Contact Information

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Class hours: T 5-8 pm
Class location: 351 DH
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Description

MATH 8/7036 Math Foundations of Learning (3)
This course will cover basic concepts and mathematical foundations of learning theory. The topics will include kernel methods, which are powerful tools in learning theory. After the review of Hilbert spaces, Reproducing Kernel Hilbert Spaces (RKHS) will be introduced, covering regularization techniques. Significant efforts will be devoted to concepts of advanced neural networks with massive reentrant connections and hierarchical structures. Freeman K sets are canonical mathematical models based on ordinary differential equations. Spatial models are addressed using partial differential equations and network theory. Fixed-point convergence, limit cycles, chaotic attractors are discussed, including spatio-temporal encoding in the style of brains. Applications in machine learning will be described, including Support Vector Machines, and various neural networks for optimization problems.
PREREQUISITES: Background in calculus and basics of functional analysis, linear algebra MATH 4/6242 or permission of the instructor.

Course Objective
The mathematical theory of learning has been developed intensively in the past half a century. Applications have gained broad popularity since the development of machine learning techniques and adaptive tools in the past 20 years. This course aims at providing solid mathematical introduction to the learning theory, which provides theoretical basis in this field for math major students. In addition, this course has an interdisciplinary appeal, as the introduced mathematical tools are of interest to students in statistics and bioinformatics, theoretical computer science and artificial intelligence, cognitive science and computer engineering. By completing this course, students will learn the mathematical theory of machine learning and also gain experience in applying these mathematical tools to solve specific practically useful problems.
Syllabus

Week 1: 8/27  Orientation. Introduction.

**Topic I: Basics of Mathematical Learning Theory**

Week 2: 9/3  Basics concepts of learning theory and Reproducing Kernel Hilbert Spaces
Week 3: 9/10  Machine learning approaches

**Topic II: Freeman K sets**

Week 4: 9/17  Mathematical models of neurons and neural populations
Week 5: 9/24  Freeman K model from KO to KIV
Week 6: 10/1  Learning in Freeman K models
Week 7: 10/8  Meaning and representations in brains and brain models

- Fall Break –

**Topic III: Learning cycles**

Week 8: 10/22  Cognitive cycle, brains as open thermodynamic systems
Week 9: 10/29  Random cellular automata approach to learning as phase transition

**Topic IV: Research Projects**

Week 10: 11/5  Project Outlines
Week 11: 11/12  Advanced topics in mathematical learning theory
Week 12: 11/19  Project review
Week 13: 11/26  Project Presentations I
Week 14: 12/3  Project Presentations II
References

Texts:
• Reading list of journal articles and conference proceedings will be distributed for this course.

Additional texts:

Evaluation

Grading will include the following components: class participation (20%), homeworks (30%), project (50%). Students at the 8000 level are expected to develop and a comprehensive project in their selected topic, while 7000 students will be evaluated based on review of the relevant literature or conceptual outline.