SPRING 2020
ENME 625: MULTIDISCIPLINARY OPTIMIZATION
(as of 1/28/2020)

Objective: To present applied and computational aspects of engineering optimization with a focus on problems that are multi-objective, need to be approximated, and are multidisciplinary – their overall system optimization problem can be decomposed and solved by multiple subsystem optimization subproblems.

Outline:

1. Introduction
2. Convexity, generalized convexity, optimality, and duality
3. Multi-objective optimization
    - 3.1. Multi-objective optimization
    - 3.2. Multi-objective genetic algorithm,
      constraint handling, solution set quality metrics
    - 3.3. Multi-objective robust optimization (under uncertainty)
4. Approximation
    - 4.1. Design of experiments
    - 4.2. Meta- (or surrogate) modeling
    - 4.3. Verification of meta-models
    - 4.4. Approximation-assisted optimization
5. Multi-Disciplinary Optimization (MDO), sensitivity analysis
    - 5.1. MDO
    - 5.2. MDO-based sensitivity and post optimality analysis

References: There is no single textbook that covers all topics intended for this course. Therefore, the course topics are collected according to the following references. Some of the references are available online:

[1] Floudas, C.A., Nonlinear and mixed-integer optimization, Oxford Univ. Press, 1995. (Chapter 1-4 will be made available on the course website.)
[2] Deb K., Multi-objective optimization using evolutionary algorithms, Wiley, 2001. (Portions to be online and/or in its entirety on reserve in Engineering Library.)
[3] Haimes, Y.Y., Tarvainen, K., Shima, T., and Thadathil, J., Hierarchical multi-objective analysis of large-scale systems, Hemisphere Pub., 1990. (Portions to be online and/or in its entirety on reserve in Engineering Library.)
[4] Forrester, A., Sobester, A., and Keane, A., Engineering design via surrogate modeling, Wiley 2008. (online)
[5] Conejo, A.J., Castillo, E., and García-Bertrand, R. Decomposition techniques in mathematical programming, Springer, 2006 (online)
[6] Papalambros, P., and D. Wilde, Principles of optimal design, Cambridge, 2017
[7] Arora, J.S., Introduction to Optimum Design, Elsevier, 2017 (online)
[8] Related articles from journals and/or conference proceedings (to be provided)

Grading: Exam I (15%); Exam II (25%: comprehensive), 4 quizzes (15%: quiz with the lowest grade has 10% and the other three 90% of the percentage), and two projects (45%: with 7% for the first half project and 38% for the second half project). There will be no final exam!

Homework: Homework will be assigned but will not be collected. Solutions to select problems will be provided.

Project: There will be two projects in the course. The objective of the first half project is to complement and reinforce topics lectured by the instructor. For the first half, I will assign multiple topics. By the midterm (see Course Timeline), you are expected to (i) review state-of-the-art on the assigned topic, and (ii) present a self-contained tutorial to the class using a set of Power Point slides. An e-copy of the first half project presentation slides which will include your notes (i.e., verbatim transcript of your presentation in the "Notes Page" of Power Point for each slide) is due to Canvas by the midterm deadline (see next table). This will serve as the report for the first half project. As part of the project slides for the first half, you are expected to submit a short "insightful question" that is limited to two slides: first slide for the question, followed by a second slide for an answer to the question. Your question and answer should be well thought of and related to a fundamental (non-trivial) concept related to the assigned topic. Moreover, your insightful question and answer must be of tutorial nature, stated concisely and clearly, and be self-contained. If appropriate, the instructor will provide extra credit and choose a few of the insightful questions and answers and distribute them in the class before the end of the semester as a part of the reading material for the course.

For the second half, the project will involve implementation of an optimization technique. As part of this second half project, you will develop a Matlab-based optimization technique and evaluate the performance of the technique on a set of test problems (details to be announced after the midterm). Your project report for the second half is to be presented to the class at the end of the semester following the same instruction for the first half project presentation, including the verbatim transcription. You are also expected to prepare a written final report for the second half project. The formatting details for the final report will be provided in the second half.

Policy: All assignments are due by the specified deadline. Late assignment will not be accepted. Exceptions will be made in accordance with the University policy. Note: It is the student's responsibility to ensure that uploads to Canvas have been successfully submitted.

All exams and quizzes will be open for (hard- or e-copy of) the above-mentioned references but closed otherwise for: class notes, lecture slides, HW/Exam/Quiz solutions, and all other references. You are not allowed to consult or connect to an outside entity (e.g., Internet) during an exam or a quiz. You can use a regular (but not programmable) scientific calculator. You may bring to Exam I and quizzes: one sheet of 8.5" × 11" paper and to Exam II two sheets of 8.5" × 11" paper with your notes on both sides – these can also be in electronic form. If you miss Exam I, due to an excused absence, the percentage missed will be added to Exam II. If you miss a quiz in the first half or second half due to an excused absence, the percentage missed will be added to Exam I or Exam II, respectively. An excused absence is the one that is consistent with the University rules and regulations and will require documentations.

While your absence from the class is highly discouraged, exceptional circumstances may arise that require you to miss a class. In the event that you miss a class, it is your responsibility to contact someone in the class or Dr. Azarm to determine the material that you missed. Please note that Dr. Azarm can assist you in identifying the material that is missed but that a detailed synopsis of a missed lecture will not be given.

For your information, the University of Maryland, College Park (UMD) has a nationally recognized Code of Academic Integrity, administered by the Student Honor Council. This code sets standards for academic integrity at UMD for all students. As a student you are responsible for upholding these standards for this course. It is very important for you to be aware of the consequences of cheating, fabrication, facilitation, and plagiarism. Violation of the Code of Academic Integrity may lead to grade reduction, course withdrawal, dismissal (suspension or expulsion) from the University. For more information on the Code of Academic Integrity or Student Honor Council, please visit http://www.shc.umd.edu. To further exhibit your commitment to the Code of Academic Integrity please sign the Honor Pledge for all exams, quizzes and assignments: “I pledge on my honor that I have not given or received any unauthorized assistance on this exam/quiz/project.”

Course Management: I will use Canvas in the course. While I occasionally but not always might inform you of a new posting (e.g., posting a new document, or solution to a quiz) it is your responsibility to review Canvas on a regular basis in case I post any new announcement, file, etc. It is also your responsibility to update your email address to ensure that you will receive my emails through Canvas. Finally, please do **send me your course related messages by way of Canvas; otherwise, they might go to my spam folder and I might never see them!**

Instructor: Dr. Shapour Azarm, Professor of Mechanical Engineering, 2155 Martin Hall, azarm@umd.edu

Office Hours: Tuesdays 2:15 - 3:15 PM (EST); other times by appointment.

Course Timeline

Class #	Date	Topic	Reading/Assignment
1	Jan 28	Course overview; Convexity	Floudas (1995): Chapter 1 & 2; Conejo et al (2006): Chapter 1
2	Feb 4	Generalized convexity; Optimality conditions	Floudas (1995): Chapter 2
3	Feb 11	Optimality conditions; ***First half project assignment***	**Quiz #1**; Floudas (1995): Chapter 3
4	Feb 18	Duality	Floudas (1995): Chapter 4; Conejo et al (2008): Chapter 4
5	Feb 25	Multi-objective optimization; Quality/performance metrics	Deb (2001): Chapters 2, 3, 8.2; Wu and Azarm (2001)
6	Mar 3	Review; First half project presentations	**Quiz #2; Power Point project presentation slides due to Canvas by Noon (EST)**
7	Mar 10	**Exam I (~75 minutes)**; First half project presentations	
	Mar 17	Spring Break	
8	Mar 24	Genetic Algorithm (GA); Multi-objective GA (MOGA); Constraint handling; ***Second half project assignment***	Deb (2001): 4.1, 4.2, 5.9, 7.3 Constraint handling: Kurpati et al. (2002)
9	Mar 31	Robust optimization	Li et al. (2006); etc.
10	Apr 7	Approximation-assisted optimization	**Quiz #3**; Forrester et al. (2008)
11	Apr 14	Multi-disciplinary optimization (MDO)	Haimes et al. (1990); other refs.
12	Apr 21	MDO (cont’d)	
13	Apr 28	Sensitivity and post optimality MDO	Azarm and Li (1990); Li and Azarm (1990)
14	May 5	Course review; Second half project presentations	**Quiz #4; Power Point project presentations due to canvas by Noon (EST)**
15	May 12	**Exam II (~90 minutes)**; Second half project presentations	**Written project report due by Noon (EST) May 15 to canvas**