BMI 871 Computational Brain-Mind
A Distance Learning Course
July 11 - July 29, 2016
http://www.brain-mind-institute.org/

Brain-Mind Institute (BMI)   Available via Internet

This course introduces computational principles of biological brain, which give rise to the various functions of mind. An emphasis is on regarding the brain as a highly integrated developmental system so that the models and principles are applicable to small biological brains (e.g., fruit flies), large biological brains (e.g., humans), and artificial ones (e.g., machines and robots). The material integrates knowledge in computer science, neuroscience, psychology (also cognitive science), biology, electrical engineering, physics, mathematics, and other related disciplines. The course is suited for faculty, senior researchers, postdocs, and graduate students in any discipline — natural sciences, engineering, and social sciences — who are interested in studying how the brain-mind works. The subjects include: Computational development of biological brains. Machine's symbolic representations. Brain's emergent representations and architectures. Brains as emergent Turing Machines. Brain's spatial representations. Brain's temporal representations. Perception, cognition, attention (bottom-up and top-down), learning, behaviors, abstraction, reasoning, decision making. Vision, audition, touch, multimodality, and integration. Modulatory system: reinforcement, motivation and emotion. The above subjects are detailed down to neuronal computation, cutting across levels of molecules, synapses, cells, circuits, systems, brains, experience, functions, and group intelligence.

Examples of fundamental discipline questions to be discussed:

Biology: How do individually autonomous cells interact to give rise to animal behaviors?

Neuroscience: From an overarching perspective, how does the brain self-organize?

Psychology: How does an integrated brain architecture realize many psychological learning models (e.g., classical conditioning and instrumental conditioning)?

Computer Science: Why is the automata theory (e.g. Turing Machine) a special case of the brain's neural network theory?

Electrical Engineering: How does a brain perform general-purpose nonlinear control, beyond Kalman filtering?

Mathematics: How does a brain perform general-purpose high-dimensional, nonlinear optimization?

Physics: How do meanings arise from physics?

Lectures: A 3-week distance learning course.

Files: The access information for the course files is from the instructor.

Instructor: Juyang (John) Weng

Course web: `http://www.brain-mind-institute.org/bmi-871.html`

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Prerequisites: Knowledge comparable to that taught in the following courses is necessary for understanding the necessity and rationale of the material to be taught.

1. BMI 811 Biology for Brain-Mind Research
2. BMI 821 Neuroscience for Brain-Mind Research
3. BMI 831 Psychology for Brain-Mind Research
4. BMI 841 Mathematics for Brain-Mind Research
5. BMI 851 Electrical Engineering for Brain-Mind Research
6. BMI 861 Brain-Automata

Physical science and social science applicants are all encouraged. Those who have not learned the automata theory are encouraged to take BMI 871. However, this course is self-contained for exams.

Text: J. Weng, *Natural and Artificial Intelligence: Introduction to Computational Brain-Mind*, BMI Press, 2012. ISBN: 978-0-9858757-2-5. Available at Amazon and the web site of the BMI Press.

Homework: There will be homework assignments, administered through LON-CAPA, an integrated system for online learning and assessment, at http://s10.lite.msu.edu. The due time for each homework is provided in Table 1 but you should complete the homework before the following lecture so that you can understand. Homework will be collected via email and some will be graded. The homework is recommended for understanding the course material and useful for exams.

Quizzes: Quizzes are short multiple-choice problems to be completed during live lectures from which the video files were taken.

Exams: Three exams, to be done during the following Sunday of each week, of 1.5 hours each. Each exam is opened during only 8:00am - 10:00am Eastern Daylight Time (EDT), 8:00pm - 10:00pm Beijing Time. Exams are closed book and must be done within the above time length. See Table 1. Reading textbook and doing homework are also important for doing well in the exams.

Exam proctor: You need to identify a keep-an-eye-on-you exam proctor who is a licensed librarian, one of your parents, or a licensed teacher. Send the proctor's name, address, email address, and proof of qualification required above to the instructor via email. Grading results of the exams are private and confidential, not known to the proctor. Ask the proctor to send a statement via email, at least 24 hours before the first exam, with email subject "BMI 871 Proctor Statement for First-Name Last-Name" to the instructor: "I guarantee to observe the responsibilities of the proctor, including the closed-book, no-access-to-electronics, and the exam time length requirements." The proctor is responsible for printing the exam before the exam and, within 1.5 hours after giving you the exam, taking a picture of your answer sheet and sending it back via email before the due time of the exam.

Table 1: Homework and Exams

Week	Day	Assignment	Due
1	1	Homework 1.1	End of Tue.
	2	Homework 1.2	End of Wed.
	3	Homework 1.3	End of Thu.
	4	Homework 1.4	End of Fri.
	5	Homework 1.5	End of Sat.
	7	Exam 1 (open 8:00am)	10:00am
2	1	Homework 2.1	End of Tue.
	2	Homework 2.2	End of Wed.
	3	Homework 2.3	End of Thu.
	4	Homework 2.4	End of Fri.
	5	Homework 2.5	End of Sat.
	7	Exam 2 (open 8:00am)	10:00am
3	1	Homework 3.1	End of Tue.
	2	Homework 3.2	End of Wed.
	3	Homework 3.3	End of Thu.
	4	Homework 3.4	End of Fri.
	5	Homework 3.5	End of Sat.
	7	Exam 3 (open 8:00am)	10:00am

Grading: Three exams equally weighted, each counted as 100%/3. Homework is not counted for the total score. Pass: the total score is 60% or above. Those who successfully pass will receive a BMI 871 Certificate.

Piazza Discussion Forum We will use Piazza as a discussion and notification forum for this class. The web site is at https://piazza.com/brain-mind_institute. You will receive an invitation to join Piazza in the first week of class. The instructor will monitor Piazza and may choose to respond to questions posted to it; other students may also do so. If you have a question, you will often find that it has already been asked and answered on Piazzaso check. Important class notifications will be sent via Piazza. Be sure that you accept the invitation to join. If you do not receive an invitation to join in the first week of class contact the instructor. However, Piazza is not always effective for asking last-minute technical questions.

Topics: The planned topics are

1. Muddiness of tasks: Who understands a task, the human programmer, the genome or the agent?

2. Brain-mind representations: symbolic models and emergent models

3. Human brain and mental development, skull open vs. skull closed

4. Animal learning theories and models

5. Brain-mind architectures, the dorsal and ventral streams and their motor causality

6. Supervised, reinforcement, and communicative learning

7. Brain areas: emergent features, working memory and long-term memory

8. Brain's spatial processing: object, background, and attention (bottom-up and top-down)

9. Brain's temporal processing: automata and spatiotemporal attention for events

10. Behaviors: concept learning, natural languages, limb manipulation

11. Modulatory system: punishment, reward, novelty, uncertainty, confidence, emotion

12. Multimodal integration through development, including vision, audition, touch

13. Skill development, skill transfers, and generalization

14. Multi-agent societies, governments, science of management, religion, and laws

15. Examples of early experimental developmental systems

16. Applications, impacts and future directions

Schedule for Dues

See Table 1, where all the items are in the North American Eastern Daylight Time (EDT). Send your completed homework before the due time to the lecturer with email Subject: BMI871 Homework W.N by Your-First-Name Your-Last-Name. Send your completed exam before the due time to the lecturer with email Subject: BMI871 Exam N by Your-First-Name Your-Last-Name. Do not use other email headers because the lecturer receives many emails everyday.

Course Schedule

- Week 1, Day 1, Monday: Chapter 1 Agents and Tasks

- Week 1, Day 2, Tuesday: Chapter 2 Representation and Search

- Week 1, Day 3, Wednesday: Chapter 3 Autonomous Development

- Week 1, Day 4, Thursday: Chapter 4 Neurons and Features (I)

- Week 1, Day 5, Friday: Chapter 4 Neurons and Features (II)

- Week 2, Day 1, Monday: Chapter 5 Properties of Representation

- Week 2, Day 2, Tuesday: Chapter 6 Brain-Mind Architecture

- Week 2, Day 3, Wednesday: Chapter 7 Spatial Processing (I)

- Week 2, Day 4, Thursday: Chapter 7 Spatial Processing (II)

- Week 2, Day 5, Friday: Chapter 8 Temporal Processing

- Week 3, Day 1, Monday: Chapter 9 Modulation (I)

- Week 3, Day 2, Tuesday: Chapter 9 Modulation (II)

- Week 3, Day 3, Wednesday4: Chapter 10 Generalization (I)

- Week 3, Day 4, Thursday: Chapter 10 Generalization (II)

- Week 3, Day 5, Friday: Chapter 11 Group Intelligence

Supplemental readings that provide background knowledge

1. M. F. Bear, B. W. Connors, and M. A. Paradiso, *Neuroscience: Exploring the Brain*, 3rd edition, Lippincott Williams & Wilkins, Baltimoore, 2007.

2. J. B. Reece, L. A. Urry, M. L. Cain, S. A. Wasserman, P. V. Minorsky, and R. B. Jackson, *Campbell Biology*, 9th edition, Benjamin Cummings Publishers, San Francisco, 2011.

3. P. S. Churchland and T. J. Sejnowsky, *The Computational Brain*, The MIT Press, Cambridge, MA, 1996.

4. M. Cole, S. R. Cole and C. Lightfoot *The Development of Children,* Freeman, New York, 2004.

5. P. Dayan, L. F. Abbott, *Theoretical Neuroscience*, Taylor & Francis, New York, NY, 2001.

6. M. Domjan, *The Principles of Learning and Behavior: Active learning edition*, Thomson/Wadsworth, Belmont, CA, 2006

7. 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.

8. J. Martin, *Introduction to Languages and the Theory of Computation*, 3rd edition, McGraw-Hill, New York, 2007.

9. E. R. Kandel and J. H. Schwartz and T. M. Jessell, *Principles of Neural Science*, 4th edition, McGraw-Hill, New York, NY, 2000.

10. W. K. Purves, D. Sadava, G. H. Orians and H. C. Heller, *Life: The Science of Biology,* 7th edition, Sinauer, Sunderland, MA, 2004.

11. K. Richardson, *Models of Cognitive Development*, Psychology Press, East Sussex, UK, 1998.

12. T. R. Shultz, *Computational Developmental Psychology*, MIT Press, Cambridge, MA, 2003.