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Fall 2012

Heuristic Methods for Optimization - Cornell University

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Heuristic Methods for Optimization
CS 5722 / CEE 5290/ORIE 5340
MWF 12:20-1:10, Fall 2012, Olin 255

DID YOU KNOW?

- Heuristic methods can be used to optimize a wide variety of problems with discrete and/or continuous decision variables and with complex objectives and constraints (including those that are not expressible in analytic form). Optimization applications include optimal design or operation of complex systems and parameter estimation for simulation models from observed data.

- This course is designed to be accessible to M.Eng. and Ph.D. students from a wide range of areas including engineering, computer science, and economics. Many former students have gone on to use the ideas and codes developed in this course in their Ph.D. theses or in their M.Eng. projects. There are also some upper level undergraduates in the course. The course is also a core course in the Computational Science and Engineering minor.

- The Artificial Intelligence research journal with the second highest Impact factor (7.62 impact for 5 yr ISI) in the world is the *IEEE Jn. of Evolutionary Computation* (which focuses on heuristic optimization methods).

- Students who want to omit the theory or the project part of the course can take this course for 3 credits rather than 4 credits. Ph.D. students can develop a project related to their own thesis research.

Instructor: Professor C. Shoemaker <cas12> , **TA:** Ying Wan <yw387>

Course of Studies Description: 3 or 4 credits. Letter or S/U. Prerequisites: graduate standing or upperclass UG standing with adequate background in computing or permission of instructor. Students with no statistics background will need to do some extra reading.

Heuristic optimization algorithms are artificial intelligence search methods that can be used to find the optimal decisions for designing or managing a wide range of complex systems. This course describes a variety of (meta) heuristic search methods including simulated annealing, tabu search, genetic algorithms, genetic programming, dynamically dimensioned search, and multiobjective methods. Algorithms will be used to find values of discrete and/or continuous variables that optimize system performance or improve system reliability. Students can select application projects from a range of application areas. The advantages and disadvantages of heuristic search methods for both serial and parallel computation are discussed in comparison to other optimization algorithms.

Projects in Heuristics Course (*Students select one topic for a team project, and students hear the introductory lectures on three of the applications.)*) *Ph.D. students can petition to do individual projects related to their research*

1. **Job Shop Scheduling** (problem from Operations Research & Information Technol.)
2. **Satisfiability** in Artificial Intelligence (problem from Computer Science)
3. **Cellular (telecommunication) Networks** (problem from Electrical Engineering)
4. **Protein Folding** (problem from Biochemistry)
5. Time-varying optimization of Systems of **Partial Differential Equations** (problem related to fluid mechanics)

Topics Covered

(1 lecture) Introduction to Search Methods
(3 lectures) Simulated Annealing
(3 lectures) Genetic algorithms
(3 lectures) Tabu Search
(2 lectures) Genetic Programming
(3 lectures) Derandomized Evolution Strategy
(2 lectures) Dynamically Dimensioned Search
(1 lecture) Applications of Combinatorial Heuristics to Real-valued Problems
(4 lectures) Applications of Heuristic Optimization in a Range of Areas
(2 lectures) Evaluation of the Relative Performance of Alternative Heuristic Methods
(2 lectures) Differential Evolution
(6 lectures) Theoretical basis for heuristic search methods and significance of results
(2 lectures) Parallel computation for Heuristic Algorithms
(2 lectures) The Advantages and Disadvantages of Heuristic Search Methods for Both Serial and
Parallel Computation in Comparison to Other Optimization Algorithms.
(2 lectures) Response Surface Methods to Enhance Heuristics
(2 lecture) Heuristics for Multiobjective Optimization

Programming and Software: Students are expected to be familiar with Matlab. For the projects, pre-programmed modules will be given to students that represent the response of the systems to changes suggested by the heuristic optimization search. As a result, computer programming will not be a major effort for engineering, physical science and CS students. The programs students write are used to explore the efficiency of existing algorithms and of the students' creative modifications of these algorithms. (Alternatively, students may write codes in another programming language, but they will not be supported with programming assistance, and it is expected that programming time required will be greater than with Matlab.)

Grading, Credits and Teams*: For students taking the course for 4 credits,* the course grade will depend upon homework assignments (20%), one prelim (25%), a final (30%), and the project (25%).
- Students taking the course for 4 credits will do both the Project and the Theory Section of the course.
- *Students taking the course for 3 credits* can elect to not do the part on "Derandomized Search" AND either not to do the project or not to do the Theory Section of the course.
- Homework will be assigned about once per week. Students can work in teams of 1 or 2 on the homework. Students are allowed to consult with each other on homework (but each team must submit its own homework assignment).
- Projects will be done in teams of 3 or 4.
- The final will be given on the university-assigned time. There might be a take-home portion of the prelim and final exams.

Class Composition: This class draws students from Computer Science, many Engineering departments, and a few departments outside the Engineering College, including AEM and Economics. The largest enrollments are from Computer Science, Operations Research and Information Engineering, Electrical and Computer Engineering, and Civil and Environmental Engineering.

Teaching Assistant/ Blackboard Web Page/Assignments: The course teaching assistant is Ying Wan who will maintain the web page (http://blackboard.cornell.edu) and offer office hours in addition to Prof. Shoemaker's office hours. Homework and project assignments as well as copies of lecture handouts from previous days are on Blackboard. Important course announcements will be posted on Blackboard.

Blackboard Discussion Board: If students have homework questions, they are encouraged to post their questions under the blackboard discussion board instead of sending Email. The TA will address those questions through the discussion board so that other students can view the answers.

Text: There will be Xerox materials to supplement the lecture material from the book "*Iterative Computer Algorithms with Applications in Engineering*" by S. Sait and H. Youssef, IEEE/Wiley Publications, 2000. The course packet will cost around $22 Students should be able to pick up the course pack in the campus bookstore by Friday Aug. 24 and maybe on Thursday. It is on the shelves with the textbooks filed under "CEE 5290". Journal articles will be available free through the Cornell library. There will also be several books on reserve at the library.

Office Hours:
Professor Shoemaker's office hours: MWF 2:30 - 3:30, Hollister 210
TA (Ying)'s office hours (starting 8/28/2012): Tue, Wed 01:30 PM- 02:30 PM, Thu 02:00 PM-4:00 PM, Hollister 203

Exams:
*Prelim Exam***: October 23, 7:30-9:00 PM** *(Please notify Professor if you have a conflict with another evening exam on Oct. 23 by 9/15)*
*Final Exam***:** Period N, Wed, Dec 12, 2012 09:00 AM – 11:30 AM

Credit hours and Grades: This course can be taken for 3 or 4 credits. With 4 credits, you complete the entire course. With 3 credits you can choose either :
  a. **Option 1** (with Theory without Project) . In this case you are responsible for all material covered in lecture and homework (including the lectures on Differential Evolution) and you do not do a project.
  b. **Option 2** (with Project and without Theory). In this case you do a project and you are not responsible for the material covered in lecture or homework about Theory or about Differential Evolution. (Hence you can miss a couple of weeks of lecture that is covering Theory topics.)
All students take the same prelim. All students will answer the Core questions on the Final. Additional questions (and additional time) will be given on the final for those taking 3 credit Option 2 or the 4 credit option.

Students should sign up through Cornell online registration for 3 or 4 credits. By September 15, 3 credit students should inform the TA by email whether they are doing Option 1 or Option 2. It is possible to change your mind later by requesting permission from the Professor, but you should indicate what you think is your choice by Sept. 15.

So whether you take the course for 3 or 4 credits is something you need to do through Cornell Registration. In past years the Graduate School has allowed Grad student to petition to change credits later in the semester (which is not possible for undergrads). Whether you are doing Option 1 or Option 2 with 3 credits is something you arrange within our course by contacting the TA.

VideoNotes from last year: This course was videotaped in 2011 . You can go to the website http://www.videonote.com/cornell to watch all these videos. All you need to do is to go to the website and select Fall 2011 and then go to CEE 5290-Heuristic Methods for Optimization. The order and content of the lectures will not necessarily be exactly the same in 2012 as they were in 2011. However the lecture topics are labeled and subtopics given so that you can find a specific topic of interest. The purpose of the Videonotes is to supplement, not to replace, attendance at live lectures.