INNOVATIVE

COMPUTATIONAL

METHODS

FOR

STRUCTURAL MECHANICS

INNOVATIVE COMPUTATIONAL METHODS FOR STRUCTURAL MECHANICS

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Preface

Following the first workshop which was held in Barcelona, Spain in 1995, a second workshop was held on the island of Santorini, Greece, June 13-15, 1997, in the framework of the Human Capital and Mobility Network "Advanced Finite Element Solution Procedures on Innovative Computer Architectures". This network and the workshops were supported by the European Union. The aim of the second workshop was to present the results of the research work carried out within the three and a half years duration of the project. The focus of activities was the development of efficient computational methodologies, using innovative computer architectures, for solving computationally demanding problems in structural mechanics.

The first four chapters are concerned with parallel solution techniques for solving linear finite element problems. Chapter 1 presents a frontal code for the solution of large sparse symmetric systems. The performance of the code is compared in a number of real engineering and industrial applications with previously published codes taken from the Harwell Subroutine Library. Chapter 2 presents dual domain decomposition techniques for the solution of large-scale linear structural analysis problems on workstation clusters. The techniques presented are based on the dual domain decomposition implementation on the interface in which the domain is partitioned into a set of totally disconnected subdomains and the subdomain equilibrium equations are established using Lagrange multipliers. The algorithms are applied according to the master-slave model for distributed computing and numerical tests are performed on ethernet-networked workstations running the message passing software PVM. Chapter 3 discusses a non overlapping domain decomposition method for solving two-dimensional elliptic problems having high variations in the matrix coefficients and high anisotropy. A new local preconditioner is described for the Schur complement that exhibits better numerical behaviour than the block Jacobi preconditioner with almost the same computational complexity. Chapter 4 deals with the parallel implementation of two domain decomposition methods, namely the Dirichlet-Neumann algorithm and the Three-Fields algorithm for elliptic boundary value problems. The algorithms are implemented on a HP-Convex Exemplar SPP 2000 S-class system following the explicit message passing style and PVM to perform interprocessor communication. An investigation is performed on communication and computation costs as well as on architectural features such as interconnected networks and cache memories.

Chapter 5 is concerned with non-conventional finite element formulations and in particular with hybrid mixed finite elements where the approximations are based on Legendre polynomials. A study is performed on "thin" bending plates where high stress gradients occur near the edges and for which the Reissner-Mindlin behaviour is assumed. Chapter 6 presents a parallel solution of large non-conventional finite element systems. The finite element model used is the implementation of the stress Hybrid

Mixed formulation for digital Walsh approximation functions. This formulation leads to systems of equations characterized by a sparse and non-overlapping block structure which makes them amenable to a natural parallelization.

Chapter 7 is concerned with parallel dynamic relaxation schemes for formfinding of tension structures. A number of interprocessor communication schemes are developed and assessed. In Chapter 8 two h-adaptive strategies for singular problems are proposed, one based upon the equidistribution of the error and the other based upon a non-uniform distribution of the error. The behaviour of the proposed strategies is studied for singular problems in plane elasticity and is compared with the standard Zienkiewicz-Zhu procedure. Chapter 9 discusses the use of NURBS in parallel and distributed mesh generation.

Chapter 10 investigates the efficiency of combinatorial optimization methods and in particular algorithms based on Evolution Strategies when incorporated into structural optimization problems. Evolution Strategies are used either on a stand-alone basis, or combined with a conventional mathematical programming technique. Furthermore, the structural analysis phase is replaced by a neural network prediction, while advanced domain decomposition techniques are incorporated for the solution of the sensitivity analysis problem. Chapter 11 describes a fully integrated design optimization approach including topology optimization using the evolutionary and homogenization methods, post-processing of the topology images by automatic and manual shape fitting techniques and shape optimization using gradient-based methods with adaptive finite element techniques. An example using a two dimensional plane stress finite element model is given to illustrate the fully integrated design optimization process.

In Chapter 12 the basic concepts and a comparison of Genetic Algorithms (GAs) and Evolution Strategies (ESs) are described. By introducing a variable coding technique, a parallel optimization method based on a combination of GAs and ESs is presented. The advantages of both GAs and ESs, like coding of genetic information and adaptation of optimization parameters, are enhanced by this method. Chapter 13 deals with computer aided design of profile extrusion dies used for polymer processing. Traditionally, dies have been designed by an expensive trial and error procedure because of the unknown flow patterns that are developed inside the dies. In this work the flow patterns inside dies are simulated using a 3D finite elements analysis and accurate material properties. The intention is to develop software to automatically determine the best die design for a given application using design sensitivity and mathematical programming techniques. In Chapter 14 a concept for the analysis and optimal design of reinforced concrete structures is described. It is based on a nonlinear optimization algorithm and a finite element program for linear and nonlinear analysis of structures. A two stage optimization problem on global (structural) and on local (cross-sectional) level is formulated. A parallelization concept for solving the two stage problem is presented.

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