HIGH-SPEED 3D HYBRID ELASTIC SEISMIC MODELING

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RESEARCH OBJECTIVES

The best tool for understanding and imaging complex structures and large offset data sets is an accurate, fully elastic 3D algorithm. The applications for such an algorithm are many (e.g., survey design, hypothesis testing, AVO evaluation, wave field interpretation, generation of test data sets for testing of new migration algorithms, and forward-calculation engines in 3D prestack migration algorithms and new full waveform inversion algorithms). While such algorithms have been developed, uniform grid sampling produces costly oversampling of high-velocity regions and unnecessarily small time-integration steps in low-velocity regions. Thus, the scale of the computer resources required to model the entire geologic section, from source locations to the depths of interest and with fully elastic representation, is prohibitive. In addition, the discretization of high-contrast boundaries (such as a salt-sediment interface) can produce high-energy diffraction events in the modeled data, which are often difficult to completely suppress even in processing. There is a critical need for an algorithm that can accurately model and image all of the elastic effects occurring in a complex structure, and at the same time be efficient enough to run on clusters of available workstations in a reasonable time. We seek to develop an efficient 3D elastic forward-modeling algorithm that will address these requirements.

APPROACH

Two critical concepts will provide for a significant improvement in computation efficiency and accuracy over what is currently available. The first critical concept is the decomposition of the original 3D model into parts (subdomains) where wave propagation will be computed, using the optimal spatial parameterization for each particular subdomain. The second critical concept is the use of a fourth-order time scheme (as opposed to the frequently used second-order schemes).

The new variable-grid-subdomain finite-difference (FD) algorithm is designed for parallel-cluster computing, utilizing a message-passing-interface technique. Using subdomains in FD modeling has several major advantages over current single-domain algorithms. For one thing, this approach uses fine gridding only in low-velocity regions (sea water, loosely compacted sediments) where it is required, allowing coarser gridding in the higher-velocity regions (salt, deep sediments). The innovative fourth-order differencing scheme enables improved accuracy in time differencing, and therefore increases the time-differencing step for the expense of extra computation within a single node. Since inter-CPU communication speed is a major bottleneck for parallel data-processing flow, the fourth-order scheme allows an increase in the computation-to-communication ratio, improving the effectiveness of parallel computations. The fourth-order time-differencing scheme has little effect on memory usage compared to second-order schemes. A required special formulation for absorbing boundary conditions is under development.

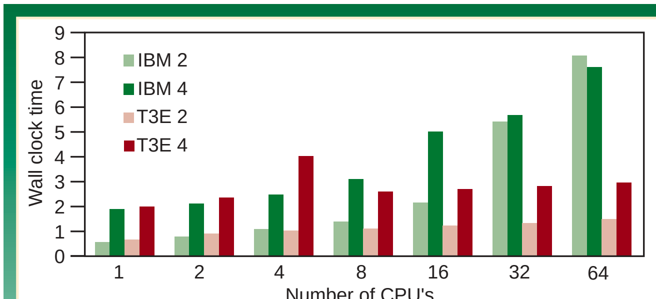

Figure 1. Summary of a set of runs, with the number of computational zones increasing linearly with the number of processors

ACCOMPLISHMENTS

Figure 1 shows a graph summarizing a set of runs performed this past year using the new variable-grid-subdomain FD algorithm scheme. The graph shows the number of computational zones increasing linearly with the number of processors. Perfect scaling results would have zero slope. Cray T3E times are encouraging. The IBM SP shows a reduction in parallel performance with increasing numbers of processors. The performance loss is less severe for the fourth-order scheme than for the second-order scheme. The IBM has slower interprocessor communications (both lower bandwidth and higher latency). (Run time reported is wall-clock time.) Cray T3E shows very efficient processor usage for both second- and fourth-order schemes. Fourth-order schemes show slower degradation of parallel performance with increasing problem size.

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