



# **Finite Element Method Simulation of 3D Deformable Solids (Synthesis Lectures on Visual Computing: Computer Graphics, Animation, Computational Photography, and Imaging)**

*Eftychios Sifakis, Jernej Barbic*

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This book serves as a practical guide to simulation of 3D deformable solids using the Finite Element Method (FEM). It reviews a number of topics related to the theory and implementation of FEM approaches: measures of deformation, constitutive laws of nonlinear materials, tetrahedral discretizations, and model reduction techniques for real-time simulation. Simulations of deformable solids are important in many applications in computer graphics, including film special effects, computer games, and virtual surgery. The Finite Element Method has become a popular tool in many such applications. Variants of FEM catering to both offline and real-time simulation have had a mature presence in computer graphics literature. This book is designed for readers familiar with numerical simulation in computer graphics, who would like to obtain a cohesive picture of the various FEM simulation methods available, their strengths and weaknesses, and their applicability in various simulation scenarios. The book is also a practical implementation guide for the visual effects developer, offering a lean yet adequate synopsis of the underlying mathematical theory. Chapter 1 introduces the quantitative descriptions used to capture the deformation of elastic solids, the concept of strain energy, and discusses how force and stress result as a response to deformation. Chapter 2 reviews a number of constitutive models, i.e., analytical laws linking deformation to the resulting force that has successfully been used in various graphics-oriented simulation tasks. Chapter 3 summarizes how deformation and force can be computed discretely on a tetrahedral mesh, and how an implicit integrator can be structured around this discretization. Finally, chapter 4 presents the state of the art in model reduction techniques for real-time FEM solid simulation and discusses which techniques are suitable for which applications. Topics discussed in this chapter include linear modal analysis, modal warping, subspace simulation, and domain decomposition.

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