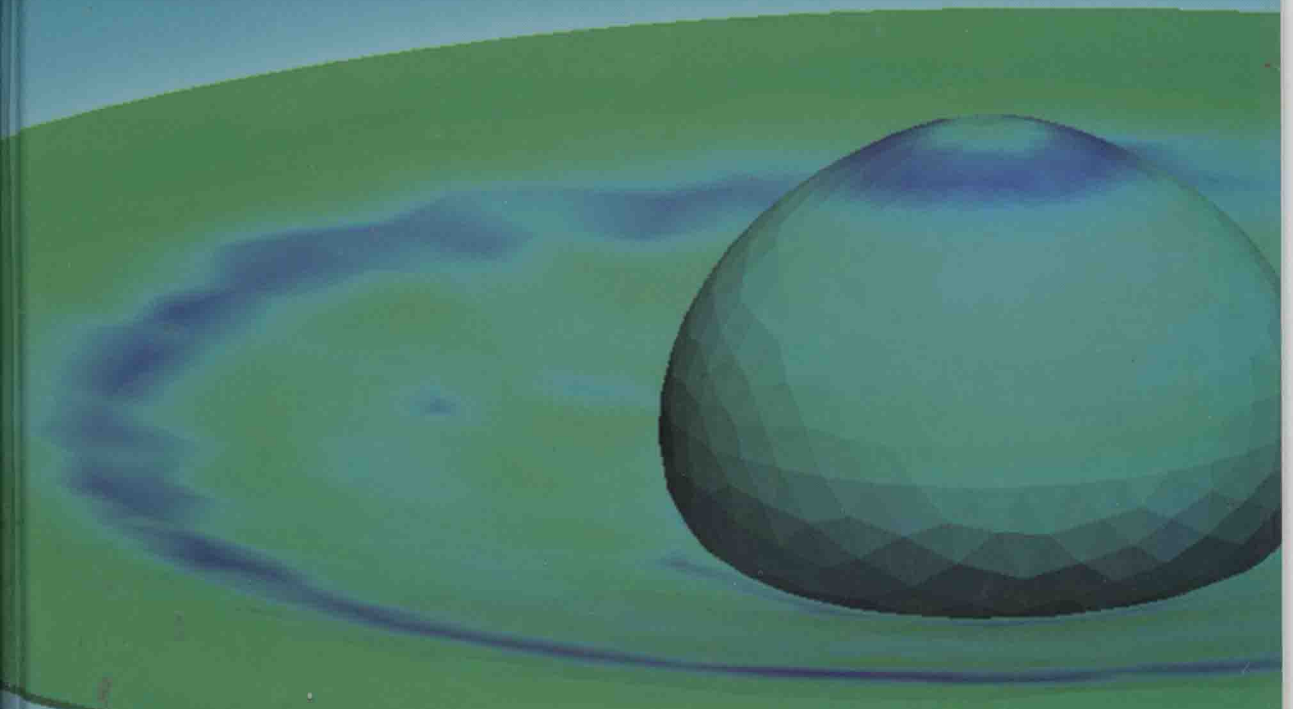
LARGE STRAIN

finite element method

A PRACTICAL COURSE

Antonio Munjiza, Esteban Rougier and Earl E. Knight



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LARGE STRAIN FINITE ELEMENT METHOD

Antonio Munjiza would like to dedicate this book to Jasna and Boney.

Esteban Rougier would like to dedicate this book to his wife Sole and to his sons Ignacio and Matias.

Earl E. Knight would like to dedicate this book to the love of his life, his best friend and confidante, Cheryl Marie.

Preface

The conventional finite element method is based on the assumption that structural system displacements under load are small and that the structural material does not stretch much under that load. Arguably, the small strain, small displacements-based finite element method is not of much use in modern scientific, engineering and technological applications. Even in classic structural engineering applications, the conventional finite element method is hardly applicable. This shift has occurred because design codes and standards have changed in recent years to include the ultimate limit state, i.e., considerations of structural collapse. As a consequence, one now has to consider both large strains (plastic strains) and large displacements. In other state of the art applications of the finite element method, finite element simulations are increasingly becoming an integral part of the so-called virtual experimentation, examples of these are biological, medical science, material science, process engineering, military and many other applications of the finite element method. In these applications the finite element simulation has to reproduce reality (as opposed to approximating reality), together with possible emergent properties such as flow, damage, failure, collapse, yield, etc.

In this context, not even the higher order theories and their finite element realizations are suitable representations of the physical realities involved. The answer is an exact formulation that encompasses an exact representation of large displacements, large strains, and material properties including anisotropy. Such a theory, when implemented in a finite element software package, must cover 2D solids, 3D solids, and 2.5D shell and membrane static and dynamic simulations.

Theoretical aspects of these formulations were resolved in the 1960s and 1970s. The finite element adaptation of these theoretical formulations has mostly taken place during the 1990s and early years of the 21st century. This work has resulted in a large body of scientific papers that have described it as the next generation of finite element packages. Nevertheless, the subject has remained a mystery for undergraduate students, postgraduate students, practicing engineers and scientist and even for users and developers of finite element software.

This book is written with the key objective of "demystifying" the subject, making it easy for students, engineers and software developers to master the minute details of the finite element method that incorporates large strains, large displacements, and material nonlinearity.

The book is written in such a way that it provides a pathway to master all the method's related subjects starting with matrices, systems of equations, scalar and vectors and progressing onto tensors of the first order, and tensors of the second order. With this knowledge base in hand, the book provides an engineering-based approach to deformation kinematics that avoids the often confusing mathematical jargon yet concentrates on the physics and uses mathematics only when necessary. At this stage, the reader is made familiar with a generalized framework for developing large strains based nonlinear material laws. This is done without any reference to the finite element method, having in mind, for example, a material modeler whose job is to solely develop material laws.

Finally, the book presents the large strain large displacement based finite element method including 2D solid, 3D solid, 2.5D membrane, plate and shell problems. These are explained in such detail that they contain all the necessary mathematical equations, algorithms and formulae that can be readily implemented into the finite element method. As such, they should be of great value for developers of finite element packages. They will also provide users of finite element packages with an enhanced understanding of the algorithmic, theoretical and formulation aspects of the finite element software they are using.

The authors hope that the book will ultimately benefit practicing engineers, scientists, undergraduate students, master students and PhD students in diverse fields of related applied subjects.

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Contents