Preface

Contemporary structural optimization has it roots in the 1960s with Lucien Schmidt's seminal paper.[1] Prior to that time there were no texts on nonlinear programming and if you wanted to do optimization you were relegated to using linear programming. Once mathematical programming was discovered by designers it was thought that engineering design, as an area of study, was over since all you had to do was formulate your design as a nonlinear programming problem and invoke some canned solver. That turned out not to be the case.

While the 1960s and 1970s were characterized by difficulties in solving even small optimization problems (forgetting for the moment optimality criteria methods), the 1990s were characterized by discussions of mathematical programming methods for solving large systems. The flavor of these discussions can be found in the fact that workers in linear programming were then solving *large* systems (Bixby et al., 1991) with, for example, 12 million variables. In fact, today (2007) the web site of Jacek Gondzio describes solving a nonlinear programming problem with 353 million rows and 1010 million columns.

These capabilities of mathematical programming solvers are part of the driving force behind this text: Surely this technology should offer hope to the structural engineer who must commonly deal with large systems. The other factor driving this work is context: We believe that the use of sequential linear programming together with the use of the incremental equations of structures can serve as a focal point about which a quite general structural optimization solver can be developed.

Then there is the question of the availability of software today. In view of the Solver package included in Microsoft EXCEL, an argument can be made that optimization software is now available to everyone. That package is used in this text along with the IMSL routines available with Digital FORTRAN (now sold as Intel FORTRAN). And clearly, all the work described in this text could have as well been done using Matlab. The reader will find a mix of this software used here. The point is that tools are now available for the solution of optimization problems. This includes some freeware available on the Internet that will be discussed later.

With regard to content, this book includes many computer programs most of which are written in FORTRAN. The excuse for focusing so heavily on computing is that contemporary structural optimization is about computing. Parenthetically, we try in this book to do justice to the history of structural optimization but surely have left things out and apologize to those authors whose work has not been properly referenced here.

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[1] The history of structural optimization has been developed carefully by Wasiutynski and Brandt (1963).

The attempt in writing this book is to help bring the methods of structural optimization into common usage like those of the finite element method. That is, when the structural engineer sits down to design something, he/she should not only have analysis tools available but should also have optimization tools available. In fact, a good case can be made for including these tools in one package since analysis can always be performed as an optimization problem. The engineer could then, for example, automatically change the structural shape as he/she attempts to satisfy some allowable stress constraints. The analysis/redesign cycle could then simply be replaced by optimization steps.

Historically, there has been a tension between proponents of classical optimization methods who claimed that the users of optimality criteria methods were lacking in theory and the users of heuristic schemes such as optimality criteria methods who at the same time claimed that the classical methods were incapable of solving real (large) structures. In view of the tools now available to the engineer, these arguments can be seen to diminish in importance although the optimality criteria methods still have enormous physical appeal.

We attempt to deal fairly with optimality criteria methods but clearly the focus is on the use of sequential linear programming and the incremental equations of structures that comprise a classical approach. The text begins with an Introduction to simple problems of optimization. Then some available tools are discussed. (This second chapter is more formal than the remainder of the text and the first-time reader might treat it lightly.) Chapter 3 introduces our central topic which is structural optimization approached via the incremental equations of structures and sequential linear programming. Chapter 4 then discusses some problems solved using optimality criteria methods. The remainder of the text offers what we see as an overview of the field of structural optimization. This includes beams and plates, dynamic systems, multicriteria methods, and a brief discussion of some ongoing work. The text closes with an Appendix containing three reprints that are regarded by the authors to be basic to the historical development of structural optimization.

Finally, it has been a pleasure to work Springer Science+Business Media and Steven Elliot our editor. For us, Springer has managed to bring the capabilities and competence of an enormous organization to bear without losing the personal touch of staff contacts. You could not ask for more than that.

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