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 edit)

Student Course Evaluation!