Syllabus for CE 380 – Modern Heuristics in Engineering Design

This course discusses traditional and heuristic optimization methods, the programs used to implement them, and their application in solving engineering design problems. Students will be introduced to a variety of methods, including "traditional" search and optimization methods, simulated annealing, tabu search, genetic algorithms, and ant colony optimization. Applications that are common to many engineering specialties (e.g. conceptual design, vehicle routing, scheduling, networking) will be discussed. You will learn how to view problems from an optimization perspective by thinking about variables, constraints & objectives, select appropriate models to represent problems, and apply strategies for solving different types of problems. You will learn how these methods work, understand the benefits and disadvantages of each method, understand how to evaluate the performance of these methods on a variety of problems, and investigate current applications of these methods on difficult problems. Students will also research the application of one or more of the methods covered in class to a design problem(s) of the student's choice in the final class project.

Prerequisite: Math 263; Basic computer experience (enough to run/edit the programs provided in class)

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Lecture: TR 9:30 am – 10:45 pm, AEC 327

Office Hours: MW 3:00 pm – 4:30 pm ; T 3:00 pm – 4:00 pm
Other times, if the door to my office is open, feel free to stop by and ask questions

References: Reading assignments, papers, and additional notes will be handed out in-class and assigned for reading, including selected sections from the Belegundu & Chandrupatla textbook *Optimization Concepts and Applications in Engineering*, Prentice Hall

Course Work: There is homework, a mid-term exam, and a final project. The engineering applications discussed in-class cover Conceptual design, Vehicle routing, Resource allocation, Planning, Scheduling, Control, and Classification. The final project involves researching the application of one or more of the methods covered to a problem(s) of your choice.

Mid-Term Exam: Evening Exam Wednesday, Oct. 17th 7 – 9 PM for classroom problems
Exam will involve both classroom and take-home problems. For the exam you can bring one sheet of paper containing original notes.

Grade Distribution:

Homework Assignments (≈ 7)	40%	Mid-Term Exam	30%
Project Proposal	5%	Project Report	20%
Project Presentation	5%		

Final Grading Scale: A ≥ 90; 90 > B ≥ 80; 80 > C ≥ 70; 70 > D ≥ 60; 60 > F

Learning Outcomes:

Students who complete this course will be able to:

- Explain the basic characteristics of engineering design optimization models, including the definition of design variables, objectives, and constraints.
- Explain how mathematical optimization methods for linear and nonlinear functions of several variables with or without constraints determine solutions and whether the global optimum is guaranteed.
- Explain the differences between different types of mathematical programming methods and heuristic methods for solving linear, integer, and nonlinear problems.
- Design mathematical optimization models (LP, IP, NLP, MILP, and MINLP) for a variety of engineering design problems using the AMPL modeling language.
- Design heuristic-based optimization models (genetic algorithms, simulated annealing, tabu search, and ant colony optimization) for a variety of engineering design problems.
- Solve problem models using existing software programs and critique the near-optimal or optimal solution obtained.
- Compare the performance of different mathematical programming methods and heuristic methods on the same engineering design problem.
- Select an appropriate optimization method for a posed engineering problem by considering the benefits and disadvantages of different methods, computational performance, and solution optimality.

A heuristic is anything that provides a plausible aid or direction in the solution of a problem but is in the final analysis unjustified, incapable of justification, and potentially fallible.

Attendance and Participation:

Regular and on-time class attendance *is required,* although no grade is assigned for attendance**.** Class participation is expected and provides an opportunity to ask *your* questions, which serve the class at large in learning the course material more thoroughly. You are responsible for material covered in class, even if absent for authorized activities.

Homework Policy:

- Homework is generally assigned once a week and collected at the beginning of class on the due date, unless otherwise specified. Late homework will be accepted only by making a prior arrangement with the instructor either during office hours or by email, subject to Lafayette College Dean's Excuse Policy outlined in section 7.3.2 of the Faculty Handbook under the heading Class Attendance.
- This class emphasizes developing professional analysis and modeling skills. All homework should be submitted on engineering paper in a professional manner, which includes neat handwriting and organization. The detail of work you provide should allow other engineers to review your work without having to ask any questions.
- Unless otherwise stated, all homework in this class is expected to be individual work. Copying the work of others, including homework, is in violation of the College's Principles of Intellectual Honesty, which can be accessed at http://www.lafayette.edu/academics/honesty.pdf. You may discuss the homework assignments with other students. All work submitted, however, must be your own and it is your responsibility to properly acknowledge the source of ideas and facts received from others, including other students. A student who commits academic dishonesty is subject to a range of penalties, including suspension or expulsion.
- If you would like to request re-grading, attach a signed statement to your work that details where you feel you lost points and submit it to me within one week after the homework or exam has been returned.

Project Information:

- The project involves researching the application of one or more of the methods covered in class to a design problem(s) of your choice. The focus of the project should be tailored to the student's area of study or interest. To provide some broad examples, the final project could compare the performance obtained by several methods on a specific design problem, compare the performance obtained by a single method on several different design problems, investigate the performance obtained using adaptive or hybrid methods, or investigate the application of multi-objective genetic algorithms to specific design problems.
- The project is expected to involve reviewing the current literature, critiquing methods and results, and summarizing important findings. Projects are not expected to include a student programming component, but students can investigate their own application of methods on a selected problem if desired.
- Each student will submit a project proposal stating the objectives and scope of their project, describing methods to be investigated, problems to be examined, and possible references. The final project report is due on the last day of class. Each student will give a presentation highlighting their results to the class during the last week of the course either in-class or at a TBD time and place.
- More information concerning project requirements, including a list of possible topics, will be provided in-class. This information will be available on the course web page after that time.

Federal Credit Hour Policy: The student work in this course is in full compliance with the federal definition of a four credit hour course. Please see the Lafayette College Compliance webpage http://registrar.lafayette.edu/additional-resources/cep-course-proposal/) for the full policy and practice statement.

Academic Integrity Statement: "Students are expected to be honorable, ethical, and mature in every regard"
No form of scholastic misconduct will be tolerated. Academic dishonesty includes cheating, fabrication, falsification, plagiarism, copying homework from other students or from solutions, etc. It is the student's responsibility to comply with *Lafayette's Student Handbook* (http://studentlife.lafayette.edu/files/2011/08/studenthandbook_1112.pdf*)* and to be familiar with the *Principles of Intellectual Honesty* (http://www.lafayette.edu/academics/honesty.pdf). Violations will be handled in accordance with the Procedural Standards in Disciplinary Proceedings outlined in the *Student Handbook.*

Students with Disabilities: The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you believe you have a disability requiring an accommodation or require assistance with academic concerns/accommodations, please contact the Office of the Dean of Studies (610-330-5080).

Although heuristics do not guarantee optimal solutions, they can be extremely valuable to problem-solving processes and good heuristics can dramatically reduce the time required to solve a problem.

Class		Date	Tentative Topic (Subject to Change)
1	T	8/28	Introduction to Search and Optimization
2	R	8/30	Why Are Problems Difficult to Solve? Discussion of Modeling
3	T	9/4	Ain't No Mountain High Enough –Search Spaces & Optimization
4	R	9/6	Got Derivatives? - Non-linear Methods
5	T	9/11	Adding Constraints to the Mix - Non-linear Problems
6	R	9/13	Adding More Constraints to the Mix - Non-linear Problems
7	T	9/18	Applications/Modeling – Optimization Models & AMPL/NEOS Too
8	R	9/20	Applications/Modeling – Solar Collector Field Layout
9	T	9/25	Got a Thousand Years or More? - Combinatorial Problems
10	R	9/27	Trees, Branches, and Pruning - Combinatorial Problems
11	T	10/2	Applications/Modeling – Reservoir Water Release/Levels
12	R	10/4	The Limits of Traditional Methods – MINLP Problems
	T	10/9	*Fall Break – No Class*
13	R	10/11	When It Pays to be Greedy - Greedy Heuristics
14	T	10/16	Global Cooling at Work – Simulated Annealing (*SA*)
	W	10/17	**MID- TERM EXAM** Evening Exam 7 – 9 pm (Class Portion)
15	R	10/18	Simulated Annealing (*SA*)
16	T	10/23	When It's Better Not to Forget – Tabu Search (TS)
17	R	10/25	It's a Jungle Out There – Genetic Algorithms (GA)
18	T	10/30	Representations, Selection, Crossover & Mutation
19	R	11/1	Handling Constraints in Heuristic Methods
20	T	11/6	Applications/Modeling – Bridge Truss Design
21	R	11/8	Considering Tradeoffs - Multi-Objective GAs *(MOGA)*
22	T	11/13	Are Ants Ever a Good Thing – Ant Colony Optimization
23	R	11/15	Ant Colony Optimization *(ACO)*
24	T	11/20	Ant Colony Optimization *(ACO)/*Swarm Optimization
	R	11/22	*Holiday Break – No Class*
25	T	11/27	Neural Networks – Self-Organizing Maps
26	R	11/29	Neural Networks - Traveling Salesman Problem
27	T	12/4	Student Presentations
28	R	12/6	Student Presentations

Software for LP, NLP, IP, MILP, and MINLP Problems:
This class will be using the free solvers available on the NEOS server (http://www.neos-server.org/neos/ for the types of solvers available). The models submitted to the NEOS server will be modeled in the AMPL Modeling Language and the AMPL environment student edition can be downloaded at http://www.ampl.com/DOWNLOADS/index.html. Jobs can be submitted to any of the NEOS solvers from any computer by downloading and using the Kestrel interface (http://www.neos-server.org/neos/kestrel.html). Additional information on how to use AMPL and NEOS will be provided in-class through handouts, in-class computer instruction, and application modeling examples.

Software for Heuristic Methods:
The basic computer programs required to solve homework problems using *simulated annealing, tabu search, genetic algorithms and ant colony optimization* will be provided in-class and discussed in detail. To complete the homework, students will modify the programs to add the objective functions and constraints of the problem being solved.

ABET Outcomes: This course focuses on ABET program outcome (a.), which involves applying math and science principles to perform engineering design search and optimization, and (c.), which involves the ability to design a system, component, or process to meet desired needs. Through optimization problem modeling and evaluating the results of stochastic methods, the course also involves ABET program outcomes(b.), which involves the ability to design and conduct experiments, analyze and interpret data and (d.), which involves identifying, formulating and solving engineering problems. Other outcomes addressed are (k.) and (j.), which involve discussing issues related to designing systems constrained by limited resources and providing opportunities to use engineering tools and programs to solve computational problems.

Hybrid methods often provide high-performing search and optimization techniques, however, developing a "self-adaptive greedy neural-fuzzy-evolutionary-annealing-approach for improved tabu search to generate expert systems for data mining" hybrid method may be a little on the extreme side!