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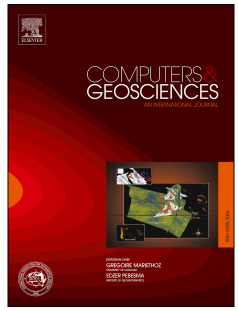

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Acoustic 3D modeling by the method of integral equations

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Abstract

This paper presents a parallel algorithm for frequency-domain acoustic modeling by the method of integral equations (IE). The algorithm is applied to seismic simulation. The IE method reduces the size of the problem but leads to a dense system matrix. A tolerable memory consumption and numerical complexity were achieved by applying an iterative solver, accompanied by an effective matrix-vector multiplication operation, based on the fast Fourier transform (FFT). We demonstrate that, the IE system matrix is better conditioned than that of the finite-difference (FD) method, and discuss its relation to a specially preconditioned FD matrix. We considered several methods of matrix-vector multiplication for the free-space and layered host models. The developed algorithm and computer code were benchmarked against the FD time-domain solution. It was demonstrated that, the method could accurately calculate the seismic field for the models with sharp material boundaries and a point source and receiver located close to the free surface. We used OpenMP to speed up the matrix-vector multiplication, while MPI was used to speed up the solution of the system equations, and also for parallelizing across multiple sources. The practical examples and efficiency tests are presented as well.

Keywords: Seismology, acoustics, integral equation, seismic modeling

1. Introduction

Modeling of wave propagation within the Earth is the cornerstone of seismic full-waveform inversion (FWI). Performing inversion in the frequency domain has many advantages, the most important of which is the possibility to invert only a few frequencies in a sequential manner, avoiding trapping to local minima (Virieux and Operto, 2009).

One of the most effective approaches to large frequency-domain simulation of acoustic waves is the finite-difference (FD) method accompanied with an iterative solver. The sparse direct solvers were also considered (Operto et al., 2007), but they are quite memory consuming. Performance of FD iterative solvers depends critically on the choice of the preconditioner applied. There is a number of preconditioners designed to date (Lahaye et al., 2017), however preconditioning usually requires a complex implementation. In this paper, we considered integral equations (IE) modeling, which reduces the size of the problem but increases the complexity of the matrix-vector multiplication.

In the method of IE (Morse and Feshbach, 1953; de Hoop, 1958; Aki and Richards, 1980; Carcione et al., 2002; Zhdanov, 2002, 2015) the total field is split into a background part due to a host model and an anomalous part due to an anomalous domain. The background part of the total field is usually calculated in an analytical or semi-analytically manner, whereas the anomalous

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