Learning, Plasticity and Development

Contributing Disciplines

- Cognitive and Behavioral Science
  - Including developmental psychology
- Systems Neuroscience
- Cellular and Molecular Neurobiology; Chemistry
- Computer Science and Statistics
- Mathematics and Physics
- Robotics and Engineering

Premises

- Contributing disciplines have offered a strong foundation for further progress
- But we really don't know how the brain solves the hard learning problems that humans and animals must solve…
- Much less, how to capture them in artificial systems
- Or how to optimize conditions so as to enhance human and machine success at learning
- To address these issues, we will need to bring the disciplines together

Key contributing elements

- A formal theory
  - Grounded in information theory and Bayesian inference
- A characterization of the information and the goal of learning
- A characterization of the affordances of the system within which learning will occur
  - System/circuit level
  - Cellular and molecular level
- Some knowledge of how these affordances change with development and experience

Payoffs

- An integrated understanding of the role of experience is shaping the emergence of intelligence, both at the physical and the functional levels
- New insights into the basis of limits on learning
- New ways of understanding how to optimize human potential through education and other interventions
- New ways of enhancing the capabilities of artificial systems that learn

Three Opportunities

- Factors that shape learning
- The role of time in learning
- Learning the causal structure of the world

1. Factors that shape learning

- All systems that learn do so within some framework; how does that framework shape the learning process?

Examples

- Factors shaping the range of songs a bird can learn to sing
- Factors shaping the ability to learn cognitive maps of external environments
- Factors shaping why it is easy to learn language but hard to learn math and physics, or even to learn to read

2. The role of time in learning

- How does the timing of experiences affect the process and outcome of learning?
  - Temporal intervals separating related events
  - Timing relative to the developmental/learning history of the organism
  - Spacing of opportunities to learn
- How do we learn to orchestrate the unfolding of behavior over time to achieve desired consequences?

3. Learning the causal structure of the world

- A reach, but not too far…
- Sense data provides evidence of underlying causes, but these are never 'directly' observed
- Yet animals and humans act as though they infer the underlying causes and act appropriately as a consequence

Examples

- We categorize objects and select them for use based on their causal properties
- We interpret actions in terms of their intended consequences
- Classical conditioning and reinforcement learning can be seen as examples of learning causal structure

Enabling factors for future research

- Good animal models
- Formal theory relevant to some aspects of the issues
- Extensive body of existing systems, cellular, and molecular neuroscience research relevant to all three themes
- Increased realization of the importance of learning for artificial systems of all kinds

What needs to be done to address these issues?

- Bring the contributing disciplines together!
  - Formal theory of learning
  - Behavior, functional imaging, neurophysiology
  - Systems and cellular neuroscience
  - Mathematical analysis of the emergent properties of complex systems
  - Robotics, machine learning, and computer science

Payoffs

- An integrated understanding of the role of experience is shaping the emergence of intelligence, both at the physical and the functional levels
- New insights into the basis of limits on learning
- New ways of understanding how to optimize human potential through education and other interventions
- New ways of enhancing the capabilities of artifical systems that learn