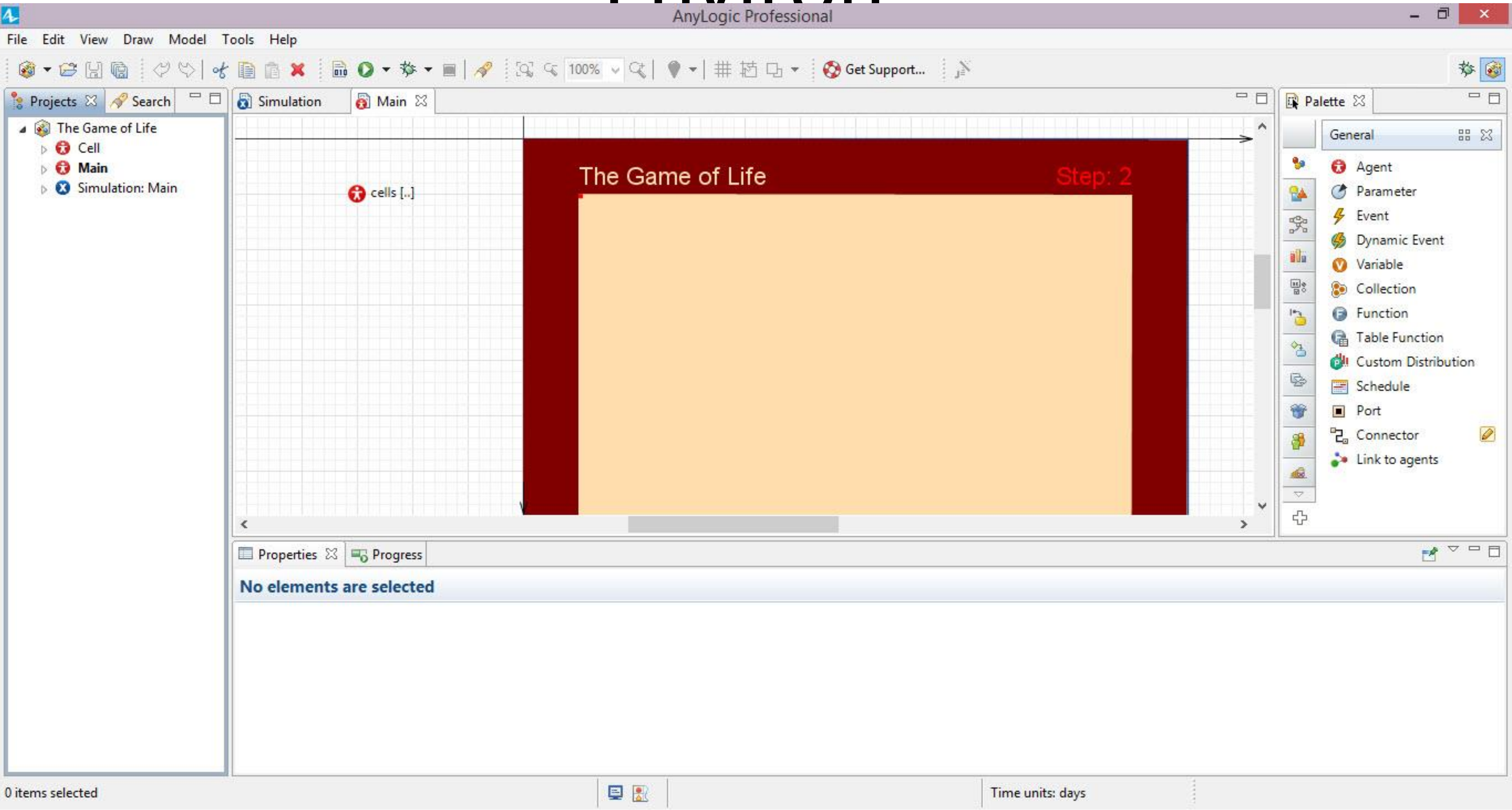
The “Game” of Life: Background

- Invented in 1970 by Mathematician Conway (modifying ideas from Von Neumann)
- Inspiration: Lifecourse of cells
  - Key dichotomy: A space contains a living element or not
  - Stylized rules for birth, death
- Cellular automaton: Uses Discrete Time (Steps) & Discrete Space (Cells) with evolving cell state
- Deterministic rules
- Illustrates the emergence of tremendous complexity from very simple rules
  - Computationally universal

The Behavioral Rules of the Game of Life

- Cells are viewed as surrounded by 4 neighbors (in cardinal directions)
- Living cells require some neighboring empty space, but also some proximity to nearby living cells
- Birth: An empty cell becomes occupied if it has an “ideal” nurturing environment around it (3 surrounding cells)
- An existing cell dies if
  - –Too isolated: It has too few neighbors (1 or 0)
  - –Too crowded: It is surrounded by other cells (4 surrounding cells)
- No mobility: Cells are born, live and die in same

Open "Main" Class
Scroll Left to See Population & Environ

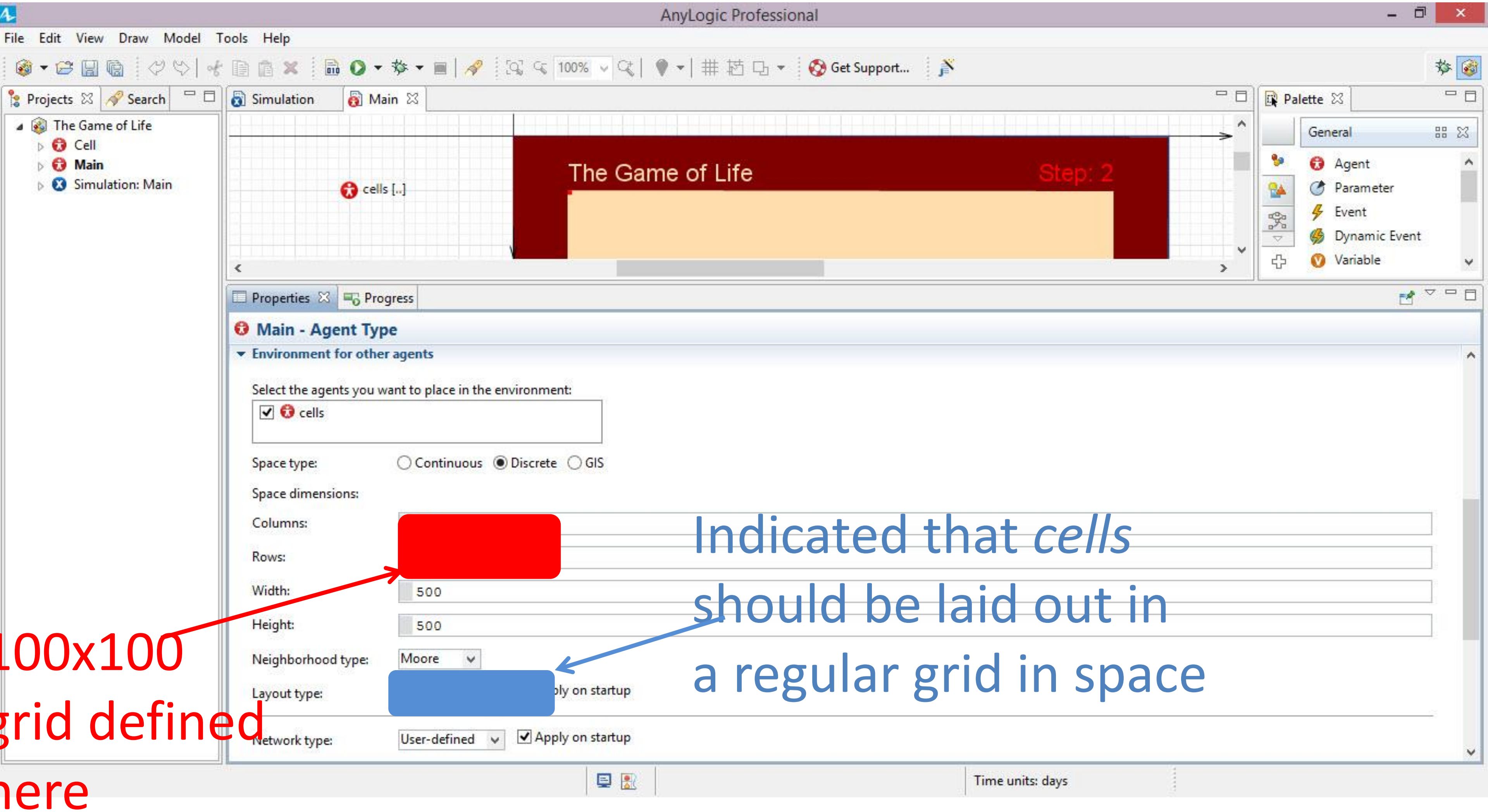


No elements are selected

0 items selected

Time units: days

Imposing the Regular 2D Structure



Main - Agent Type

Environment for other agents

Select the agents you want to place in the environment:

☑ cells

Space type: ○ Continuous ● Discrete ○ GIS

Space dimensions:

Columns:

Rows:

Width: 500

Height: 500

Neighborhood type: Moore

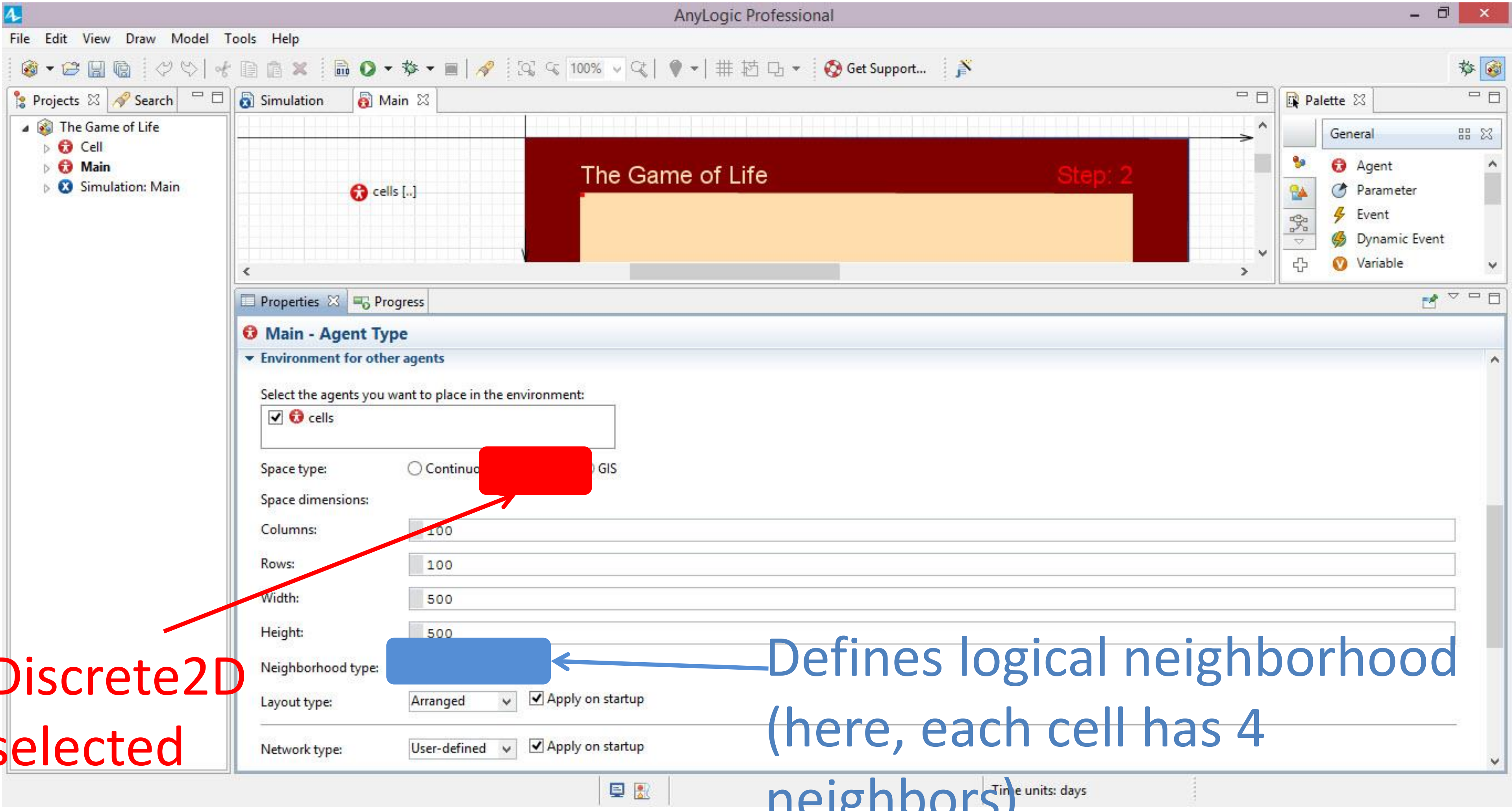
Layout type: ...ply on startup

Network type: User-defined ☑ Apply on startup

100x100
grid defined
here

Indicated that *cells* should be laid out in a regular grid in space

Environment: Enabling Discrete **Space** (Cells)



Main - Agent Type

Environment for other agents

Select the agents you want to place in the environment:

☑ cells

Space type: ○ Continuo ○ GIS

Space dimensions:

Columns: 100

Rows: 100

Width: 500

Height: 500

Neighborhood type:

Layout type: Arranged ☑ Apply on startup

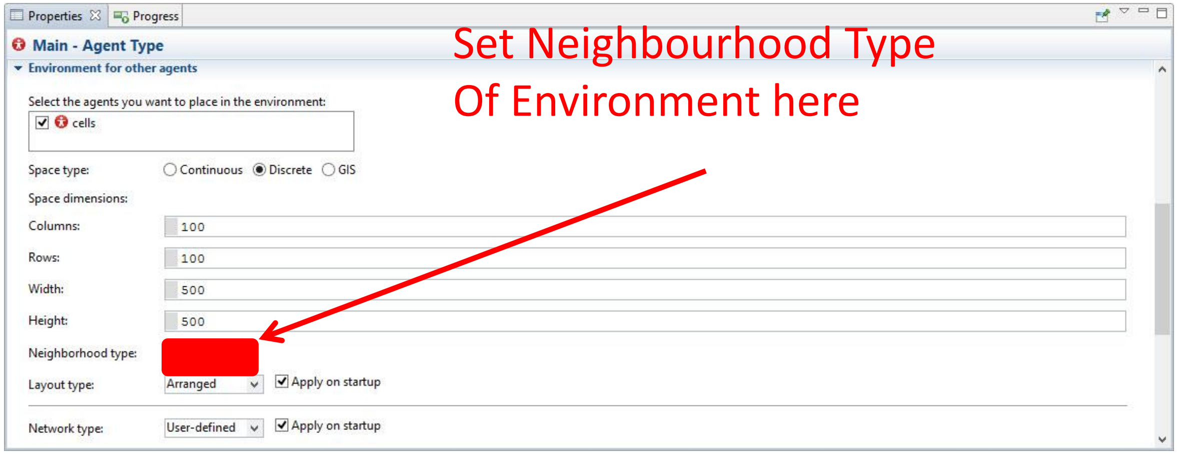
Network type: User-defined ☑ Apply on startup

Discrete2D selected

Defines logical neighborhood (here, each cell has 4 neighbors)

Neigbourhood Models

- Moore: Cardinal directions
  - NORTH,SOUTH,EAST, WEST
- Euclidean
  - NORTH, SOUTH, EAST, WEST, NORTHEAST, NORTHWEST, SOUTHEST,SOUTHWEST



Properties ☒ Progress

Main - Agent Type

Environment for other agents

Select the agents you want to place in the environment:

☑ cells

Space type: ○ Continuous ● Discrete ○ GIS

Space dimensions:

Columns: 100

Rows: 100

Width: 500

Height: 500

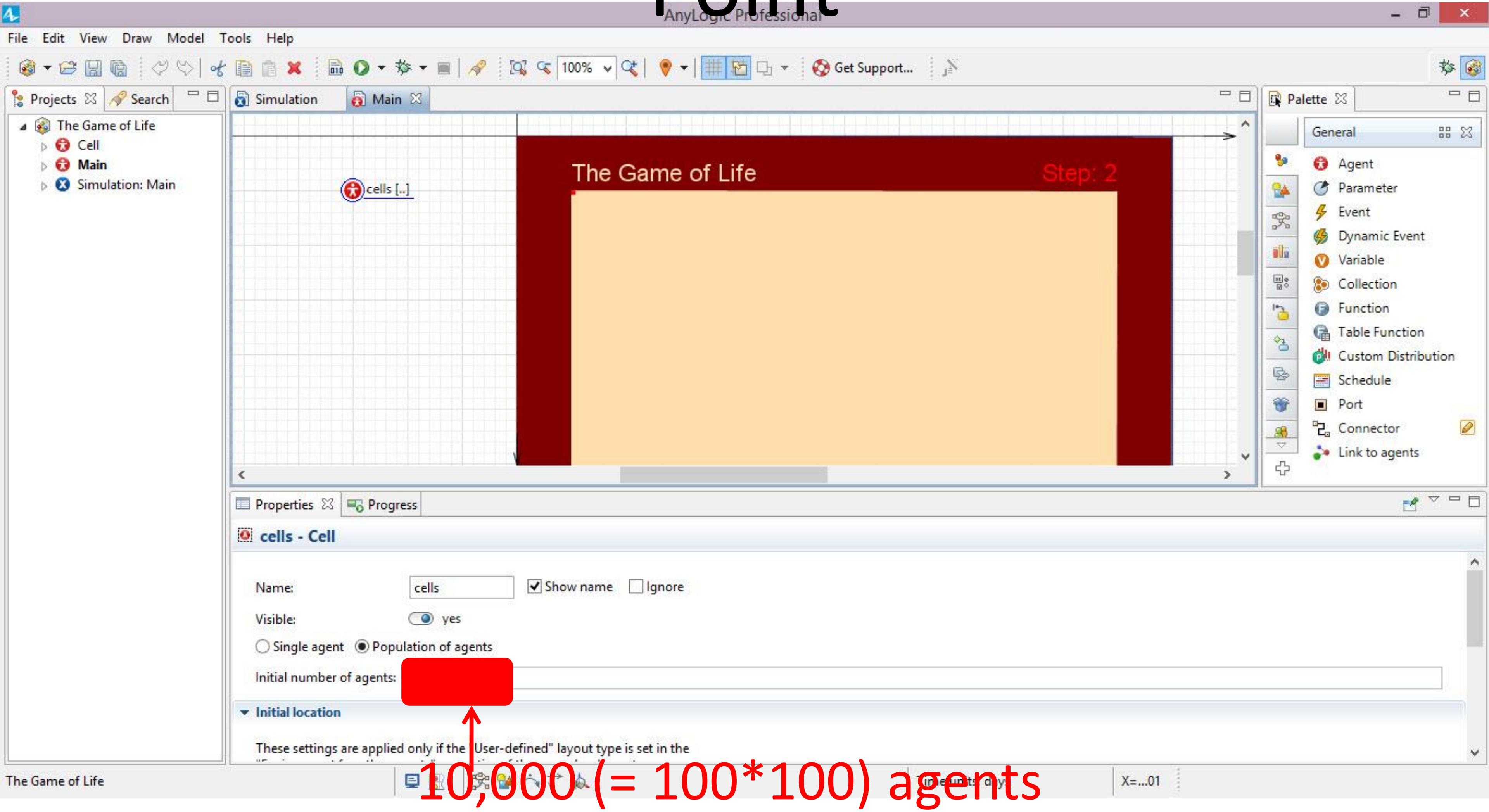
Neighborhood type: [redacted]

Layout type: Arranged ☑ Apply on startup

Network type: User-defined ☑ Apply on startup

Set Neighbourhood Type
Of Environment here

Population: One Cell Agent per Grid Point



cells - Cell

Name: cells ☑ Show name □ Ignore

Visible: yes

○ Single agent ● Population of agents

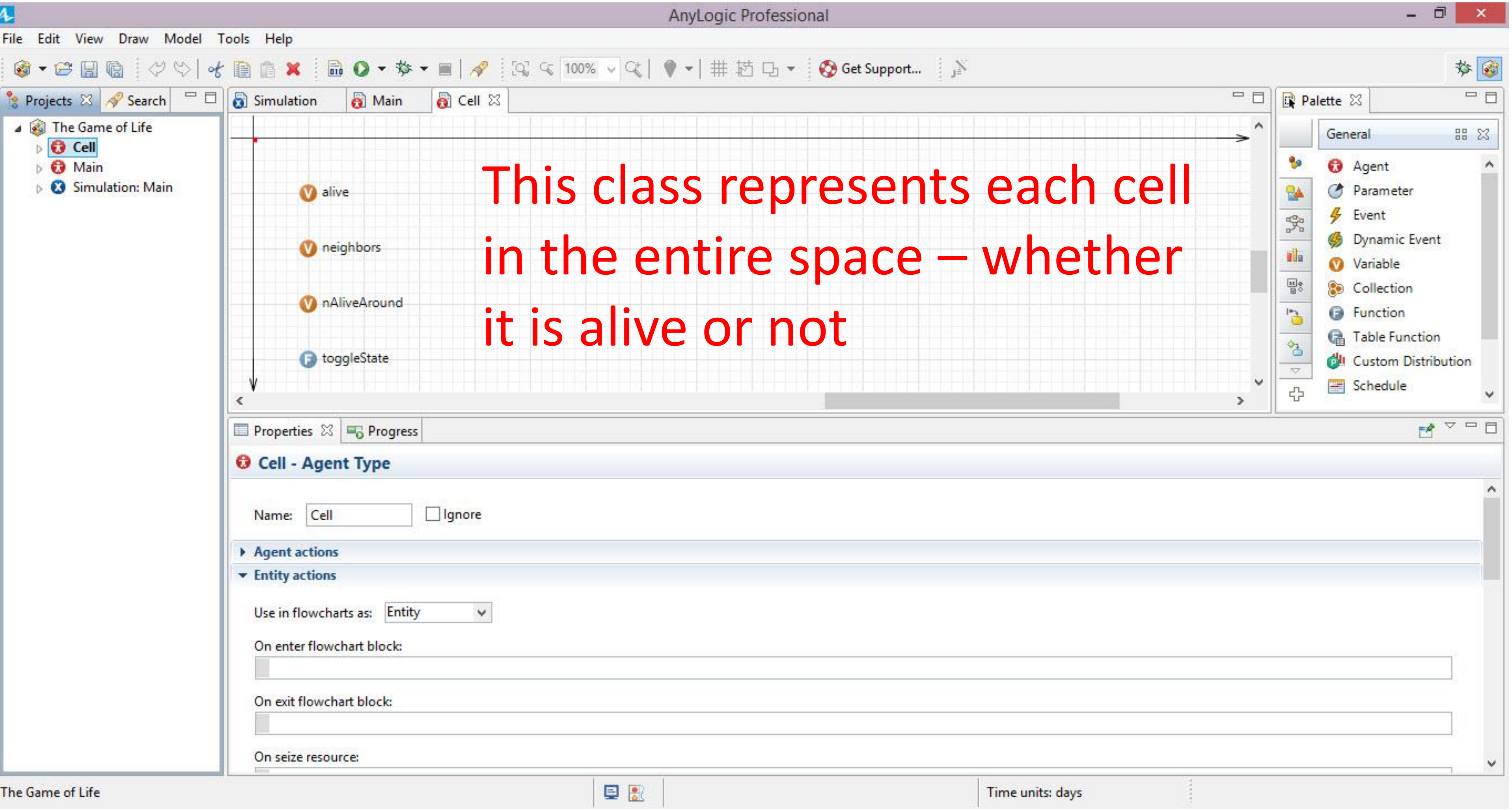
Initial number of agents: [redacted]

Initial location

These settings are applied only if the "User-defined" layout type is set in the

10,000 (= 100*100) agents

View the “Cell” Class



Cell - Agent Type

Name: Cell □ Ignore

Use in flowcharts as: Entity

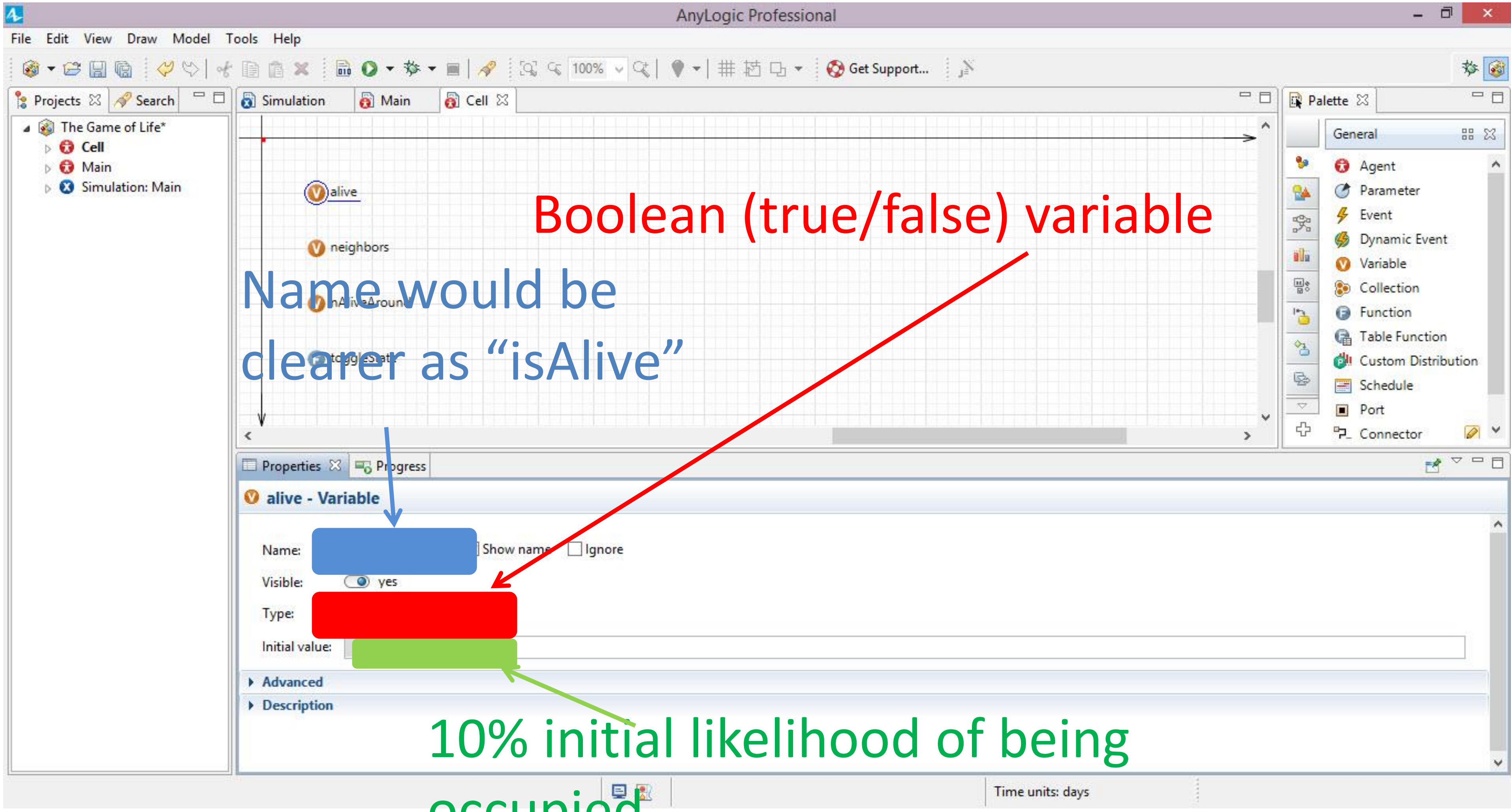
On enter flowchart block:

On exit flowchart block:

On seize resource:

This class represents each cell in the entire space – whether it is alive or not

Cell Variables: “alive”



alive - Variable

Name: □ Show name □ Ignore

Visible: yes

Type:

Initial value:

▸ Advanced

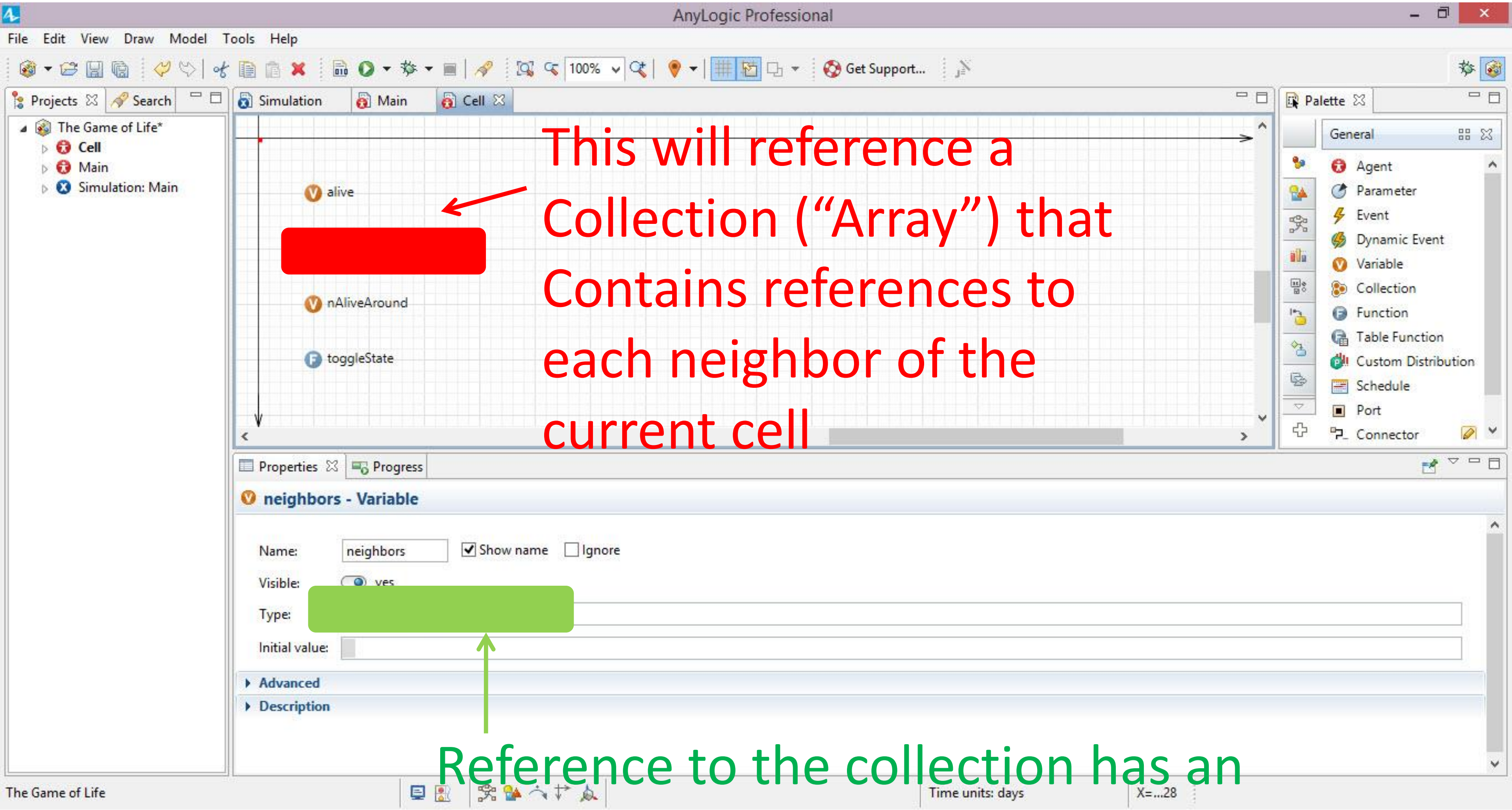
▸ Description

Boolean (true/false) variable

Name would be clearer as “isAlive”

10% initial likelihood of being occupied

Cell Variables: “neighbors”



[redacted]

neighbors - Variable

Name: neighbors ☑ Show name □ Ignore

Visible: yes

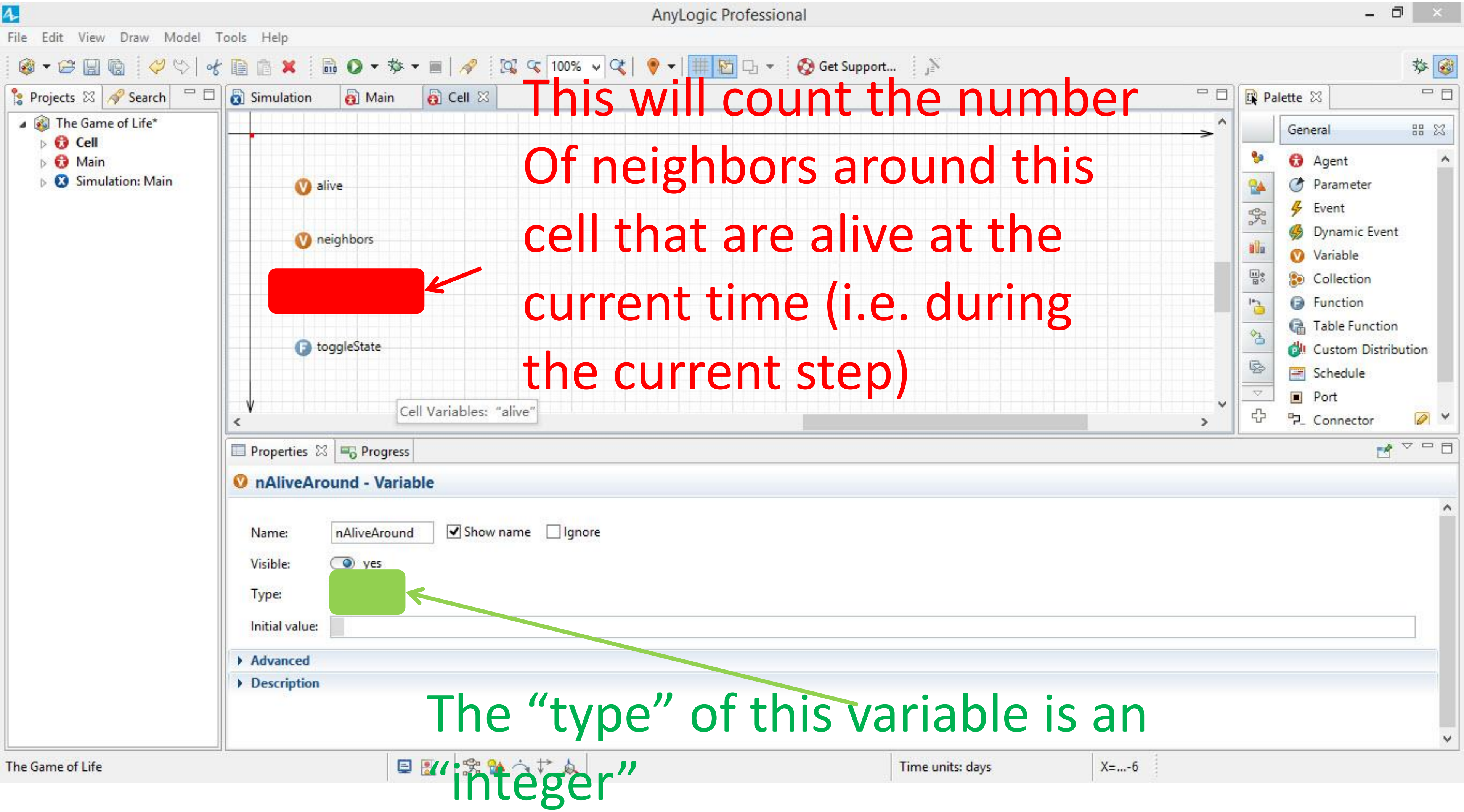
Type: [redacted]

Initial value:

This will reference a Collection (“Array”) that Contains references to each neighbor of the current cell

Reference to the collection has an “Array” type

Cell Variables: “nAliveAround”



[redacted]

nAliveAround - Variable

Name: nAliveAround ☑ Show name □ Ignore

Visible: yes

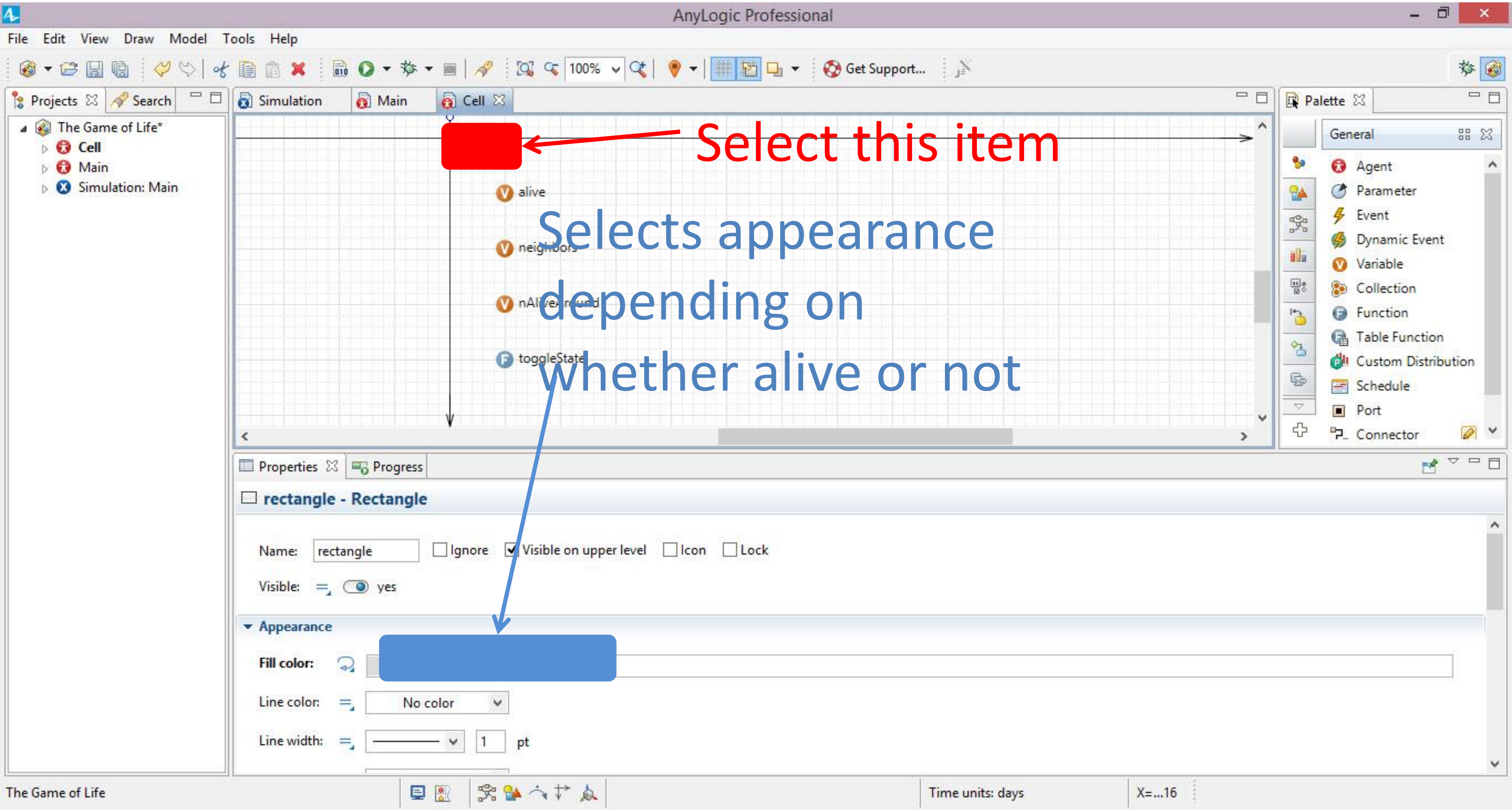
Type: [redacted]

Initial value:

This will count the number Of neighbors around this cell that are alive at the current time (i.e. during the current step)

The “type” of this variable is an “integer”

Visual Representation of Cell (Click on Cell Icon at Origin)



Select this item

Selects appearance depending on whether alive or not

☐ rectangle - Rectangle

Name: rectangle ☐ Ignore ☑ Visible on upper level ☐ Icon ☐ Lock

Visible: yes

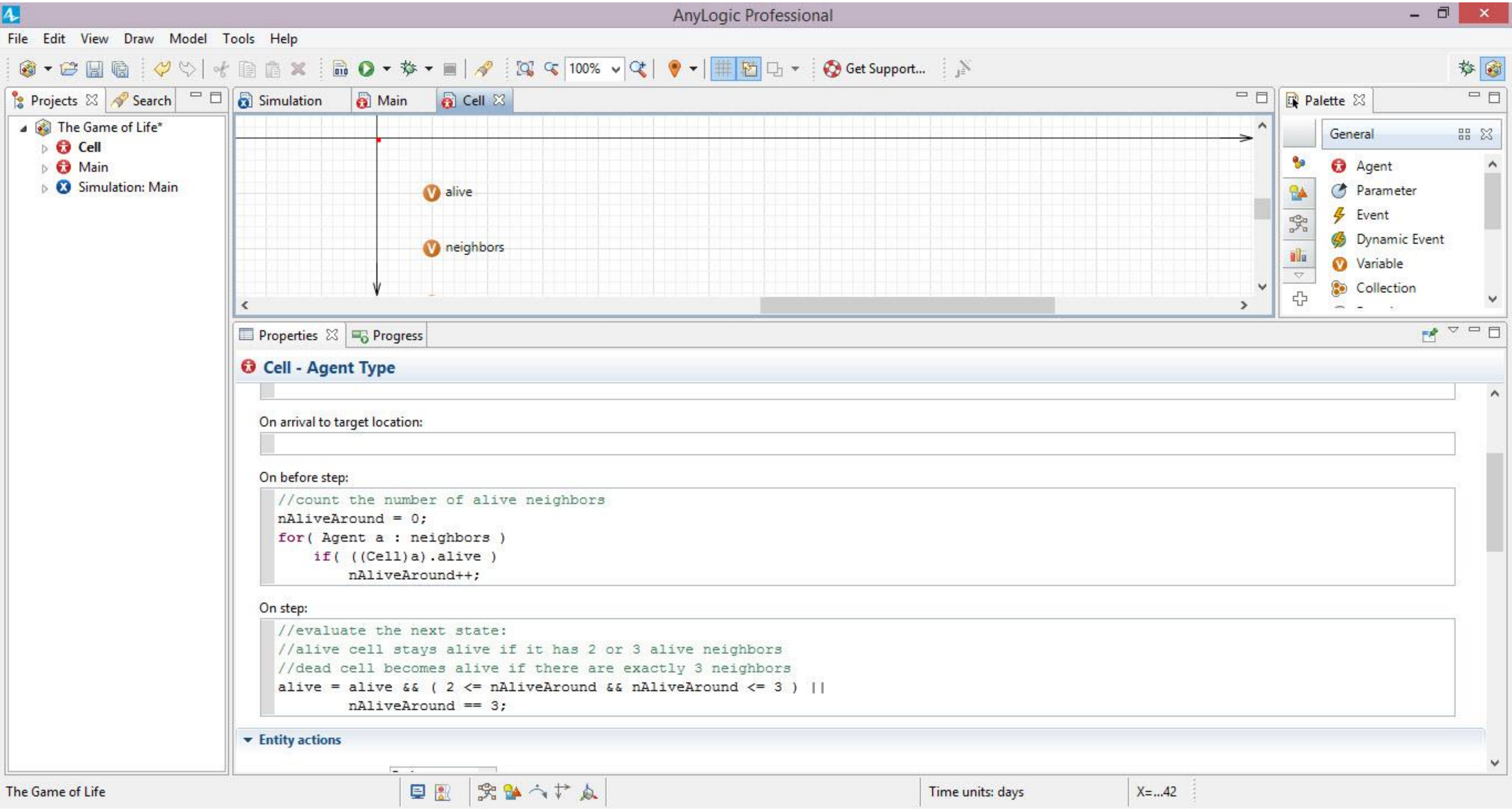
Appearance

Fill color:

Line color: No color

Line width: 1 pt

Cell Update Logic
("Agent" Properties of "Cell")



Cell - Agent Type

On arrival to target location:

On before step:

```
//count the number of alive neighbors
nAliveAround = 0;
for( Agent a : neighbors )
    if( ((Cell)a).alive )
        nAliveAround++;
```

On step:

```
//evaluate the next state:
//alive cell stays alive if it has 2 or 3 alive neighbors
//dead cell becomes alive if there are exactly 3 neighbors
alive = alive && ( 2 <= nAliveAround && nAliveAround <= 3 ) ||
        nAliveAround == 3;
```

Entity actions

Two Key Models of Time in Anylogic: Continuous (Asynchronous) Time

- This is what we have dealt with to this point
- Here, every agent is updated at a different time, according to events
- No two agents are typically likely to be updated at exactly the same time during most of model execution, so when considering the state of other agents they “see” the last situation where the other agent has been updated

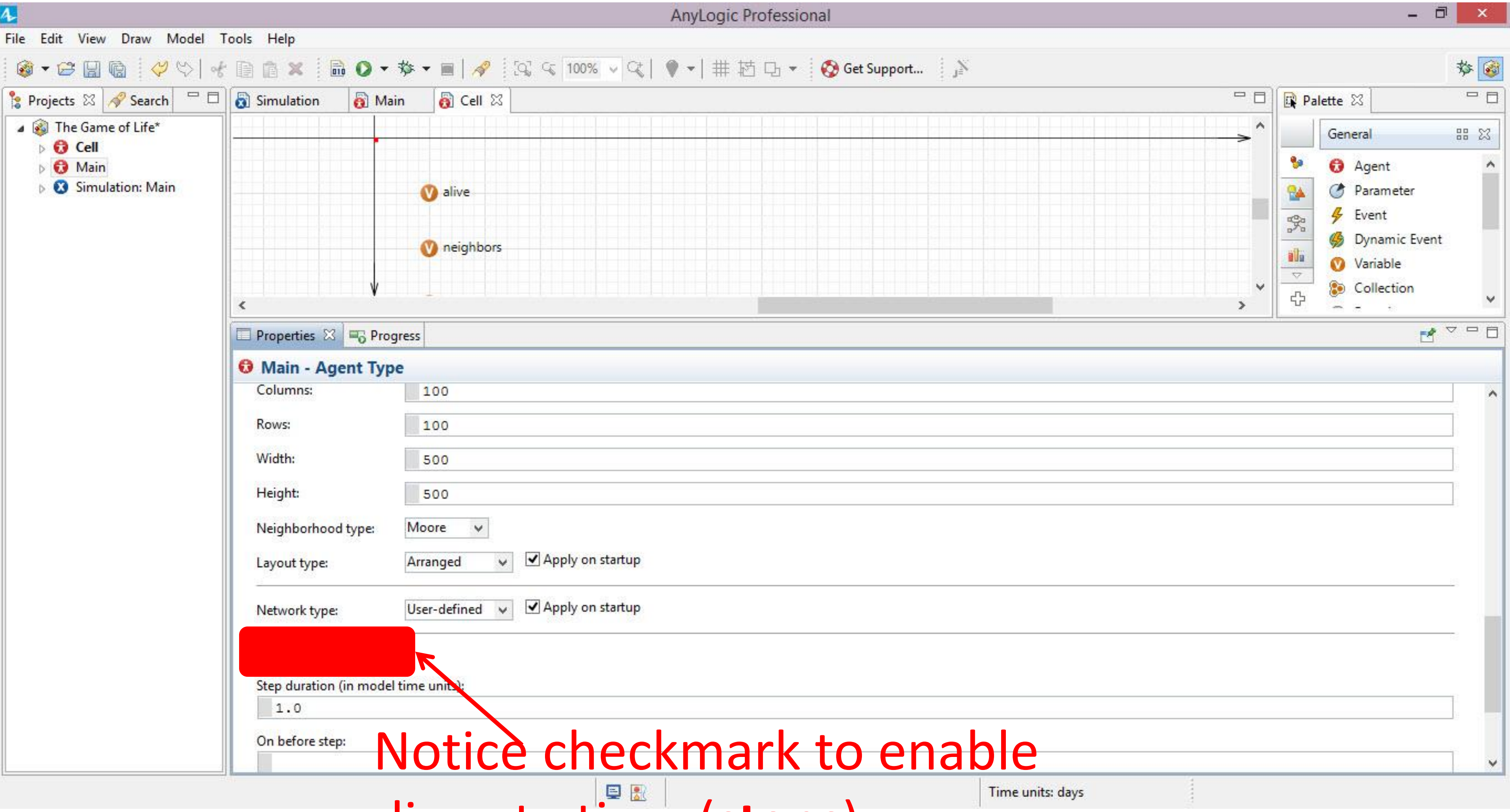
Two Key Models of Time in Anylogic: Discrete (Synchronous) Time

- Here, agents all change in lockstep, separated by fixed "time steps"
- When computing agent behavior (to determine agent state in the next timestep), our enquiries about agent state (e.g. using *getAgentAtCell* or *getAgentNextToMe*) need to ask about the situation ***in the current timestep***
  - We gather needed information regarding current state in "On Before Step", and changes are performed in "On Step".
- This is similar to what we saw in System Dynamics – the changes over the next small interval of time (Δt)

Enabling Discrete (Synchronous) Time

- When enable the steps, the various handlers for synchronized time (e.g. “On before step”, “On step”, “On after step”) etc.) are executed
  - Both environment and agents have “On before step” and “On after step” handlers
  - “On before step” for environments is executed before the corresponding method for agents
  - “On after step” for environments is executed after the corresponding method for agents
- Synchronous time can be enabled via the class's “General” page
  - Click checkbox “Enable steps”

Environment: Enabling Discrete **Time**



Main - Agent Type

Columns: 100

Rows: 100

Width: 500

Height: 500

Neighborhood type: Moore

Layout type: Arranged ☑ Apply on startup

Network type: User-defined ☑ Apply on startup

[redacted]

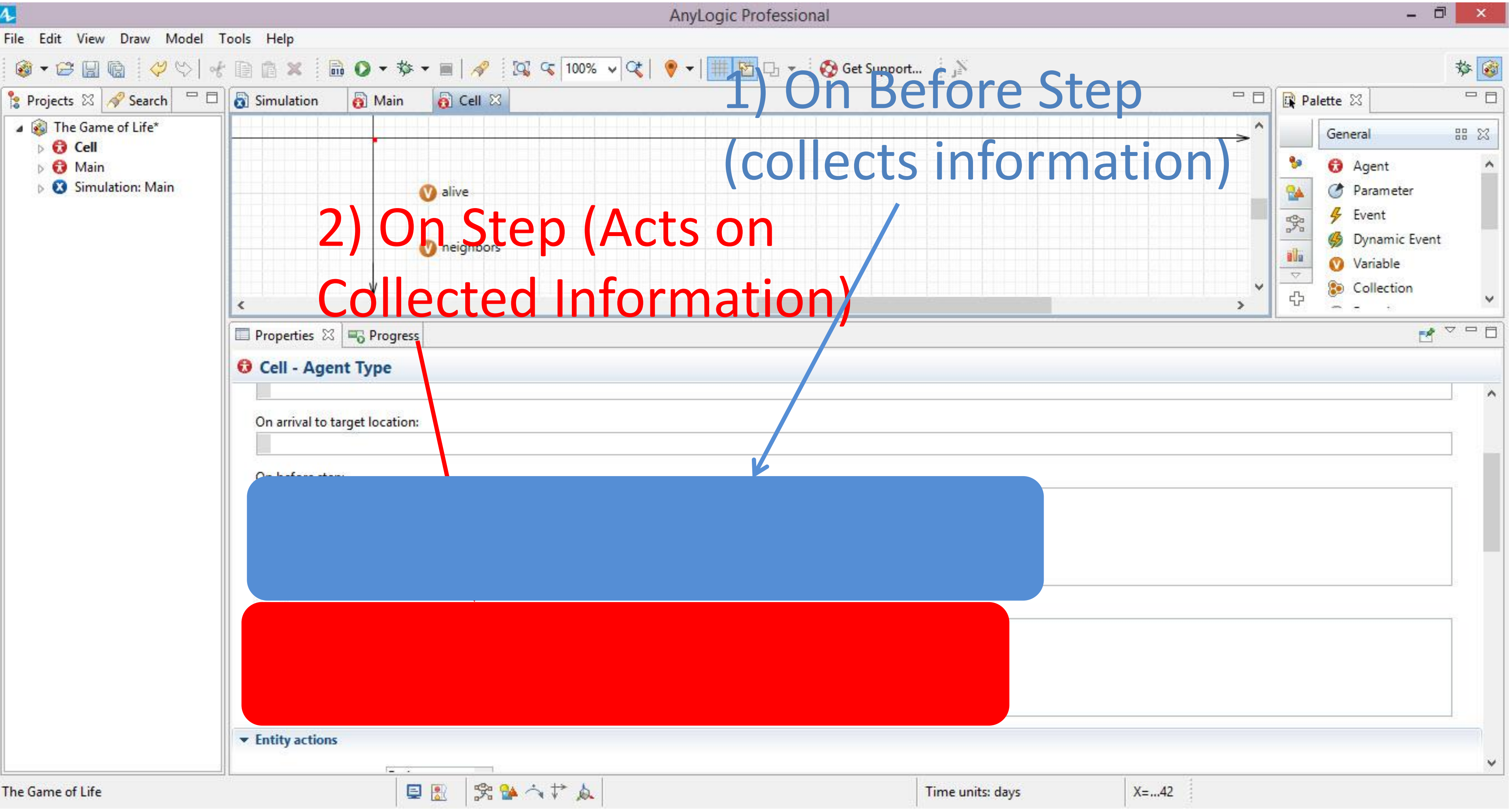
Step duration (in model time units):

1.0

On before step:

Notice checkmark to enable discrete time (**steps**)

Cell Update Logic
("Agent" Properties of "Cell")

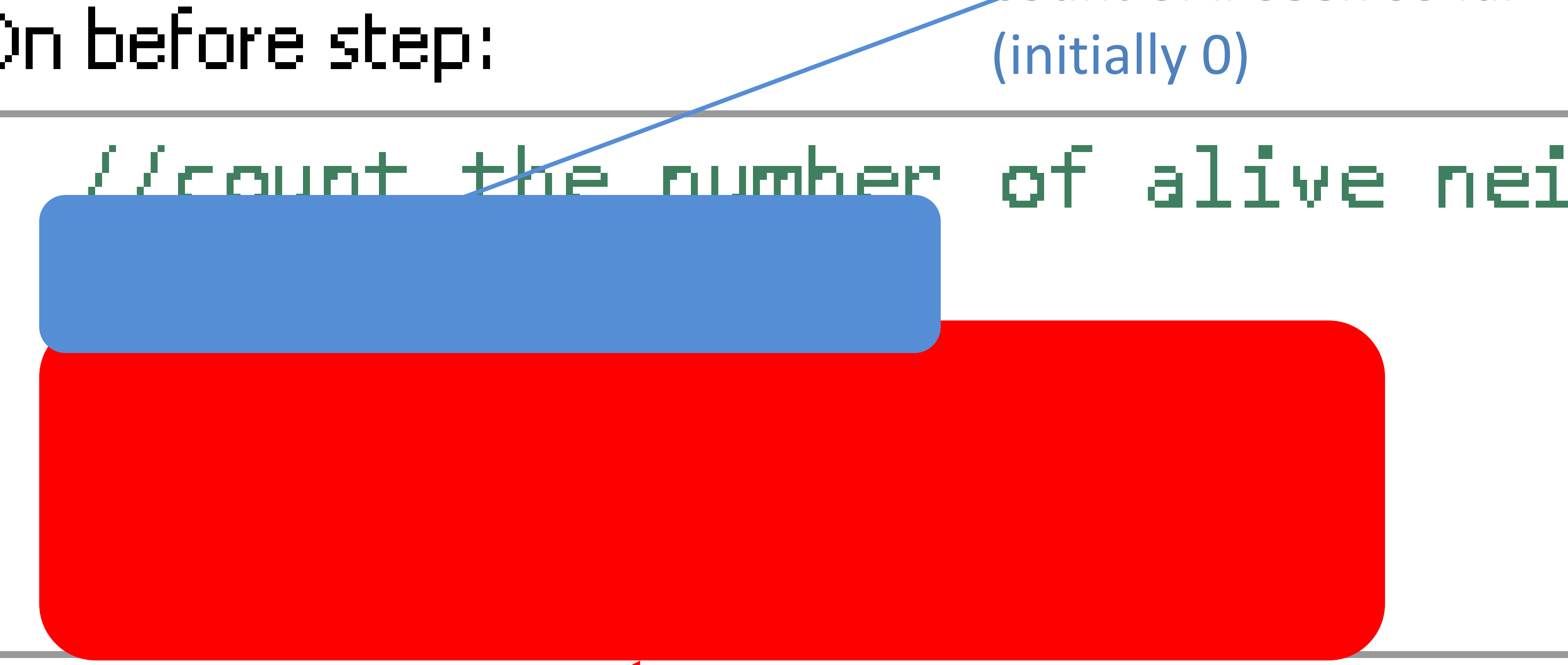


1) On Before Step (collects information)

2) On Step (Acts on Collected Information)

On Before Step: Collecting the Information

This records a running count of # seen so far (initially 0)



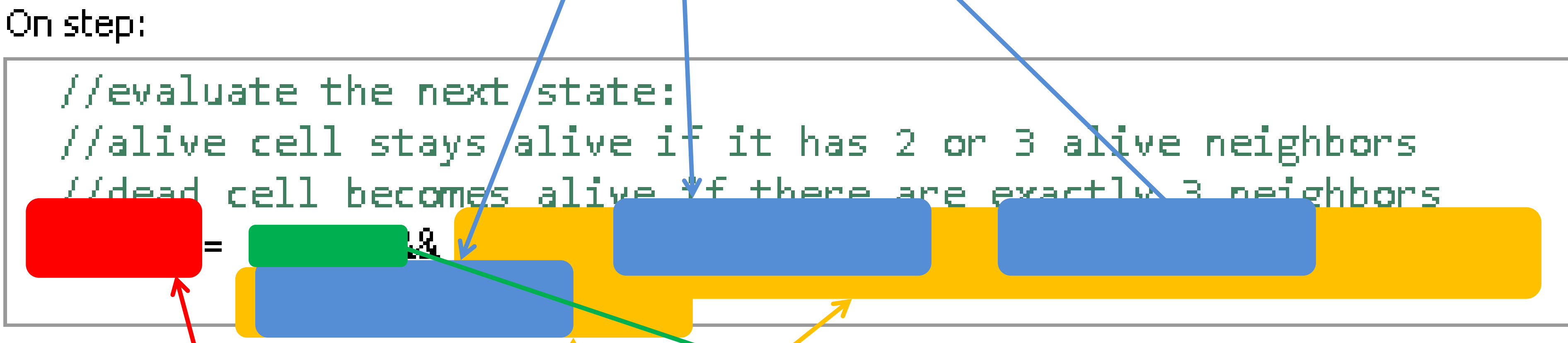
On before step:

```
//count the number of alive nei
```

2) Loops through each of the neighbors. Every time we see a live neighbor, increment the count of alive neighbors

On Step: Performing the Update based on Observed Information

Reminder: This is the information collected in “On Before Step”

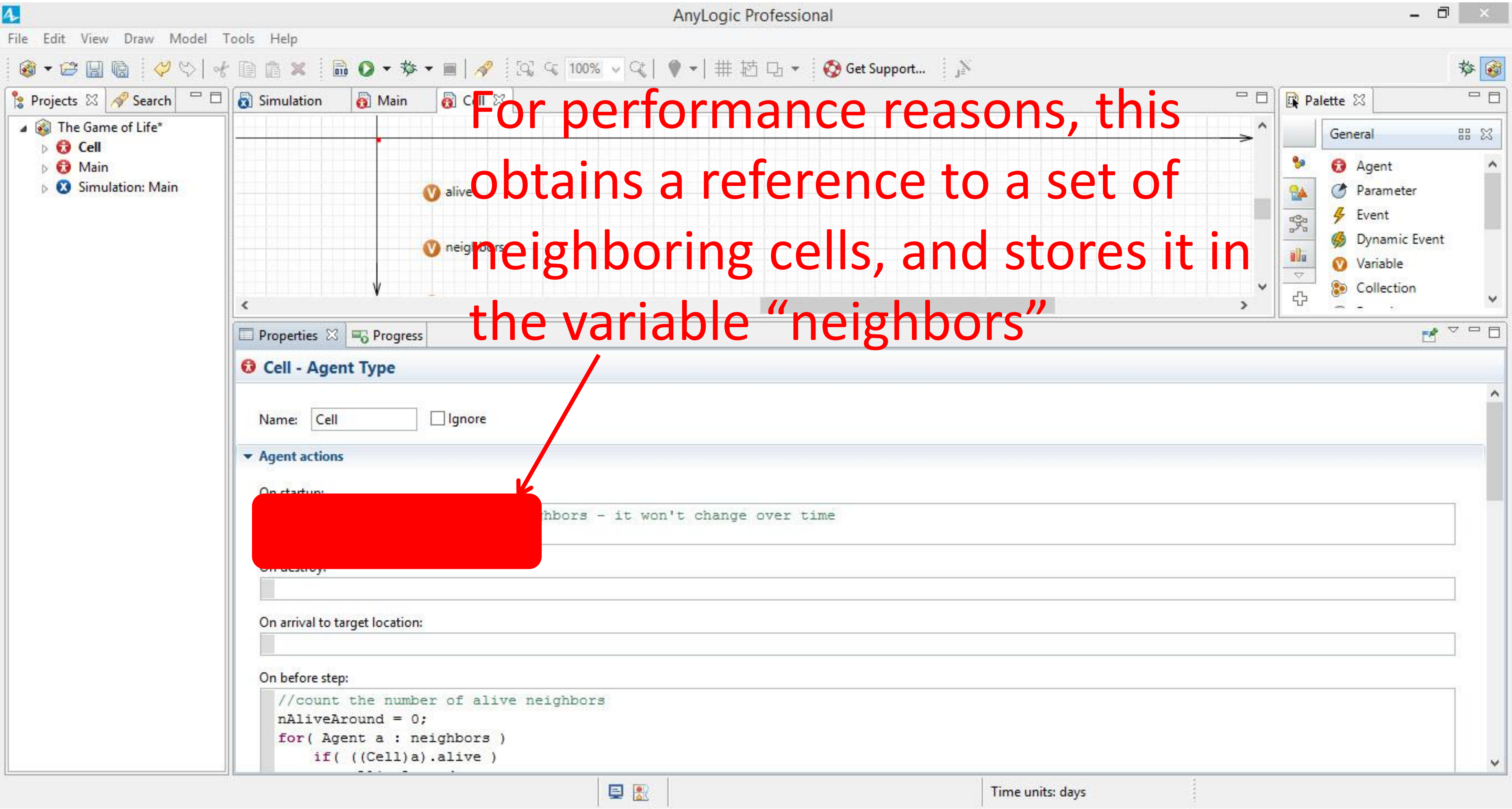


On step:

```
  //evaluate the next state:
  //alive cell stays alive if it has 2 or 3 alive neighbors
  //dead cell becomes alive if there are exactly 3 neighbors
          =         &&
```

Here, we are updating our aliveness status (represented by the “alive” variable) based on our current status & characteristics of the local environment.

Obtaining the List of Neighboring Cells at Startup



For performance reasons, this obtains a reference to a set of neighboring cells, and stores it in the variable "neighbors"

Cell - Agent Type

Name: Cell ☐ Ignore

[redacted]

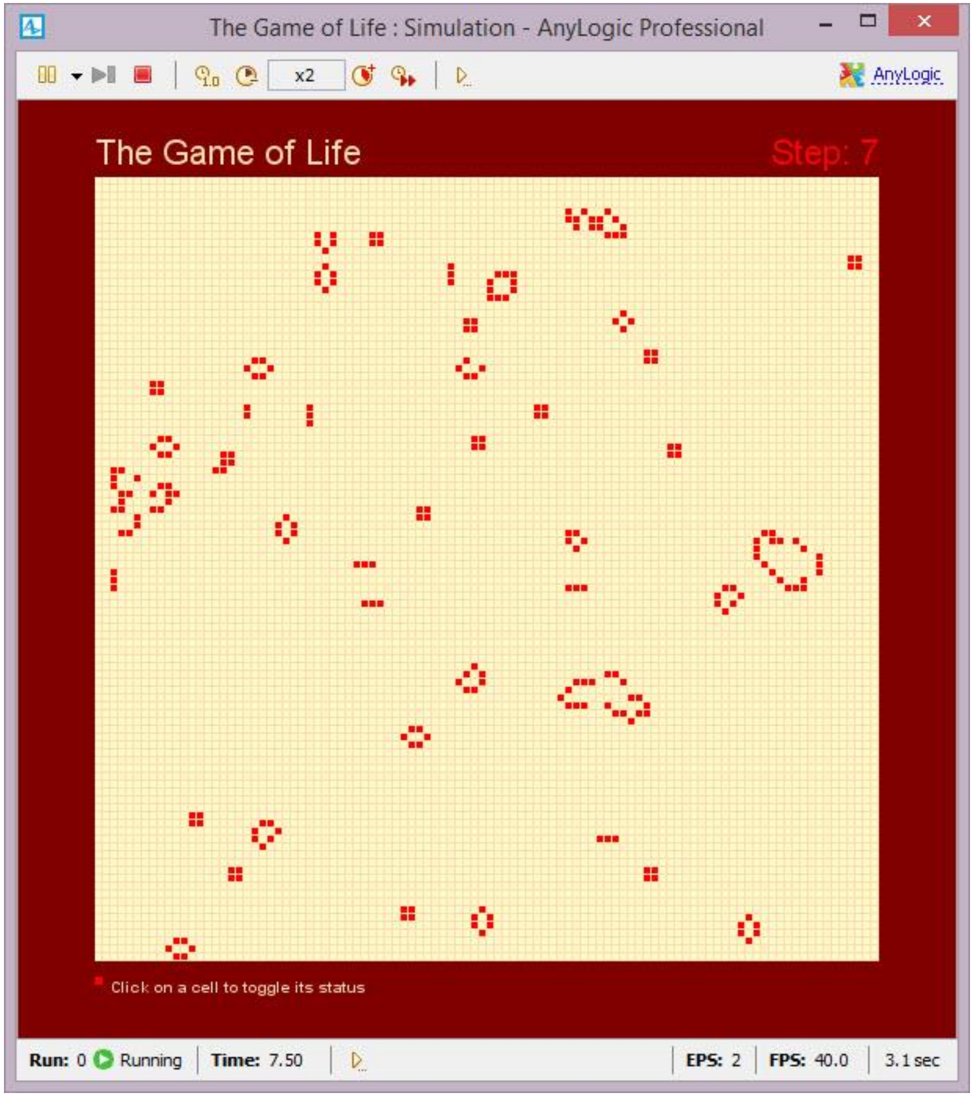
On arrival to target location:

On before step:

```
//count the number of alive neighbors
nAliveAround = 0;
for( Agent a : neighbors )
    if( ((Cell)a).alive )
```

Time units: days

Running the Model



The Game of Life : Simulation - AnyLogic Professional

The Game of Life

Step: 7

Click on a cell to toggle its status

Run: 0 Running | Time: 7.50 | EPS: 2 | FPS: 40.0 | 3.1 sec