Intelligent Robotics in 30 Minutes

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Outline

- Introduction
  - Why is it hard to be smart?
  - What works?
- Behavior Oriented Design
  - Modular Control
  - Action Selection
  - Iterative Development

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Why is it hard to be smart?

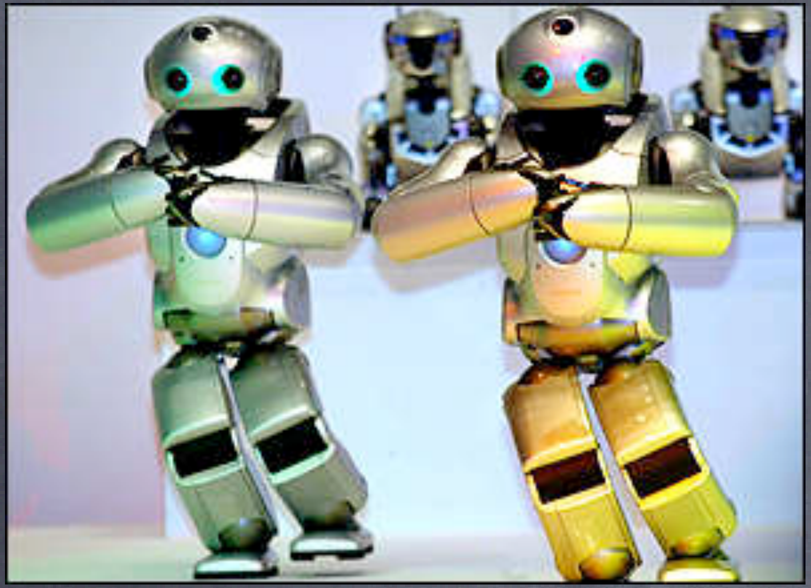
- Pretend you bought a robot, and it came with 100 things it knew how to do without being told.
- For example, eat, sleep, turn right, turn left, step forward, step backward, pick things up, drop them...
- Now pick a goal for your robot.
- For example, flying to Tokyo.

Sanyo robot watchdog

The hardness of smartness (2)

- Suppose you can't be bothered to tell your robot exactly how to get to Tokyo, so you have it guess.
- If getting to Tokyo takes one step, the robot may have to try 100 different things.
- If it takes two steps, the robot may have to try each thing after each thing:

$$100^2 = 10,000$$



The hardness of smartness (3)

- If the robot doesn't know how many steps it takes to go to Tokyo, it might get caught in an infinite loop.
- For example, it might eat, sleep, work, eat, sleep, work, eat, sleep, work... and never buy a passport.
- When computer scientists say "hard" they mean "pretty much intractable."

Sony SDR-4Xs. Pictures from BBC

Intelligence & Design

- Combinatorics is the problem, search is the only solution.
- The task of intelligence is to focus search.
  - Called bias (learning) or constraint (planning).
  - Most `intelligent' behavior has no or little real-time search (not cognitive).
- For artificial intelligence, most focus from design.

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Intelligence

- What matters is expressing the right behaviour at the right time.
- Decompose the problem:
  - Behaviour module: combination of code and mechanism.
  - Action selection: detect when to express which behaviour.
  - Both require good perception.

What works

- Modularity: simplifies design (Brooks 1986), allows locally-optimal representations (Bryson PhD 2001, Bryson IJCAI 2001).
- Action selection (sequencing): specifies goal prioritisation and ordering (Bryson JETAI 2000, PhD).
- Iterative develop & test: cycle in increasing complexity (object-oriented design; agile development (Beck 2000, Bryson IJCAI, PhD).

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Behavior Modules

- Generate & control actions.
- Sense & interpret perception for actions.
- Store & maintain memory for perception.

Behavior Modules

- Objects (in an object-oriented language):
    - Methods provide interface with other modules, including action selection.

Example for BURST

- Recognize gate and compute trajectory to centre.
  - Do this at 10Hz, adjust velocity slowly, bad frames won't matter if there aren't too many.
  - OR
  - Remember previous 3 guesses, don't report new one if too different.

Issues of Modularity

Get Fuzzy (Conley 2006)

Issues of Modularity

- How do you get ordered behavior for the complete agent?
- How do you decide what goes in which module?

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Simple Action Selection

- Sets of productions
  - A sense (recognize your context) and an action.

What is an action?

- In robotics / real-time systems, actions must be very brief, because the context shifts very quickly.
  - Drive through the hoop is a dangerous atomic action, what if you turn a little?
  - Increase thrust towards hoop center is safer, it can be reevaluated frequently.
  - Sometimes open loop is necessary.

Simple Action Selection

- Sets of productions
    - A sense (recognize your context) and an action.
- Sadly, robotics isn't simple.

Context in Action Selection

- Recognize gate and compute trajectory to centre (production).
- What if you are already through gate and were just looking for a floating target?
- Don't want to be inappropriately "captured" by action in the wrong context.

Contextual Action Selection

- Sequence: when one production is finished, move to next one.
- Hierarchy: allow several productions to operate within one higher-level context.
- Priority: if more than one production could fire, say which is most important.

Example for BURST

- Top of hierarchy is a sequence: through gate, drop weight, surface under balloon.
- Prioritised productions for drop weight:

1. If stopped over target, drop weight.
2. If see floor target, halt on top.
3. [default], go towards beacon.

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Behavior Oriented Design

1. Add a behavior module: how to act.
2. Add a bit of plan: when to act.
3. Test it works.
4. Go back to 1.

Behavior Oriented Design

- If a module is getting too big and complicated, take it a part, connect the parts with plans.
- If a plan is getting too complicated, break it up with hierarchy OR build a smarter module to solve some of the problems
  - Often perception is key!

Bryson's first law of intelligent robotics

No robot works the first time you run it.

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Building Intelligence

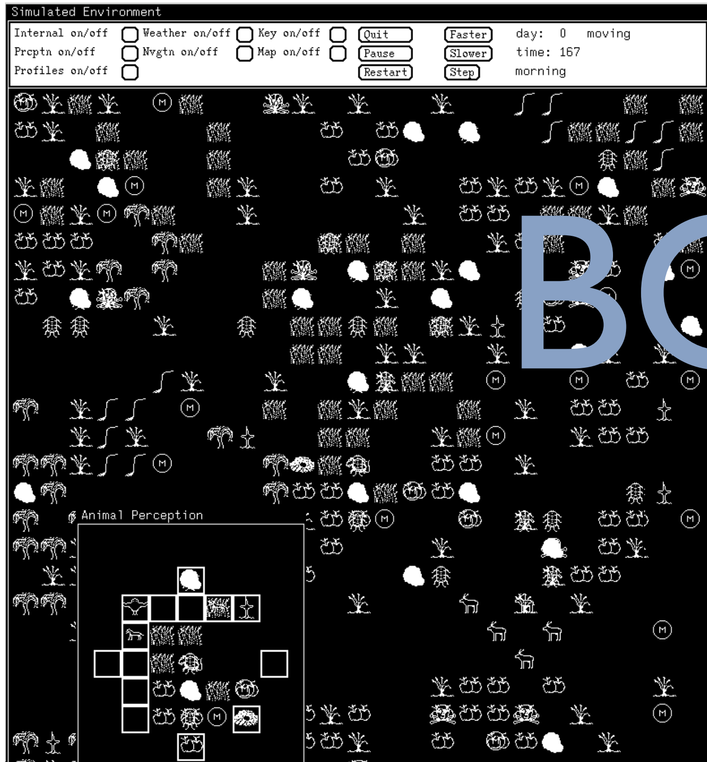
- AI normally associated with clever algorithms.
- No one algorithm produces working systems from a vision (or even first-cut specs.)
- Behavior Oriented Design is a methodology.
  - Optimize balance between human and machine search for the right behavior.

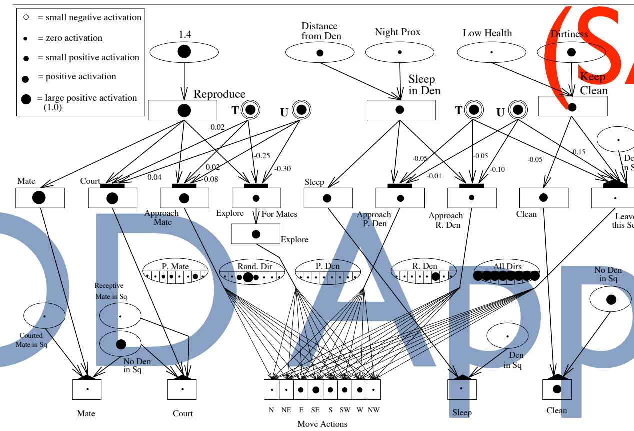
Intelligent Systems

- Complete, complex agents:
  - Multiple, potentially conflicting goals.
  - Multiple, mutually exclusive means of achieving a goal.
- Robots:
  - Real-time, dynamic environments.
  - Sense and change (act in) that environment.

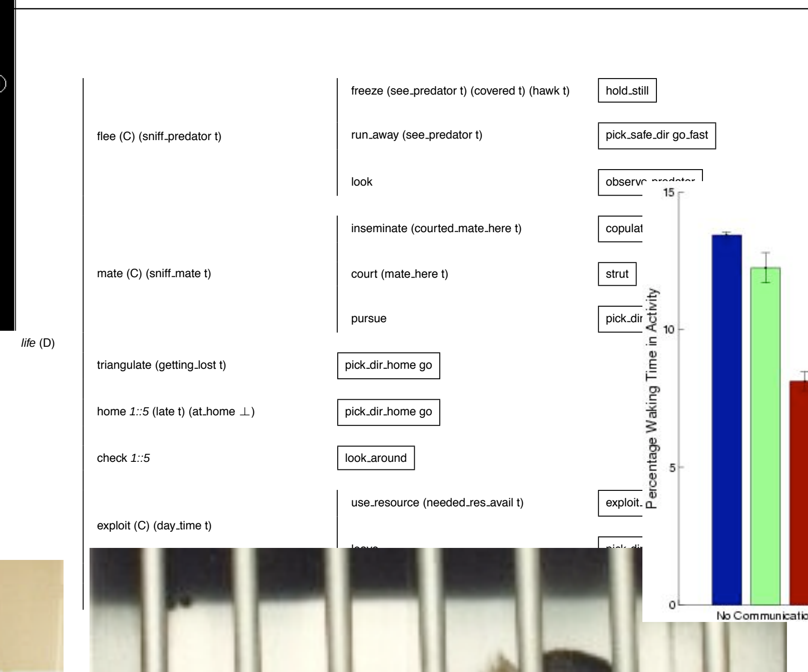
BOD Applications

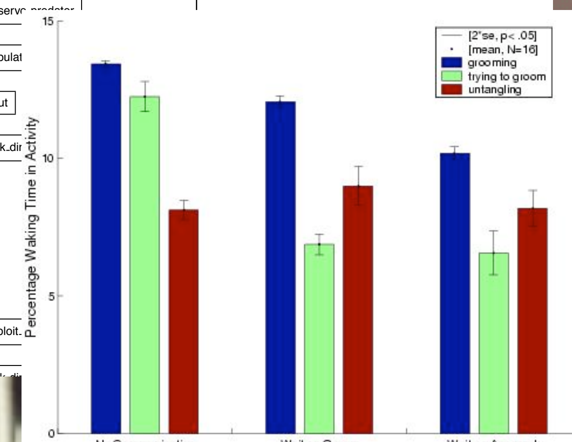
(SAB 2000)

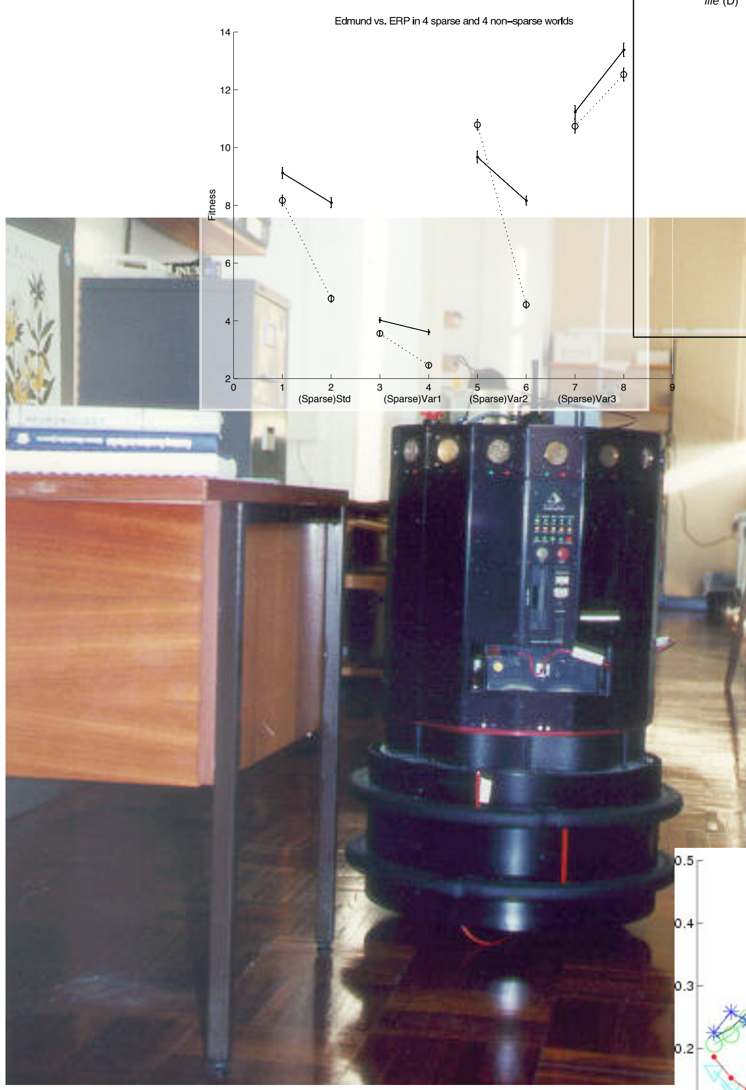


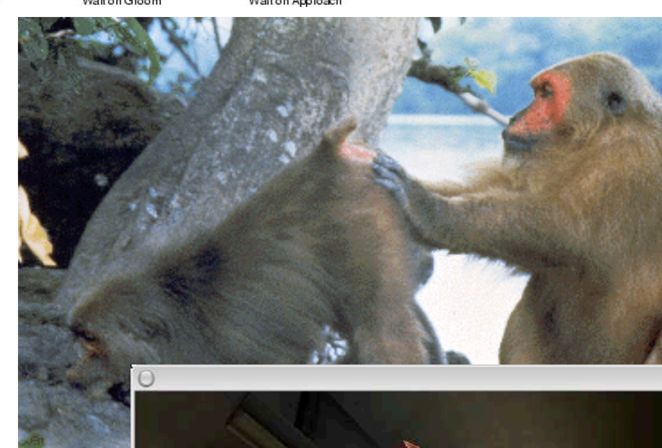


(VR(J) 2000)



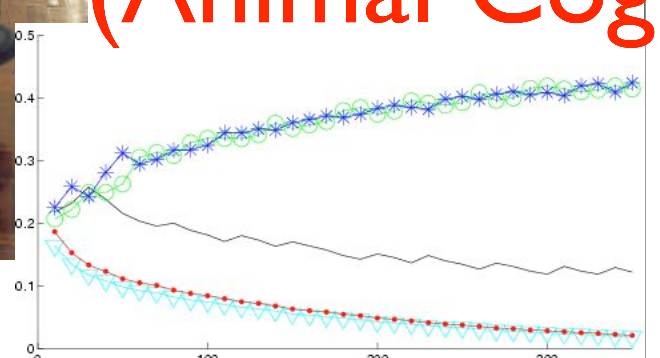


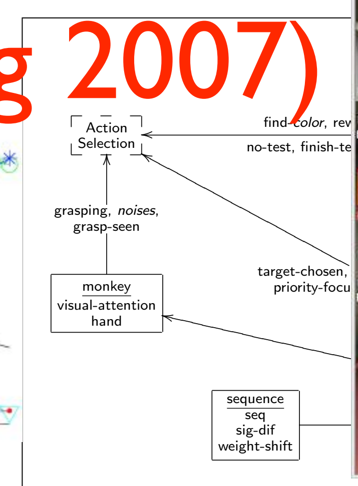




(WRAC 2003)

(Animal Cog 2007)





(IVA 2005)

(ATAL 1997)

Intelligence

- What matters is expressing the right behavior at the right time: action selection.
- Conventional AI planning searches for right set of actions, requires sets of primitives.
- Learning searches for the right parameter values, requires primitives *and* parameters.
  - *parameter:* variable state.
  - Evolution and development *are* learning.