Computational Models of Neural Systems

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- Schedule: Mon./Weds. from 4:00 to 5:20 PM in WeH 4615A
- Credit: 12 units (CMU), 4 credits (Pitt),
  or 1 core unit (CS/Robotics)
- Evaluation:
  exercises, project, midterm and take-home final exam
- Course materials:
  Readings books are available in the E&S Library or from my administrative assistant in Wean Hall 8124.

  Handouts are available in:
  /afs/cs.cmu.edu/academic/class/15883-s03/handouts
  or
  http://www.cs.cmu.edu/afs/cs/academic/class/15883-s03

Who Should Take This Course

- Computer scientists who want to learn about the brain.

  No prior neuroscience background required.

- Neuroscientists who want a computational perspective.

  Focus on representations and algorithms, rather than anatomy and physiology.

- Cognitive scientists who want to know more about brains as information processing devices.

  Taking the“brain as computer’’ metaphor seriously requires learning as much as possible about both.

Varieties of "Neural Networks"

The term *neural networks* covers several distinct fields:

- Artificial Neural Networks (ANNs)
- Connectionist Models
- Computational Neuroscience
- Neural Modeling

Some investigators work in more than one area.

Courses in all four areas are available to CMU and Pitt students.

Artificial Neural Networks

- Goal: pattern recognition, adaptive control, time series prediction.
- Connection to biology: uses simple, ‘‘neuron-like’’ computing elements, massive parallelism, local computation.
- Major tool: backpropagation learning..
- Major successes: speech recognition (TDNNs), robot control (ALVINN), OCR, financial forecasting.
- Typical journals:
  Neural Computation
  Neural Networks
  IEEE Transactions on Neural Networks
- Typical conferences:
  NIPS (Neural Information Processing Systems)
  INNS (International Neural Network Society) Meeting
  various IEEE conferences
- Courses available:
  15-782: Introduction to Artificial Neural Networks

Connectionist Models

- Goal: model properties of cognition in a brain-like way:

  Massively parallel constraint satisfaction.

  Representations based on distributed activity patterns rather than discrete symbolic structures.

- Connection to biology: No closer than the ANN models.

- Major tools: (1) backprop, (2) spreading activation networks.

- Major successes: reproducing psychological effects (such as the word superiority effect, or error patterns in aphasia) not covered by previous models.

- Typical journals: Cognitive Science, Connection Science

- Typical conferences:

  Cognitive Science Conference

- Courses available:

  PDP modeling courses in CMU's Psychology Department, taught by David Plaut.

Computational Neuroscience

- Goal: model information processing in real neural systems, based on anatomical, physiological , and behavioral data.

- Connection to biology: models vary in their level of abstraction, but generally refer to anatomy if not specific neural circuits. (Often the precise anatomy is unknown.)

- Major tools: home-grown models. Some use of backprop.

- Major success: models of development of the visual system explain the organization of ocular dominance columns and orientation columns.

- Typical journals:
  Neural Computation
  Journal of Computational Neuroscience
  occasional articles in many other journals

- Typical conferences:
  NIPS, CNS, Neurosciences Meeting

- Courses available:
  15-883: Computational Models of Neural Systems

Neural Modeling

- Goal: understand the biophysics of single neurons, or small circuits of neurons.
- Major tools: compartmental modeling programs such as GENESIS or NEURON.
- Typical result: new understanding of electrical properties of Purkinje cells in the cerebellum.
- Typical journals:
  - Journal of Computational Neuroscience
  - Journal of Neurophysiology (occasional modeling articles)
- Typical conferences:
  - CNS (Computational Neuroscience Meeting)
- Courses available:
  - Neural modeling course taught by Bard Ermentrout at Pitt: a CNBC core course.

Organization of this Course

- Specific domain (e.g., the hippocampus)
  - Background lecture: anatomy and physiology.
  - Family of models (e.g., associative memory models)
    - One or more papers in each family.
    - Class discussion.
    - Occasionally, experimentation with a Matlab model.

- Small programming project.
- Mid-term exam.
- Final exam.