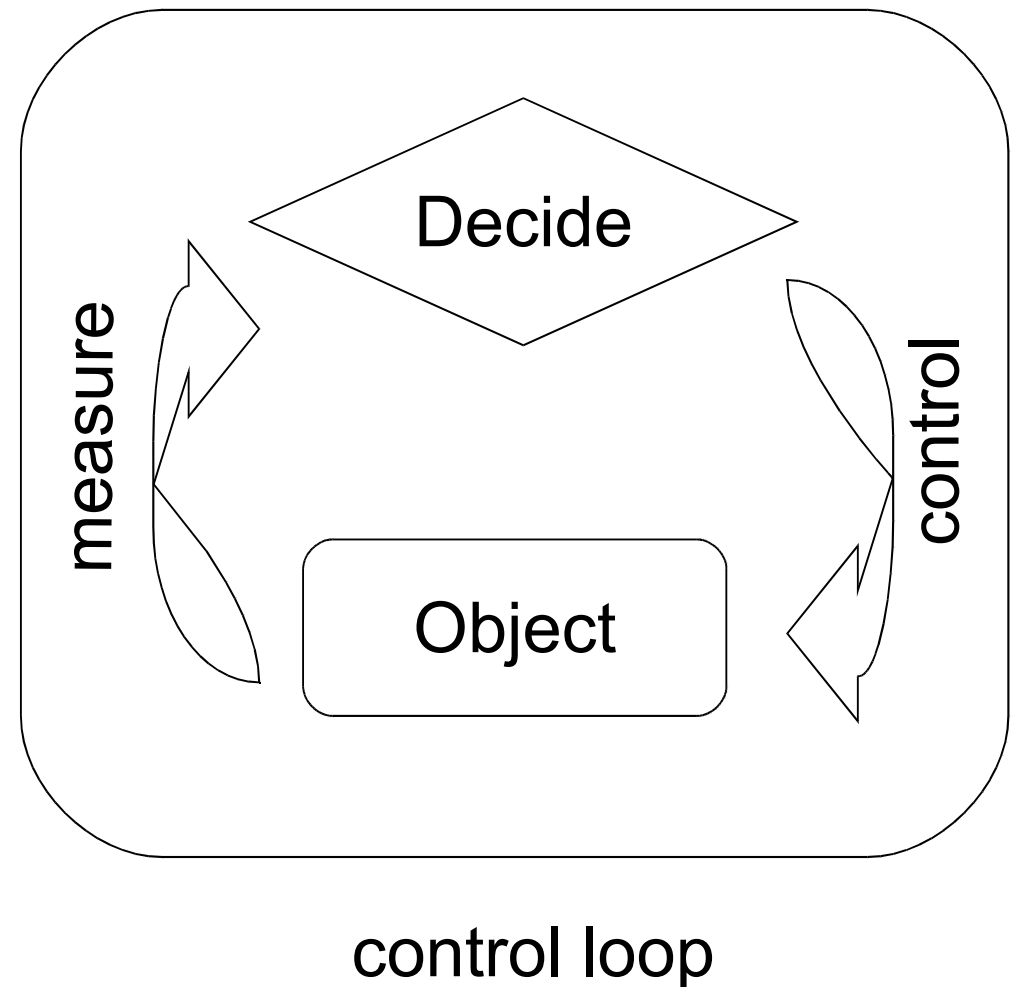


Self-organizing algorithms

Márk Jelasity

Centralized Mindset: Control Loop

- problem solving, knowledge (GOFAI)
- design, planning
- development, evolution
- control (achieving stability)
- distributed computing architectures
- source of order and complexity in general



Decentralization

- design is achieved by genetic variation and natural selection (Darwin)
- knowledge also evolves (“memes” of Dawkins)
- knowledge representation is potentially decentralized (neural networks)
- markets are regulated by the “invisible hand” (Adam Smith)
- sociological phenomena (eg segregation) is emergent (Schelling)
- etc

Decentralization: the only way

- Daniel Dennett goes further and points out that all order must originate from a decentralized process: evolution (in a broad sense)
 - “sky hook” vs. “crane”
 - even consciousness cannot be “sky hook” and it really is decentralized
- D. Dennett, *Darwin's dangerous idea* (1996)
- Why do we insist?
 - human psychology, related to power structures in society? Maybe inherited (human ethology)?

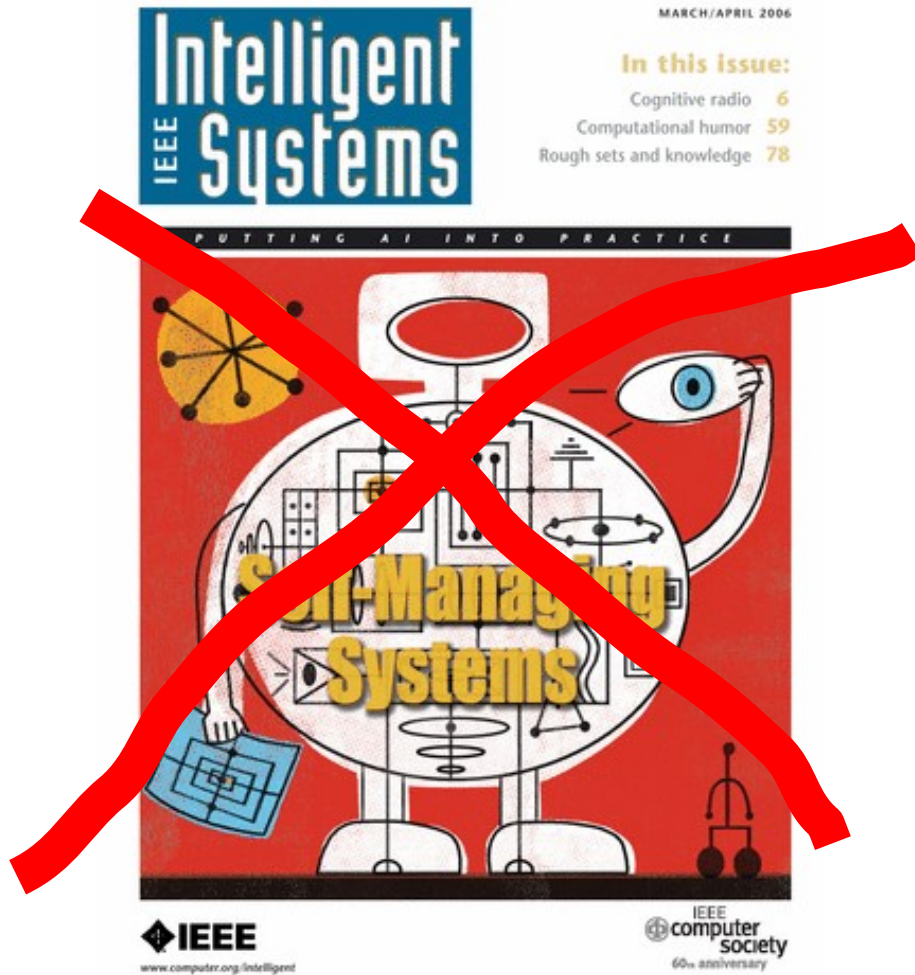
Why do we care?

- some things can be understood (modeled) only this way
 - pattern formation, development, regeneration, etc in biology
 - concept learning, knowledge representation, creative thinking, etc in AI
 - sociology, economics, ecology, chemistry, physics, geography, etc
- good algorithms for existing problems in OR, AI, etc
 - cheap, simple, robust, fairly efficient and effective

Why do we care?

- parasitic emergence: design can be centralized but the world is not
 - unpredictable chaotic dynamics
 - unwanted emergent properties (complex networks), eg power grid
- sometimes centralized thinking does of course work
 - control theory, Google, etc
 - keeping an open eye does not hurt

Misconceptions are really deep



- we edited a special issue of IEEE IS
- cover art (out of our control) reflects centralized thinking: the very thing we argue against in the editorial

What we do NOT cover?

- Complexity research
 - emergence of order and “spontaneous” increase in complexity from simple rules
 - attempting to capture and scientifically study the essence of complexity for its own sake
 - in general, not interested in “boring” systems that converge to an equilibrium
 - keywords: chaos, fractals, cellular automata, self-organizing criticality: on the edge of chaos, etc
 - even Godel's theorem, Church thesis and so on
 - very important concepts; unfortunately often overhyped, inflated and/or misunderstood

What do we cover?

- understanding and using emergence
 - emergence to solve problems
 - we are interested in **convergent** systems; building, calculating, etc, something specific and in a way predictable despite disturbing factors and noise
 - swarm intelligence, artificial evolution, p2p protocols
- “parasitic” emergence in complex networks
 - emergent properties of complex networks that are there we like it or not
- some learning approaches with a decentralized and emergent flavor

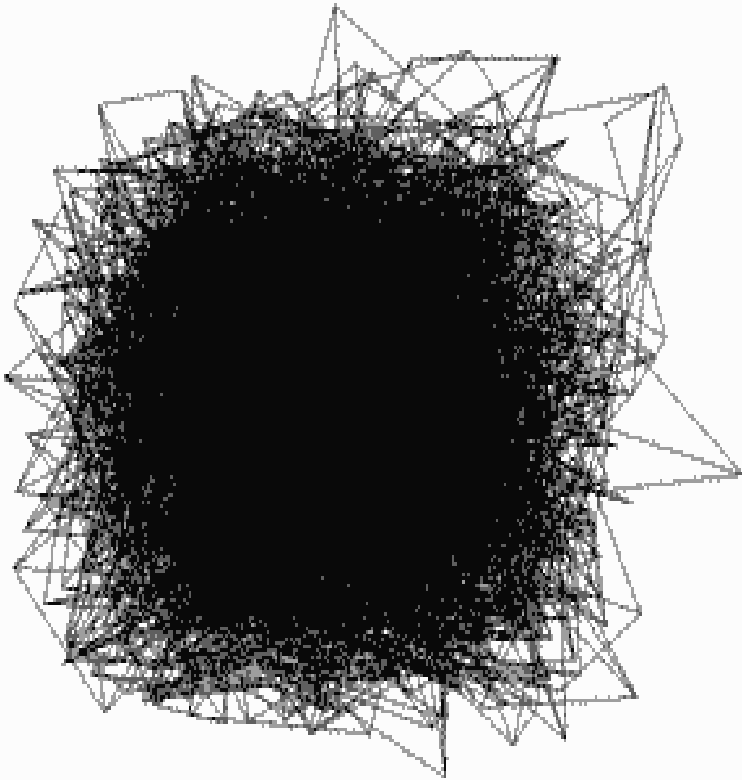
Swarm Intelligence

- ant foraging behavior and its application to routing in computer networks
- ant task allocation and its application to solving combinatorial optimization problems
- self-assembly and building of structures in ant colonies
- Eric Bonabeau, Marco Dorigo, and Guy Theraulaz. *Swarm Intelligence: From Natural to Artificial Systems*. Oxford University Press, 1999.

Complex networks

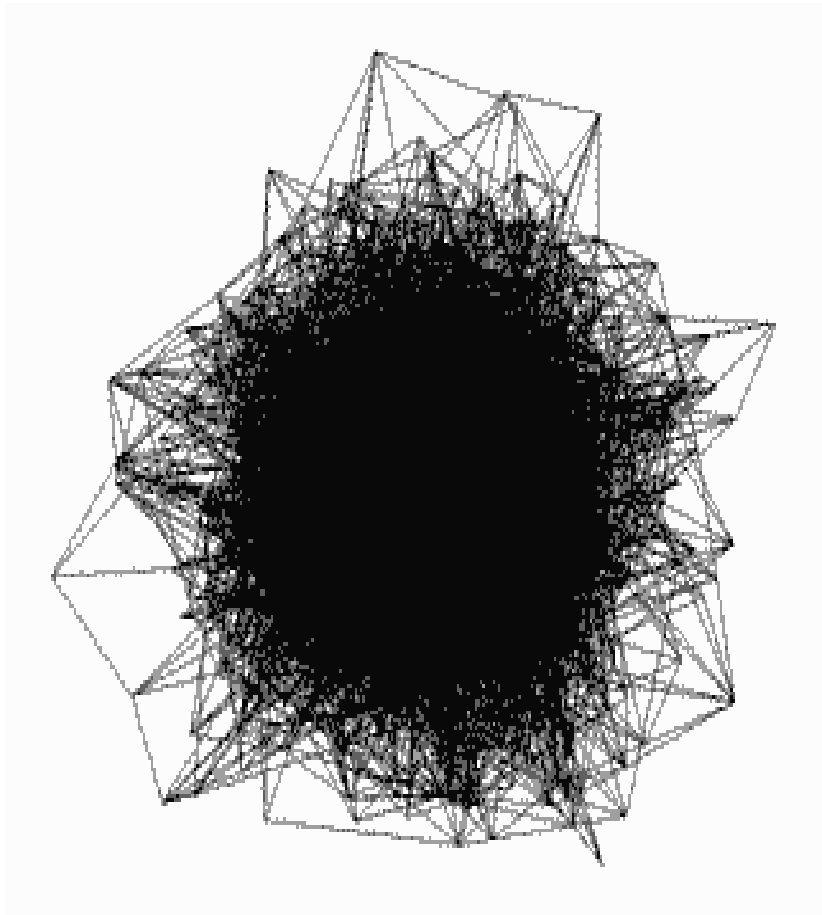
- models and properties of complex networks
- exploiting the information in emergent complex networks (collective intelligence)
 - PageRank algorithm for webpage ranking and similar approaches
- Réka Albert and Albert-László Barabási.
Statistical mechanics of complex networks. Reviews of Modern Physics, 74(1):47–97, January 2002.

Eigenvectors



- self-organization can often be expressed as an eigenvector finding problem
 - PageRank
 - Graph layout
 - trust management
 - virtual coordinates

self-organizing networks



- in p2p systems the overlay network topology is important
- self-organizing overlay networks are cheap, robust and generic

Other selected topics

- evolution
 - evolutionary computing, tag-based group selection
- self-organizing maps
- amorphous computing at MIT
- epidemics and gossip