Self-learning Neural Algorithms (a.k.a Artificial Neural Networks)

- **2017 Fall Graduate Course in Computer Science and Engineering and Brain Science**
  - 컴퓨터공학부: Artificial Neural Networks
  - 뇌과학협동과정: Computational Neuroscience
- **Instructor**: Byoung-Tak Zhang
- **Main TA**: Jiseob Kim (jkim@bi.snu.ac.kr)
- **Sub TA**: Je-Hwan Ryu (jhryu@bi.snu.ac.kr)
- **Class Room**: ~~302-209~~302-107
- **Time**: Tue & Thu, 14:00-15:15h
- **Textbooks**:
  - Haykin, S. (2009). Neural Networks and Learning Machines, 3rd Ed., Pearson.
  - 장병탁 (2017). 딥러닝, 홍릉출판사
- **Evaluation**:
  - Two exams (80%)
  - Homework (10%)
  - Participation and discussion (10%)
- **Announcement**:
  - (07/25) Welcome to the class!
  - (09/13) If you cannot come to the class due to attending a conference, please email the TA (both of us) at least a week prior to the date with the documentative reference (e.g., invoice of the registration).
  - (09/13) The schedule is updated. Please check it.
  - (09/19) Mid-term Exam date is fixed to ***Oct. 26***.
  - (09/19) No classes in Week 4 (09/26, 09/28). Makeup class will be on ***Oct. 12 at 19:30*** at the ***same class room***.
  - (09/28) Newer version of Ch 11. slides have been uploaded.
  - (10/09) ***Homework #1*** is announced. Please look inside this file for the details.
  - (10/09) There will be a Problem Solving Session by TA on Oct. 19. There will be a lecture (as usual) on Oct. 17.
  - (10/17) Late submissions of HW#1 is accepted at the beginning of the class on Oct. 19. This submission will get 80% of the credit.
  - (10/17) The scope of the Mid-term Exam is up to Ch. 11.
  - (10/19) Solution for HW#1 is uploaded. Check it.
  - (10/27) The class on the next Thursday (Nov. 2) will be replaced by PACS-2017 conference. Students are required to attend the conference session **14:00-15:30 The Neural Code at the Base of Perception, Action, and Cognition, Christoph von der Malsburg**. Registration is not needed to enter this session (this is agreed with the staffs). There is going to be the attendance check in the lobby of the conference venue (Engineering House).
  - (11/01) Students can attend the **whole** PACS-2017 conference (both Thu and Fri)

without registration (Go to the registration desk and tell them you are taking Prof. Byoung-Tak Zhang's class).
  - (11/13) Thursday (Nov. 16)'s lecture will be given in a ***different building***. Please come to ***Mogam Hall, Building #500*** Campus Map.
  - (11/14) Final Exam date is fixed to ***Nov. 30***. Also, there will be a makeup class on ***Nov. 21 at 19:00*** at the ***same class room*** due to schedule adjustment.
  - (11/22) ***Homework #2*** is out. Please look inside this file for the details.
  - (11/28) Solution for HW#2 is uploaded. Check it.
  - (12/15) NEW Attendance, Mid-term, Final Exam Score is uploaded. You can claim your score visiting TA office (Room 417, Building 138) on 18(Mon), 19(Tue) from 1PM to 4PM. Note that homework scores are not yet included, but we will not run the claim hours for the homework scores.

- **Course Description**:

  We study "self-learning" networks, i.e. models that learn in an unsupervised and "self-supervised" way without the help of an explicit teacher. These models are neuro-biologically inspired and, usually, self-organizing, dynamic, recurrent, and auto-encoding networks. We examine the principles of neural learning algorithms from the historical models, such as Willshaw-von der Malsburg feature maps, Linsker models, Kohonen's self-organizing maps, Grossberg models, recurrent networks, Anderson's brain-state-in-a-box, actor-critic networks, Hopfield's associative memory, Boltzmann machines, and deep belief networks. We study mathematical tools for approximation and optimization of the neural learning models. These include information-theoretic algorithms, such as maximum entropy, mutual information, and KL divergence as well as the statistical-mechanical methods, such as Markov chains, Metropolis algorithms, Gibbs sampling, and simulated annealing. We also examine the neurodynamic models of self-supervised, end-to-end learning to solve the challenging problems, such as time series prediction and reconstruction. These include Markov decision processes, approximate dynamic programming, reinforcement learning, sequential Bayesian estimation, Kalman filtering, particle filtering, real-time recurrent learning, dynamic reconstruction of a chaotic process.

- **Schedule**

Week	Topics	Slides
Week 1 (9/5, 9/7)	**Learning in Neurodynamic Self-organizing Systems** • Neural Networks, Unsupervised / Self-supervised Learning • Mathematics for Neural Learning **Principal-Components Analysis (Ch. 8)** • Principal Component Analysis • Hebbian-Based Maximum Eigenfilter **Hebbian-Based PCA (Ch. 8)**	PDF

	• Generalized Hebbian Algorithm • Kernel PCA	
Week 2 (9/12, 9/14)	**Self-organizing Maps (Ch. 9)** • Willshaw-von der Malsburg Model • Kohonen's SOM Model	
Week 3 (9/19, 9/21)	**Information-Theoretic Learning Models (Ch. 10)** • Maximum Entropy, Kullback-Leibler Divergence • Mutual Information, Infomax, ICA	
Week 4 (9/26, 9/28) _No Class_	**Statistical-Mechanical Learning Methods (Ch. 11)** • Statistical Mechanics, Markov Chains • Metropolis, Gibbs Sampling Simulated Annealing	
Week 5 (10/3, 10/5)	***Korean Thanksgiving Holiday***	
Week 6 (10/10, *10/12*) *MakeUp Class*	**Deep Neural Networks (Ch. 11)** • Boltzmann Machines • Deep Belief Networks	 (Same as Week 4)
Week 7 (10/17, 10/19)	**Dynamic Programming (Ch. 12)** **Problem Solving Session by TA**	
Week 8 (10/24, 10/26)	**Summary (10/24)** ***Mid-term Exam (10/26)***	
Week 9 (10/31, 11/2)	**Dynamic Programming (Ch. 12)** • Markov Decision Process, DP, Bellman Equation • ADP, Reinforcement Learning, TD, Q • (11/2) ***PACS-2017***. Please see the announcement.	 (Same as Week 7)
Week 10 (11/7, 11/9)	**Neurodynamic Models (Ch. 13)** • Dynamic Systems, Attractors, Chaos • Hopfield Models, Dynamic Reconstruction	
Week 11 (11/14, *11/16*) *Classroom Change*	**Bayesian Filtering (Ch. 14)** • State Space Models • Kalman Filters, EKF, CKF	
Week 12	**Particle Filters (Ch. 14)** • Approximate Bayesian Filtering • Particle Filters, SIR Algorithm	

(*11/21*, 11/23) *MakeUp Class*	**Dynamic Recurrent Networks (Ch. 15)** • Recurrent Network Architectures • Backpropagation through Time	
Week 13 (11/28, *11/30*)	**Real-Time Recurrent Learning (Ch. 15)** • RTRL Algorithm, Vanishing Gradients • EKF Algorithm for Training RMLP ***Final Exam (11/30)***	
Week 14 (12/5, 12/7)	**Review and discussion**	