Bridges To Computing

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Agent Based Programming & Simulations

Lecture 2: Multi-Agent Systems

References

- Russell, Stuart J.; Norvig, Peter (2003), Artificial Intelligence: A Modern Approach (2nd ed.), Upper Saddle River, New Jersey: Prentice Hall, ISBN 0-13-790395-2, http://aima.cs.berkeley.edu/ , chpt. 2
- Stan Franklin and Art Graesser (1996); Is it an Agent, or just a Program?: A Taxonomy for Autonomous Agents; Proceedings of the Third International Workshop on Agent Theories, Architectures, and Languages, Springer-Verlag, 1996
- An Introduction to Multiagent Systems, by Michael Wooldridge, John Wiley & Sons, Ltd (2002).

Content

- Types of Agents
  - Agent Defined
  - Agent Types
  - Intelligent Agents
- Multi-Agent Systems
  - Defined
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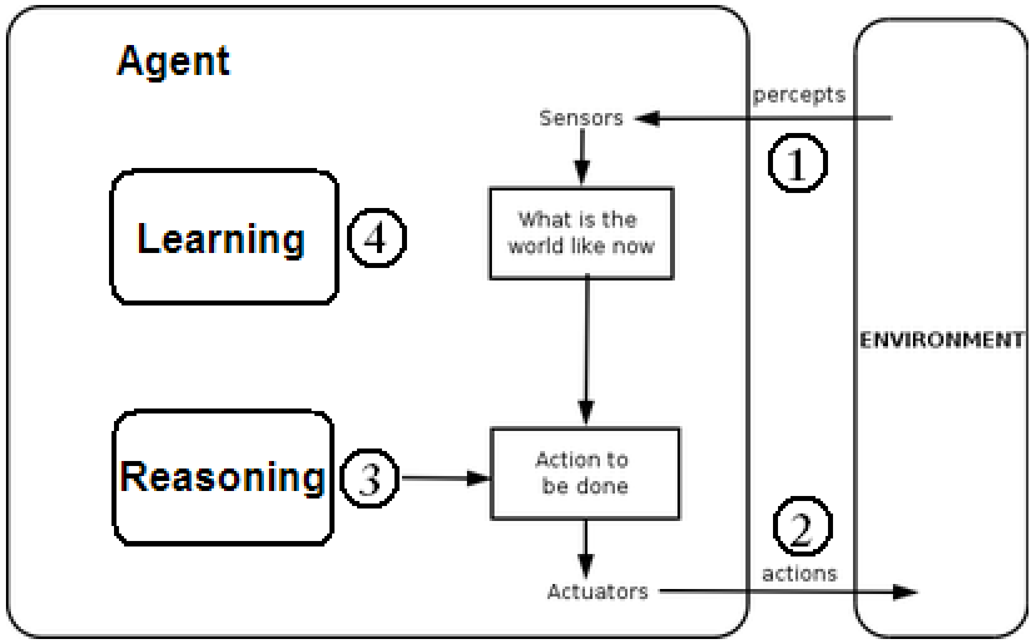
- Continuing with NetLogo

Agent Defined

- An Agent "is an autonomous entity which observes and acts upon an environment and directs its activity towards achieving goals." Russell & Norvig 2003,
- NOTE: A "software agent" usually implies a program, a "computer agent" can be a hardware/software combination, and an "intelligent agent", can be anything (including people/groups of people).

Components of an Agent



1. Sensors
2. Actuators/Effectors
3. Reasoning (maybe be very simple "if-then")
4. Learning (**optional**, defines an "intelligent agent")

Basic Agent Types

- Simple reflex agents -> If condition then action.
  - Can accomplish simple tasks quickly, unlikely to find "optimal" solution
    - If (distance-to-wall < 5) { turn right } else { turn left }
    - *NOTE: Algorithm above will eventually find door out of room.*
- Model-based reflex agents -> A model-based reflex agent keeps track of the current state of the world using an internal model (create a model). It then chooses an action based on tests performed on the model.
  - Slow
    - (1) Make map of room. (2) Calculate path(s) to door (3) Execute path
  - Can find optimal solution in some cases.

Intelligent Agents

- **Goal-based agents**
  - Goal-based agents are model-based agents which store information regarding situations that are desirable. This allows the agent a way to choose among multiple possibilities, selecting the one which reaches a goal state.
- **Learning agents**
  - Learning has an advantage that it allows the agents to initially operate in unknown environments and to become more competent than its initial knowledge alone might allow.
  - Learning is difficult, time-consuming and has to be done within some other methodology (neural-networks, reinforcement learning, etc.)

Multi-Agent System

- "A multi-agent system is one that consists of a number of agents which interact with one another. In the most general case, agents will be acting on behalf of users with different goals and motivations. To interact successfully, they will require the ability to cooperate, coordinate and negotiate with each other, much as people do. " (Wooldridge)
- A Multi-Agent system is... an environment in which many (well, two or more) agents exist and interact.

Properties of multi-agent systems

1. Individual agents are self-interested
   - Agent pursue their own individual goals
   - There may be team rewards for a group of agents achieving a goal together... but
2. Cooperation is not governed,
   - Cooperation (and altruism) are emergent (if happens at all)

Note: Compare this to "distributed systems", where

1. goals are only group-based
2. cooperation is engineered to be inherent in the system

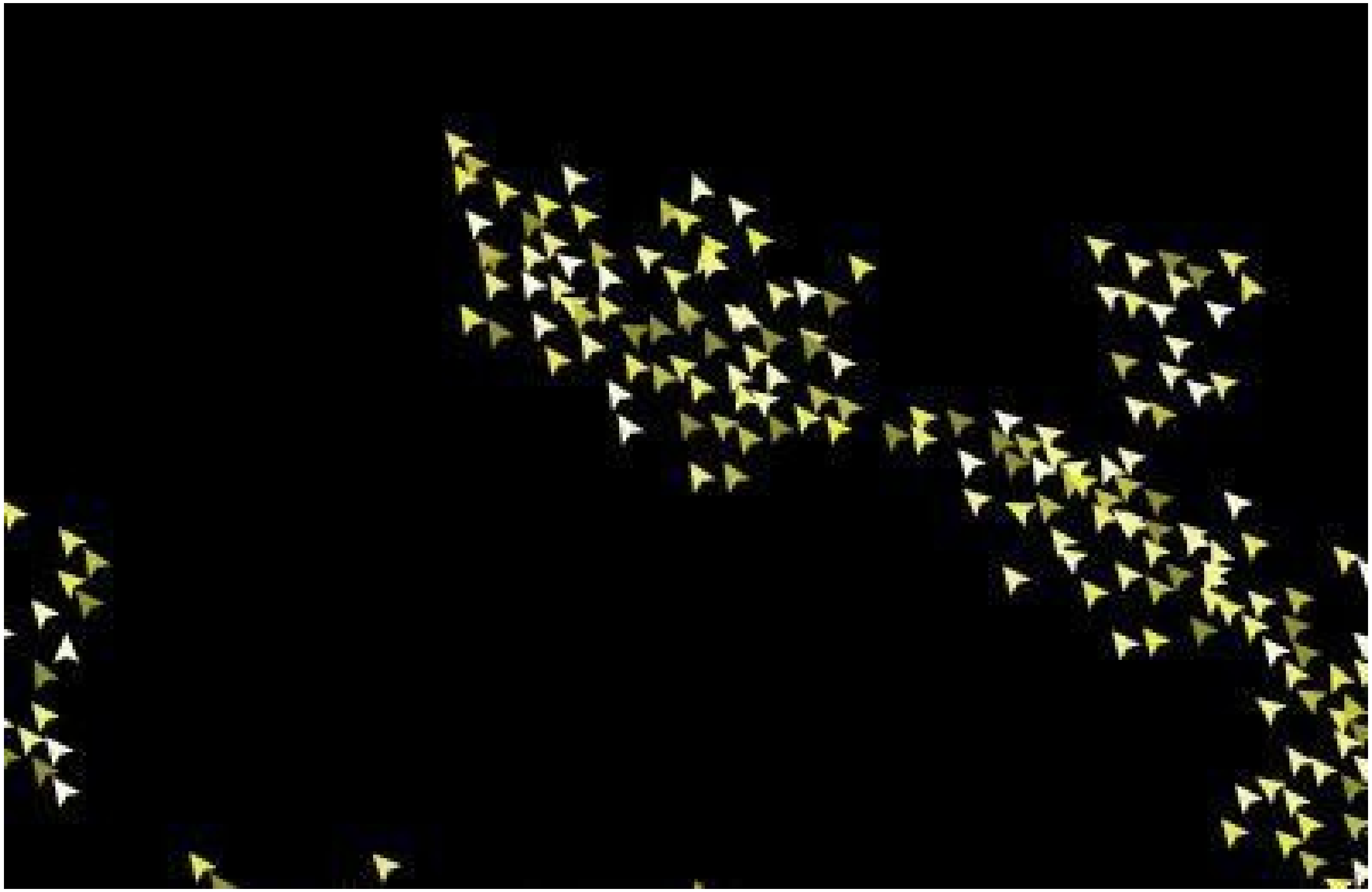
Multi-Agent Systems… Why?

Are there advantages to using Agent-Based programming?

Yes!

1. **Complexity**: Some problems are so complex that they are basically impossible to model as a single program.
   - Examples: Weather, Internet, Travel Systems
2. **Emergent Behavior**: Some types of behavior are very difficult to program in directly but can result as a side effect of individual agents selfishly pursuing their own very simple goals.

The Flocking Program - Emergent Behavior (link)

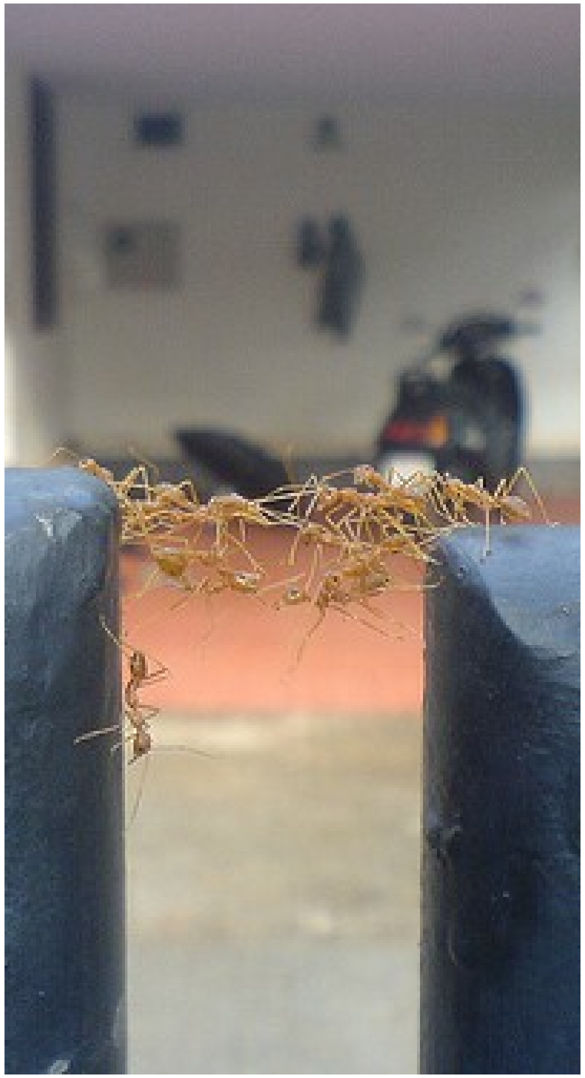


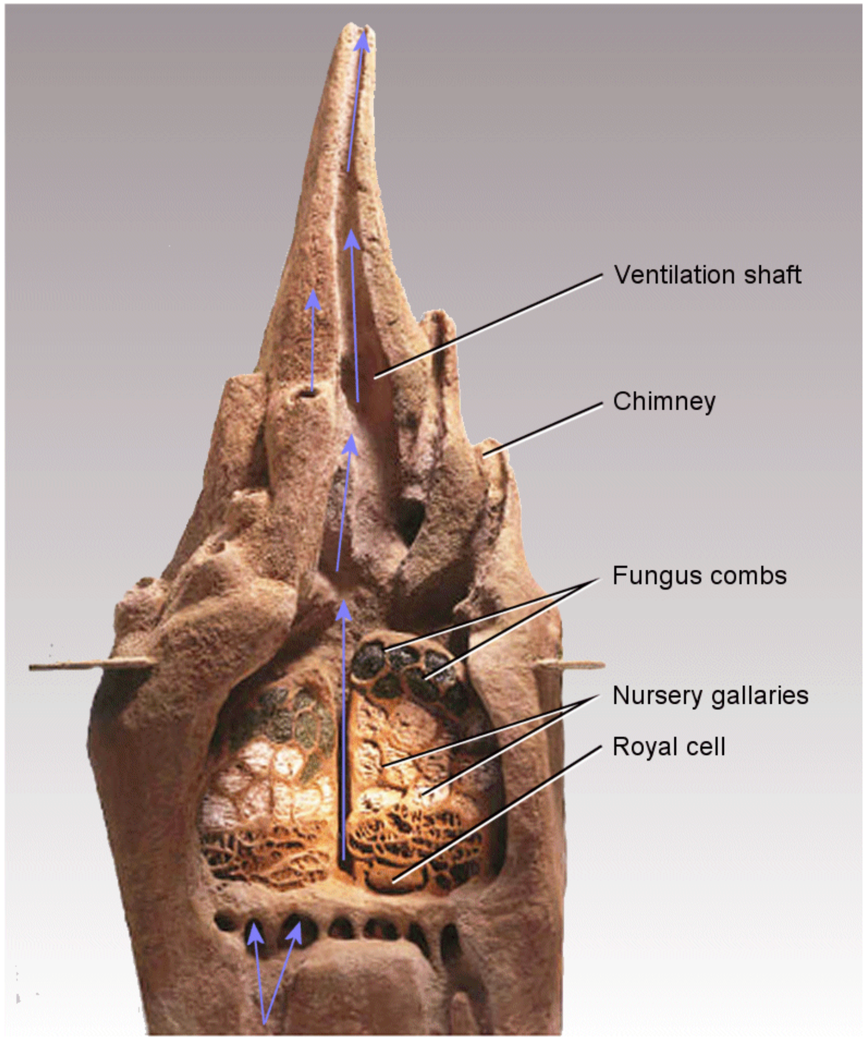
Research Areas – Multi-Agent Systems

Key Research Areas

1. Agent design (micro level): How do we design individual agents to operate (accomplish their own goals) effectively?
2. Society Design (macro level): How do we design *groups* of agents, or *societies*, to operate effectively together?
3. Hive Intelligence (abstract level): Can simple agents, working together, effectively demonstrate high level reasoning abilities? Can simple agents, working together, accomplish very complex tasks?

Ants & Termites (Hive Intelligence)





continuing with NetLogo

NetLogo Imperative Programming

1. Sequence ->
   1. Left-Right, Top Down
   2. Buttons can also call procedures.
2. Selection -> (link)
   1. if condition [commands]
   2. ifelse condition [commands1] [commands2]

   Example:

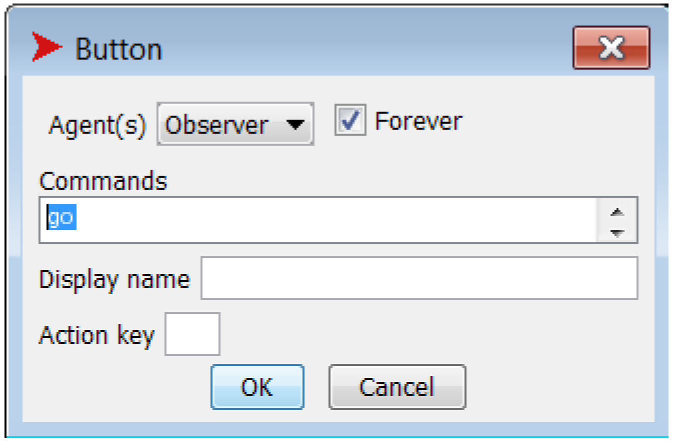
```
ask patches [
        ifelse pxcor > 0
        [ set pcolor blue ]
        [ set pcolor red ]
]
```

NetLogo Imperative Programming (cont)

3. Repetition -> (link1)
   1. while [reporter] [commands]

      Example:

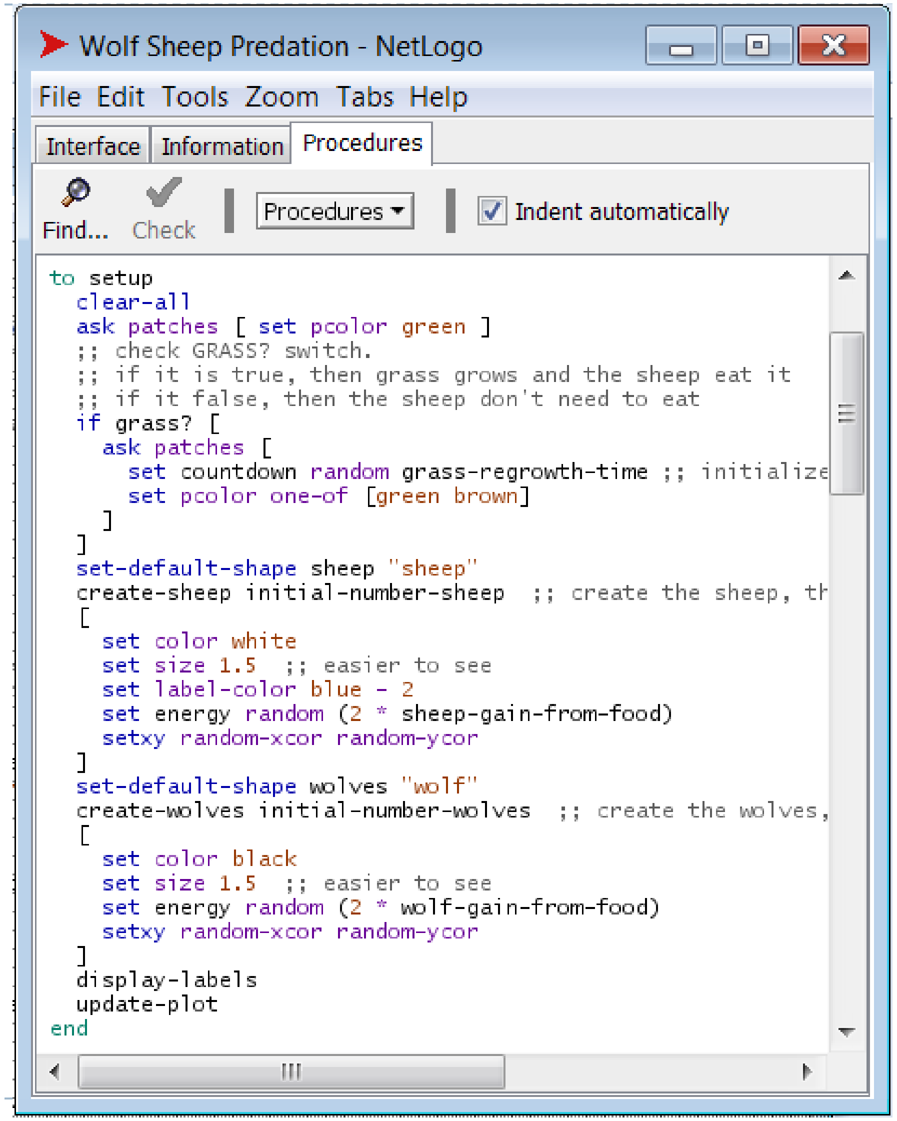
      ```
      ask turtles [
              while [ xcor < 5 ] [
                      right random 360
                      forward 1
              ]
      ]
      ```
   2. Forever buttons -> The advantage of a forever button is the user can click the button to stop the loop.



Agent(s) Observer
[✓] Forever
Commands
go
Display name
Action key

NetLogo Procedural Programming

- A procedure (or function) is created using the reserved keyword 'to'.
- The name of the function follows 'to'.
- The end of a procedure is marked by the 'end' keyword.
- Procedures can be called by other procedures or by buttons on the interface.

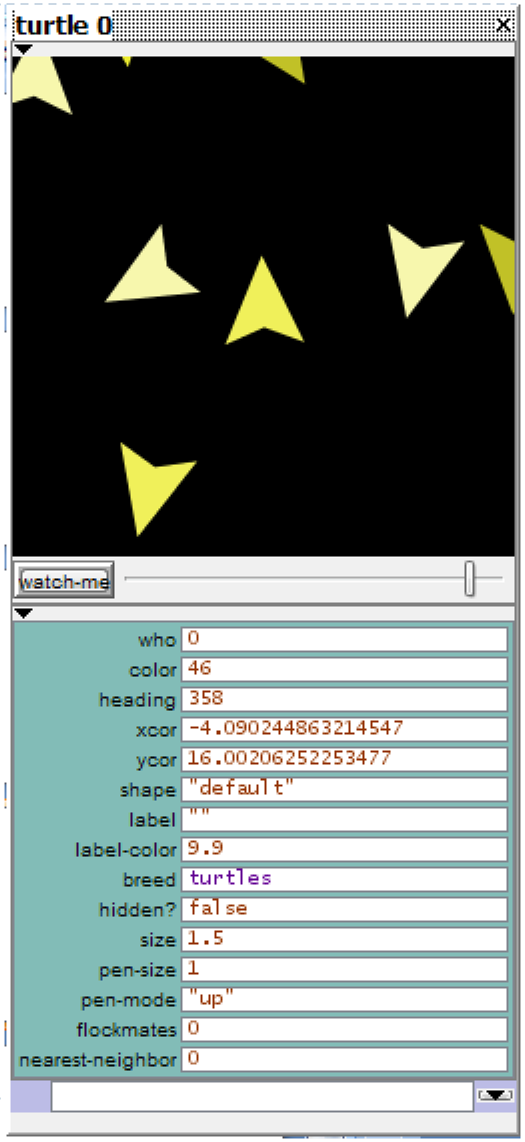


Wolf Sheep Predation - NetLogo
File Edit Tools Zoom Tabs Help
Interface Information Procedures
Find... Check
Procedures
Indent automatically

```
to setup
  clear-all
  ask patches [ set pcolor green ]
  ;; check GRASS? switch.
  ;; if it is true, then grass grows and the sheep eat it
  ;; if it false, then the sheep don't need to eat
  if grass? [
    ask patches [
      set countdown random grass-regrowth-time ;; initialize
      set pcolor one-of [green brown]
    ]
  ]
  set-default-shape sheep "sheep"
  create-sheep initial-number-sheep  ;; create the sheep, th
  [
    set color white
    set size 1.5  ;; easier to see
    set label-color blue - 2
    set energy random (2 * sheep-gain-from-food)
    setxy random-xcor random-ycor
  ]
  set-default-shape wolves "wolf"
  create-wolves initial-number-wolves  ;; create the wolves,
  [
    set color black
    set size 1.5  ;; easier to see
    set energy random (2 * wolf-gain-from-food)
    setxy random-xcor random-ycor
  ]
  display-labels
  update-plot
end
```

NetLogo Agents as Objects

- In the previous lab we introduced the "primitives" for the turtle and patch agents.
- Some of those primitives were member variables (facts about the agents) and other primitives were functions (procedures).
- The agents in NetLogo are also objects.
- Unlike regular objects agents in NetLogo can "see" their enviroment and each other.



who	0
color	46
heading	358
xcor	-4.090244863214547
ycor	16.00206252253477
shape	"default"
label	""
label-color	9.9
breed	turtles
hidden?	false
size	1.5
pen-size	1
pen-mode	"up"
flockmates	0
nearest-neighbor	0

NetLogo **Sensors** and **Effectors**

- Agents in Netlogo can use special primitives (built in functions) to "see" their environment.

turtles-here	(returns a list of turtles nearby)
patches-here	(returns a list of patches nearby)
turtles-at	(returns a list of turtles at a specific location)
patches-at	(returns a list of patches at a specific location)
self	(returns local state information)

- Agents can also use special primitives (built in functions) to "affect" their environment, including other agents (**ask**).

setxy	(change a turtles location)
set color	(change a turtles color)
set pcolor	(change a patches color)
hatch	(create NEW turtles)
die	(deletes a turtle)

Groups, Sets, Lists

- When you use the command *ask turtles [ ]* we are actually sending command to a set (group, or list) consisting of all the turtles in the program.
- In NetLogo we can create what are called AgentSets literally sets (groups, lists) of agents.
- We can then send commands to the agents in that set.

  Examples: (with) (turtles-here) (any?) (in-radius)

  - ask patches **with** [pcolor = red]
  - ask patch 0 0 [ask **turtles-here**
  - if **any?** turtles with [color = red]
  - ask turtles [ask patches **in-radius** 3

Breeds

- Breeds can be thought of as a customizable agentset.

  ask dogs [forward 1]

- Officially a breed is like a "subtype" of turtle:
  - it has all the attributes of turtle,
  - plus any new attributes declared for the breed.
- Breeds can be declared and customized in your code

  breed [dogs dog]

  dogs-own [flea-count]

- Breed is actually an attribute, which can be reset.
  - show [breed] of turtle 0
  - ask turtle 0 [set breed dogs]

General Program Outline

```
globals [ … ]       ;; global variables (also defined with sliders, …)
turtles-own [ … ]   ;; user-defined turtle variables (also <breeds>-own)
patches-own [ … ]   ;; user-defined patch variables

to setup
  clear-all
  ;; setup-patches
  ;; setup-turtles
  ;; setup-plots

end

to go

  ;; update-turtles
  ;; update-patches
  update-plots

  tick

end

;;;;;;;;;;;;;;;;;;;

to update-plots
  set-current-plot “my-plot”
  set-current-plot-pen “my-pen”
  plot some-number
end
```

DON'T PANIC

- You will have several labs on NetLogo.
- Lost of help is available online:
  - Fantastic (short) NetLogo Quick Guide
  - Full Netlogo Manual
  - NetLogo Dictionary

The End