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APPLICATIONS OF THE MODAL SUMMATION TECHNIQUE TO THE THEORETICAL SITE RESPONSE ESTIMATION*

F. ROMANELLI[†,‡], F. VACCARI[†,‡], and G. F. PANZA[‡,§]

[†] *Dipartimento di Scienze della Terra, Via E. Weiss 4, 34127 Trieste, Italy*
[‡] *INGV, Rome, Italy*
[§] *The Abdus Salam International Centre for Theoretical Physics, Miramar, Italy*

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A practical definition of site effect, that accounts for both the seismological and engineering point of view, is the one given by Field[7]: "the unique behavior of a site, relative to other sites, that persists given all (or most) of the potential sources of earthquake ground motion in the region". This definition implicitly indicates the difficulties connected with a correct estimate (or prediction) of the site effect. We estimate theoretical site responses adopting several techniques and using different seismic motion types. Our results confirm that the identification of the site behavior with a set of resonance frequencies can be a very difficult task, especially when the amplification levels seem to be "azimuthally" dependent. We show that the adoption of simplified models can lead to misleading conclusions concerning the seismic response of sedimentary basins. The results suggest that, in order to perform an accurate estimate of the site effects in complicated geometries, it is necessary to make a parametric study that takes into account the complex combination of the source and propagation factors.

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EARTHQUAKE GROUND MOTION SIMULATION THROUGH THE 2-D SPECTRAL ELEMENT METHOD*

ENRICO PRIOLO

Istituto Nazionale di Oceanografia e Geofisica Sperimentale (OGS), Trieste, Italy
Borgo Grotta Gigante 42/c, I-34010 Sgonico (Trieste), Italy
epriolo@ogs.trieste.it

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The application of the 2-D Chebyshev spectral element method (SPEM) to engineering seismology problems is reviewed in this paper. The SPEM is a high-order finite element technique which solves the variational formulation of the seismic wave propagation equations. The computational domain is discretised into an unstructured grid composed by irregular quadrilateral elements. This property makes the SPEM particularly suitable to compute numerically accurate solutions of the full wave equations in complex media. The earthquake is simulated following an approach that can be considered "global", that is all the factors influencing the wave propagation — source, crustal heterogeneity, fine details of the near-surface structure, and topography — are taken into account and solved simultaneously. The basic earthquake source is represented by a 2-D point double couple model. Ruptures propagating along fault segments placed on the model plane are simulated as a finite summation of elementary point sources. After a general introduction, the paper first gives an overview of the method; then it concentrates on some methodological topics of interest for practical applications, such as quadrangular mesh generation, source definition and scaling, numerical accuracy and computational efficiency. Limitations and advantages of using a 2-D approach, although sophisticated such as the SPEM, are addressed, as well. The effectiveness of the method is illustrated through two case histories, i.e. the ground shaking prediction in Catania (Sicily, Italy) for a catastrophic earthquake, and the analysis of the ground motion in the presence of a massive structure.

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THE VARIATIONAL INDIRECT BOUNDARY ELEMENT METHOD: A STRATEGY TOWARD THE SOLUTION OF VERY LARGE PROBLEMS OF SITE RESPONSE*

FRANCISCO J. SÁNCHEZ-SESMA† and ROSSANA VAI†,‡

†*Instituto de Ingeniería, UNAM; Cd. Universitaria, Apdo 70-472; Coyoacán 04510; México D. F., Mexico*

‡*Instituto Mexicano del Petróleo; Eje Central L. Cárdenas 152; Gustavo A. Madero 07730; México D. F., Mexico*

sesma@servidor.unam.mx

rox@gauss.iingen.unam.mx

ELINA DRETTA

ADK SA; Themistokelous 106; 10681 Athens; Greece

e.dretta@adk.net

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Boundary integral equation approaches and their discretization into boundary element methods (BEM) have been useful to obtain solutions for numerous problems in dynamic elasticity. Well documented advantages over domain approaches are dimension reduction, relatively easy fulfillment of radiation conditions at infinity, and high accuracy of results. In spite of dimension reduction, the computational cost at high frequencies may easily exceed the capacity of computing facilities. To overcome this problem, Galerkin's ideas may be used. The Indirect Boundary Element Method (IBEM) equations are the starting point of the proposed methodology. The boundary force density is expanded in terms of a complete set of functions. Weighting functions from the same complete set are used to minimize the error of this approximation. Once a significant subset is selected, the size of the resulting linear system is much smaller than that of the IBEM method as currently applied. Moreover, with appropriate trial functions, some matrix operations can be reduced to Fourier transformations.

In what follows, the formulation and some examples for scalar problems are presented. Simple 2-D topographies are studied, but the extension to 3-D realistic configurations may well be treated on the same basis.

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EFFICIENCY AND OPTIMIZATION OF THE 3-D FINITE-DIFFERENCE MODELING OF SEISMIC GROUND MOTION*

PETER MOCZO, JOZEF KRISTEK, and ERIK BYSTRICKÝ

Geophysical Institute, Slovak Academy of Sciences,
Dúbravská cesta 9, 842 28 Bratislava, Slovak Republic.
geofpemo@savba.sk

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We present a tutorial introduction to the 3-D finite-difference modeling of seismic ground motion in elastic and viscoelastic media with special emphasis on its computational efficiency. We consider four basic types of the finite-difference schemes — the displacement-stress, displacement-velocity-stress and velocity-stress schemes on a staggered grid, and displacement scheme on a conventional grid. Their memory requirements in the case of perfectly elastic medium, elastic medium with aposteriori approximate attenuation correction, and realistic viscoelastic medium are reviewed. We also present application of the powerful optimization techniques to the 3-D fourth-order displacement-stress and displacement-velocity-stress modeling in the case of viscoelastic medium whose rheology is based on the generalized Maxwell body. Description of a medium using material cell types and use of a discontinuous grid with combined memory optimization makes it possible to simulate earthquake ground motion in realistic large-scale models.

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THREE-DIMENSIONAL GROUND MOTION SIMULATIONS FOR LARGE EARTHQUAKES ON THE SAN ANDREAS FAULT WITH DYNAMIC AND OBSERVATIONAL CONSTRAINTS*

KIM B. OLSEN

Institute for Crustal Studies UCSB, Santa Barbara, CA 93016-1100, USA

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I have simulated 0–0.5 Hz viscoelastic ground motion in Los Angeles from **M** 7.5 earthquakes on the San Andreas fault using a fourth-order staggered-grid finite-difference method. Two scenarios are considered: (a) a southeast propagating and (b) a northwest propagating rupture along a 170-km long stretch of the fault near Los Angeles in a 3D velocity model. The scenarios use variable slip and rise time distributions inferred from the kinematic inversion results for the 1992 **M** 7.3 Landers, California, earthquake. The spatially variable static slip distribution used in this study, unlike that modeled in a recent study,[1] is in agreement with constraints provided by rupture dynamics. I find peak ground velocities for (a) and (b) of 49 cm/s and 67 cm/s, respectively, near the fault. The near-fault peak motions for scenario (a) are smaller compared to previous estimates from 3D modeling for both rough and smooth faults.[1,2] The lower near-fault peak motions are in closer agreements with constraints from precarious rocks located near the fault. Peak velocities in Los Angeles are about 30% larger for (b) 45 cm/s compared to those for (a) 35 cm/s.

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MODIFICATIONS OF THE GROUND MOTION IN DENSE URBAN AREAS*

DIDIER CLOUTEAU and DENIS AUBRY

Laboratoire de Mécanique des Sols-Structures-Matériaux, CNRS UMR 8579,
École Centrale de Paris, Grande Voie des Vignes,
92295 Châtenay-Malabry CDX, France

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The main motivation of this work is to analyze whether or not the presence of buildings is able to modify the seismic field significantly. We first present a numerical method able to account for a three-dimensional building distribution resting on a layered elastic-half-space. The proposed method is based on a variational coupling between Boundary Elements and modal representation for the buildings. Provided with the hypothesis of a stochastic homogeneous distribution of these buildings or a deterministic periodic one, a realistic model of an entire city may be accounted for. This method is applied to practical situations and it is shown that modifications of the incident field occur mainly for soft layered soils. However from an engineering point of view, it appears that the amplification levels are not significantly modified even in these extreme cases. Nevertheless, a strong scattering of the response inside the city depends on the nearby buildings can be observed.

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NUMERICAL SIMULATIONS OF STRONG GROUND MOTION DURING DESTRUCTIVE EARTHQUAKES IN HOKKAIDO, JAPAN*

MITSUKO FURUMURA†

Hokkaido Univ., Kita-ku N10W8, Sapporo 060-0810, Japan
mitsuko@eos.hokudai.ac.jp

TAKASHI FURUMURA‡

Hokkaido Univ. Edu., Midorigaoka 2-34-1, Iwamizawa 068-8642, Japan
furumura@iwa.hokkyodai.ac.jp

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Seismic wave propagation in Hokkaido, Japan, for large destructive earthquakes are simulated by the 3-D finite-difference method. The simulation results indicate that the peak ground velocity distribution for an inland earthquake is nearly circle, but for a plate-boundary earthquake it is irregular, due to influence of lateral heterogeneity in the crust and upper mantle beneath the Hokkaido region.

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†Present address: Earthquake Research Center, Association for the Development of Earthquake Prediction, Sarugaku-Cho 1-5-18, Chiyoda-ku, Tokyo, 101-0064, Japan, E-mail: furumura@erc.adep.or.jp

‡Present address: Earthquake Research Institute, University of Tokyo, Yayoi 1-1-1, Bunkyo-ku, Tokyo, 113-0032, Japan, E-mail: furumura@eri.u-tokyo.ac.jp

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APPLICATION OF THE INTEGRAL LAGUERRE TRANSFORMS FOR FORWARD SEISMIC MODELING*

G. V. KONYUKH, B. G. MIKHAILENKO, and A. A. MIKHAILOV

Institute of Computational Mathematics and Mathematical Geophysics, Siberian Division Russian Academy of Sciences, Pr. Lavrentieva, 6, Novosibirsk, 630090, Russia
mikh@sscc.ru

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The paper presents some efficient algorithms based on the application of the integral Laguerre transform for approximation of temporal derivatives. Some specific features of employing this algorithm for the first and the second order equations with respect to time are considered. A few examples of calculation of seismic fields for the layered medium model with drastically contrast elastic parameters and for the 2-D heterogeneous medium model are presented.

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PARALLEL 3D FOURIER SPECTRAL SIMULATION OF STRONG GROUND MOTION IN OSAKA BASIN DURING THE 1995 KOBE EARTHQUAKE

TAKASHI FURUMURA

Hokkaido University of Education, Midorigaoka 2-34-1
Iwamizawa 068-8642, Japan
furumura@iwa.hokkyodai.ac.jp

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Numerical 3D simulation of strong ground motion in Osaka basin during the 1995 Kobe (Hyogo-ken Nanbu) earthquake is conducted by using a parallelized Fourier spectral method. During the parallel computing the 3D wavefield are separated into three-coordinate system, and the calculation is conducted concurrentry with a use of inter-processor communications via a computer network.

The simulation results for the Kobe earthquake clearly demonstrate that the complex 3D subsurface structure, and the relation to source fault location, plays an very important role on the generation of strong ground motion on the surface.