Course EE 380N **Optimization of Engineering Systems** **Spring 2018** **Unique Number 16019** Meeting time: Tuesdays and Thursdays, 2:00pm to 3:15pm, ECJ 1.214	**Ross Baldick** **Professor** **Department of Electrical and Computer Engineering** **UT Administration Building EERC 7.872** **The University of Texas at Austin** Tel: (512) 471-5879 Email: baldick@ece.utexas.edu WWW: www.ece.utexas.edu/~baldick **Office hours: Tuesdays and Thursdays, 3:30pm to 4:45pm, EERC 7.872.** **Please email me if you want to see me outside of these office hours.**

Course description:

Formulation and solution of continuous optimization problems in engineering design. This course will cover optimization of engineering systems, emphasizing how to formulate problems so that you can apply off-the-shelf software to solve them. We will use MATLAB in the course, motivating the analysis and algorithms with a number of case studies. The main areas of study will be: solution of simultaneous equations and non-linear optimization problems.

The course illustrates how to think about and describe problems to make them amenable to solution by optimization software. In brief: formulation of problems to facilitate their solution. Five general problem classes are considered:

- linear systems of equations,
- non-linear systems of equations,
- unconstrained optimization,
- equality-constrained optimization, and
- inequality-constrained optimization.

Topics to be covered in the class will include: characteristics of problems and their solutions, transformation of problems, formulation of linear simultaneous equations problems, solution of linear simultaneous equations, sparsity of linear equations and sparsity techniques, sensitivity analysis for linear equations, formulation of non-linear simultaneous equations problems, solution of simultaneous equations by Newton's method, sensitivity analysis for non-linear equations, formulation of non-linear optimization problems, optimality conditions for convex non-linear programs, review of "classical" optimization techniques, interior point techniques applied to convex non-linear problems, sensitivity analysis for optimization problems. If time permits, there will be an introduction to semi-definite optimization.

Expectations

I expect that you will spend seven to ten hours per week *outside* of class on this course to read the lecture notes, review the class material, and work on homeworks. I assume that you have a strong mathematical background and, moreover, there is a heavy homework burden in this class and a class project. If you do not have the mathematical background for the class or you are not prepared to work diligently on long and hard homeworks and on the project, please do not sign up for this class!

I expect you to have read over lecture notes *ahead* of class so that class time is used efficiently to explain concepts. Lecture notes are posted at the instructor home page www.ece.utexas.edu/~baldick. Look under "Teaching Plans and Course Web pages" for "Optimization of Engineering Systems." There is also a downloadable file of Appendices that includes pre-requisite material together with an Errata to the textbook and to the homework exercises.

Please come to office hours with prepared questions.

I may have to cancel one or two classes during the semester in order to attend conferences. We will schedule make-up classes for these cancelled classes since the semester will be extremely full of material to cover.

I do not take attendance and you are free to attend or not attend class as you choose. However, if you come to class, please be prompt. Please be seated in class by the time the start-of-class bell rings. If a homework is due, please put it on the desk in the classroom prior to the star-of-class bell.

Textbook

- Ross Baldick, *Applied Optimization: Formulation and Algorithms for Engineering Systems,* Cambridge University Press 2006.
- There is also a downloadable file of Appendices that includes pre-requisite material together with an Errata to the textbook and to the homework exercises. (See Homework 0 for detailed instructions.)

Pre-requisites:

The class will assume some familiarity with concepts from real analysis such as sequences and limits, calculus, proofs, and will also assume familiarity with MATLAB. The mathematical pre-requisites for the class are contained in Appendix A of the course notes, which can be found at Appendices. We will use the MATLAB Optiimization Toolbox extensively and you will need to have access to it, either on your own computer or through ECE resources.

Homework and project policy:

Homeworks will include problems from the textbook and will be assigned approximately once per week, except during the weeks of the mid-terms. The homework exercises include a mixture of theoretical work and the solution of problems, using graphical, analytical, and software techniques. All homeworks must be done individually. Each student must turn in an honest individual attempt.

This course has a heavy homework load, with some very difficult problems, and I encourage you to discuss difficult homework problems both with classmates and with me in office hours. However, copying of homeworks will not be tolerated. If you are not prepared for a heavy homework load then this course is not for you!

There will also be a class project that will involve three parts.

All homeworks and the project must be turned in to pass the course, but late homeworks will be awarded a grade of zero unless permission for late submission is sought and given in advance of the due date.

Quiz and exam policy:

There will be two mid-term exams and no final. No make-up exams will be given. Excused absence from a mid-term exam must be obtained in advance. In this case, the student's other mid-term exam grade will be substituted for the missed exam. Unexcused absences from a mid-term will result in a grade of zero for that exam. Excused absences from exams will be made only in extreme circumstance (serious illness, death in the immediate family, etc). Requests for excused absences should be made in advance in writing and must be supported by appropriate documentation.

Exam dates:

- Mid-term I: Thursday, March 29; 2:00 to 3:15pm in class,
- Mid-term II: Thursday, May 3; 2:00pm to 3:15pm in class.

Grading policy:

A final score will be calculated based on:

- Homeworks 30%

- Project 20%
- Mid-term I 25%
- Mid-term II 25%

Homework 0:

Complete by the beginning of class on Tuesday, January 23.

1. Go to the instructor home page www.ece.utexas.edu/~baldick and look under "Teaching Plans and Course Web pages" for "Optimization of Engineering Systems." Download and print Appendices.
2. Read Appendix A. Confirm that you are familiar with at least 80% of the material in Appendix A. If you are not familiar with this material then you *do not* have the pre-requisites to take this course. I advise dropping the course if you are not familiar with at least 80% of the material in Appendix A.
3. Purchase the textbook; print out the Errata to the textbook; and read chapters 1, 2, and 3. We will only be covering these chapters briefly in class; however, there will be homework assigned from these chapters and you will be responsible for understanding the material in these chapters.

Homework 1:

Due Thursday, January 25, on the desk in the classroom by the time the start-of-class bell rings. Turn in solutions to exercises 2.1 through 2.10 from the textbook.

Project:

You will describe, formulate, and solve a system of equations problem or an optimization problem. Ideally, the problem should be drawn from your research; however, if you do not have a suitable problem, I will ask you to either develop a problem from the homework exercises or solve a case study that is specified in the book but that we will not otherwise cover in lectures. The project will be due in three parts, involving the description, formulation, and solution, respectively. Although the course is focused on continuous and convex optimization problems, you can choose a different type of problem if it is drawn from your own research, since the emphasis in the project is on *formulation* of problems. I strongly encourage you to come to office hours to discuss your problem in advance of February 22 in order to make sure that it is suitable for the project.

Part 1: Due Thursday, February 22, on the desk in the classroom by the time the start-of-class bell rings. Describe in words the problem that you are going to formulate and solve. The problem should be drawn from your research; however, if you do not have a suitable problem then please talk to me about the project during office hours well prior to February 22 and I will suggest a problem for you to consider. The description in words does not have to be extremely detailed, but should indicate the background, the issues, and the goal of applying optimization to the problem. As an example of the level of detail expected, look at the description of the problem in homework exercise 2.8. Four or five paragraphs is sufficient. The point of this Part is to describe the problem in *words*, so minimize the use of equations in the description.

Part 2: Due Thursday, March 22. Formulate the problem that you are going to solve. Each aspect of the description of the problem that you turned in for Part 1 should be represented in the formulation. The solution to homework exercise 2.8 shows an example of a formulation, as do the various case studies we are studying. You should add to the material turned in for Part 1 so that the description and detailed formulation are all in one document. This part should include detailed formulation using equations to precisely, mathematically describe the problem. Make sure to be explicit about the decision variables and the equations describing the simultaneous equations or the optimization formulation, including objective and constraints.

Part 3: Due Thursday, April 19 (third-last week of classes): Solve a small instance of the problem using MATLAB or using an optimization tool of your choice. You should turn in a document that includes the material from Parts 1 and 2, together with the discussion of solving the problem instance.

Other information:

Allegations of Scholastic Dishonesty will be dealt with according to the procedures outlined in Appendix C, Chapter 11, of the General Information Bulletin, http://www.utexas.edu/student/registrar/catalogs/.

The University of Texas at Austin provides, upon request, appropriate academic adjustments for qualified students with disabilities. For more information, contact the Office of the Dean of Students at 471-6259, 471-4241 TDD, or the College of Engineering Director of Students with Disabilities, 471-4321.

Classroom evacuation for students:

All occupants of university buildings are required to evacuate a building when a fire alarm and/or an official announcement is made indicating a potentially dangerous situation within the building. Familiarize yourself with all exit doors of each classroom and building you may occupy. Remember that the nearest exit door may not be the one you used when entering the building. If you require assistance in evacuation, inform your instructor in writing during the first week of class. For evacuation in your classroom or building:

1. Follow the instructions of faculty and teaching staff.

2. Exit in an orderly fashion and assemble outside.

3. Do not re-enter a building unless given instructions by emergency personnel.