Overview of GeoFEM:
Parallel FE Solid Earth Simulator
Tiger and Snake

Project Overview

The Ministry of Education, Culture, Sports, Science and Technology (former Science and Technology Agency), Japan has begun an Earth Simulator project from the fiscal year of 1997 for predicting various Earth phenomena through the simulation of virtual Earth placed in a supercomputer. The specific research topics of the project are as follows:

1) Development of a high performance massively parallel processing computer: ‘Earth Simulator’ (40 TFlops / Peak Performance, 10 TB Memory)
2) Modeling of atmospheric and oceanic field phenomena and high-resolution simulations
3) Modeling and simulation of solid earth field phenomena
4) Development of large-scale parallel software for the Earth Simulator.

GeoFEM is in charge of the topics 3) and 4) developing the system in two phases as:
Phase I: GeoGEM/Tiger (1997-1998): Multi-purpose parallel finite element software, which may be applied to various fields in engineering and sciences as well as becoming the basis for the solid earth simulator to be developed in Phase II.
Phase II: GeoFEM/Snake (1999-2001): A software system optimized for the Earth Simulator and specialized for the simulation of solid earth phenomena such as mantle-core convection, plate tectonics, seismic wave propagation and their coupled phenomena.

System Configuration

GeoFEM is composed of ‘analysis modules’ for structural / electromagnetic thermal fluid / wave propagation simulations and ‘platform’ for parallel I/O / equation solvers / visualization functions. System is designed to be pluggable such that each analysis module is replaceable and that communications among PEs are done implicitly in platform. Platform includes a ‘coupler’, supporting communications among analysis modules for multi-disciplinary computations. ‘Utilities’ i.e. mesh partitioners and pre/post viewer are also supplied.
Parallel & Vector Performances

A linear elastic problem with $10^5$ DOFs (35,937,000 nodes, 32,768,000 elements) is solved by localized ICCG on SR2201 using 1,000 PEs with the parallel performance (CPU usage ratio) of more than 95%. ICCG tuned for SMP parallel / vector hybrid system attains 969 Mflops for 2.0*10^5 DOF problem on SX4 (1PE, 2 Gflops peak), 16.2 Gflops for 2.7*10^7 DOF problem on SR2201 (252 PEs, 75.6 Gflops peak) and 20.1 Gflops for 10^8 DOF problem on SR8000 (16 SMP nodes (128 PEs), 128 Gflops peak). Based on our performance estimation, GeoFEM is expected to attain over 10 Tflops on the Earth Simulator.

Applications & Portability

GeoFEM has been applied to various engineering and solid earth problems as shown here. Computational environments to which GeoFEM has been ported are: SR2201, SR8000, SX4, VPP5000, Pentium cluster (Linux), Alpha cluster, etc.

Further Developments

Towards the final goal of GeoFEM project, following issues are focused on:
Parallel multigrid solvers, Parallel adaptive analysis with dynamic load balancing, Optimization for Earth Simulator, Multi-disciplinary couplers, Parallel visualization tools, Extension of framework, Realistic solid earth simulations.

Research Collaborations:
APEC Cooperation for Earthquake Simulation (ACES)
QUAKES (Univ. of Queensland)
FhG/SCAI
NEC-Europe
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