Book review

Nonlinear Finite Element Techniques Using an Object-Oriented Code by A. Vila, A. Rodriguez-Ferran and A. Huerta, Gran Capitan, 1995, ISBN: 84-87867-64-2.

With the advent of cheap, high speed computer technology, engineers and scientists have pushed the limits of computational analysis. This has brought about many different numerical methods and software codes that implement these numerical methods. One of these numerical methods is the finite element method. This computational method has become a staple in any computational scientist's toolbox. This method has been used for a variety of problems ranging from simple linear analysis to the more complex and computationally challenging nonlinear analysis. One software package that can be used for a nonlinear analysis is called Castem2000. This book describes the use and the implementation of Castem2000 as well as giving some background to the underlying mathematics involved.

The book is in part a textbook, book of pseudocode, and a reference or user's manual for Castem2000. It consists of eight chapters spanning 181 pages, and was published in 1995 by the International Center for Numerical Methods in Engineering. The authors do not explicitly say who the intended audience of the book is, but in this reviewer's opinion, the book can be used by anyone who wishes to implement nonlinear equation solvers, or even a user of Castem2000 or any other nonlinear analysis code. The text gives an excellent theoretical background to different numerical methods of solving nonlinear equations, as well as a balanced approach in promoting the utility of Castem2000.

The authors start with a summary of the entire book. This summary is a swift and excellent way to figure out if this book is intended for a particular reader. The summary gives a brief overview of the various numerical methods discussed, such as full Newton–Raphson methods, modified and quasi-Newton Methods, secant-Newton methods and others, as well as an introduction to Castem2000. Castem2000 employs an object-oriented approach to software design which makes passing data to and from the software easier. Castem2000 is also unique in that it employs a Lagrange multiplier method to solving a set of nonlinear equations.

Chapter 1 is an introduction to nonlinearity, and why nonlinear analysis is apropos in many situations. This is achieved by example. An example of geometric nonlinearity and material property nonlinearity are presented to show typical situations where a linear analysis will give incorrect results. This really forms the motivation behind the implemented software and the book itself. The authors then derive equations for linear and nonlinear cases. Each set of equations can be solved numerically using many of the techniques discussed later in the book.

Chapter 2 is intended to get the reader acquainted with the programming environment (Castem2000). Castem2000 is an object-oriented code that can be executed with the use of sets of instructions. These instructions create, use and destroy various "objects" that pass data to and from the software. These objects include things such as points, meshes, stiffness matrices and stress fields. Typical lines of instruction are given in this chapter as well as sets of instructions that can be used to solve a complex problem.

Chapter 3 through Chapter 8 give an overview (both theoretically and applied) to the various methods that can be used to solve sets of nonlinear equations. These five chapters are arranged typically from the easiest numerical method to the hardest as well as a historical arrangement. The authors present in Chapter 3 the Newton–Raphson method. The chapter begins with the motivation behind an iterative approach to solving a problem through a problem involving material nonlinearity. The nonlinear equations are formulated in such a way that an iterative approach is imperative. The Newton–Raphson iterative technique is then presented both derivationally and algorithmically (this is especially suitable for software designers and implementers). The authors go on to present the role that Castem2000 can play in using the Newton–Raphson method as well as modifications to the Newton–Raphson method. The problem is then formulated in such a way that Lagrange multipliers can be used to solve the problem. The use of Lagrange multipliers is unique to Castem2000.

Chapter 4 presents changes that can be made to the Newton–Raphson method that give a lower computational cost per iteration. These methods, known as the quasi-Newton methods, may require more iterations to converge to a solution, but overall will de-

Shock and Vibration 5 (1998) 209–210
ISSN 1070-9622 / $8.00

crease the amount of time needed to find a solution in many situations. Various quasi-Newton methods are discussed (such as the Broyden method). These methods are discussed through derivation as well as with an algorithm that will appeal to software designers and implementers. The chapter closes with many examples that can be used to compare the various quasi-Newton methods. These examples include a truss problem, a small strain analysis of a perfectly plastic material in the form of a hollow cylinder subject to inner pressure, a thin shell sphere, a material necking problem and a thermal problem. These examples run a wide range and can be used as a reference for deciding which Castem2000 procedures should be used in various situations.

Chapter 5 is an extension of the preceding chapters. The goal of this chapter is to show how quasi-Newton methods can be made faster using acceleration techniques. These acceleration techniques applied to the quasi-Newton methods create a new method called the secant-Newton methods. Once again, the secant-Newton methods are discussed through a derivation. An algorithm for an implementation of the methods is then given. A Lagrange multiplier method of the secant-Newton methods is also given. The use of the Lagrange multipliers is unique to Castem2000 as of the publishing of this text. The same examples presented in Chapter 4 are used to compare the various secant-Newton methods.

The authors bring all of the data presented in the previous chapters together in Chapter 6. This data includes the number of iterations and the time for each iteration. This chapter directly compares all of the methods discussed up to this point. A reader can very easily conclude what method is best for various situations.

Chapters 7 and 8 discuss more techniques that can be used to speed up the Newton iterative techniques discussed in the previous sections of the book. These methods include line searches (in Chapter 7) and arc length methods (in Chapter 8). The authors are very consistent in the way that the subject material is discussed. The techniques are derived and shown in an algorithmic form. Numerical examples are given as well.

The text closes with some concluding results made by the authors. A summary of the subject material is given as well as a brief history of the development of Castem2000 at the Commissariat a l'Energie Atomique in France.

This book is very interesting. The material is presented in a very clear and lucid way. The title of the book can be quite misleading though. For example, finite element methods are not discussed fully as in other texts. Elements, nodes and boundary conditions are really not presented at all. It seems that Castem2000 takes care of these things internally. This is a double edged sword. It makes the life of a computational scientist easier because he or she does not need to think of such things, but whatever is created by Castem2000 must be trusted. Also, even though Castem2000 is an object-oriented code, the authors really don't show why or how it is object-oriented other than the bundling of data members with data methods. Other object-oriented methods (such as inheritance and polymorphism) are not discussed.

Brian C. Mansfield
Milford, OH 45150
USA