9: Robots & Biological Intelligence

- Outline
  - Themes of embodied cognition
  - Braitenberg's "vehicles"
  - A biological perspective
    - Cricket phonotaxis
  - Brooks' subsumption architecture
    - 'Herbert' and 'Cog'
  - Social and communicative abilities
    - 'Kismet'
  - Is internal representation necessary?

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Themes

- Low-level systems
  - Simple, complete systems
- Embodiment
  - Body and environment are important for adaptive behaviour
- Emergence
  - Complex behaviour emerges from collections of simple systems
- Contrast with emphasis on single aspects of cognition

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Why the 'low-level' approach?

- Solutions to problems of advanced cognition shaped by solutions to basic problems?
  - Locomotion
  - Sensing
  - Action selection
- Does it make sense to isolate vision, planning etc.?
  - They are tightly interrelated in biological systems

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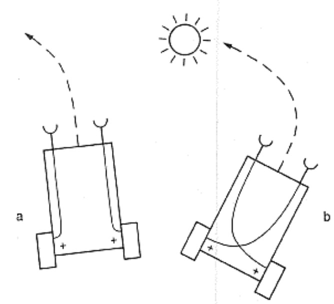
Braitenberg's "Vehicles" (1984)

- Fear and Aggression



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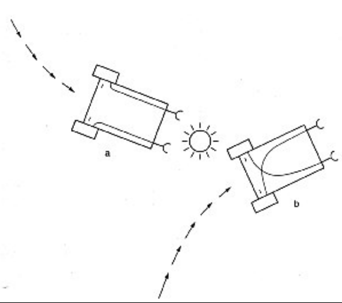
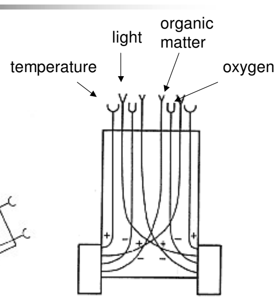
Love and Exploration / Complex Behaviour





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Cricket Phonotaxis (Webb, 1995)

- Phonotaxis = detect and move toward a sound source
- Male crickets produce song
- Female crickets seem to:
  - Hear and identify the appropriate (species-specific) 'song'
  - Localise the source
  - Move toward it
- Task decomposition
  - Sequence of subtasks

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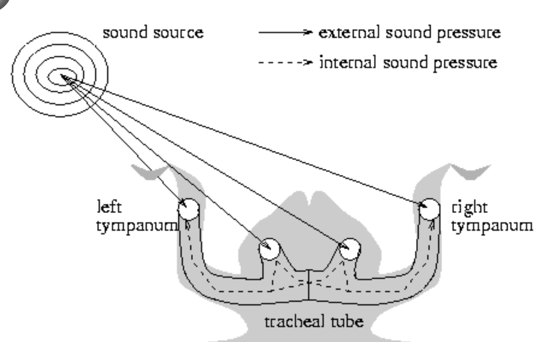
Cricket anatomy



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An alternative account

- Tracheal tube only transmits sounds of the correct species
  - Song is heard/'identified'
- Sound will seem louder on one side
  - Sound source is localised
- Ears are connected to neurons, which will fire when a threshold is reached
- One side fires first
- The cricket turns to this side
  - Moves towards male
- No internal representations

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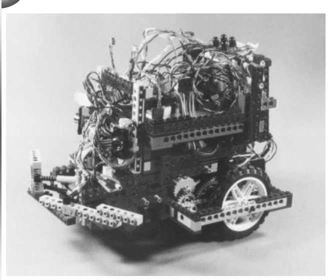
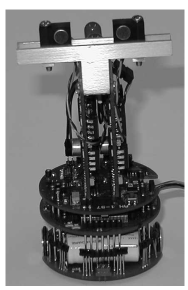
Cricket robot





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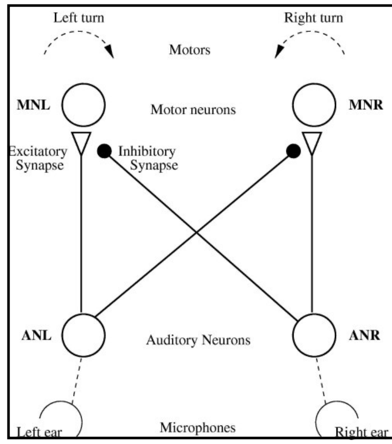

Simulated Neural network used in robot cricket

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"Herbert" (Connell, 1989)

- Robot collects soft-drink cans
- Collection of simple sensors and simple behavioural routines
  - Obstacle avoidance
  - Random locomotion
  - Visual system (to detect tables and cans)
  - Arm to grasp cans
- No planning
- No internal model of the world

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Subsumption Architecture (Brooks, 1986)

- Several layers of circuitry
- Each layer is functionally equivalent to a simple whole system, e.g.
  - Obstacle avoidance
  - Exploration
  - Recognition
- Layers work in parallel
- Simple interaction between layers

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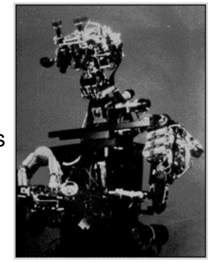
Rat navigation (Mataric, 1991)

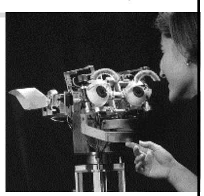
- "Action-oriented representation" (Clark, 1997)
- Internal map
  - – Combination of sensory and motor readings
  - – Map = recipe for action
  - – No need to reason with map
- Integrated model of perception, cognition and action
- But –does this sort of approach scale up to more complex robots (and human intelligence)?

Cog – a humanoid robot (Brooks et al., 1998)

- Goal: Study human intelligence
- Hypotheses:
  - – Human-like intelligence requires human-like interactions with the world
    - Interactions with humans
    - Requires a human-like body
  - – Intelligence is emergent from
  - – many independent processes
    - Sensory-motor couplings
    - Little internal processing
    - Subsumption architecture

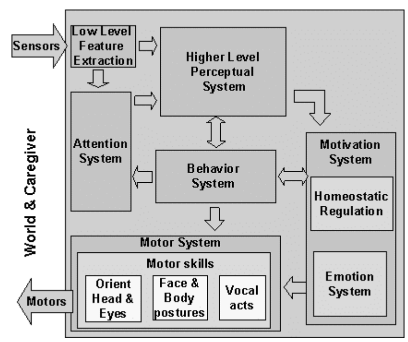


Kismet – a social robot (Breazeal, 1998)



- Inspired by infant social development
- Engages in natural and expressive face-to-face interaction
- Perceives a variety of natural social cues from visual and auditory channels
- Delivers social signals to the human caregiver through gaze direction, facial expression, body posture, and vocal babbles
- Learns from human caregiver

Kismet's architecture



Is internal representation necessary?

- No internal representations, planning, 'inner models'
- But these concepts are used in cognitive science to explain a different set of behaviours
  - – Behaviour without real or immediate stimuli
    - Planning a holiday
    - Imagining "what if…?"
  - – Response to nonnomic properties of the stimulus
    - Nomic = properties subject to physical laws
      - – Detecting a sound
    - Nonnomic = properties not subject to physical laws
      - – "being a shirt"

Learning Outcomes

- Understand the 'real world' approach to cognition.
- Understand how robots can demonstrate that certain behaviours can be produced without complex representational systems
- Be aware that this approach has not demonstrated that 'higher-level' cognition can be explained so simply.

For next week, read:

- Boden, M. A. (1996). Autonomy and artificiality. In M. A. Boden (Ed.), The philosophy of artificial life. Oxford: OUP.

Cognitive Science: Lecture 9: Robots: Reading

Breazeal (Ferrell), C. & Scassellati, B. (2000). Infant-like social interactions between a robot and a human caretaker. *Adaptive Behavior*, 8 (1). [http://www.ai.mit.edu/projects/lbr/hrg/2000/Kismet-AB.pdf]

Brooks, R. A., (1989). How to build complete creatures rather than isolated cognitive simulators. In K. VanLehn (Ed.), *Architectures for intelligence*. Hillsdale, NJ: Erlbaum [http://www.ai.mit.edu/people/brooks/papers/how-to-build.pdf]

Brooks, R. A., (1990). Elephants don't play chess. *Robotics and Autonomous Systems*, 6, 3-15. [http://www.ai.mit.edu/people/brooks/papers/elephants.pdf]

Brooks, R. A., (1991). Intelligence without representation, *Artificial Intelligence Journal*, 47, 139–159 [http://www.ai.mit.edu/people/brooks/papers/representation.pdf]

Brooks, R.A., (2001). The relationship between matter and life. *Nature*, 409, 409–411. [http://www.ai.mit.edu/people/brooks/papers/nature.pdf]

Brooks, R. A., Breazeal, C., Marjanovic, M., Scassellati, B. & Williamson, M. (1998). The Cog project: building a humanoid robot, in C. Nehaniv, (Ed.), *Computation for metaphors, analogy and agents*, (Vol. 1562 of Springer Lecture Notes in Artificial Intelligence), Springer-Verlag. [http://www.ai.mit.edu/projects/lbr/hrg/1998/springer-final-cog.pdf]

Clark, A. (2001). *Mindware*. Oxford: OUP. Chapter 5 (pp. 91-95), Chapter 6 (pp. 103-112).

Dawson, M. R. W. (2004). Minds and machines. Oxford: Blackwell. Chapter 7.

Pfeifer, R. & Scheier, C. (1999). *Understanding intelligence*. Cambridge, MA: MIT Press. Chapter 4 (in study pack).
Webb, B (2000) What does robotics offer animal behaviour? *Animal Behaviour*, 60, 545-558. [http://www.stir.ac.uk/staff/psychology/bhw1/phonotaxis/animal_behaviour.pdf]

Webb, B (2001) Can robots make good models of biological behaviour? *Behavioral and Brain Sciences*, 24 (6). [http://www.bbsonline.org/documents/a/00/00/04/18/index.html]

On the web – the MIT Humanoid Robotics Group pages:
http://www.ai.mit.edu/projects/humanoid-robotics-group/index.html
FOR NEXT WEEK, READ:
Boden, M. A. (1996). Autonomy and artificiality. In M. A. Boden (Ed.), *The philosophy of artificial life*. Oxford: OUP. [Available in study pack]