CHAPTER

1

Introduction

This manual contains solutions for most of the exercises in the textbook, *Introduction to Optimum Design*, Fourth Edition. It also contains suggestions for organization of undergraduate and graduate level courses on the subject of optimization. A few copies of exams and projects for an undergraduate course that can be common to most branches of engineering are also included.

The philosophy of the fourth edition of the book is to *explain an organized approach to engineering design optimization in a rigorous and yet simplified manner, illustrate basic concepts and procedures with simple examples, and demonstrate their applicability to engineering design problems*. The key step in the optimum design process is formulation of a design problem as an optimization problem. This is emphasized and illustrated with examples. In addition, insights and interpretations of optimality conditions are discussed and illustrated.

Three main objectives were set for the fourth edition: (1) to enhance presentation of the basic material, (2) to illustrate the numerical process of refinement of an initial formulation of a design optimization problem, and (3) to reorganize the advanced material.

The first objective is achieved by making the material more concise, organizing the material with more second, third and fourth level headings, and illustrating the example problems with more details.

The second objective is achieved by describing and illustrating the numerical process for refinement of the initial problem formulation in Chapter 6: Optimum Design: Numerical Solution Process and Excel Solver. Generally, an initial formulation of a design problem is inadequate in producing an acceptable optimum solution for the problem. It may even be infeasible. Therefore it is critically important to reexamine the formulation and adjust the constraint limits and other parameters to obtain an acceptable solution. Thus several iterations may be necessary in order to

obtain the final formulation for a design optimization problem. Other aspects of the numerical solution process are also discussed in this chapter.

The third objective is achieved by consolidating all the nature-inspired methods in Chapter 17: Nature-inspired Search Methods. Also all the direct search methods are now consolidated in Chapter 11: More on Numerical Methods for Unconstrained Optimum Design. In addition most of the practical design optimizations are now presented in Chapter 14: Practical Applications of Optimization.

The material of the book can be broadly divided into three parts. Part I, Chapters 1 to 5 contains basic concepts related to optimum design and optimality conditions. Part II, Chapters 6 to 14 contains mostly numerical methods for continuous variable optimization problems and their applications. Part III, Chapters 15 to 19 containing advanced and modern topics on optimum design including methods that do not require derivatives of the functions of the problem.

The material of the Fourth Edition can be used to construct several different types of courses depending on instructor's preference and the learning objectives for the course. Three types of courses are suggested; however, several variations of them are possible:

Undergraduate/First Year Graduate Level Course

- Formulation of optimization problem (Chapters 1 and 2)
- Optimization concepts using the graphical method (Chapter 3)
- Optimality conditions for unconstrained and constrained problems (Chapter 4)
- Use of Excel and MATLAB illustrating optimum design of practical problems (Chapters 6 and 7)
- Linear programming (Chapter 8)
- Numerical methods for unconstrained and constrained problems (Chapters 10 and 12).

Use of Excel and MATLAB is introduced around mid-semester so that students have a chance to formulate and solve more challenging project-type problems by the end of the semester. Note: advanced project type exercises and sections with advanced material are marked with an "*" in the text which may be omitted for this course.

In this course no prior knowledge of design or optimization is assumed. The basic background needed for the course is the vector and matrix algebra and fundamental vector calculus. Some background in engineering analysis is also assumed. Most junior and senior level students will have the background to take this course.

First Graduate Level Course

- Theory and numerical methods for unconstrained optimization (Chapters 1-4, 10, 11)
- Theory and numerical methods for constrained optimization (Chapters 4-7, 12, 13)
- Linear and quadratic programming (Chapters 8, 9).

Pace of material coverage is faster. Compared to the undergraduate course, some advanced topics on optimization, such as rate convergence, inexact line search, quasi-Newton methods and derivation of some of the algorithms, are covered. Students also code some of the algorithms into computer programs and solve practical problems.

Second Graduate Level Course

- Advanced topics on optimum design: duality theory in nonlinear programming, rate of convergence of iterative algorithms, derivation of numerical methods, direct search methods (Chapters 1 to 14)
- Methods for discrete variable problems (Chapter 15)
- Nature-inspired search methods (Chapter 17)
- Multi-objective optimization (Chapter 18)
- Global optimization (Chapter 16)
- Response surface methods, robust design, and reliability-based design optimization (Chapter 19)

Students write computer programs to implement some of the numerical method and solve practical problems.