

VIII. Review of Key Concepts

Natural Computation

- Tolerance to noise, error, faults, damage
- Generality of response
- Flexible response to novelty
- Adaptability
- Real-time response
- Optimality is secondary

Attractors

- Classes
 - point attractor
 - cyclic attractor
 - chaotic attractor
- Basin of attraction
- Imprinted patterns as attractors
 - pattern restoration, completion, generalization, association

Wolfram's Classes

- Class I: point
- Class II: cyclic
- Class III: chaotic
- Class IV: complex (edge of chaos)
 - persistent state maintenance
 - bounded cyclic activity
 - global coordination of control & information
 - order for free

Energy / Fitness Surface

- Descent on energy surface / ascent on fitness surface
- Lyapunov theorem to prove asymptotic stability / convergence
- Soft constraint satisfaction / relaxation
- Gradient (steepest) ascent / descent
- Adaptation & credit assignment

Complex Systems

- Many interacting elements
- Local vs. global order: entropy
- Scale (space, time)
- Phase space
- Difficult to understand
- Open systems

Many Interacting Elements

- Massively parallel
- Distributed information storage & processing
- Diversity
 - avoids premature convergence
 - avoids inflexibility

Complementary Interactions

- Positive feedback / negative feedback
- Amplification / stabilization
- Activation / inhibition
- Cooperation / competition
- Positive / negative correlation

Biased Randomness

- Exploration vs. exploitation
- Blind variation & selective retention
- Innovation vs. incremental improvement
- Pseudo-temperature
- Diffusion
- Mixed strategies

Pattern Formation

- Excitable media
- Amplification of random fluctuations
- Symmetry breaking
- Specific difference vs. generic identity
- Automatically adaptive

Emergence & Self-Organization

- Microdecisions lead to macrobehavior
- Circular causality (macro / micro feedback)
- Coevolution
 - predator/prey, Red Queen effect
 - gene/culture, niche construction, Baldwin effect

Stigmergy

- Continuous (quantitative)
- Discrete (qualitative)
- Coordinated algorithm
 - non-conflicting
 - sequentially linked

Emergent Control

- Stigmergy
- Entrainment (distributed synchronization)
- Coordinated movement
 - through attraction, repulsion, local alignment
 - in concrete or abstract space
- Cooperative strategies
 - nice & forgiving, but reciprocal
 - evolutionarily stable strategy

Doing Research in Bio-inspired Computation

Keeping Abreast of Research

- An interdisciplinary field, so it's not sufficient to read just computing journals
- General science: to keep abreast of potentially relevant research
- Complex systems: integrative and overarching research
- Specific bio-inspired journals: neural networks, cognitive science, evolutionary computing, artificial life, swarm intelligence, etc.
- There are more journals than you can read, so subscribe to science news feeds, etc.

General Science Journals

- *Science* (AAAS)
 - via library you have full internet access
 - go to www.sciencemag.org for podcasts, webinars, etc.
- *Nature*
 - via the library you have full internet access
 - go to www.nature.com for podcasts, etc.
 - also *Nature Neuroscience*, *Nature Reviews Neuroscience*, etc.
- *Science News*, *Scientific American*, *Scientific American Mind*, etc.

Journals Especially Relevant to Bio-inspired Computing

- *Natural Computing*
- *Artificial Life*
- *Adaptive Behavior*
- *Int. Journ. Bio-inspired Computation*
- *Intl. Journ. of Unconventional Computing*
- many neural network journals
- *Physica D*
- *Advances in Complex Systems*
- *Biological Cybernetics*
- *Complex Systems* (Wolfram)
- *Intl. Journ. of Nanotechnology and Molecular Computation* (which I founded)

End-of-course Survey!