

ME 517
Optimization in Design
Winter 2008

Instructor: Professor Ping (Christine) Ge
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Office Hours: MW 2:30 – 4pm

Class Hours

Lecture: MWF 11 - 11:50 am

Course Learning Outcomes

By the completion of this course, students must demonstrate the capability to:

1. Construct optimization design models for engineering problems in terms of design variables, feasible region, objective function, equality/inequality constraints, and degree of freedom (DoF);
2. Use monotonicity analysis, graphical representation, and elimination techniques jointly to examine the adequacy and find the analytical solutions of the optimization design models;
3. Apply optimality conditions (necessary and sufficient) to analytically solve unconstrained/ constrained optimization problems with multiple variants and single objective function;
4. Apply *Gradient* and *Newton* -based iterative methods to numerically solve unconstrained/constrained optimization problems with multiple variants and single objective function;
5. Examine the robustness of the optimization solutions using sensitivity analysis
6. Develop a technical report on an optimization design project based on a real world engineering problem

Text

Principles of Optimal Design: Modeling and Computation (Second Edition), 2000, Papalambros, P. Y. , and Wilde, D. J., Cambridge University Press

Grading

Homework	25%
Term Project	50%
+ Final Exam	25%
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Total	100%

Deadlines: Homework will be due at the beginning of the class on the Mondays immediately following the week in which the assignment is given (see the Class Schedule).

Policy: Unannounced late homework and project proposal/reports will not be accepted. Five days notice will be required to negotiate any late homework and project proposal/reports.

Requirements for the Term Project

A project on a mechanical design optimization problem is required. The project results are presented in two documents, and they are:

- 1) project proposal;
- 2) final project report.

The two documents are graded separately, and the distribution is:

Project Proposal	20%
+ Final Project Report	30%
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Term Project	50%

In the following, the requirements for each document are described.

1) Project Proposal – Forming the Model

During the first four weeks, a project proposal must be completed (**due on the Friday in the 4th week**).

- 1.1) Required Contents (the following outline is recommended for the report writing organization structure)
 - identify a real world engineering design problem for optimization
 - o the final selection of the problem is subject to the instructor’s approval. It is highly recommended that you start this part as early as possible.
 - explain why an optimization approach is considered to solve this problem
 - o provide well-written motivation, background, and engineering problem description
 - construct the optimization design model, including assumptions, any analysis models, and any derivations
 - o design variables? why?
 - o objective function? why?
 - o constraints? why?
 - o summarize the model in the standard O.D.M form
 - conduct pro-optimization analysis for a well-bounded optimization design problem model
 - o use Monotonicity Analysis to examine the adequacy of the model
 - addition of any new design variables, constraints, and updated objective function? why?
 - deletion of any existing design variables and constraints? why?
 - your judgment and justifications for the adequacy of the constructed model
 - o apply optimality conditions and graphical representations to verify (if possible) the above conclusions

1.2) Grading

The proposal must be prepared in MS word processor and with professional manner. It should not be more than 12 pages for the above required contents (11 point, Times New Roman, single-spaced). The grading criteria are:

- completeness of the required work described above (15/20)
- clarity in writing, graphs, tables, and illustration (5/20)

2) Final Project Report – Solving the Model

At the end of the term, a final project report is required (**due on the Friday in the 10th week**).

2.1) Required Contents (the following outline is recommended for the report writing organization structure)

- Introduction
 - ◆ Project objective
 - ◆ motivation and background for using the optimization design approach
 - ◆ engineering design problem description
 - ◆ initial optimization design problem model (based on engineering common sense, understanding the problem, and intuition)
- Pro-optimization analysis for a well-bounded optimization design problem model
 - ◆ describing the process to combine monotonicity analysis with various assumptions and elimination techniques to sort out well-boundedness of the initial model
 - ◆ use Monotonicity Analysis to examine the adequacy of the model
 - addition of any new design variables, constraints, and updated objective function? why?
 - deletion of any existing design variables and constraints? why?
 - summarize your justifications for the adequacy of the selected model
 - ◆ apply optimality conditions and graphical representations to verify (if possible) the above conclusions
- Optimization Implementation Process
 - ◆ examination and conclusion on if an analytical solutions exists by directly applying optimality conditions (KKT)
 - ◆ examination of possible iterative optimization algorithms and justification for your selection; describe 4 possible iterative optimization methods for your model and discuss the effectiveness of each to find the minimum using your model
 - ◆ describing the execution process and summary of the execution results, including starting points (base cases), optimal points, stopping criteria, execution time (estimation in magnitude), and other execution process control parameters used.
- Post-optimization analysis
 - ◆ sensitivity analysis at each of the above optimal points: give $\pm 5\%$ to the design variable values at the optimal point(s); use a “ 6σ ” quality metric to derive the standard variance of the objective function at the optimal point(s);
 - ◆ discuss the robustness of your optimal results and potential ways to enhance the robustness if necessary (be specific to your design problem).
- Discussion of the results
 - from an engineering designer’s perspective
 - from an engineering manager’s perspective
 - from an imaginary (but make sense) customer group’s perspective
- Conclusions and recommendations for the future improvements of the current optimization process

2.2) Grading

The report must be prepared in MS word processor and with professional manner. Each of them should not be more than 20 pages for the above required contents (11 point, Times New Roman, single-spaced). The grading criteria are:

- completeness of the required work described above (20/30)
- clarity in writing, graphs, tables, and illustration (10/30)

2.3) Deadline

The final project report (both electronic and hardcopy) is due at christine.ping-ge@orst.edu and ROG416, by 5:00 PM, Friday in the dead week (Week 10).

Class Schedule

Week	Lecture Content	Text Reading	Homework/ Project
Week 1	<u>Introduction</u> Course objectives, grading; Design and optimization processes; Selecting a design problem for the term project.	Syllabus Chapters 1, 2 & 8	/starting the project proposal/
Week 2	<u>General Concepts of Optimization Theory</u> Optimization model, objective functions, maxima and minima, optimality conditions	Chapters 1, 2 & 8	Problems 1.4, 1.8, 2.4 a & b
Week 3	<u>Pre-optimization</u> Constrained optimization and constraint activity; Monotonicity analysis, Parametric optimization design	Chapter 3, 6	Problems 3.4, 3.5, 3.10
Week 4	<u>Pre-optimization</u> (cont'd) Monotonicity analysis applications in mechanical design problems	Chapter 3, 6	Problem 6.9, 6.11 <u>Project proposal due</u>
Week 5	<u>Unconstrained Optimization</u> First order necessary and second order sufficient optimality conditions, Zero, First Order Methods Second Order Methods (SUMT)	Chapter 4	Problems 4.7, 4.16, 4.20
Week 6	<u>Constrained Optimization with Equality Constraints</u> Relevant linear algebra concepts, Lagrange multipliers, generalized reduced gradient method	Chapter 5	/prepare final project report/
Week 7	<u>Constrained Optimization with Inequality and Equality Constraints</u> KKT conditions and use, Optimization solvers in Excel	Chapter 5	Problems 5.2, 5.7, 5.12, 5.14
Week 8	<u>Iterative Numerical Methods</u> (cont'd) Feasible directions, interior and exterior penalty functions, Augmented Lagrange multiplier method	Chapter 7	/prepare final project report/
Week 9	<u>Iterative Numerical Methods</u> Linear Programming and Non-linear Programming	Chapter 7	/prepare final project report/
Week 10	<u>Post-optimization</u> Sensitivity Analysis (SA), Taguchi's method and Quality engineering	Hand out	<u>Final project report due</u>
Final Week	Final Exam: TBD		