Syllabus

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Office Hours: 6:50pm-7:50pm M, 2:00pm-4:00pm Tu (or by appointment)

General Information (2008-2010 Graduate Bulletin)

Course Description: An advanced lecture course on a new topic in computer science. The course is primarily designed for M.S. students, but can be taken by Ph.D. students as well.
Prerequisites: Limited to CSE graduate students; others, permission of instructor.
Credits: 3
Grading: ABCDF
Fulfilling Program Requirements: May be repeated for credit as the topic changes, but cannot be used more than twice to satisfy CSE major requirements for M.S.

Overview

The need to study and solve problems in complex systems, and specially complex networks, has given rise to a variety of so called computational “network-based” models. Despite the specific differences in the nature of the settings and problems each model addresses, there is striking commonality on some of the kinds of algorithms that have been developed to solve the different problems. One such class of algorithms is inherently based on so called propagation processes, in which “local information” (with respect to the network graph) is passed between nodes in the network with the ultimate goal of achieving some “global” objective. Of course, the precise type of information propagated depends highly on the specific setting and problem, as are the notions of “local” and “global.”

Propagation-based algorithms have had tremendous practical success in areas such as near-optimal coding in digital communication, planning, scheduling and other resource allocation problems in AI, speech recognition, the analysis of digital circuits in electrical engineering, the determination of protein structure in computational biology, and stereo and image restoration in computer vision, to name a few. The now widely famous PageRank algorithm, which is fundamental to the way in which Google rank pages, also has an interpretation as a propagation algorithm.

This course will cover the fundamental ideas behind propagation-type processes and other similar algorithms that have been used to solve problems in a wide variety of network-based models.
There will be an emphasis on highlighting and exploring commonalities between the different propagation processes and algorithms among the different models. The interest is on applying existing or developing novel propagation-based algorithms to new domains. There is also interest in potentially gaining or providing alternative insight into the behavior of propagation algorithms (empirically and theoretically), and perhaps even improving upon them.

**Purpose:** To introduce students to a variety of basic network-based models used in different contexts and the problems they address, to expose students to state-of-the-art propagation methods and their applications in a variety of domains, and prepare students for continuing research and development work in the area

**Objectives:** To familiarize students with network-based models and propagation algorithms to the degree that they can further adapt and/or apply such algorithms to new domains

**Goals:** At the end of the course, students should be able to

- describe and explain
  1. the basic network-based models and their fundamentals,
  2. the basic problems addressed by such models,
  3. the basic propagation-based algorithms and their fundamental properties;

- summarize and present previous work and current methods;
- apply existing models and algorithms; and
- recognize and develop simple variants of propagation-type algorithms as applied to similar problems and network-based models.

**Content**

**Organization:** The course format involves formal lectures, discussions and presentations, some led by the students themselves. Reading material from a variety of sources, including textbooks, tutorials, classical and recent research papers, and other possible web content, will be handed out, posted or assigned to supplement the lectures.
Tentative List of Topics

- **Constraint Networks and Constraint Propagation for Constraint Satisfaction Problems (CSPs)**
  - *Framework:* constraint satisfaction problems (CSPs)
  - *Graphical Model:* constraint network
  - *Problems:* finding consistent/satisfying assignments
  - *Propagation algorithm:* constraint propagation and generalizations
  - *Related Methods:* backtracking search; dynamic programming; variable elimination; join/clique trees
  - *Concepts:* primal, hidden and dual representations; compact representation and handling special constraints (e.g., binary, context-sensitivity); chordal graphs and triangulation; treewidth

- **Survey Propagation for Boolean Satisfiability**
  - *Framework:* Satisfiability ($k$-SAT)
  - *Graphical Model:* factor graphs
  - *Problems:* finding consistent/satisfying assignments of boolean formulas
  - *Propagation algorithm:* survey propagation
  - *Related Methods:* DPLL
  - *Concepts:* random boolean formulas, solution space, phase-transitions, satisfiability threshold, local/greedy methods

- **Inference in Probabilistic Graphical Models**
  - *Framework:* probability theory
  - *Models:* Markov random fields; Markov networks; Bayesian networks
  - *Concepts:* Gibbs distributions; conditional independence; Hammersley-Clifford Theorem; context-sensitive independence; reasoning under uncertainty; inference formulation of CSPs
  - *Problems:* most-likely assignment and MAP estimation; posterior distributions and belief inference
  - *Propagation algorithm:* belief propagation and generalizations
  - *Related Methods:* clique/junction trees; max-/sum-product algorithm; mean-field approximation

- **Relevance in Networks**
  - *Framework:* Markov processes with sparse transitions, social network theory
  - *Problems:* rank nodes by “relevance”
− Models: random walk on a graph
− Propagation algorithm: PageRank
− Concepts: centrality

● Influence in Networks

− Framework: social network theory, non-cooperative game theory
− Problems: studying diffusion processes; computing stable outcomes; identifying the most “influential” individuals in a social network
− Models: linear threshold models (LTMs); generalized threshold models (GTMs); influence games
− Concepts: diffusion processes, cascading, tipping point, sub-modularity

● Nash Propagation for Graphical Games

− Framework: Noncooperative game theory
− Problems: computing stable outcomes (i.e., Nash equilibria)
− Model: Graphical games
− Propagation algorithm: NashProp
− Concepts: CSP formulation; graphical potential games and connections to probabilistic inference; iterated dominance; best-response dynamics

● Arrow-Debreu Propagation for Graphical Economics

− Framework: mathematical economics and competitive economies
− Problems: computing equilibrium/market-clearing prices and consumer goods’ bundles
− Models: graphical economies
− Propagation algorithm: ADProp

● Economics of Social Networks

− Framework: Fisher economies and social network theory
− Problems: computing market-clearing prices
− Models: bipartite buyer-seller economies
− Main algorithm: primal-dual network-flow algorithms
− Concepts: random graphs, Erdős-Rényi, preferential attachment

● Belief-state Inference in Stochastic Graphical Models

− Framework: Stochastic processes
− Problems: Viterbi/most-likely sequence; belief-state inference/updating
Models: factored hidden Markov models (fHMMs); temporal/dynamic Bayesian networks (DBNs)

Propagation algorithms: Viterbi and forward-backward algorithms

NOTE: The list of topics, as well as the emphasis on each topic, will likely vary depending on the background and interests of the course participants.

Assessment

Course Project: Students complete a research project on a relevant topic. The specific problem requires the instructor’s approval. Possible projects include, but are not limited to, an application of a particular model and technique to a specific problem, the development of a system based on network model ideas to solve a particular problem for a particular application domain, or novel experimental evaluations and comparisons of one or various propagation techniques. Ideally, the project would incorporate a combination of theoretical and experimental work. Projects that involve exclusively theoretical work may be permitted only under very close consultation with the instructor and should involve a narrowly and clearly defined problem description and line-of-attack. Students periodically submit progress reports to monitor the project’s development. Students give a presentation and submit a written report on the results of the project by the end of the course.

Before each of the presentations, students must have a draft ready and meet with the instructor prior to each of their presentations. The exact due dates will be specified in the course schedule.

Student Evaluations: Students performance will be evaluated based on their level of participation during the discussions, and the quality of their topic oral presentation and written report, as well as their project’s proposal, progress reports, oral presentation and final written report. There may also be sporadic written and/or code/implementation homework assignments (at the discretion of the instructor).

All required work must be performed and turned in to receive a grade for the course.
Grades: The following table shows the amount and weighting of each evaluation component in the course.

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<th>Criteria</th>
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<td>Homework</td>
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Final grades will be assigned using the traditional grading scale (90-100=A, 80-89=B, 70-79=C, 60-69=D, 0-59=F), with deviations at the instructor’s discretion.

General University Statements

**Americans with Disabilities Act:** If you have a physical, psychological, medical or learning disability that may impact your course work, please contact Disability Support Services, ECC (Educational Communications Center) Building, room128, (631) 632-6748. They will determine with you what accommodations, if any, are necessary and appropriate. All information and documentation is confidential.

**Academic Integrity:** Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person’s work as your own is always wrong. Faculty are required to report any suspected instances of academic dishonesty to the Academic Judiciary. For more comprehensive information on academic integrity, including categories of academic dishonesty, please refer to the academic judiciary website at [http://www.stonybrook.edu/uaa/academicjudiciary/](http://www.stonybrook.edu/uaa/academicjudiciary/)

**Critical Incident Management:** Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of Judicial Affairs any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students’ ability to learn. Faculty in the HSC Schools and the School of Medicine are required to follow their school-specific procedures.

**Student Disruptions:** Stony Brook University expects students to maintain standards of personal integrity that are in harmony with the educational goals of the institution; to observe national, state, and local laws and University regulations; and to respect the rights, privileges, and property of other people.