



PARALLEL FRAMEWORK FOR EARTHQUAKE INDUCED RESPONSE COMPUTATION OF THE SDOF STRUCTURE

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Abstract. Parallel computing briskly diminishes computation time through simultaneous use of multiple computing resources. In this research, parallel computing techniques have been developed to parallelize a program for obtaining a response of single degree of freedom (SDOF) structure under earthquake loading. The study uses Distributed Memory Processors (DMP) hardware architecture and Message Passing Interface (MPI) compilers directives to parallelize the program. The program is made parallel by domain decomposition. Concurrency in the program is created by dividing the program into two parts to run on different computers, calculating forced response and free response of the first half and the second half. Parallel framework successfully creates concurrency and finds structural responses in significant lesser time than sequential programs.

Keywords: parallel computing, SDOF, parallel framework, earthquake response, parallelization, computation cost.

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Introduction

Parallel computing is simultaneous use of multiple computing resources to solve a computing problem in a reduced computation time. Such parallel computing is the best way to increase the computation speed and reduce run time of a program. Its application is rapidly increasing in the field of scientific and engineering computations (Chan *et al.* 2005; Polychronopoulos 1988; Wilkinson, Allen 2005). The approach surprisingly makes the calculations and simulations time efficient based on multi-core processors in addition to clusters. All major applications in different fields of science and technology are employing parallel computing for high speed computations and getting results in lesser time. Most desktop and laptop systems now ship with dual-core microprocessors or quad-core processors, which are best suited for parallel computing. Parallel programming is different from sequential computing, in which a problem/program is divided into a number of small instructions or tasks called threads, which are executed in the processor one by one.

To make many processors simultaneously work on a single program, the program must be divided into smaller independent chunks so that each processor can work on separate chunks of the problem (Wilkinson, Allen 2005). Distributed Memory Processors (DMP) is the computer hardware architecture, which is used in the research. DSM

systems require a communication network to connect inter-processor memory (ordinary computers). To parallelize programs on DMP, the Message Passing Interface (MPI) compilers directives have to be used. In this case first find or create concurrency in the program and then by using MPI commands send concurrent parts of the program from the master computer to different computers; different computers perform operations on it and send back the results to the master computer, which is arranged and written by master computer (Polychronopoulos 1988).

The specialty of this research is that the master computer acts as a worker during the computation time and then it also collects the results from the worker, arranges the data and at the end displays the results. Parallel computing techniques (Fig. 1) have been implemented to parallelize a program for the response of the single degree of freedom structure against typical earthquake force. The program aimed at finding a response of the SDOF structures is created concurrently in the program by dividing the program into two parts, finding forced response and free response of the first half and the other part. Each part is executed on a different computer, and as SDOF Structure is linear and homogeneous, results can be added. In this way, the program for finding a response of the SDOF structure is parallelized. Time reduction in parallel programs can be seen over sequential programs in the presented results. Using multiple computing devices

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Structural Response Computations In Earthquake Engineering

A. H. Barbat, Juan Miquel Canet



Structural Response Computations In Earthquake Engineering:

Structural Response Computations in Earthquake Engineering A. H. Barbat, Juan Miquel Canet, 1989 *Computational Structural Dynamics and Earthquake Engineering* Manolis Papadrakakis, Dimos C. Charmpis, Yannis Tsompanakis, Nikos D. Lagaros, 2008-12-04 The increasing necessity to solve complex problems in Structural Dynamics and Earthquake Engineering requires the development of new ideas innovative methods and numerical tools for providing accurate numerical solutions in affordable computing times This book presents the latest scientific developments in Computational Dynamics Stochastic Dynam **Computational Methods in Earthquake Engineering** Manolis Papadrakakis, Vagelis Plevris, Nikos D. Lagaros, 2016-12-22 This is the third book in a series on Computational Methods in Earthquake Engineering The purpose of this volume is to bring together the scientific communities of Computational Mechanics and Structural Dynamics offering a wide coverage of timely issues on contemporary Earthquake Engineering This volume will facilitate the exchange of ideas in topics of mutual interest and can serve as a platform for establishing links between research groups with complementary activities The computational aspects are emphasized in order to address difficult engineering problems of great social and economic importance **Introduction To Computational Earthquake Engineering (Third Edition)** Muneo Hori, 2018-06-14 This book provides rigorous foundations of applying modern computational mechanics to earthquake engineering The scope covers the numerical analysis of earthquake wave propagation processes and the faulting processes and also presents the most advanced numerical simulations of earthquake hazards and disasters that can take place in an urban area Two new chapters included are advanced topics on high performance computing and for constructing an analysis model This is the first book in earthquake engineering that explains the application of modern numerical computation which includes high performance computing to various engineering seismology problems Computational Mechanics in Structural Engineering F.Y. Cheng, F. Zizhi, 2003-10-04 Proceedings of Sino US Joint Symposium Workshop on Recent Developments and Future Trends of Computational Mechanics in Structural Engineering Beijing China September 24 28 1991 Computational Modelling of Concrete Structures Günther Meschke, Bernhard Pichler, Jan G. Rots, 2018-01-31 The EURO C conference series Split 1984 Zell am See 1990 Innsbruck 1994 Badgastein 1998 St Johann im Pongau 2003 Mayrhofen 2006 Schladming 2010 St Anton am Arlberg 2014 and Bad Hofgastein 2018 brings together researchers and practising engineers concerned with theoretical algorithmic and validation aspects associated with computational simulations of concrete and concrete structures Computational Modelling of Concrete Structures reviews and discusses research advancements and the applicability and robustness of methods and models for reliable analysis of complex concrete reinforced concrete and pre stressed concrete structures in engineering practice The contributions cover both computational mechanics and computational modelling aspects of the analysis and design of concrete and concrete structures Multi scale cement and concrete research experiments and modelling Aging concrete from very early ages to decades long durability

Advances in material modelling of plain concrete Analysis of reinforced concrete structures Steel concrete interaction fibre reinforced concrete and masonry Dynamic behaviour from seismic retrofit to impact simulation Computational Modelling of Concrete Structures is of special interest to academics and researchers in computational concrete mechanics as well as industry experts in complex nonlinear simulations of concrete structures

Computational Mechanics '88 S.N. Atluri, G. Yagawa, 2013-11-11 The aim of this Conference was to become a forum for discussion of both academic and industrial research in those areas of computational engineering science and mechanics which involve and enrich the rational application of computers numerical methods and mechanics in modern technology The papers presented at this Conference cover the following topics Solid and Structural Mechanics Constitutive Modelling Inelastic and Finite Deformation Response Transient Analysis Structural Control and Optimization Fracture Mechanics and Structural Integrity Computational Fluid Dynamics Compressible and Incompressible Flow Aerodynamics Transport Phenomena Heat Transfer and Solidification Electromagnetic Field Related Soil Mechanics and MHD Modern Variational Methods Biomechanics and Off Shore Structural Mechanics

Computational Methods, Seismic Protection, Hybrid Testing and Resilience in Earthquake Engineering Gian Paolo Cimellaro, Satish Nagarajaiah, Sashi K. Kunnath, 2014-09-16 The book is a tribute to the research contribution of Professor Andrei Reinhorn in the field of earthquake engineering It covers all the aspects connected to earthquake engineering starting from computational methods hybrid testing and control resilience and seismic protection which have been the main research topics in the field of earthquake engineering in the last 30 years These were all investigated by Prof Reinhorn throughout his career The book provides the most recent advancements in these four different fields including contributions coming from six different countries giving an international outlook to the topics

Mechanics of Structures and Materials XXIV Hong Hao, Chunwei Zhang, 2019-08-08 Mechanics of Structures and Materials Advancements and Challenges is a collection of peer reviewed papers presented at the 24th Australasian Conference on the Mechanics of Structures and Materials ACMSM24 Curtin University Perth Western Australia 6-9 December 2016 The contributions from academics researchers and practising engineers from Australasian Asia Pacific region and around the world cover a wide range of topics including Structural mechanics Computational mechanics Reinforced and prestressed concrete structures Steel structures Composite structures Civil engineering materials Fire engineering Coastal and offshore structures Dynamic analysis of structures Structural health monitoring and damage identification Structural reliability analysis and design Structural optimization Fracture and damage mechanics Soil mechanics and foundation engineering Pavement materials and technology Shock and impact loading Earthquake loading Traffic and other man made loadings Wave and wind loading Thermal effects Design codes Mechanics of Structures and Materials Advancements and Challenges will be of interest to academics and professionals involved in Structural Engineering and Materials Science

Computational Mechanics M. W. Yuan, 2004 Computational Modelling of Concrete Structures Gunther Meschke, René

de Borst, Herbert Mang, Nenad Bicanic, 2006-03-16 This conference proceedings brings together the work of researchers and practising engineers concerned with computational modelling of complex concrete reinforced concrete and prestressed concrete structures in engineering practice The subjects considered include computational mechanics of concrete and other cementitious materials including masonry Advanced discretisation methods and microstructural aspects within multi field and multi scale settings are discussed as well as modelling formulations and constitutive modelling frameworks and novel experimental programmes The conference also considered the need for reliable high quality analysis and design of concrete structures in regard to safety critical structures with a view to adopting these in codes of practice or recommendations The book is of special interest to researchers in computational mechanics and industry experts in complex nonlinear simulations of concrete structures *Application Of High-performance Computing To Earthquake-related Problems* Muneo

Hori, 2024-07-02 With the continued improvements in computing power and digital information availability we are witnessing the increasing use of high performance computers to enhance simulations for the forecasting of hazards disasters and responses This major reference work summarizes the theories analysis methods and computational results of various earthquake simulations by the use of supercomputers It covers simulations in the fields of seismology physical geology earthquake engineering specifically the seismic response of structures and the socioeconomic impact of post earthquake recovery on cities and societies Individual chapters address phenomena such as earthquake cycles and plate boundary behavior tsunamis structural response to strong ground motion and post disaster traffic flow and economic activity The methods used for these simulations include finite element methods discrete element methods smoothed particle hydrodynamics and multi agent models among others The simulations included in this book provide an effective bird s eye view of cutting edge simulations enhanced with high performance computing for earthquake occurrence earthquake damage and recovery from the damage combining three of the major fields of earthquake studies earth science earthquake engineering and disaster mitigation related social science The book is suitable for advanced undergraduates graduates and researchers in these fields *Computational Stochastic Mechanics* P.D. Spanos, C.A. Brebbia, 2012-12-06 Over a period of several years the field of probabilistic mechanics and computational mechanics have progressed vigorously but independently With the advent of powerful computational hardware and the development of novel mechanical techniques the field of stochastic mechanics has progressed in such a manner that the inherent uncertainty of quite complicated systems can be addressed The first International Conference on Computational Stochastic Mechanics was convened in Corfu in September 1991 in an effort to provide a forum for the exchanging of ideas on the current status of computational methods as applied to stochastic mechanics and for identifying needs for further research The Conference covered both theoretical techniques and practical applications The Conference also celebrated the 60th anniversary of the birthday of Dr Masanobu Shinozuka the Sollenberger Professor of Civil Engineering at Princeton University whose work has contributed in such a

great measure to the development of Computational Stochastic Mechanics A brief summary of his career and achievements are given in the Dedication This book comprises some of the papers presented at the meeting and covers sections on Theoretical Reliability Analysis Damage Analysis Applied Reliability Analysis Theoretical Random Vibrations Stochastic Finite Element Concept Fatigue and Fracture Monte Carlo Simulations Earthquake Engineering Applications Materials Applied Random Vibrations Applied Stochastic Finite Element Analysis and Flow Related Applications and Chaotic Dynamics The Editors hope that the book will be a valuable contribution to the growing literature covering the field of Computational Stochastic Mechanics

Structural Dynamic Systems Computational Techniques and Optimization Cornelius T.

Leondes, 1999 Conventional seismic design has been based on structural strength in the initial design of structures resulting in lateral force resisting systems with sufficient strength to be able to absorb and dissipate the seismic For important structures such as urban high speed road systems high rise buildings hospitals airports and other essential structures which must be quite functional after an earthquake modern seismic structural design techniques have been developed with a view toward eliminating or significantly reducing seismic damage to such structures This volume is a comprehensive treatment of the issues involved in modern seismic design techniques for structure with a view to significantly enhancing their capability of surviving earthquakes to an adequate degree i.e. enhancing the ability of structural systems to withstand high level earthquakes

Computational Modeling of Masonry Structures Using the Discrete Element Method Sarhosis, Vasilis, Bagi, Katalin, Lemos, José V., Milani, Gabriele, 2016-06-09 The Discrete Element Method DEM has emerged as a solution to predicting load capacities of masonry structures As one of many numerical methods and computational solutions being applied to evaluate masonry structures further research on DEM tools and methodologies is essential for further advancement Computational Modeling of Masonry Structures Using the Discrete Element Method explores the latest digital solutions for the analysis and modeling of brick stone concrete granite limestone and glass block structures Focusing on critical research on mathematical and computational methods for masonry analysis this publication is a pivotal reference source for scholars engineers consultants and graduate level engineering students

Structural Seismic Design

Optimization and Earthquake Engineering: Formulations and Applications Plevris, Vagelis, 2012-05-31 Throughout the past few years there has been extensive research done on structural design in terms of optimization methods or problem formulation But much of this attention has been on the linear elastic structural behavior under static loading condition Such a focus has left researchers scratching their heads as it has led to vulnerable structural configurations What researchers have left out of the equation is the element of seismic loading It is essential for researchers to take this into account in order to develop earthquake resistant real world structures Structural Seismic Design Optimization and Earthquake Engineering Formulations and Applications focuses on the research around earthquake engineering in particular the field of implementation of optimization algorithms in earthquake engineering problems Topics discussed within this book include but

are not limited to simulation issues for the accurate prediction of the seismic response of structures design optimization procedures soft computing applications and other important advancements in seismic analysis and design where optimization algorithms can be implemented Readers will discover that this book provides relevant theoretical frameworks in order to enhance their learning on earthquake engineering as it deals with the latest research findings and their practical implementations as well as new formulations and solutions

Insights and Innovations in Structural Engineering, Mechanics and Computation Alphose Zingoni, 2016-11-25 *Insights and Innovations in Structural Engineering Mechanics and Computation* SEMC 2016 Cape Town South Africa 5-7 September 2016 The papers reflect the broad scope of the SEMC conferences and cover a wide range of engineering structures buildings bridges towers roofs foundations offshore structures tunnels dams vessels vehicles and machinery and engineering materials steel aluminium concrete masonry timber glass polymers composites laminates smart materials

International Journal of Computational Methods and Experimental Measurements - Volume 3, Issue 1, 2015-03-31 The International Journal of Computational Methods and Experimental Measurements CMEM provides the scientific community with a forum to present the interaction between the complementary aspects of computational methods and experimental measurements and to stress the importance of their harmonious development and integration The steady progress in the efficiency of computers and software has resulted in the continuous development of computer simulation which has influenced all scientific and engineering activities As these simulations expand and improve the need to validate them grows and this can only be successfully achieved by performing dedicated experimental tests Furthermore because of their continual development experimental techniques are becoming so complex and sophisticated that they need to be controlled by computers with the data obtained processed by means of computational methods The aim of the Journal is to review the latest work in computational methods and experimental measurements with a view to achieving harmonious development and interaction between the two

Intelligent Computational Paradigms in Earthquake Engineering Nikos D. Lagaros, Yiannis Tsompanakis, 2007-01-01 This book contains contributions that cover a wide spectrum of very important real world engineering problems and explores the implementation of neural networks for the representation of structural responses in earthquake engineering It assesses the efficiency of seismic design procedures and describes the latest findings in intelligent optimal control systems and their applications in structural engineering

Provided by publisher Duality System in Applied Mechanics and Optimal Control Wan-Xie Zhong, 2006-04-11 A unified approach is proposed for applied mechanics and optimal control theory The Hamilton system methodology in analytical mechanics is used for eigenvalue problems vibration theory gyroscopic systems structural mechanics wave guide LQ control Kalman filter robust control etc All aspects are described in the same unified methodology Numerical methods for all these problems are provided and given in meta language which can be implemented easily on the computer Precise integration

methods both for initial value problems and for two point boundary value problems are proposed which result in the numerical solutions of computer precision Key Features of the text include Unified approach based on Hamilton duality system theory and symplectic mathematics Gyroscopic system vibration eigenvalue problems Canonical transformation applied to non linear systems Pseudo excitation method for structural random vibrations Precise integration of two point boundary value problems Wave propagation along wave guides scattering Precise solution of Riccati differential equations Kalman filtering HINFINITY theory of control and filter

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