MAE 552: Heuristic Optimization for Engineering Design

Contact and Relevant Information

Spring 2016

University at Buffalo-SUNY

Course Information
Units: 3
Time: Mo, We, Fr: 3:00 - 3:50 PM
Lecture Hall Location: Norton 216

Instructor Name: Dr. Souma Chowdhury
Office: 246 Bell Hall
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Office Hours: Mo, We: 4.00 - 5:00 PM.

Course Description & Grading

Course Description:

Numerical Optimization is a methodical process for developing superior system designs, with applications transcending disciplinary boundaries within and beyond Science and Engineering (e.g., designing spacecraft and wind turbines to Artificial Intelligence and sophisticated trading systems). This methodical process leverages ***algorithms*** that interact with an abstraction of the system behavior in the search for optimum designs under given conditions. ***Heuristic algorithms*** comprise one of the most popular classes of such algorithms. They combine mathematical formulations with clever heuristics (often mimicking efficient processes observed in nature); and unlike more conventional gradient-based algorithms, they generally do not require the knowledge of derivatives of the functions that represent the behavior of the system being optimized.

The primary objective of this course is to introduce students to the theory and use of heuristic optimization algorithms. More specifically, the MAE 552 course is a fast-paced graduate-level course that will focus on the philosophy, construction, implementation, and engineering design applications of heuristic algorithms. This course will expose students to the characteristics of different classes of optimization problems and to the basics of nature-inspired algorithms that offer powerful solutions to these problems. Other special topics in this course include non-nature-inspired heuristic algorithms (e.g., tabu search), surrogate modeling, and surrogate-based optimization with heuristic algorithms. MATLAB will be used as the primary computational tool to apply optimization in the context of lectures and ensuing exercises in this course.

The expected learning outcomes for students of this course are: (1) an understanding of the characteristics of diverse optimization problems; (2) the knowledge of available heuristic algorithm choices and their suitability for diverse problems; and (3) the knowledge/experience of how to use computer programming to implement these algorithms. These learning outcomes are expected to enrich the students' knowledge of the core MAE field of Design and Optimization in particular and contemporary computing techniques in general, as well as uniquely prepare them for tackling interdisciplinary problems. The objectives and learning outcomes of this course do not lend itself well to traditional courses that are mainly focused on exams, and hence the grade for MAE 552 will rely upon exams, homework assignments, and a term project.

Prerequisites:

Linear Algebra and basic Statistics is essential. Students should have basic programming abilities in MATLAB. Previous knowledge of optimization is helpful, but not required.

Textbooks (*for Reference*):

- Dan Simon, *Evolutionary Optimization Algorithms*, April 2013, Wiley, ISBN: 978-0-470-93741-9
- Kalyanmoy Deb, *Multi-Objective Optimization using Evolutionary Algorithms*, July 2001, Wiley, ISBN: 978-0-471-87339-6
- Achille Messac, *Optimization in Practice with MATLAB – For Engineering Students and Professionals*, Cambridge Press, 2015, ISBN: 9781107109186.

Pertinent Handouts will also be given in class.

Broad Course Topics

- Introduction to Optimization and Essential MATLAB Tools
- Optimization Characteristics: Nonlinear/ Constrained/ Multiobjective/ Discrete
- Genetic Algorithms: Basics and Variations
- Multi-objective Genetic Algorithms (e.g., MOGA, NSGA, SPEA)
- Swarm Intelligence and Particle Swarm Optimization
- Ant Colony Optimization
- Constraint Handling in Heuristic Optimization
- MATLAB-based Implementations: Genetic and Swarm Intelligence Algorithms
- Non-Nature-inspired Algorithms: Nelder Mead, Pattern Search, and Tabu Search
- Surrogate Modeling and Surrogate-based Optimization
- Optimization Applications: in Energy, Aerospace Eng., & Artificial Intelligence

Course Requirements:

1. **Six Homework Assignments**: Each assignment will have pen and pencil based problems and problems that require students to develop software codes/functions written in MATLAB. Each assignment will need an approximately estimated 10-12 hours of student work in addition to related class lectures. The homework submission schedule is outlined in the tentative course schedule (see page 8).

2. **One Term Project** (3-member teams): Each team will perform a term project that will require defining, formulating, and solving an original and practical design-optimization problem. For the term project, each team needs to prepare and submit a 2-3 page abstract (in week 7), and a detailed report and codes developed therein (in week 15). In addition, each team will present their completed project in front of the entire class. It is expected that each team member will spend 40-50 hours on the project (Team Hours total: 120-150 hours). The project abstract and report submission and the presentation schedules are outlined in the tentative course schedule (see page 8).

3. **Two Exams** (equal weightage)**:** Exam 1 will be conducted during week 7 of the course. Exam 2 will be conducted during week 14 of the course.

Grading Policy:

<u>Individual Grade (70%)</u>

Exam 1 + Exam 2:	40% (20% + 20%)
Homeworks:	30% (6 x 5%)

<u>Team Project Grade (30%)</u>

Project Abstract (Midterm):	5%
Final Project Presentation:	5%
Final Project Report:	15%
Final Project Codes:	5%

Homework Assignments:

Homework assignments will be posted on Blackboard at the UBlearns website one week before they are due. The due dates of homework assignments are listed in the tentative course schedule (see page 8). **Homework assignments submitted late will be reduced in score by 25% for each calendar day delay.**

Term Projects:

This is one of the main activities in this class. Grades for the projects will be assigned on a team basis, unless otherwise specified. Peer evaluations of each project will be required. These peer evaluations, in addition to evaluation by the instructor, are used to assess individual participation on the team projects and will influence each individual's grade. A peer evaluation form will be used for the peer evaluation purposes. Initial project discussion and team allocation will be completed within 4 classes into the course, and the project topics will be finalized by the 3rd week of the course. Post submission of *project abstract* by each team, a mid-term evaluation of the projects will be carried out during the instructor's office hours on or about week 9 after the classes begin. Project allocation discussions should be carried out with the instructor during his office hours. For office hours, see the first page of this document. ***No late projects will be accepted.***

Project Report Policy:

All project reports (and HW Assignments) must be submitted at the beginning of class on the assigned due date. Late project reports are inherently unfair to the other students/groups in the class. As a result, any late project reports will not be accepted. Though primarily graded on technical correctness, reports should be tidy, clear, and professionally presented. Written material (paragraphs, pages of discussion and the like) must be typed and presented in professional manner with proper title, table of content, figure and table indexes and formatting. Recommendations and templates for the project report structure will be provided in class. Project report submission and project presentation schedules are listed in the tentative course schedule (see page 8). *Attendance on the project presentation days is a must. A roll sheet will be distributed on the project presentation days!!!*