CSE941 Selected Topics in Artificial Intelligence: Computational Brain-Mind

CSE, Michigan State University Fall 2011

This course will cover computational principles based on which the brain-mind works. The material integrates advances in computer science, neuroscience, psychology, biology, electrical engineering and mathematics. The course is designed to suit graduate students in natural sciences, engineering, and social sciences who are interested in studying how the brain-mind works. The subjects include epigenesis; development; brain-mind architectures; dorsal and ventral streams; brain areas; features; self-organization; cell mechanisms; biological basis of working, long-term, episodic, and manipulatory memories; perception; cognition; autonomy in learning; brain processes for vision, audition, touch and motor behaviors; bottom-up attention; top-down attention; incremental learning; scaffolding; skill transfer; motivational systems; modulatory systems; autonomous reasoning; decision making; planning; self awareness; and consciousness. The subject matter cuts across levels of cells, circuits, systems, brains, experience, and functions. An emphasis is brain-mechanisms that are applicable to practical applications. Compared with traditional computer methods, why the brain methods appear to be more computational efficient, more robust, and of a lower computational complexity? The material covered potentially may lead to new subjects and approaches in computer science, neuroscience, psychology, biology, electrical engineering and mathematics.

A prior similar offering at MIT Spring 2007: http://stellar.mit.edu/S/course/9/sp07/9.915J/. Last offering at MSU: Fall 2009 (students can repeat the course because of new topics and material).

Lectures: Mondays and Wednesdays 10:20am - 11:40am Room 2320 Engineering Building

Instructor: Juyang (John) Weng

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Office hours: Tuesdays and Thursdays 5:00pm-6:00pm.

Course web: `http://www.cse.msu.edu/~cse941/`

Prerequisites: Each student chooses one of the two tracks:

Track 1: Knowledge comparable to that taught in the following courses, or permission of the instructor.

1. CSE 331 Algorithms and Data Structures
2. MTH 314 Linear algebra
3. STT 441 Probability and Statistics

Track 2: A bachelor degree in biology, psychology, neuroscience, linguistics, laws, political science, philosophy, or permission of the instructor.
Send an email to weng@cse.msu.edu with your background information and your student ID number if you need a registration override.

Text: Manuscript by J. Weng, material available online after each lecture.

Paper presentations: Each student will give 1-2 paper presentations and a project presentation, each taking 15 minutes plus 5 minutes for questions.

Assignments: We will have papers assigned to read, project proposal, project progress report and project final report.

Projects: Each student will work on a project and write a research report (about 6-8 pages of conference proceedings format).

Project proposal: Topic, motivation, literature survey, expected novelty of the work, expected importance of the work, expected conclusions, planned experimental work.

Project progress: Add: exposition of the new theory, methods, and experiments.

Project final report: Add: experimental results, analysis of the results, conclusions.

Exam: One final exam (35%). Track 1 and Track 2 will have different final exams.

Grading: Paper presentations: 10%; Project proposal: 15%; Project progress: 15%; Project final report: 20%; Participation of discussion: 5%.

Topics: The planned topics are

1. Muddiness of tasks: Who understands the tasks, the human programmer, the genome or the agent?
2. Overview of brain-mind representations: symbolic models and emergent models
3. Human mental development, results from neuroscience and developmental psychology
4. Overview of animal learning theories and models
5. Brain-mind architectures, dorsal and ventral streams
6. Supervised, reinforcement, and communicative learning
7. Brain areas: working memory and long-term memory
8. Brain's spatial processing: Attention (bottom-up and top-down)
9. Brain's temporal processing: Temporal attention for events
10. Behaviors: concept learning, natural languages, limb manipulation
11. Modulatory system: punishment, reward, novelty, and confidence
12. Unification and integration of mental capabilities through development, including vision, audition, touch, language, reasoning, decision making, planning, object manipulation and navigation (information fusion and sensor fusion)
13. Machine and human autonomous thinking and its development
14. Examples of experimental developmental systems
15. Applications, impacts and future directions

Supplemental Readings

The following readings are on reserve at the Engineering Library.

- W. K. Purves, D. Sadava, G. H. Orians and H. C. Heller, *Life: The Science of Biology,* 7th edition, Sinauer, Sunderland, MA, 2004.
- M. Cole, S. R. Cole and C. Lightfoot *The Development of Children,* Freeman, New York, 2004.
- M. Domjan, *The Principles of Learning and Behavior: Active learning edition*, Thomson/Wadsworth, Belmont, CA, 2006
- K. Richardson, *Models of Cognitive Development*, Psychology Press, East Sussex, UK, 1998.
- E. R. Kandel and J. H. Schwartz and T. M. Jessell, *Principles of Neural Science*, 4th edition, McGraw-Hill, New York, NY, 2000.
- J.L. Elman and E. A. Bates and M. H. Johnson and A. Karmiloff-Smith and D. Parisi and K. Plunkett, *Rethinking Innateness: A Connectionist Perspective on Development*, MIT Press, Cambridge, MA, 1996.
- T. R. Shultz, *Computational Developmental Psychology*, MIT Press, Cambridge, MA, 2003.

Time Schedule

- Week 1, Wednesday, 08/31/2011: Introduction, Ch1 Agents and Tasks (Mon. 9/5 holiday)
- Week 2, Monday, 09/12/2011: Ch2 Representation and Search
- Week 3, Monday, 09/19/2011: Ch3 Autonomous Development
- Week 4, Monday, 09/26/2011: Ch4 Neurons and Features
- Week 5, Monday, 10/03/2011: Ch5 Properties of Representation
- Week 6, Monday, 10/10/2011: Ch6 Brain-Mind Architecture
- Week 7, Monday, 10/17/2011: Ch7 Spatial Processing
- Week 8, Monday, 10/24/2011: Ch8 Temporal Processing
- Week 9, Monday, 10/31/2011: Ch9 Neural Modulation
- Week 10, Monday, 11/07/2011: Ch10 Generalization and Thinking (Project proposal due: Sunday 11/13)
- Week 11, Monday, 11/14/2011: Paper presentations I
- Week 12, Monday, 11/21/2011: Paper presentations II (Thurs. 11/24 - Fri. 11/25 holidays, Project progress due: Sunday 11/27)

- Week 13, Monday, 11/28/2011: Paper presentations III
- Week 14, Monday, 12/05/2011: Project presentations
- Week 15, Monday, 12/12/2011: Final exam week. Final exam 10am-noon, Thursday 12/15 (Project final report due: Sunday 12/18)