ME555/MFG555- Design Optimization

Winter 2016

Instructor Information

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General Information

Course Description

The purpose of this course is to introduce the student to mathematical modeling, optimization theory, and computational methods for analytical and simulation-based optimal system design. The student will learn to (i) develop proper mathematical models to formulate design optimization problems and (ii) develop and apply appropriate optimization algorithms to solve them.

Prerequisites

No previous knowledge on optimization is expected or required; however, basic understanding of calculus and linear algebra is assumed. Students are also expected to have basic programming and computer skills (MATLAB preferred) as computational work will be required for assignments and the team project. Students will use software packages of their choice (such as MATLAB, iSIGHT, OPTIMUS, etc.) to model and solve design optimization problems, and learn to program optimization algorithms in MATLAB.

Coursework and Grading

There will be 5 homework problem sets, 2 midterm exams, and 1 group project.

- Homework must be turned in at the beginning of class on the day it is due. Home- work turned in during class will be penalized according to the instructor's judgment.

- The group project will be a combination of individual projects done by the group members. Each member of the group will formulate and solve a design optimization problem where these individual problems will be subsystems of an overall system level problem.

The grade distribution is: homework 20%, exams 15% each, project 40%, class participation 10%.

Course Materials

Textbook

The course textbook will be provided to students on CTools/Canvas. The official textbook is:

> **Principles of Optimal Design: Modeling and Computation,** 3rd Edition, by P.Y. Papalambros and D.J. Wilde, Cambridge University Press, 2015

However, the 2nd edition of the book can also be used if preferred.

Course Schedule

Lecture	Topic	Description
Lectures 1-3	Modeling and problem formulation	Basic concepts and formulations, boundedness, parametrization, model reduction, constraint activity, monotonicity principles and analysis
Lectures 4-5	Unconstrained optimization	Function approximation, optimality conditions, convexity, gradient method, Newton method
Lectures 6-7	Model construction	Design of experiments, linear regression, neural nets, kriging, regularization, cross-validation
Lecture 8	Review Session	A review of optimization basics, unconstrained optimization and model construction
Lectures 9-10	Derivative-free optimization	Genetic algorithm/programming, simulated annealing, pattern search
Lectures 11-13	Constrained optimization	Feasible directions, regular points, Lagrange multipliers, generalized reduced gradient method, Karush-Kuhn-Tucker (KKT) conditions, sensitivity analysis
Lectures 14-19	Numerical optimization	Global and local convergence, termination criteria, scaling, line search, quasi-Newton methods, penalty methods, sequential quadratic programming, active set strategies, degeneracy
Lectures 20-21	Systems design	Partitioning and coordination methods in optimal system design, Analytical Target Cascading (ATC)
Lecture 22	Review Session	A review of derivative-free optimization, constrained optimization, numerical optimization and systems design

Exam and Project Deliverable Dates

Date	Subject
January 11	Project groups are finalized
January 25	Project proposals due
February 8	Midterm Exam 1
February 24	Project progress reports due
April 6	Midterm Exam 2
April 13, 18	Project presentations
April 22	Final project reports due

Honor Policies

All students in the class are presumed to be decent and honorable, and all students in the class are bound by the College of Engineering Honor Code. You may not seek to gain an unfair advantage over your fellow students; you may not consult, look at, or possess the unpublished work of another without their permission; and you must appropriately acknowledge your use of another's work.

Homework: You may discuss this homework assignment with your fellow students at the conceptual level, but must complete all calculations and write-up, from scrap to final form, on your own. Verbatim copying of another student's work is forbidden. You may not consult homework solutions from a previous term unless they are made available in a publicly accessible form (no unfair advantage can be sought).

Group Project Work: All group work is to be completed only within your own group. Your group can receive help only from the course instructors. At no time may you receive help from someone who is not a current instructor. You cannot speak with other groups about the problems, conceptually or otherwise, and you may not at anytime look at, borrow, or possess another group's work.

CAEN Remote Access Instructions

All students will have access to the College of Engineering's remote software environment, or CLSE (CAEN Lab Software Environment). See the following instructions for remote access:

https://sites.google.com/a/umich.edu/isd-public/remotesoftware

Class schedule: MECHENG/MFG 555 - Design Optimization, Winter 2016

Week	#	Date	Topic
1	1	6-Jan	Course logistics; Introduction to optimal design (Ch. 1)
2	2	11-Jan	Optimization problem formulation, constraints, feasibility, boundedness, activity (Ch. 1)
	3	13-Jan	Monotonicity and example (Ch. 3)
3		18-Jan	Martin Luther King, Jr. Day. No Regular Classes.
	4	20-Jan	Unconstrained Optimization (Ch. 4): FONC, SOSC, Convexity
4	5	25-Jan	Unconstrained Optimization (Ch. 4): Gradient/Newton, examples
	6	27-Jan	DOEs, metamodeling, least squares (Ch.2)
5	7	1-Feb	Neural Nets, Kriging (Ch.2)
	8	3-Feb	Review Ch. 3, 4
6		8-Feb	Mid-term exam 1
	9	10-Feb	Derivative-free optimization (Ch. 7)
7	10	15-Feb	Derivative-free optimization (Ch. 7)
	11	17-Feb	Constrained Optimization (Ch. 5): Reduced gradient; Lagrangian; FONC
8	12	22-Feb	Constrained Optimization (Ch. 5): KKT conditions, example and geometry
	13	24-Feb	Constrained Optimization (Ch. 5): Scaling, sensitivity analysis
		29-Feb	SPRING BREAK
		2-Mar	SPRING BREAK
9	14	7-Mar	Constrained Optimization (Ch. 5): GRG
	15	9-Mar	Active set strategies (Ch. 6)
10	16	14-Mar	Penalty methods; Augmented Lagrangian (Ch. 6)
	17	16-Mar	Quasi-Newton methods; inexact line search (Ch. 6)
11	18	21-Mar	SQP (Ch. 6)
	19	23-Mar	SQP (Ch. 6)
12	20	28-Mar	Systems Design (Ch. 8)
	21	30-Mar	Systems Design (Ch. 8)
13	22	4-Apr	Review Ch. 5, 7
		6-Apr	Mid-term exam 2
14	23	11-Apr	Invited talk
	24	13-Apr	Project presentations
15	25	18-Apr	Project presentations