Annual Report for Research Work in the fiscal year 2006

Research Area:
High Performance Computing for Multi-scale and Multi-physics Phenomena

Research Theme
Integrated Predictive Simulation System for Earthquake and Tsunami Disaster

Name of Research Director, Belonging and Title:
Mitsuhiro Matsu’ura, Graduate School of Science, University of Tokyo, Professor
§1. Outline of Research Work

The aim of our research project is to develop an integrated simulation system for predicting earthquake and tsunami disasters, which covers the entire multi-scale processes related to earthquakes, such as tectonic stress accumulation due to relative plate motion, earthquake generation, seismic wave/tsunami propagation, and building oscillation. For reliable prediction we assimilate observed data from the nation-wide seismic and geodetic networks to the computer simulation. In 2006, integrating correlative basic models, we developed three combined simulation systems for earthquake generation, strong ground motion/tsunami propagation, and building oscillation. In 2007 we develop a platform and data grid that support combined simulations and parallel data management. In 2008-2010 we integrate the three combined simulation systems into a unified system, and make simulations for the prediction of earthquakes and tsunami disasters in realistic scenarios. The integrated simulation system will make a major contribution toward the reduction of earthquake and tsunami disasters.

§2. Content of Research Work

Objects and methods

In the first phase of the project (2005-2007) we develop three combined simulation systems for earthquake generation, strong ground motion/tsunami propagation, and building oscillation. We also develop a platform for combined simulations. The integrated simulation system consists of six basic simulation models (plate motion, tectonic stress accumulation, earthquake rupture propagation, seismic wave propagation, tsunami propagation, and building oscillation), three data analysis programs (geodetic data, seismic data, and strong ground motion data), and a platform that supports combined simulations and parallel data management, as shown in Fig.1.

Fig.1. The integrated predictive simulation system for earthquake and tsunami disaster
In the second phase (2008-2010) we will integrate the three combined systems into a unified system, and make simulations for the prediction of earthquakes and tsunami disasters in realistic scenarios.

Our project team has six research groups: 1) Matsu’ura group for the predictive simulation of earthquake generation cycles, 2) Furumura group for the integrated simulation of seismic wave propagation and tsunami generation/propagation, 3) Okuda group for the development of a platform and data grid that support combined simulations and parallel data management, 4) Ichimura group for the coupling simulation of seismic wave propagation and building oscillation, 5) Nagashima group for the coupling simulation of seismic wave propagation and oil-tank sloshing, and 6) Fukuyama group for the combined simulation of earthquake rupture and seismic wave propagation.

Results of the research
In 2006, through the collaborative research between the six research groups, we developed three combined simulation systems for earthquake generation, strong ground motion/tsunami propagation, and building oscillation. We also progressed the development of a platform and data grid that support combined simulations and parallel data management. The details are summarized below.

1) Predictive simulation of earthquake generation cycles
Matsu’ura group and Fukuyama group developed a simulation system for earthquake generation cycles at plate boundaries, and made the combined simulations of quasi-static stress accumulation, dynamic rupture and seismic wave propagation for the 1968 and 2003 Tokachi-oki earthquakes.

Fig. 2 Combined simulations of quasi-static stress accumulation and dynamic rupture propagation in the source region of the 1968 Tokachi-oki earthquake (Hashimoto, Fukuyama & Matsuura, 2006). Top: States stress accumulation at 60 yr and 120 yr after the 1968 Tokachi-oki earthquake. Bottom: Corresponding dynamic rupture propagation.
2) Integrated simulation for seismic wave and tsunami propagation
Frumura group developed an integrated simulation model for seismic wave propagation and tsunami generation/propagation for accurate prediction of tsunami disasters caused by subduction-zone earthquakes. The integration model for earthquake and tsunami is implemented to the Earth Simulator and a PC cluster for the simulation of strong ground motion and tsunami from the 1944 Tonankai earthquake (Mw8.1).

3) Large-scale coupling simulation through $M \times N$ parallel data redistribution
Ichimura group, Nagashima group and Okuda group developed a prototype of framework for large-scale parallel coupling simulations through $M \times N$ parallel data redistribution under SPMD environment. Coupling simulations for seismic response of multi-tanks for oil-storage with fluid-structure interaction have been demonstrated.
4) Development of a platform for combined simulation

Okuda group developed a parallel visualization method for large-scale distributed data sets in numerical simulations with background voxel’s. In this method, information of distributed unstructured meshes for FEM has been mapped to background voxel’s with adaptive mesh refinement (AMR). Simplification of boundary surface id also applied for reducing data size.

Fig. 5 Temperature distribution of a southwest Japan model with various types of background resolution (Okuda and Nakajima, 2006).

Situation of the progress

In 2006 our project team has developed three combined simulation systems for earthquake generation, strong ground motion/tsunami propagation, and building oscillation. The project is progressing on schedule.

§3. Formation of Research Work

Research Director

Mitsuhiro Matsu’ura, Professor

Graduate School of Science, University of Tokyo

The aim of Matsu’ura group is to develop a predictive simulation system for earthquake generation cycles at plate interfaces in and around Japan, combining a tectonic stress accumulation model, a dynamic rupture propagation model, a geodetic data inversion program, and a CMT data inversion program.
Main Research Collaborators

Takashi FURUMURA, Associate Professor
Earthquake Research Institute, University of Tokyo
The aim of Furumura group is to develop an integrated simulation system for seismic wave propagation and tsunami generation/propagation, and predict strong ground motion and tsunami in and around Japan.

Hiroshi OKUDA, Professor
Research Into Artifacts, Center for Engineering, University of Tokyo
The aim of Okuda group is to develop a hierarchical simulation platform and data grid, which support combined simulations and parallel data management.

Tsuyoshi ICHIMURA, Associate Professor
Graduate School of Science and Engineering, Tokyo Institute of Technology
The aim of Ichimura group is to develop a fast and accurate simulation model for coupling strong ground motion and building oscillation.

Toshio NAGASHIMA, Associate Professor
Faculty of Science and Technology, Sophia University
The aim of Nagashima group is to develop a fast and accurate simulation model for dynamic response of industrial plants such as oil storage tanks against seismic waves.

Eiichi FUKUYAMA, Senior Researcher
Earthquake Research Division, National Research Institute for Earth Science and Disaster Prevention.
The aim of Fukuyama group is to develop a combined simulation code for dynamic rupture and seismic wave propagation, and make realistic earthquake simulations based on earthquake generation physics.

§4. Publication of Research Results

(4—1) Publication of Thesis (The original Work)
① Number of Publications (4 times-Domestic, 14 times-International)
② Detailed Information of Thesis
[1] Fukahata, Y. and M. Matsu’ura, Quasi-static internal deformation due to a dislocation source in a multilayered elastic/viscoelastic half-space and an equivalence theorem, Geophys. J. Int. 166,


(4 — 2) **Patent Application**

① Cumulative Number
   1) Patent Applications in the fiscal year 2006 (Domestic- 0 Cases, Oversea- 0 Cases)
   2) Cumulative number of Patent Applications for the research period of CREST
      (Domestic- 0 Cases, Oversea- 0 Cases)