

# Important Tools and Perspectives for the Future of AI

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Attempting to formalize the essence of living and life-like systems: a **bio-logic**.

## Properties of ALife Systems:

- **Synthetic**: Bottom-up, multiple interacting agents.
- **Self-Organizing**: Global structure emerges from local interactions.
- **Self-Regulating**: Distributed (non-global) control (self-maintaining, autopoietic)
- **Adaptive** Learning and/or evolving.
- **Complex**: On the edge of chaos; dissipative.

*Mindware* (pg. 135), Andy Clark, 2001

*This is the idea that you do indeed get full-blown human cognition by gradually adding bells and whistles to basic (embodied and embedded) strategies of relating to the present at hand.*

- I am, therefore I think.
- Cornerstone belief of The New AI, a.k.a. Situated and Embodied AI (SEAI).
- A bottom-up, Alife-inspired approach to AI.
- Focus on (real and simulated) adaptive robots that learn (or evolve) to perform basic sensorimotor tasks with increasing degrees of cognitive demand.

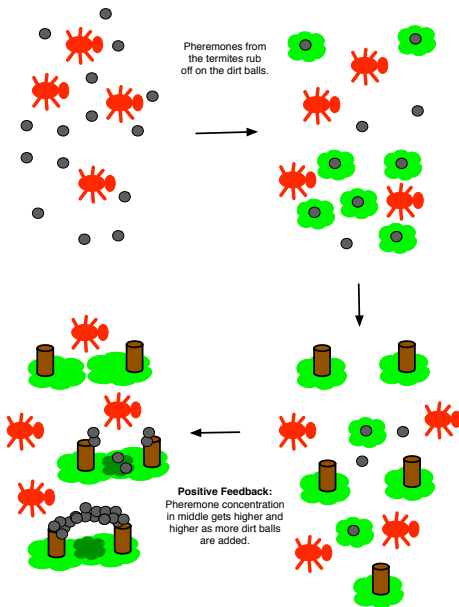
## Properties of Swarms

- Simple agents, following simple behavioral rules, interacting to form complex structures.
- Driven by what often appears to be random activity, but with
- the accentuation of some behaviors/trends (**positive feedback**),
- and the damping of others (**negative feedback**).
- **Stigmergic** - agents signal one another indirectly, via their changes to the environment.

## Advantages

- 1 Flexible - easily adapts to environmental change.
- 2 Robust - tolerates the failure of one or many components/agents.
- 3 Distributed Control - no need to centralize decision making. Can rely on emergence.

# Stigmergy: Emergent Structure from Indirect Signals.



# Swarms

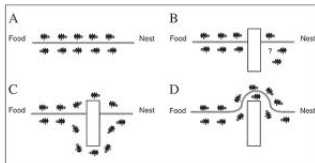
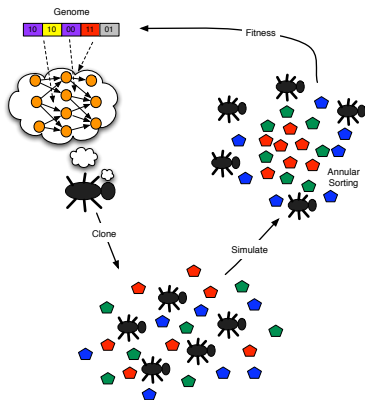


Figure 2. A, Ants in a pheromone trail between nest and food. B, an obstacle interrupts the trail. C, ants find two paths to go around the obstacle. D, a new pheromone trail is formed along the shorter path.



# Swarm Projects at DIS



- Annular Sorting: Vegard Hartmann(2005) & Andre Heie Vik(2005)
- Templated Collective Construction: Jrgen Braseth (2007)
- Swarm Robotics: Jannik Berg & Camilla Karud (2011)



# The Intelligence and Utility of Swarms

- **Mistaken Genius:** In emergent systems, intelligence is often **in the eye of the observer** (who sees the global pattern), but not in the brain of the agent, which only *understands* local interactions.
- Unfortunately, given a desired global pattern, it is very hard to reverse engineer the necessary set of local interactions. Evolutionary algorithms are very helpful here. Thus, the rules themselves emerge from an evolutionary process.
- **Applications:** animation, telecommunications, internet routing, passenger and freight scheduling, assembly-line task selection, and many more
- **General Implications:** Intelligent behavior need not involve intelligent planning and coordination. Emergence, when properly harnessed, can do sophisticated things.

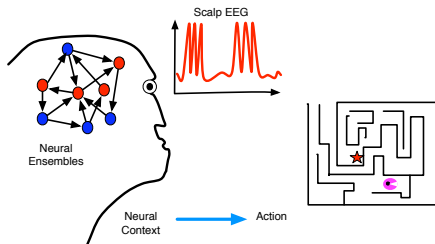
# Cybernetic Organism (Cyborg)

- Organisms with artificial devices to assist in various regulatory, perceptive or motor activities.
- The deeper the intrusion, the more impressive. Hearing aid -vs- cochlear implant -vs- pacemaker -vs- prosthetics wired to neural circuits.



Figure: (CW from upper left) Kevin Warwick; Original cyborg image; Kate Moss (youth as cyborgs via tight ties to social media); Pentagon cyborg insect spies.

# Brain-Computer Interfaces (BCI)



- 1 Ask subject to think about an activity (e.g. moving joystick left)
- 2 Register brain activity (EEG waves - non-invasive) or (Neural ensembles - invasive)
- 3 ANN training case = (brain readings, joystick motion)

## Sample applications (Millan, in *Handbook of Brain Theory and NNs*, 2003)

- Keyboards (3 keystrokes per minute)
- Artificial (prosthetic) hands
- Wheelchairs
- Computer games

# Natural Born Cyborgs (Andy Clark, 2003)

- But why this (somewhat superficial) requirement of connecting under the skin? Humans have many forms of physical aids, some external: eyeglasses, crutches, body armor, etc.
- What about **cognitive aids**??

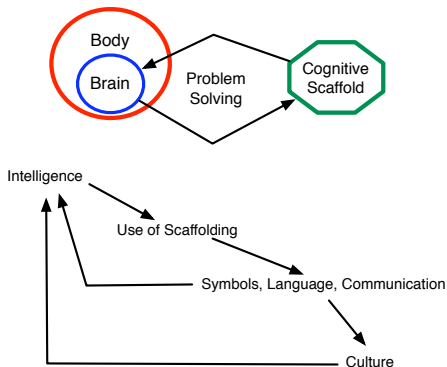
Clark, pg. 26

What the human brain is best at is learning to be a team player in a problem-solving field populated by an incredible variety of nonbiological props, scaffoldings, instruments and resources. In this way, ours are essentially the brains of natural-born cyborgs, ever eager to dovetail their activity to the increasingly complex technological envelopes in which they develop, mature and operate.

## Human brain

- massively parallel pattern recognition system
  - powerful sensory processor
  - sophisticated motor controller
  - highly plastic
  - but with a very small working memory (WM).
- 
- Scaffolding (via paper+pencil, computing devices, etc.) makes up for WM deficit.
  - Brain's plasticity enables fruitful coupling with the scaffolding, i.e. via symbols (which require some minimum amount of WM and attention).
  - Solving puzzles, math problems, etc. = Stigmergic communication of brain with itself via the scaffolding.

# Scaffolding and the Bootstrapping of Intelligence



Today, the world-wide web provides an unprecedented information resource, lending a huge intelligence boost to any organism that can properly interface with it.

# Could AI Systems Bootstrap Intelligence?

- AI systems have huge working memories (and thus need no scaffolding) and
- interface seamlessly with the WWW, but
- currently trail the brain w.r.t. pattern recognition and motor control.
- But this could change, since
- computer technology is evolving a lot faster than human brains.
- Soon, they may be evolving together... at least until machines get tired of helping us.

\* Cognitive Incrementalism disputes an AI's ability to become ultra-smart simply by surfing the web.

# The Singularity

Vernor Vinge (1983) and Ray Kurzweil (2005)

