Biomedical Modeling: Introduction to the Agent-based epidemic modeling

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Why An Epidemic Model?

- The study of how disease is distributed in populations and the factors that influence or determine this distribution
- Epidemics have been responsible for great losses of life and have acted as a population control (Black Plague, Spanish Influenza)and are still a cause of concern today and in the future (SARS, H1N1 Swine Flu)
- The study is important in understanding and preventing the spread of disease throughout a population.

http://www.solarnavigator.net/animal_kingdom/animal_images/death_black_plague_street_scene.jpg

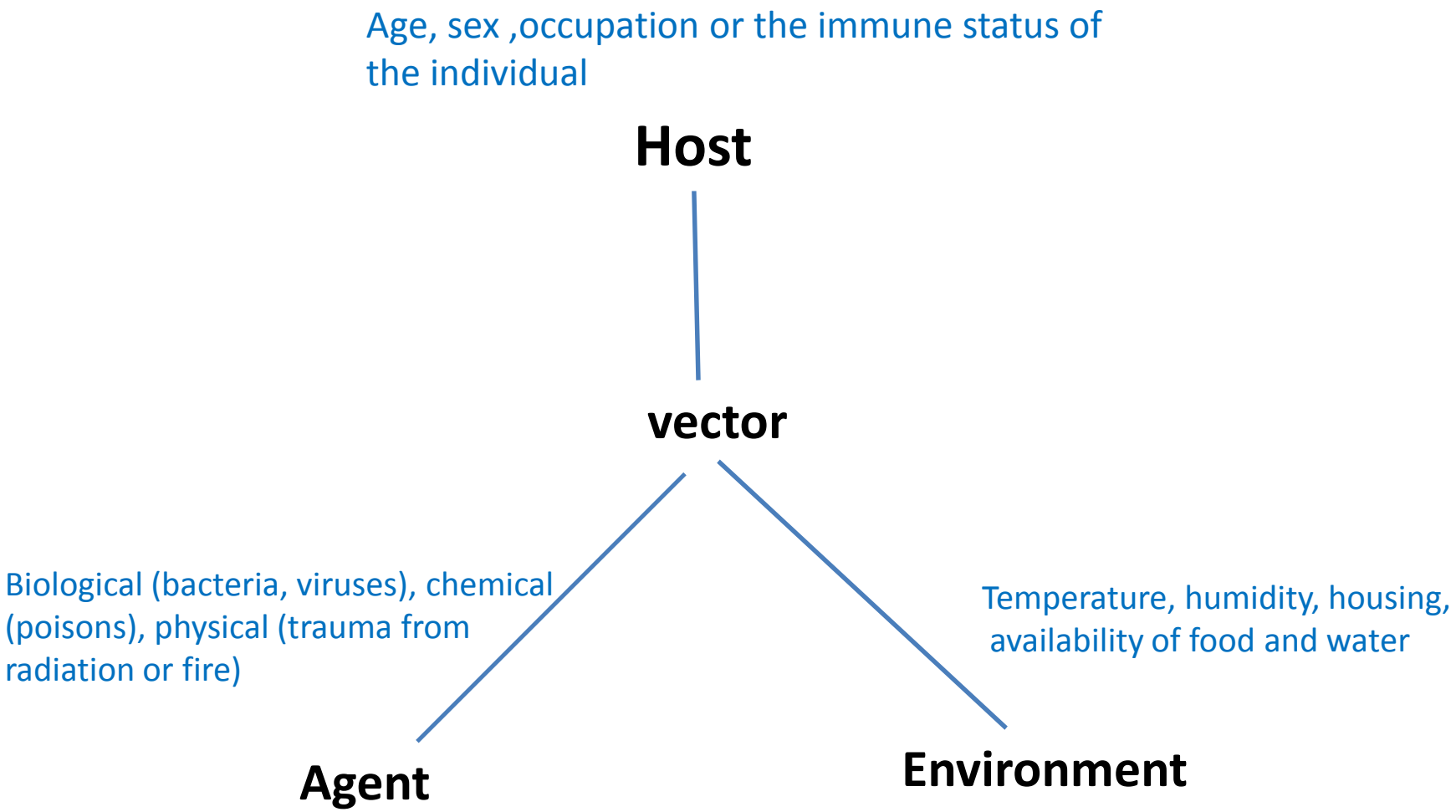
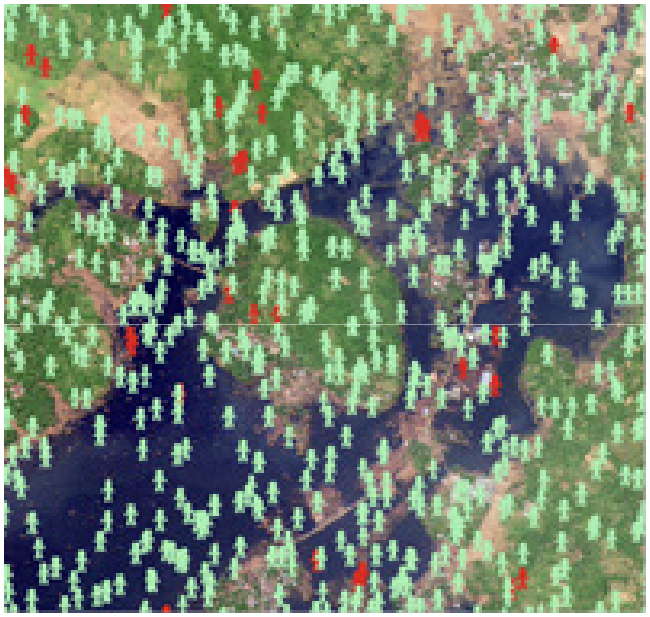


Fig1. *The epidemiologic triad of a disease*

Why Agent-Based?

- Originally tried System Dynamics
- Agent-Based Modeling makes more sense
  - Individual behaviors differ and can greatly affect the course of an epidemic outbreak
  - A user can observe an individual agent over time
  - Good visual representation



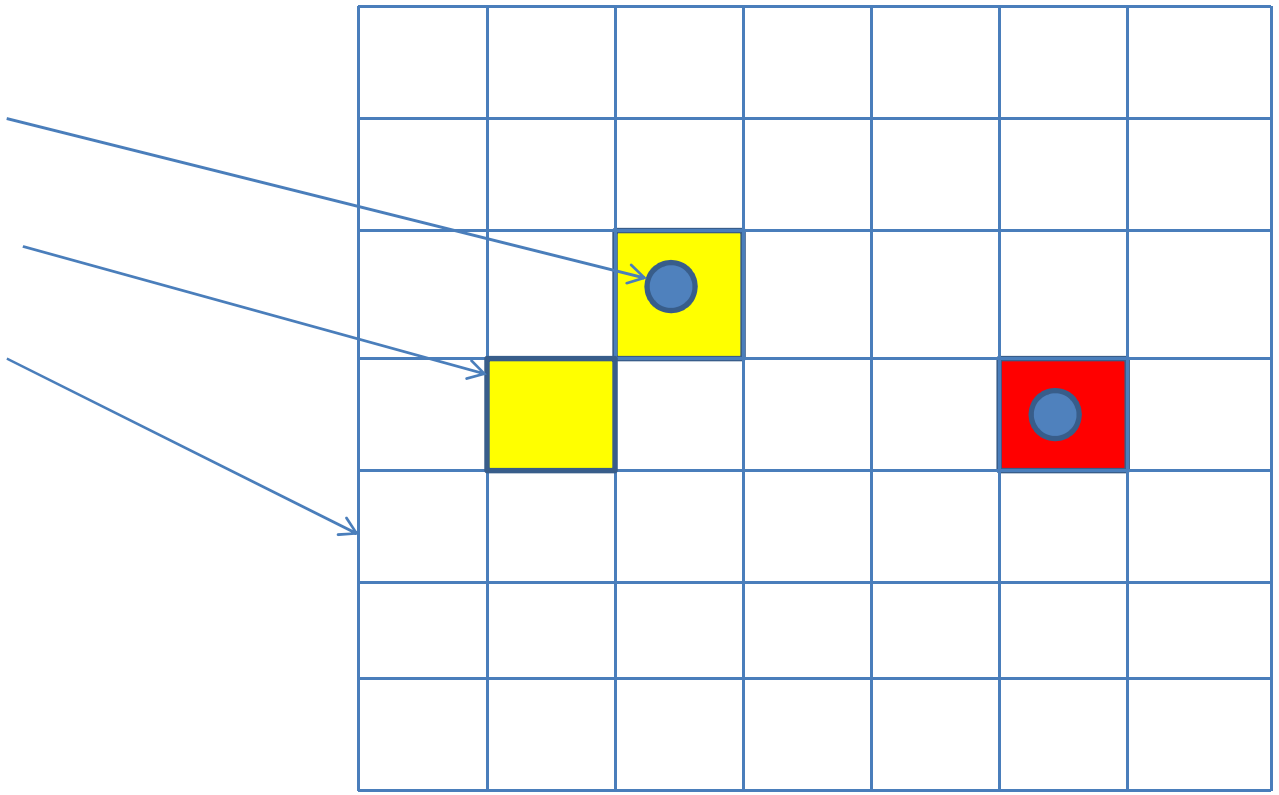
Features of Agent-based Modeling (ABM)

- Rule-based
- Discrete-event/Discrete-time
- Spatial
- Parallelism
- Stochastic
- Ease to translate conceptual models to executable form

An, G., Mi, Q., Dutta-Moscato, J., Vodovotz, Y., Agent-based Models in translational systems biology, *Wiley Interdisciplinary Reviews: System Biology and Medicine*, 2009 Volume1, Issue 2: 159-171

Components of ABM

- Turtle
- Patch
- Space

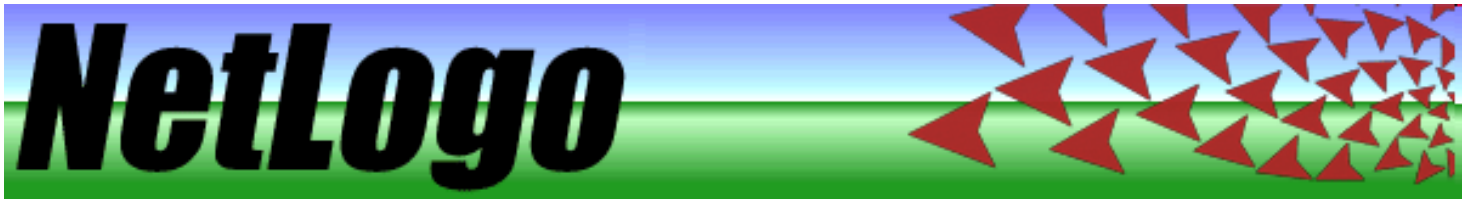


Two Samples

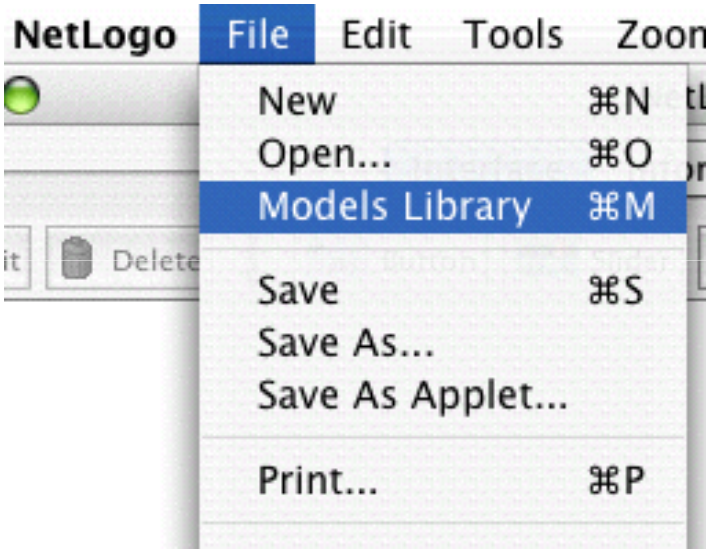
- AIDS
- Tyhoid Fever on Disaster Area

ABM tool: **NetLogo**

- NetLogo 4.1 (Developed at Northwestern)
- User friendly programming environment and simple language (Logo like)
- Cross-platform support
  - Windows, Linux, Mac
- Depends on Java
- Free!



Tutorial 1: Sample model (Wolf Sheep Predation)



- Press the "setup" button.

  What do you see appear in the view?

- Press the "go" button to start the simulation.

  As the model is running, what is happening to the wolf and sheep populations?

- Press the "go" button to stop the model.

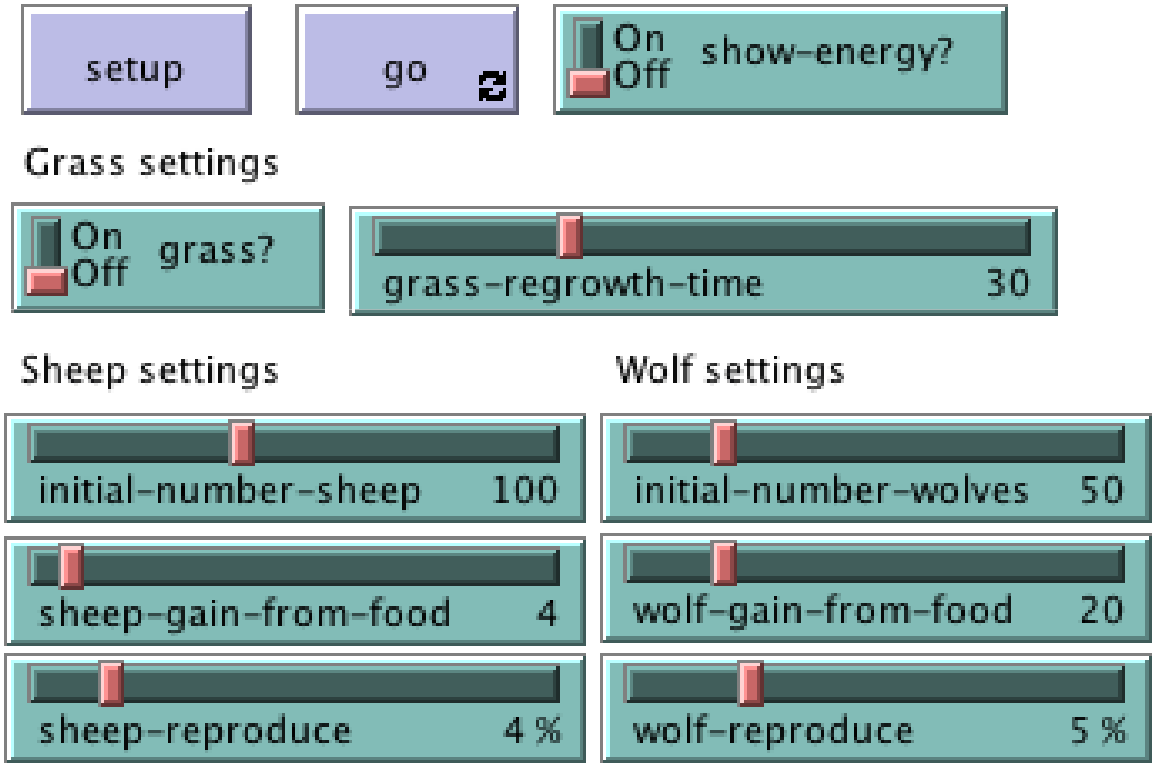
Controlling the Model: Buttons

"forever" button

"once" button

Controlling speed: Speed Slider

Adjusting Settings: Sliders and Switches



- Press "setup" and "go" and let the model run for about a 100 time-ticks. (Note: there is a readout of the number of ticks right above the plot.)
- Stop the model by pressing the "go" button.

What happened to the sheep over time?

Let's take a look and see what would happen to the sheep if we change one of the settings.

- Turn the "grass?" switch on.
- Press "setup" and "go" and let the model run for a similar amount of time as before.

What did this switch do to the model? Was the outcome the same as your previous run?

What would happen to the sheep population if there was more initial sheep and less initial wolves at the beginning of the simulation?

- Turn the "grass?" switch off.
- Set the "initial-number-sheep" slider to 100.
- Set the "initial-number-wolves" slider to 20.
- Press "setup" and then "go".
- Let the model run for about 100 time-ticks.

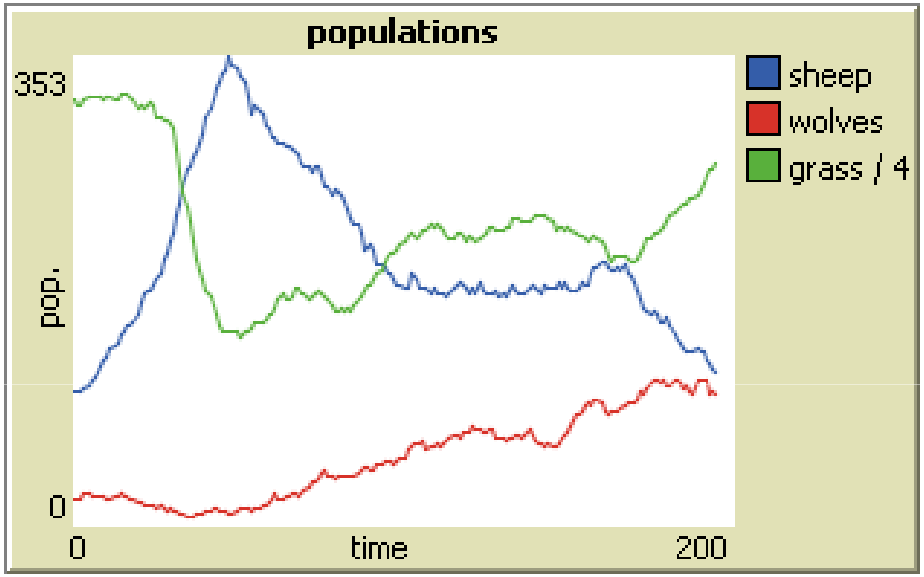
What other sliders or switches can be adjusted to help out the sheep population?

- Set "initial-number-sheep" to 80 and "initial-number-wolves" to 50. (This is close to how they were when you first opened the model.)
- Set "sheep-reproduce" to 10.0%.
- Press "setup" and then "go".
- Let the model run for about 100 time ticks.

What happened to the wolves in this run?

Gathering Information: Plots and Monitors

Plot



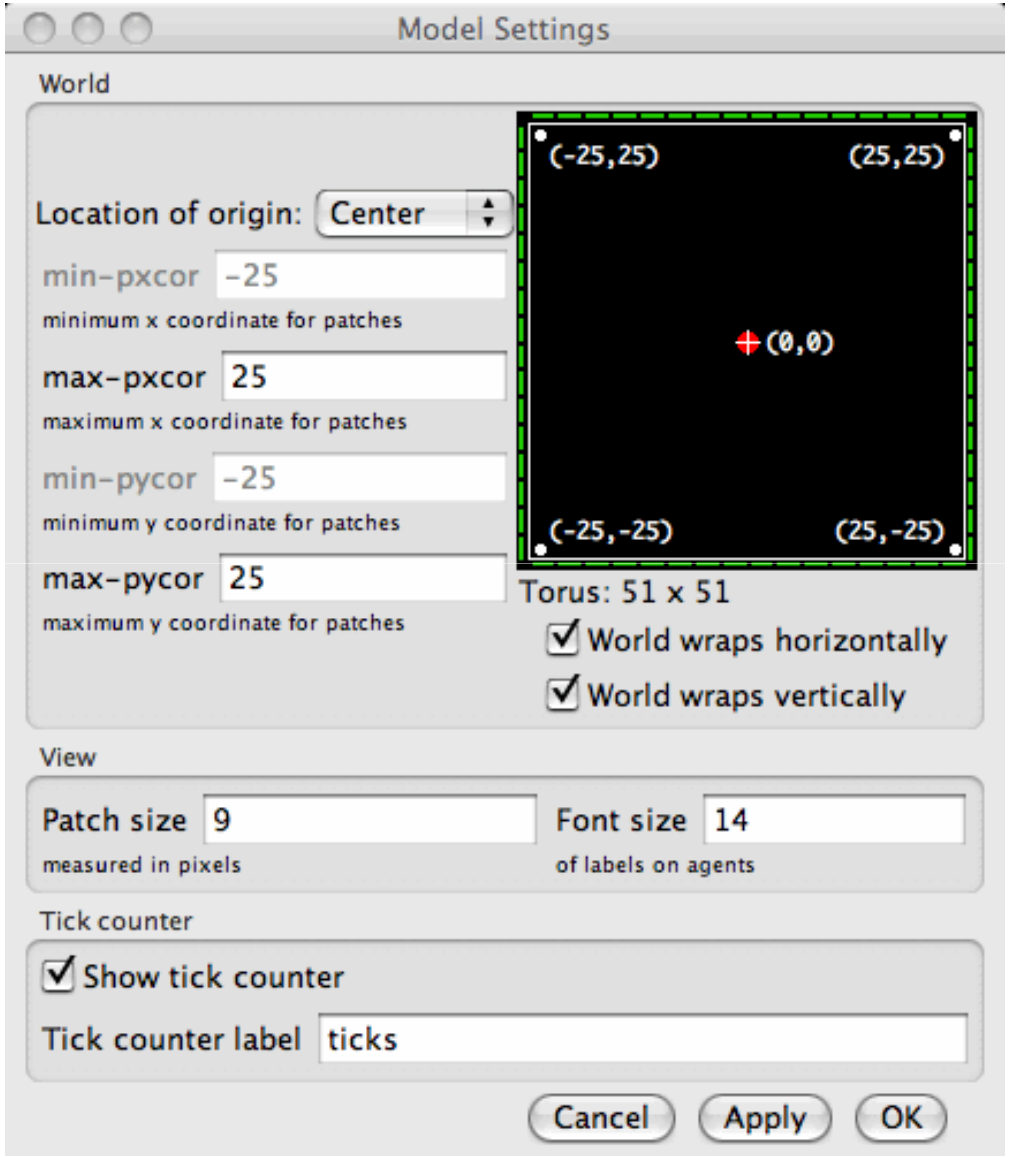
Monitor

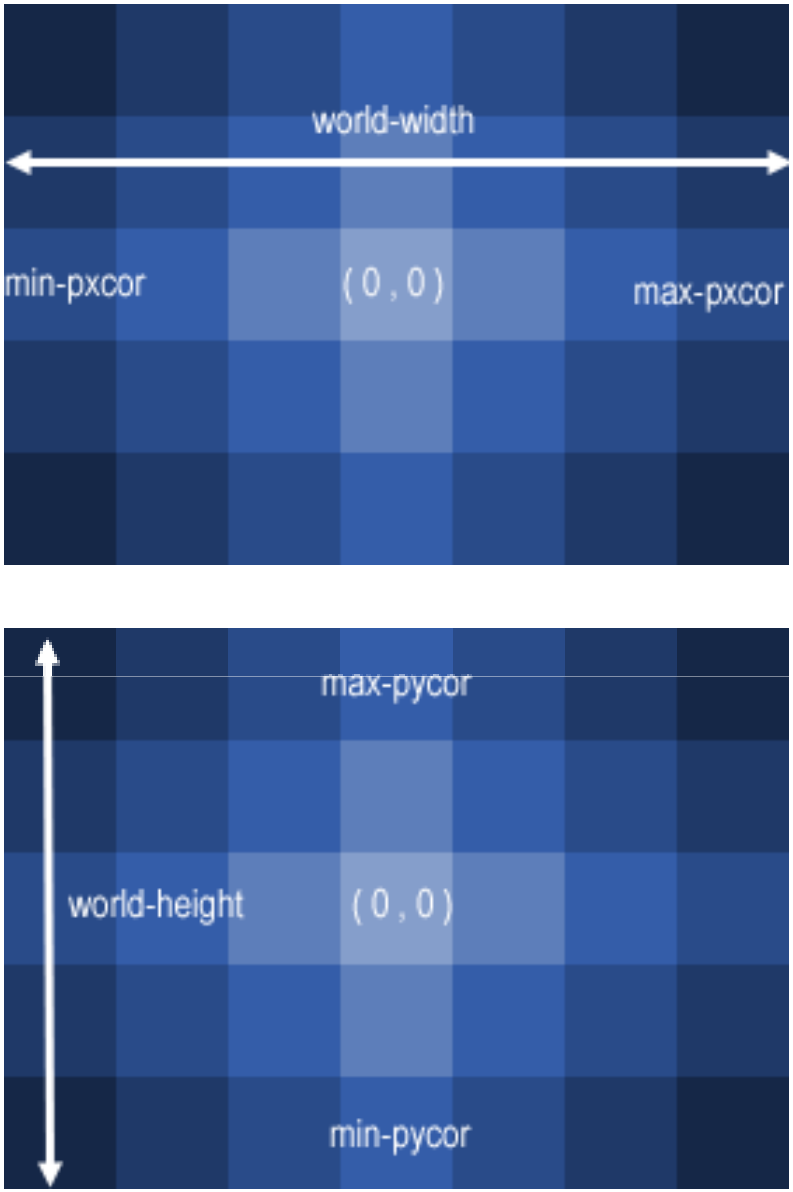
time-ticks	sheep	wolves	grass / 4
0	0	0	0

Controlling the View

. Press "setup" and then "go" to start the model running.
. As the model runs, move the speed slider to the left.
What happens?
This slider is helpful if a model is running too fast for you to see what's going on in detail.
. Move the speed slider to the middle.
. Try moving the speed slider to the right.
. Now try checking and unchecking the view updates checkbox.
What happens?

Press “Settings”

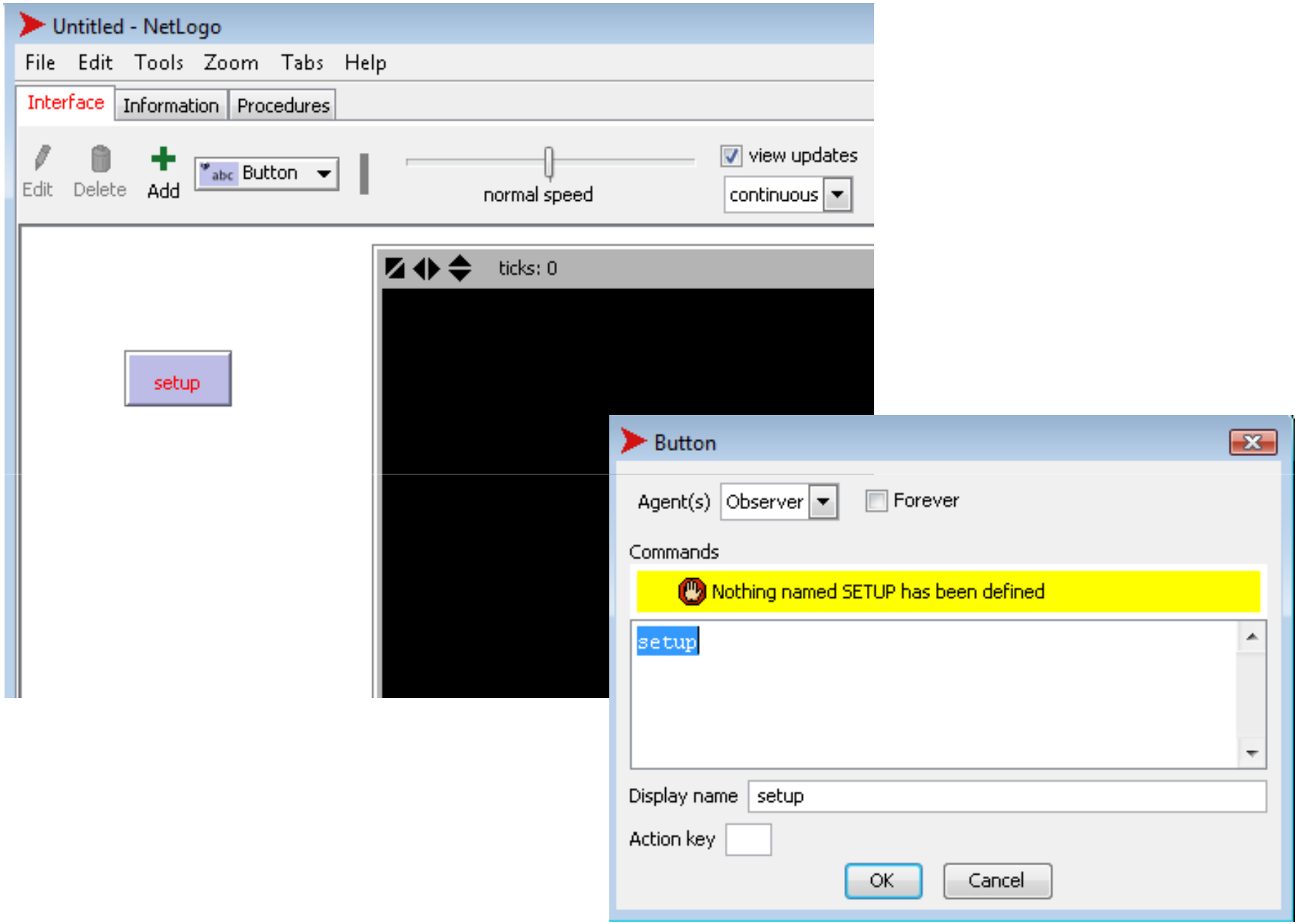


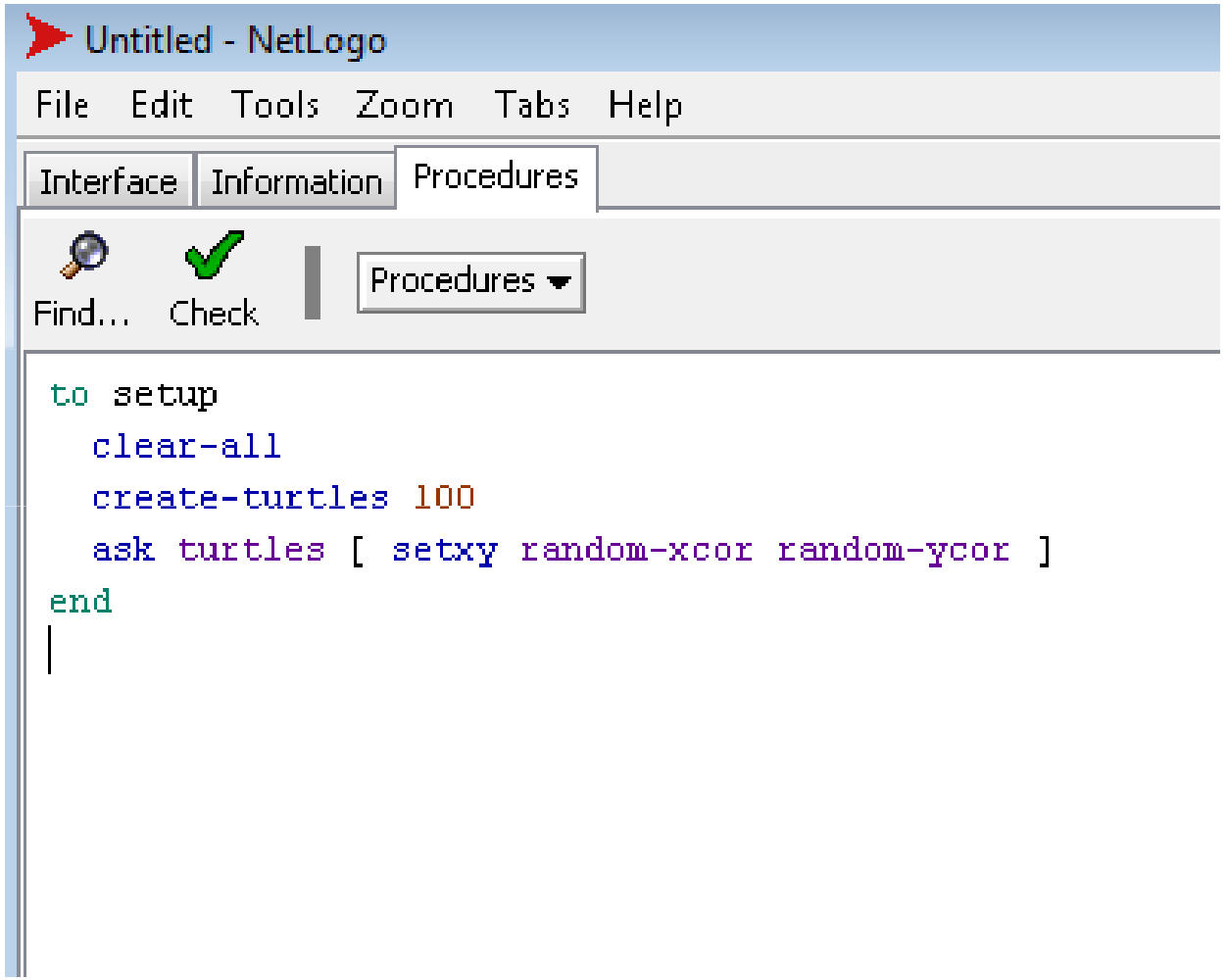


In these diagrams, max-pxcor is 3 , min-pxcor is -3, max-pycor is 2 and min-pycor is -2.

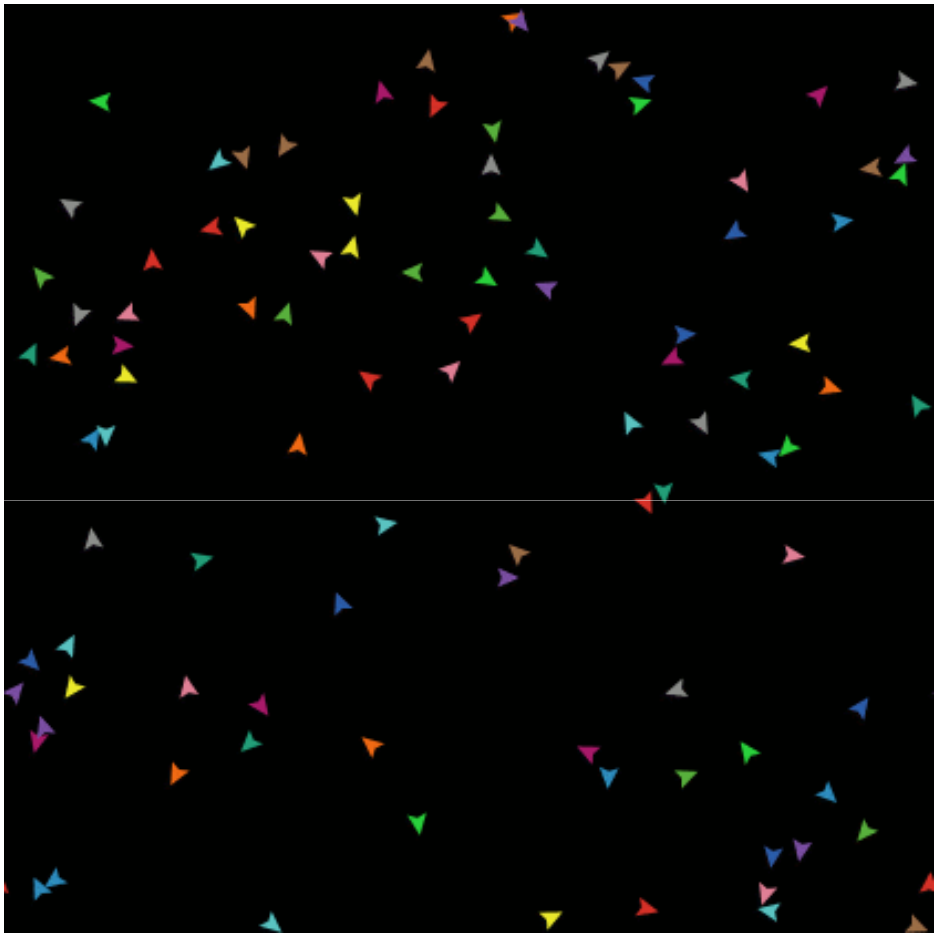
Tutorial 2: Procedures

- You will now learn to write procedures that make turtles move, eat, reproduce, and die.
- You will also learn how to make monitors, sliders, and plots.

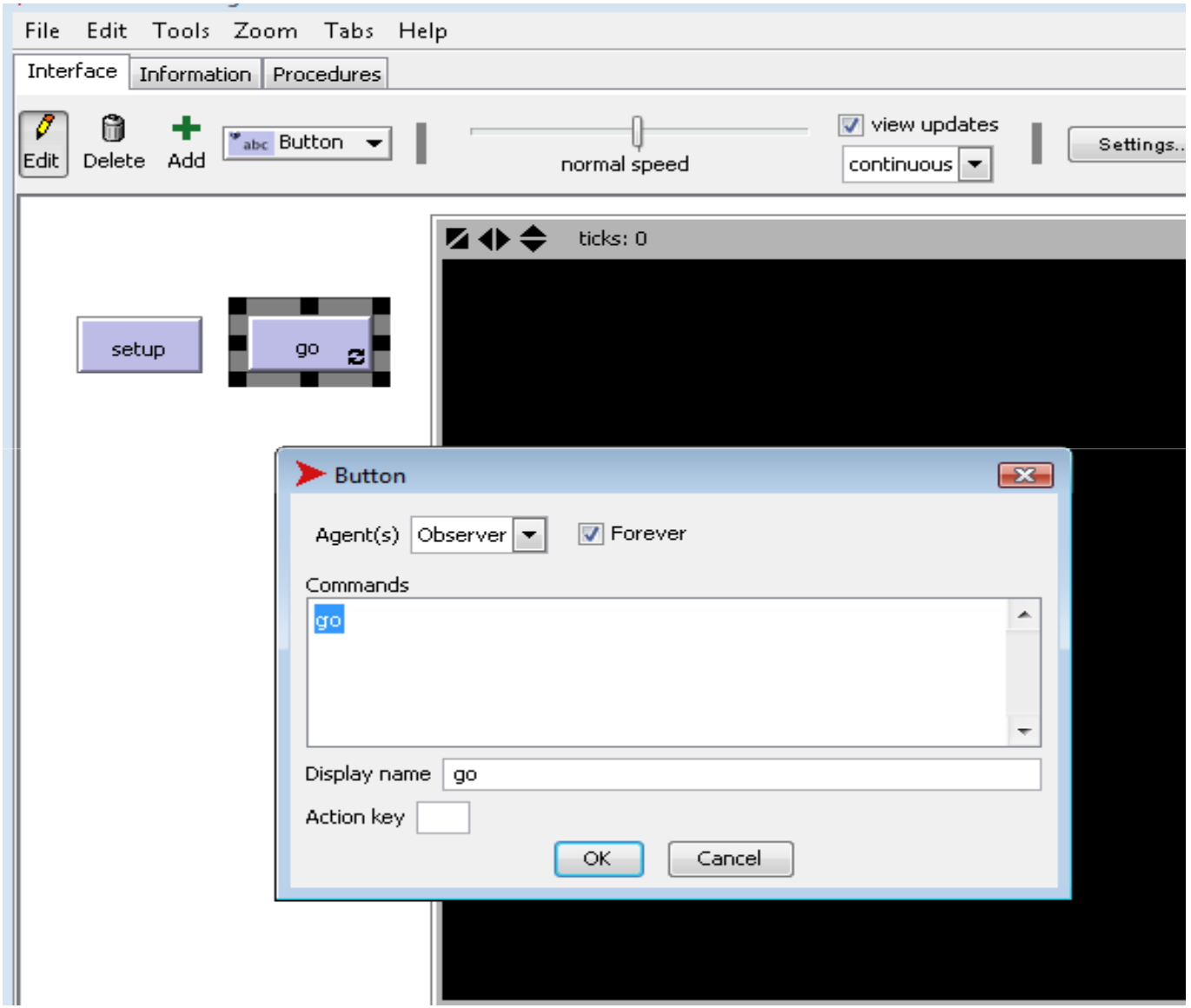

Untitled - NetLogo
File Edit Tools Zoom Tabs Help
Interface Information Procedures
Edit Delete Add
Button
normal speed
view updates
continuous
ticks: 0
setup
Button
Agent(s) Observer
Forever
Commands
Nothing named SETUP has been defined
setup
Display name setup
Action key
OK
Cancel

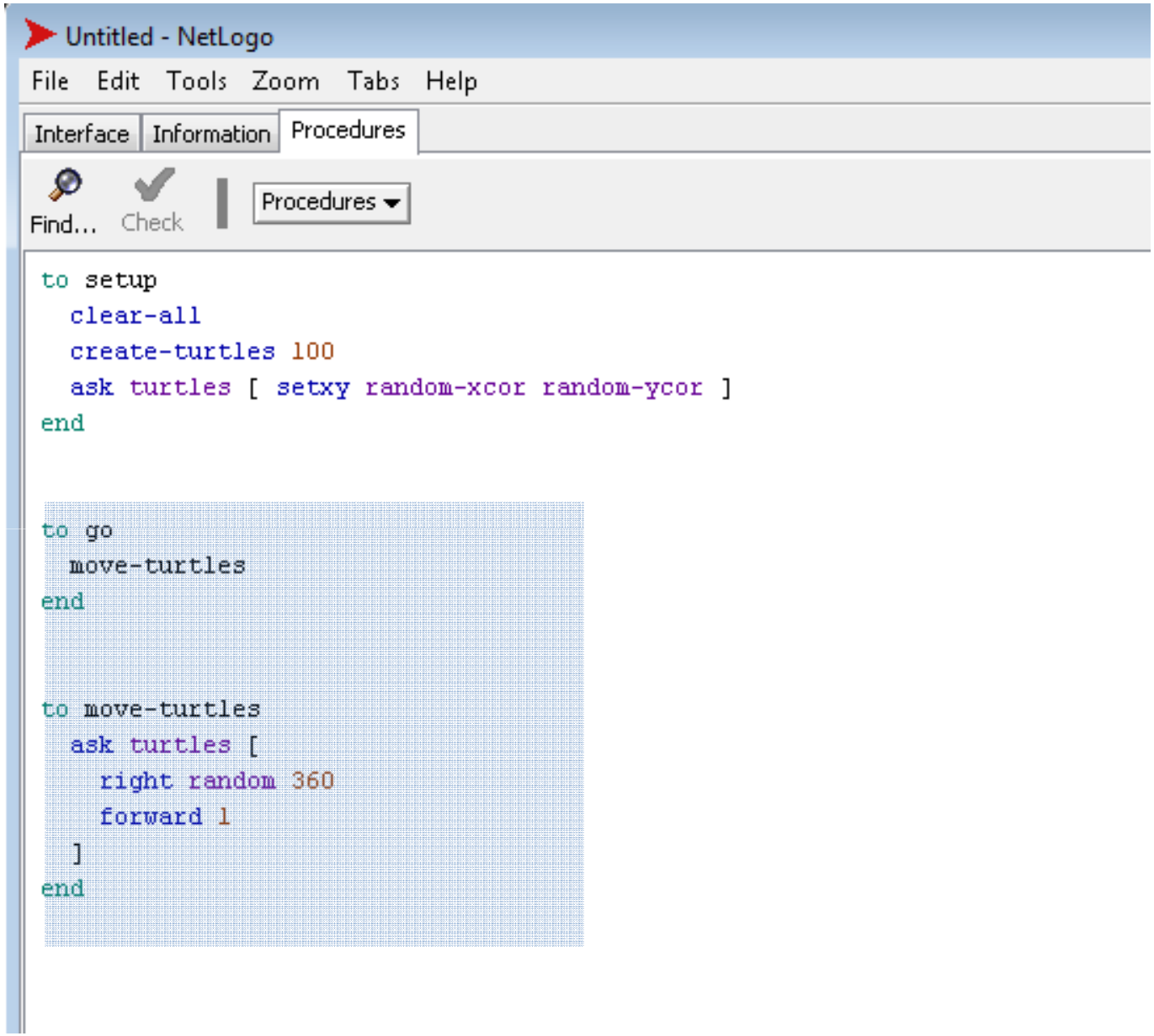

Untitled - NetLogo
File Edit Tools Zoom Tabs Help
Interface Information Procedures
Find... Check
Procedures
to setup
clear-all
create-turtles 100
ask turtles [setxy random-xcor random-ycor]
end

Press “setup”

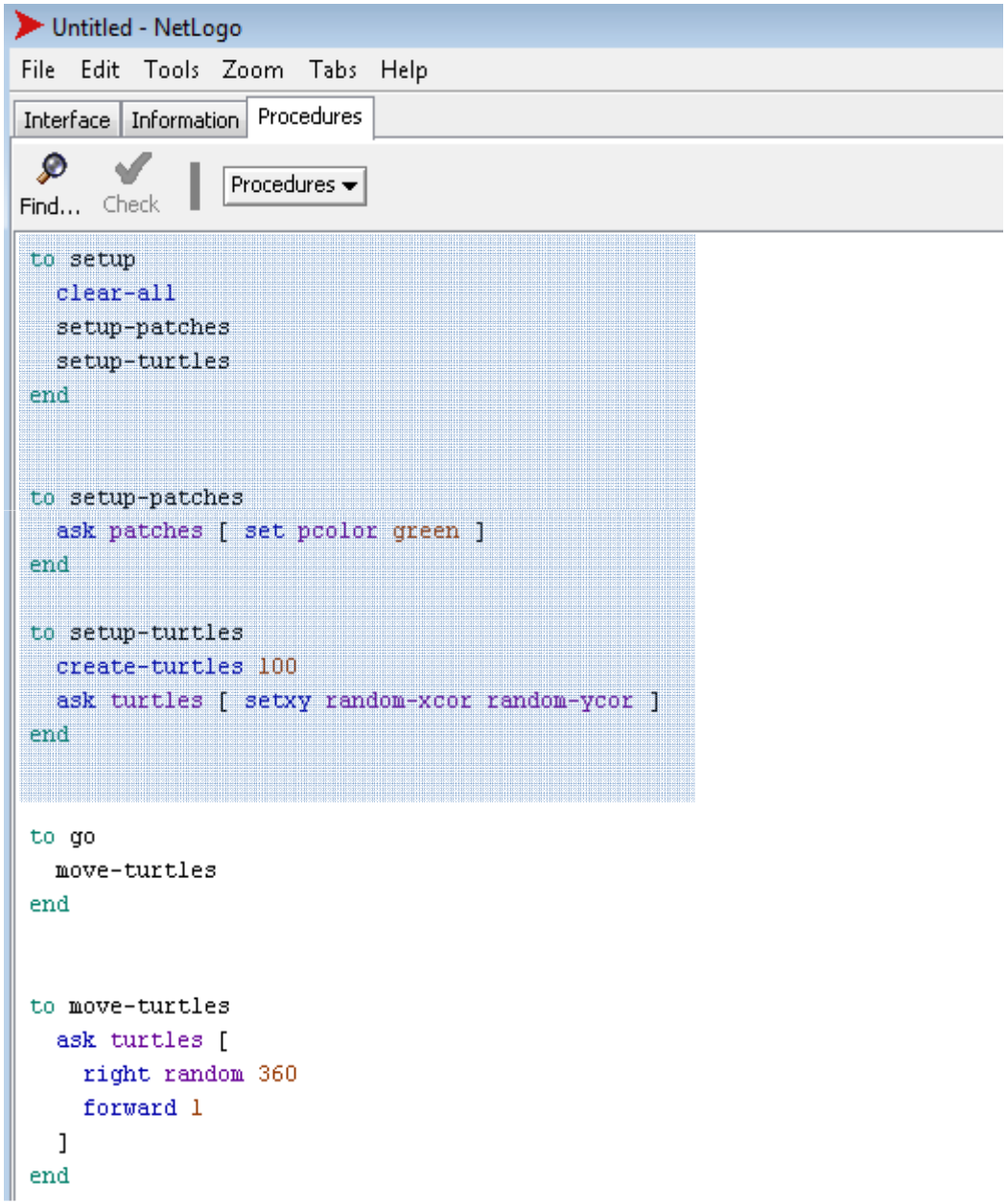


Add “go” button

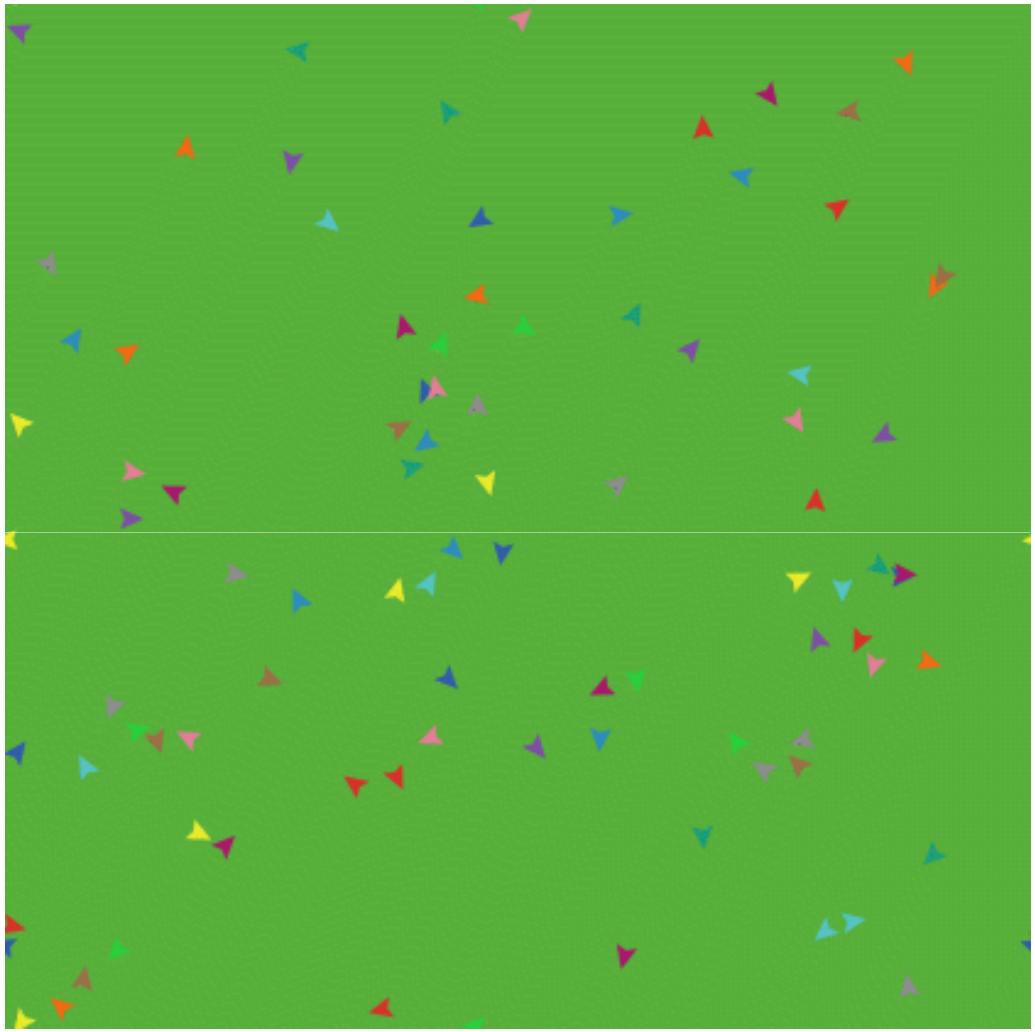



Untitled - NetLogo
File Edit Tools Zoom Tabs Help
Interface Information Procedures
Find... Check
Procedures
to setup
clear-all
create-turtles 100
ask turtles [setxy random-xcor random-ycor]
end
to go
move-turtles
end
to move-turtles
ask turtles [
right random 360
forward 1
]
end

Patches and variables



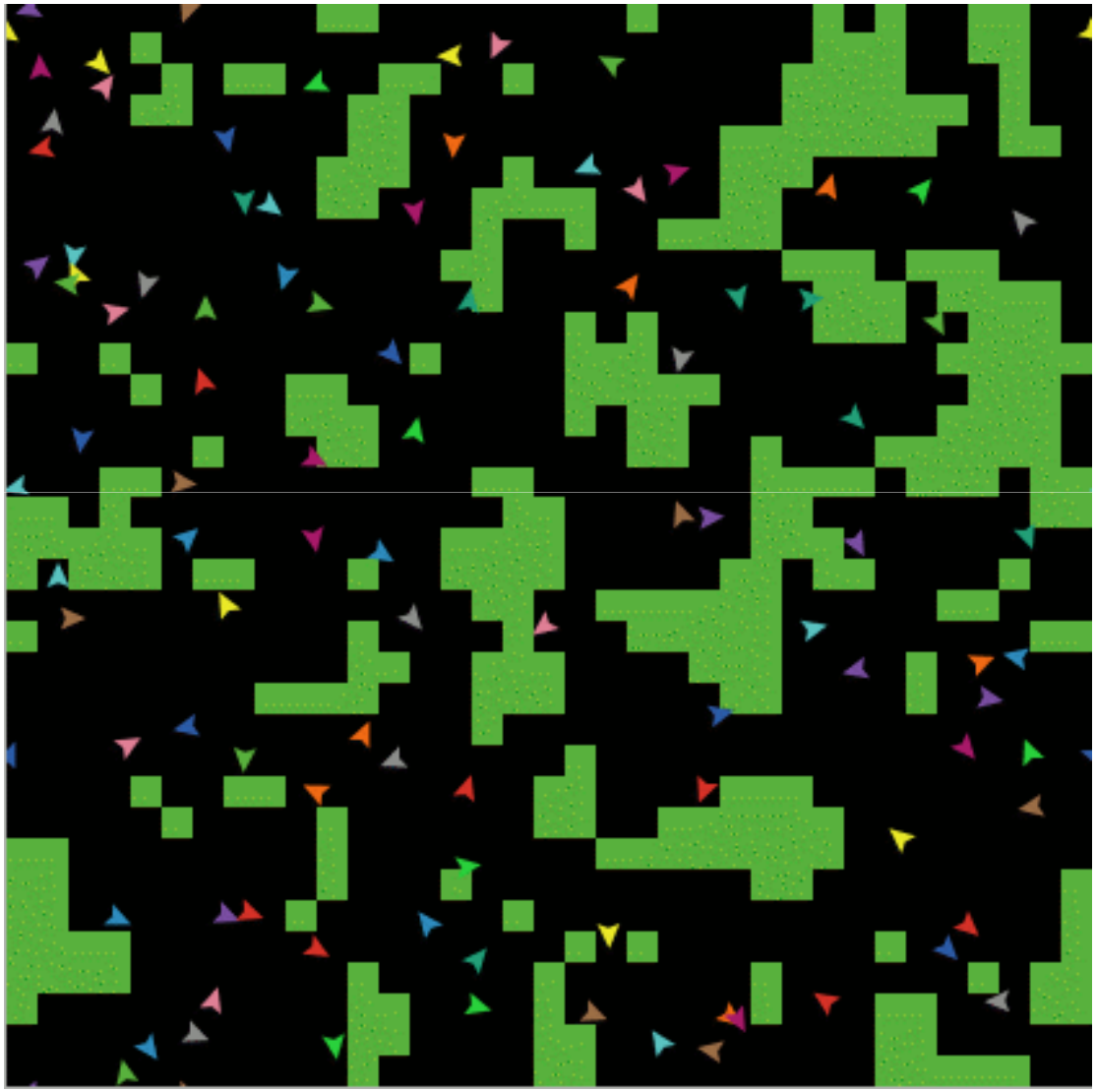
Result



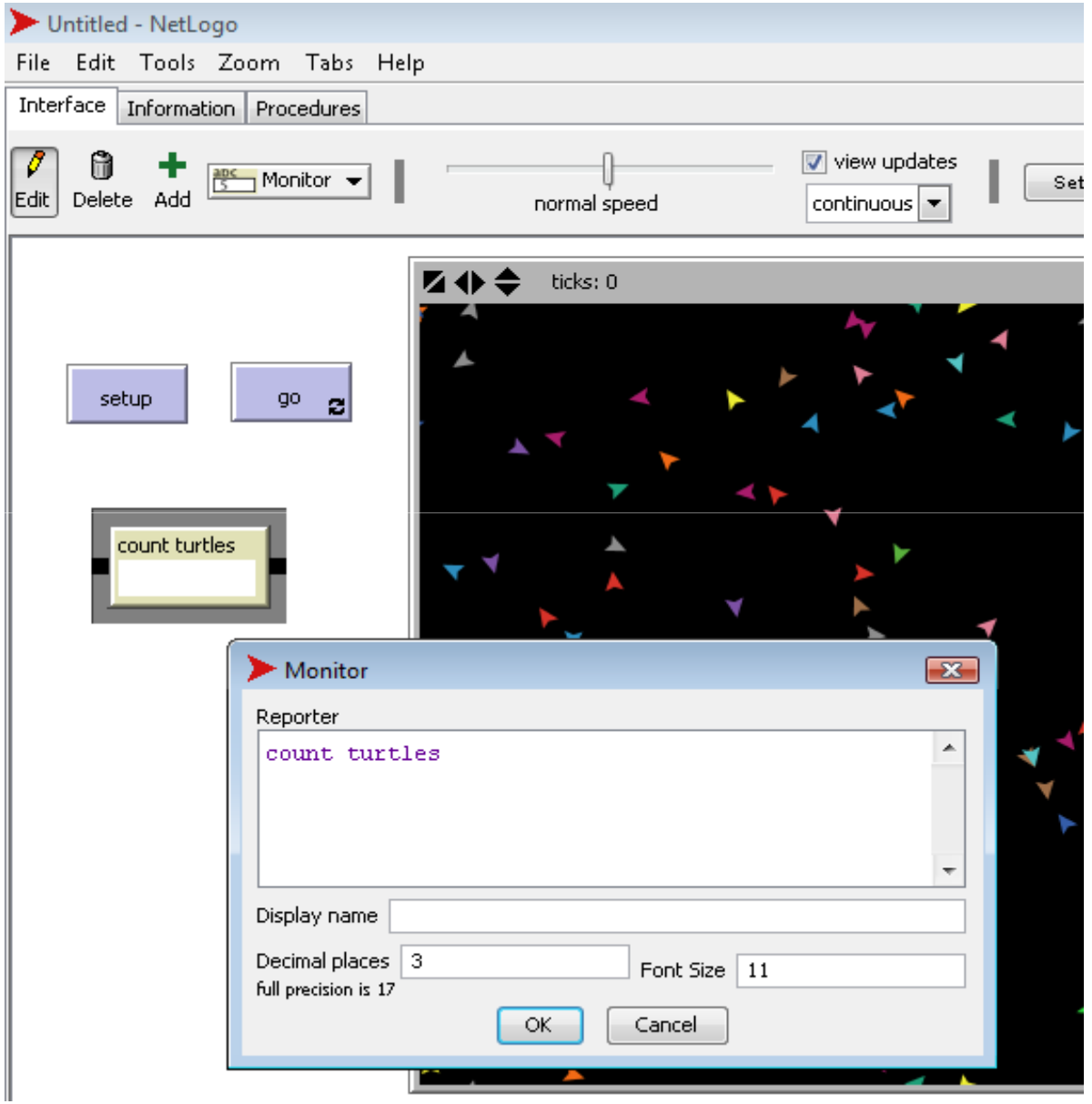
Turtle variables

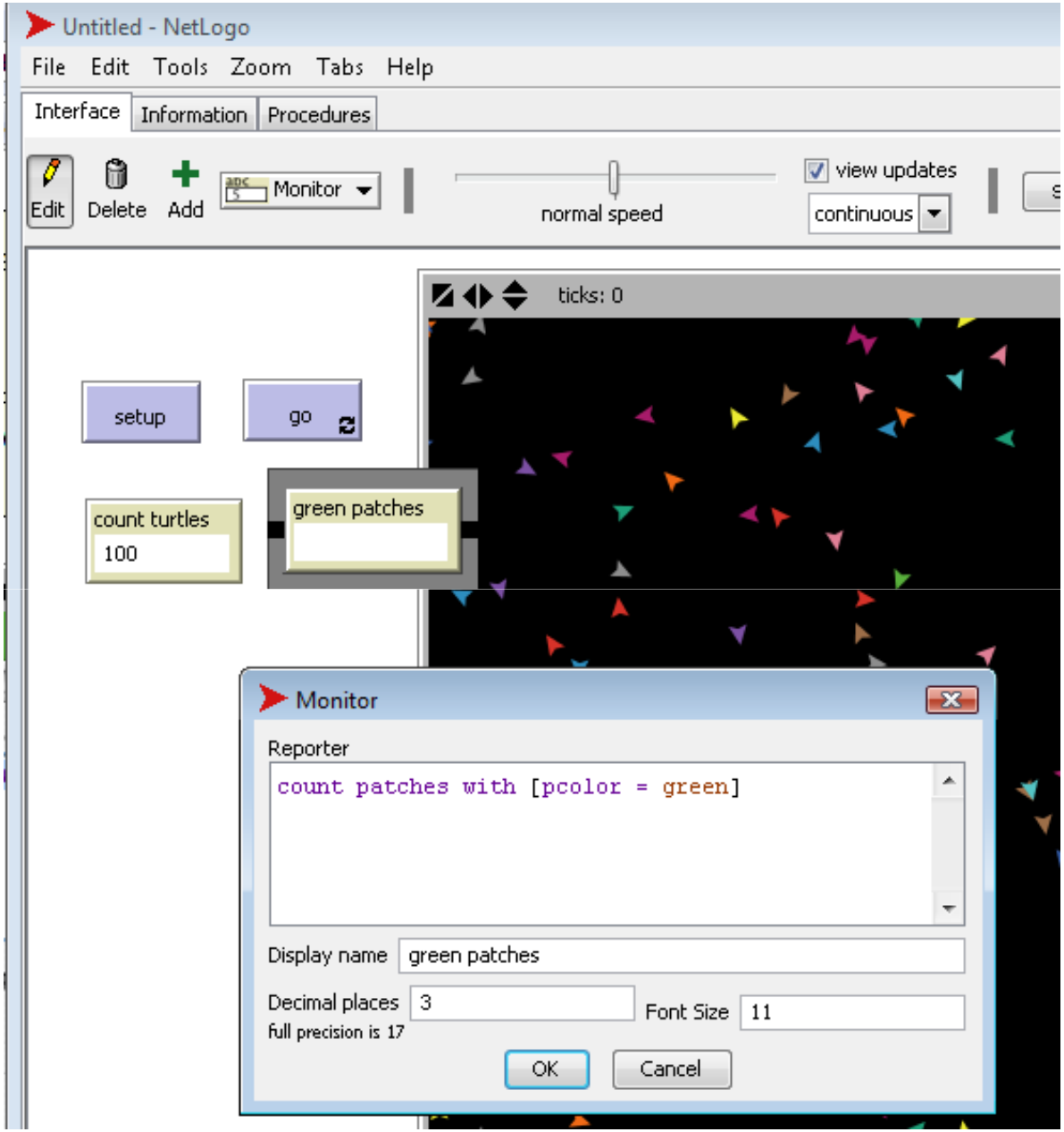
```
turtles-own [energy]

to go
  move-turtles
  eat-grass
end

to eat-grass
  ask turtles [
    if pcolor = green [
      set pcolor black
      set energy (energy + 10)
    ]
  ]
end

to move-turtles
  ask turtles [
    right random 360
    forward 1
    set energy energy - 1
  ]
end
```

Result

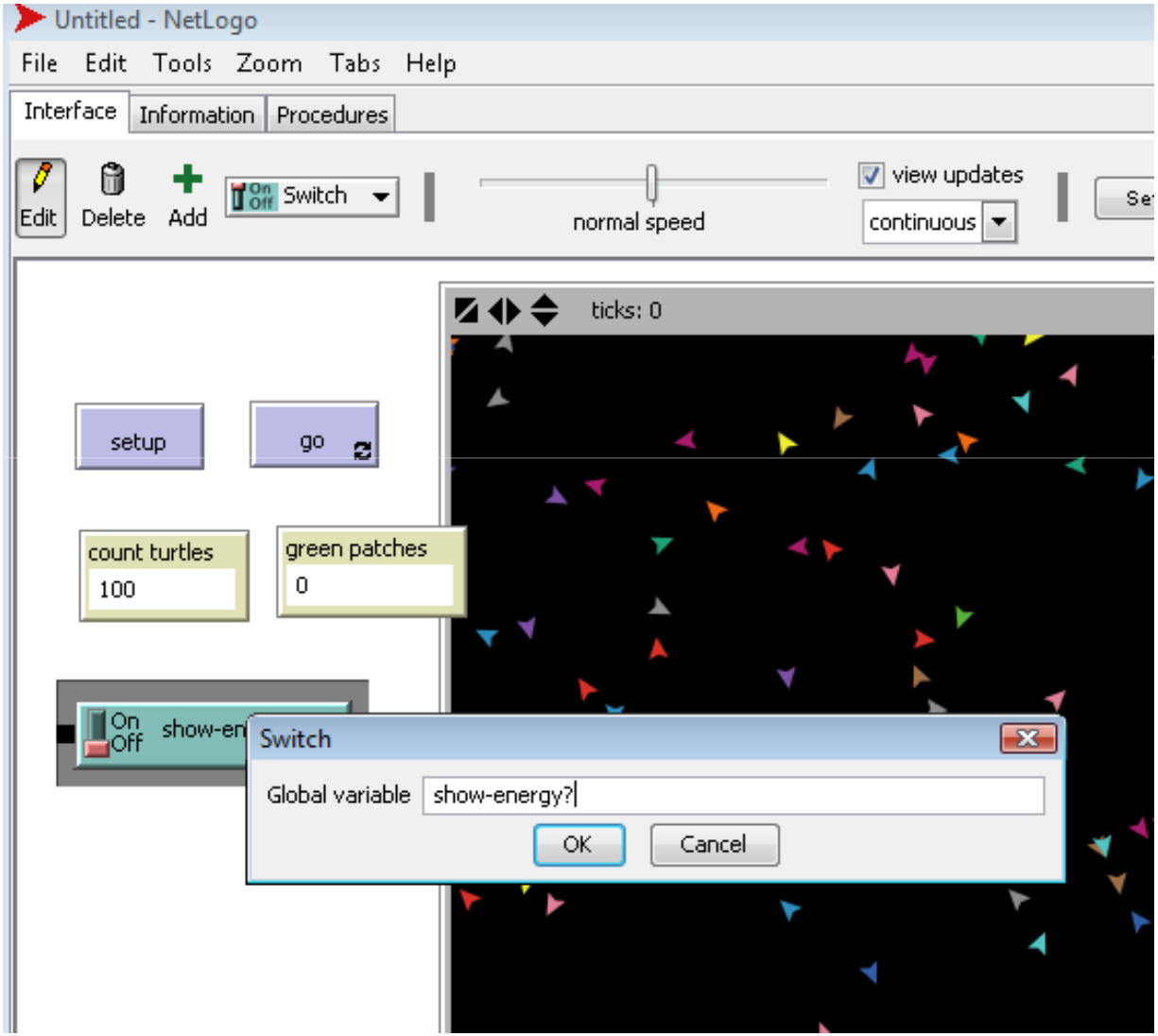


Monitors


Untitled - NetLogo
File Edit Tools Zoom Tabs Help
Interface Information Procedures
Edit Delete Add Monitor
normal speed
view updates
continuous
ticks: 0
setup
go
count turtles
Monitor
Reporter
count turtles
Display name
Decimal places 3
Font Size 11
full precision is 17
OK Cancel

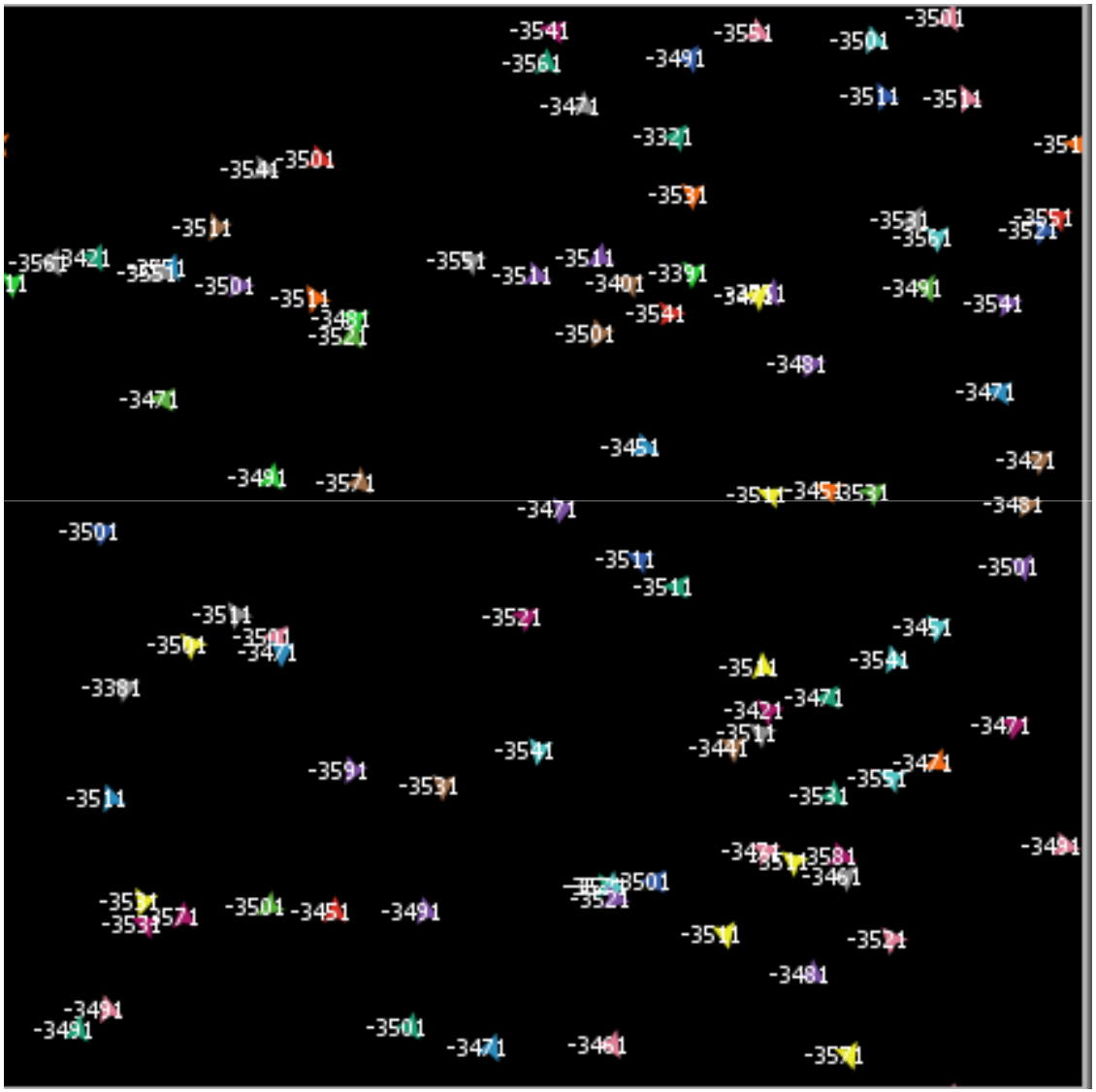

Untitled - NetLogo
File Edit Tools Zoom Tabs Help
Interface Information Procedures
Edit Delete Add Monitor
normal speed
view updates
continuous
ticks: 0
setup
go
count turtles
100
green patches
Monitor
Reporter
count patches with [pcolor = green]
Display name
green patches
Decimal places
3
full precision is 17
Font Size
11
OK
Cancel

Switches and labels



```
to eat-grass
  ask turtles [
    if pcolor = green [
      set pcolor black
      set energy (energy + 10)
    ]

    ifelse show-energy?
      [ set label energy ]
      [ set label "" ]

]
end
```

Result



More procedures

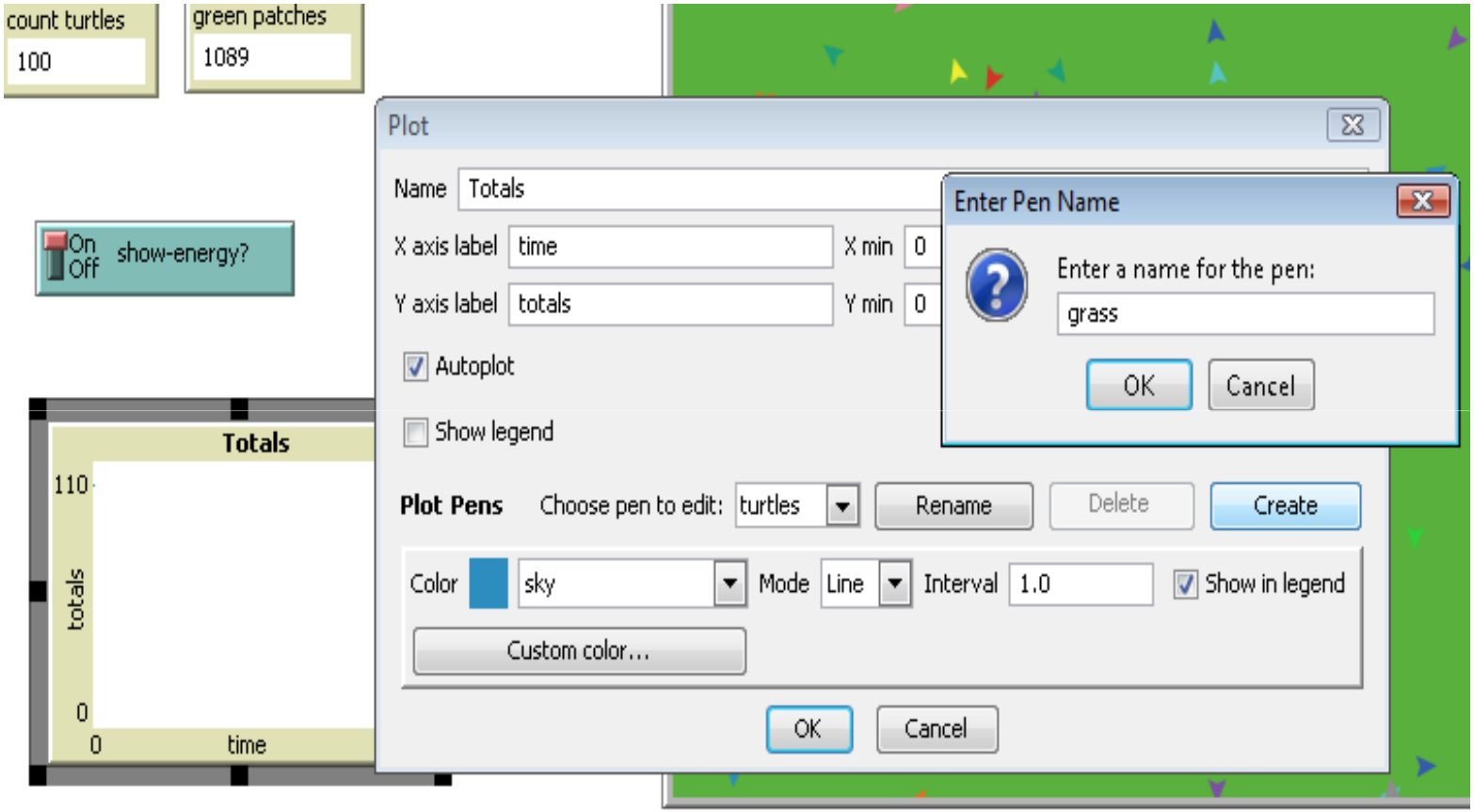
```
to go
  move-turtles
  eat-grass
  reproduce
  check-death
  regrow-grass
end
```

```
to reproduce
  ask turtles [
    if energy > 50 [
      set energy energy - 50
      hatch 1 [ set energy 50 ]
    ]
  ]
end

to check-death
  ask turtles [
    if energy <= 0 [ die ]
  ]
end

to regrow-grass
  ask patches [
    if random 100 < 3 [ set pcolor green ]
  ]
end
```

Plotting

```
to setup
  clear-all
  setup-patches
  setup-turtles
  do-plots
end

to go
  move-turtles
  eat-grass
  reproduce
  check-death
  regrow-grass
  do-plots
end
```

```
to do-plots
  set-current-plot "Totals"
  set-current-plot-pen "turtles"
  plot count turtles
  set-current-plot-pen "grass"
  plot count patches with [pcolor = green]
end
```


count turtles
100
green patches
1089
On
Off
show-energy?
Totals
110
totals
0
0
time
Plot
Name
Totals
X axis label
time
X min
0
Y axis label
totals
Y min
0
Autoplot
Show legend
Plot Pens
Choose pen to edit:
turtles
Rename
Delete
Create
Color
sky
Mode
Line
Interval
1.0
Show in legend
Custom color...
OK
Cancel
Enter Pen Name
Enter a name for the pen:
grass
OK
Cancel

SPARK is available at: www.pitt.edu/~cirm/SPARK