Dynamical Systems and Cognitive Science

The attribution problem

- If mind is caused by something inside of us, what exactly is it that one must assume is IN THERE in order to account for the organized behavior one can observe?
  - A robot that loves light

Braitenberg’s Vehicle 2

Cricket Phonotaxis

The importance of sensor placement

- Three tasks: Tune, locate, locomote
- No representations
- No computations
- A dynamic state space a lot like Vehicle #2

Vehicle #2 state space

No communication
Little persuasiveness

A lot of Persuasiveness

What is the brain doing?

• The brain is revealed not as an engine of reason or quiet deliberation, but as an organ of environmentally situated control. (*Mindware*: 95)

More Persuasiveness

Key features of the dynamical systems approach

1. The discovery of powerful but low-dimensional descriptions of systemic unfolding.
2. The provision of intuitive, geometric images of the state space of the system.
3. Isolating control parameters and collective variables.
4. Using the technical notion of coupling to model and track processes involving continuous reciprocal causality among the multiple subsystems. (Watt governor, e.g.)

What sort of explanation do we want?

• Perception – computation – action loop?
• Well, what needs to be explained?
• The answer to that depends on where we place the boundaries of the unit of analysis.
  – Boundary at skin of the creature -> explain behavior in terms of brain processes
  – Boundary around creature/environment dynamical system -> explain powerful regularities in the behavior of the complex dynamical system composed of brain, body and world. (Finger waggling, Infant stepping, e.g.)
Dynamical Cognitive Science

- Body and world (and hence time, movement, etc.) all matter and can play powerful roles in adaptive problem solving.
- Neural, bodily, and environmental elements are intimately intermingled in continuous **mutual** and reciprocal causality.
- The traditional “input – compute – act” cycle cannot explain such systems.

Representation, re-represented

- In addition to on-line processes, there may be **off-line** stand-ins for …
  - Clark says, “real-world environment” and “extraneural (in this case bodily) states of affairs.”
  - Or... the on-line processes themselves. And these encompass the brain, body, world system.
  - Perception/action/imagination all together in (motor) emulators.

Radical Embodied Cognition

- Structured, symbolic, representational, and computational views of cognition are mistaken. Embodied cognition is best studied using noncomputational and nonrepresentational ideas and explanatory schemes, and especially the tools of dynamic systems theory.

Cognitive Incrementalism:
the BIG issue

- What in general is the relation between the strategies used to solve basic problems of perception and action and those used to solve more abstract or higher level problems? (*Mindware*: 135)
- Are the neural mechanisms of higher thought fully continuous with mechanisms of on-line action control?
- Or, are other sorts of processes needed?

Radical embodiment position
(Kirsh)

Behaviour can be partitioned into task-oriented activities or skills, each of which has its own sensing and control requirements which can be run in parallel with others. (Bag of tricks) There is a partial ordering of the complexity of activities such that an entire creature, even one of substantial complexity, can be built incrementally by first building reliable lower-level behavioural skills and then adding more complex skills on top in a gradual manner. (Cognitive incrementalism)
Radical Embodiment (continued)

There is more information available in the world for regulating task oriented activities than previously appreciated; hence virtually no behavioural skill requires maintaining a world model. (the world is its own best model)

Only a fraction of the world must be sampled to detect this task-relevant information. Smart perception can index into the world cleverly, extracting exactly what is needed for task control without solving the general vision problem. (Active Sensing, Change blindness)

Radical Embodiment (continued)

The hardest problems of intelligent action are related to the control issues involved in coordinating the various behavioural abilities so that the world itself and a predetermined dominance or preference ordering will be sufficient to decide which activity layer has its moment in the sun.

Today the earwig... tomorrow man

Hard to do without conceptual representation

• Activities which involve other agents, since these often will require making predictions of their behaviour.
• Activities which require response to events and actions beyond the creature’s current sensory limits, (the absent and the abstract).

Hard to do without conceptual representation

• Activities which require understanding a situation from an objective perspective such as when a new recipe is followed, advice is assimilated, a strategy from one context is generalized or adapted to the current situation. All these require some measure of conceptualization.

Hard to do without conceptual representation

• Activities which require some amount of problem solving, such as when we wrap a package and have to determine how many sheets of paper to use, or when we rearrange items in a refrigerator to make room for a new pot.
• Activities which are creative and hence stimulus free, such as much of language use, musical performance, mime, self-amusement.
Wideware: a possible solution

• The brain is revealed not as an engine of reason or quiet deliberation, but as an organ of environmentally situated control.
• Neural, bodily, and environmental elements are intimately intermingled in continuous mutual and reciprocal causality.
• Now put this brain and body in a cultural environment (a ship for example). Can the interactions among these biological processes and cultural stuff (wideware) produce the missing high level processes?