Intro to Artificial Life

CSCI 5582, Fall 2005
Assignments

• Braitenberg (at website by tomorrow)
• Problem Set 5 due Dec. 13 in class
• Problem Set 4 due today
• Problem Set 3 available in my lab (DLC 1B-10) at 4 PM tomorrow
• Final Exam Saturday 12/15, 10:30-1 in this room; open textbook, readings, notes; bring a calculator; no laptops
• Review session: 4-6 PM Thursday 12/13
Some words on the final exam

- 8 questions of which you should answer 7 (14 points apiece)
- If you answer all 8, the best 7 will be counted
- Open book/notes; bring a calculator!; no computers, please
- Show your work! (Lots of partial credit.)
Artificial Life: Experimental Biology

- Braitenberg’s *Vehicles*
- Dawkins’ *Artificial Watchmaker*
- Lindgren’s “*PD World*”
- Brooks’ “*Intelligence without Representation*”
Review of Bayesian Network
Problems from PS 3
Figure 1
Vehicle 1, the simplest vehicle. The speed of the motor (rectangular box at the tail end) is controlled by a sensor (half circle on a stalk, at the front end). Motion is always forward, in the direction of the arrow, except for perturbations.
Figure 2.
Vehicle 2, with two motors and two sensors; otherwise like Vehicle 1. The connections differ in a, b, and c.
Figure 3
Vehicles 2a and 2b in the vicinity of a source (circle with rays emanating from it). Vehicle 2b orients toward the source, 2a away from it.
Figure 4
Vehicle 3, with inhibitory influence of the sensors on the motors.
Figure 5
A multisensorial vehicle of brand 3c.
Figure 6
A nonlinear dependence of the speed of the motor $V$ on the intensity of stimulation $I$, with a maximum for a certain intensity.
Figure 7
Trajectories of vehicles of brand 4a around or between sources.
Figure 8
Various bizarre kinds of dependence of the speed of the motor (ordinate) on the intensity of stimulation (abscissa) in Vehicle 4b.
Dawkins’ “Blind Watchmaker”

• A model of an “evolution-like” system
• The major similarity to biological evolution: differentiation between genotype (which is hidden) and phenotype (which is the target of selection)
Lindgren’s PD World: Preliminaries

• Every creature has a given “memory” for previous PD rounds.
• An M-length history looks like this:
  \[ a(m-1), \ldots a(1), a(0) \]
  where \( a(0) \) is the other player’s last action, \( a(1) \) is my last action, \( a(2) \) is the other player’s next-to-last action, \( a(3) \) is my next-to-last action, and so forth.
Memory in PD Creatures

• Thus, a creature with memory 1 remembers only the other player’s previous action. A creature with memory 2 remembers the previous round for both players; a creature with memory 4 remembers the previous two rounds for both players; and so forth.

• Here are the sorts of situations that a memory-3 creature can take into account:
  
  0 0 0
  0 0 1 (other guy cooperated on last round)
  1 1 0 (other guy defected on last round)

And so forth.
# All Possible Memory-1 Creatures

<table>
<thead>
<tr>
<th>Other guy’s last move</th>
<th>Creature 1</th>
<th>Creature 2</th>
<th>Creature 3</th>
<th>Creature 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>All-defect</td>
<td>Tit for tat</td>
<td>Anti-tit-for-tat</td>
<td>All-C</td>
</tr>
</tbody>
</table>
Making a Mem-3 creature

<table>
<thead>
<tr>
<th>Oth nxt-last</th>
<th>My prev</th>
<th>Other prev</th>
<th>My move</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
Possible PD Creatures

• In summary, then: a memory-N creature needs a $2^N$ bit table to specify its responses.
• There are $2^{(2^N)}$ possible memory-N creatures. (2 possible memory-0 creatures; 4 memory-1 creatures; 16 memory-2 creatures; 256 memory-3 creatures; etc.)
Successive Generations in the PD World

- In a given generation, each creature plays the PD game against all other creatures. Thus, the performance of a creature is determined by the prevalence of other “compatible” creatures in the population surrounding it.
- High-scoring creatures are more likely to survive to the next generation.
- When a new generation is created, there is a certain probability for point mutations (switching a bit), gene duplication (increase in memory by 1 without changing behavior), and gene splitting (loss of one unit of memory, with either half of the genome returned).
FIGURE 1 The evolution of a population of strategies starting with equal fractions of the memory one strategies [00], [01], [10], and [11] is shown for the first 600 generations. The fractions of different strategies are shown as functions of time (generation).
“Intelligence Without Representation” (Brooks, 1991)

“We must incrementally build up the capabilities of intelligent systems, having complete systems at each step of the way and thus automatically ensure that the pieces and their interfaces are valid.”

“At each step we should build complete intelligent systems that we let loose in the real world with real sensing and real action. Anything less provides a candidate with which we can delude ourselves.”
An “Unexpected Conclusion” and “Radical Hypothesis”

• When we examine very simple level intelligence we find that explicit representations and models of the world simply get in the way. It turns out to be better to use the world as its own model.

• Representation is the wrong unit of abstraction in building the bulkiest parts of intelligent systems.
Slogans of the “Brooks Style” of AI Design

• “Intelligence without representation”
• “The world is its own best representation”
• Working on “horizontal” microworlds (a complete creature) as opposed to “vertical” microworlds (a complete task)
• A “layered” architecture, often consisting of weakly communicating simple processors
• Avoidance of a “central processor”, and emergent behaviors
• A focus on physical (as opposed to “virtual”, or simulated) test cases
Some Themes of Embodied Cognition

- Problems with the “disembodied brain” paradigm of AI and Cognitive Science
- Integrating action and cognition
- Emergent behavior
- Kinesthetic/bodily experience as component of language, memory, images
- Role of bodily experience in the development of language and mathematics