

A Grid Computing Infrastructure for MEG Data Analysis

Nakagawa, S¹, Kosaka, T², Date, S², Shimojo, S³, Tonoike, M¹

¹Institute for Human Science and Biomedical Engineering (HSBE), National Institute of Advanced Industrial Science and Technology (AIST), Japan

²Graduate School of Information Science and Technology, Osaka University, Japan

³Cybermedia Center, Osaka University, Japan

Corresponding Author: Nakagawa, S., 1-8-31 Midorigaoka, Ikeda, Osaka 563-8577, Japan
Phone: +81-72-751-8785, Email: s-nakagawa@aist.go.jp

ABSTRACT

Magnetoencephalography (MEG) is widely used for studying brain functions, but clinical applications of MEG have been less prevalent. One reason is that only clinicians who have highly specialized knowledge can use MEG diagnostically, and such clinicians are found at only a few major hospitals. Another reason is that MEG data analysis is getting more and more complicated, and deals with a large amount of data, and thus requires high-performance computing. These problems can be solved by the collaboration of human and computing resources distributed in multiple facilities. A new computing infrastructure for brain scientists and clinicians in distant locations was therefore developed by the Grid technology, which provides virtual computing environments composed of geographically distributed computers and experimental devices. A prototype system connecting an MEG system at the AIST in Japan, a Grid environment composed of PC clusters at Osaka University in Japan and Nanyang Technological University in Singapore, and user terminals in Baltimore was developed. MEG data measured at the AIST were transferred in real-time through a 1-GB/s network to the PC clusters for processing by a wavelet cross-correlation method, and then monitored in Baltimore. The current system is the basic model for remote-access to MEG equipment and high-speed processing of MEG data.

KEY WORDS

Grid computing, Remote experiment, Parallel computation, MEG

INTRODUCTION

Magnetoencephalography (MEG), a widely accepted method for studying brain functions, is completely noninvasive and provides a high degree of temporal resolution. Clinical applications of MEG, however, are comparatively rare. One of the problems is that only clinicians with highly-specialized knowledge can use MEG diagnostically, and such clinicians are found at only a few major hospitals. Another is that MEG data analysis is getting more and more complicated by developments of new methods. For example, source estimations using a real-shape head model and finite-element calculation deal with a large amount of data. Such analyses sometimes need expensive computing resources.

These problems lead to a need for the collaboration of geographically distributed researchers and clinicians sharing access to MEG systems and computing resources.

In this study, a prototype of an infrastructure enabling geographically distributed researchers to collaborate and share access to the MEG devices and computing resources needed for remote cooperative experiments and high-performance analyses of brain functional data was developed using Grid computing technology [Foster, 2004], which provides a large-scale but low-cost computing infrastructure by aggregating resources distributed in multiple facilities.

METHODS

1. Grid computing

Grid computing is a method for developing a computing infrastructure by aggregating resources distributed in multiple facilities. This method has been studied since the latter half of 1990s. Its original aim was to acquire a large amount of computing power by aggregating a large number of computers distributed on the Internet. Since this scheme does not require a facility to provide a supercomputer or a large-scale computer cluster, it can reduce the cost of high-performance computing substantially.

Grid computing requires middleware to federate heterogeneous computing resources and make it possible to use them as one integrated computing resource. The Globus Toolkit [The Globus Alliance, 2004] is one example of such middleware and it is widely utilized because of its pioneering contribution to scientific communities. Currently, a wide range of research projects are investigating the use of the Globus Toolkit and its applications in scientific computing.

One application of Grid computing is large-scale parallel computing. Multiple computing resources in a Grid environment can generate synergy to accelerate complex data analyses. Because communication delays between the resources are problematic, a Grid is most suited for computation that does not require frequent communication or synchronization of the activities of the resources. This kind of computation is common in studies of brain function, and Grid computing can be expected to be a useful tool for the processing of MEG data.

2. Application of Grid computing to MEG data analysis

MEG data were measured by a whole-head neuromagnetometer (Neuromag-122™, 122ch, 400 Hz A/D sampling, 32-bit quantized) in a magnetically shielded room at Kansai Center of AIST in Ikeda, Japan. The applicability of Grid computing to the analysis of brain function was evaluated by using it for wavelet cross-correlation analyses [Mizuno-Matsumoto, 2002] and Independent Component Analysis (ICA) [Kaishima, 2002] [Hyvarinen, 2001], both of which require relatively large amounts of computation. The analysis methods were parallelized because the wavelet cross-correlation analyses of the data in one MEG channel is independent of the processing of the data in any other channels. These methods were implemented into an experimental Grid environment composed of two PC clusters at the Cybermedia Center of Osaka University in Suita, Japan, and one PC cluster at Nanyang Technological University in Singapore. The Grid environment consisted of 60 PCs, and was developed by utilizing the Globus Toolkit. During measurements, MEG data were transferred via a 1-GB/s network in real-time from the MEG system to the Grid environment. In addition, a real-time video transfer system was developed to monitor the MEG activity at the MEG facility. Fig. 1 shows a screen shot of these systems.



Figure 1. A Screen shot of the user interface in a remote site. The user interface visualizes a subject and MEG data.

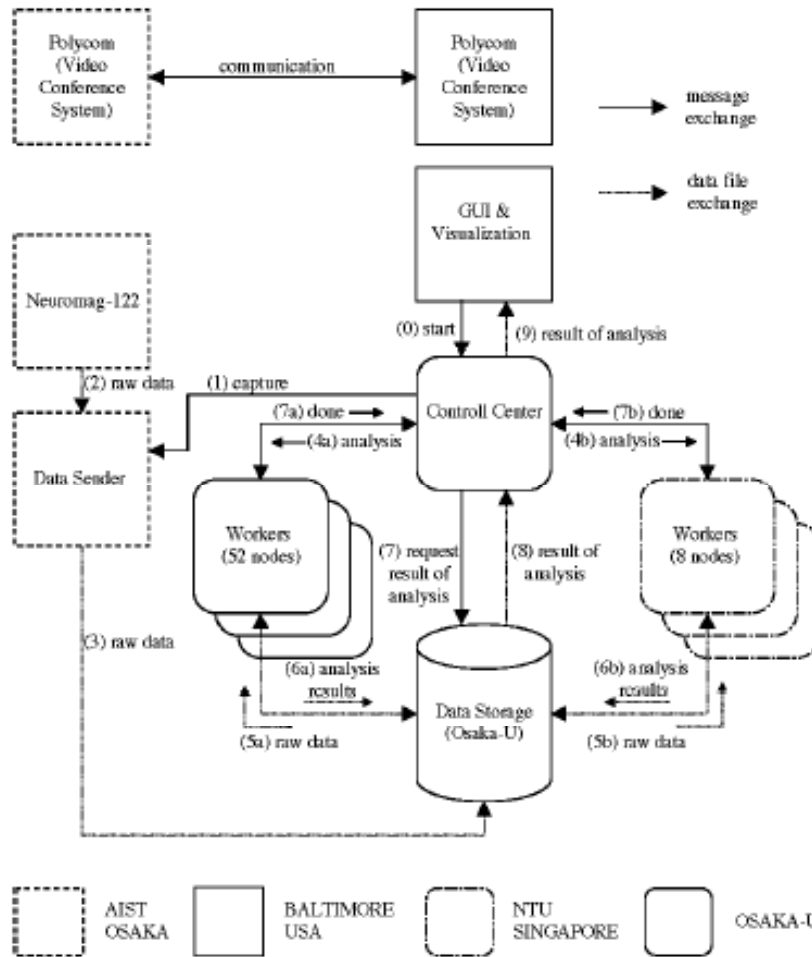


Figure 2. The structure of our prototype system. This system aggregates resources in geographically-distributed four sites: a neuromagnetometer in AIST Kansai, Japan, the user terminal at Baltimore, USA, and PC clusters in Osaka University, Japan and NTU, Singapore.

3. Experiment connecting four sites

The experiment was conducted by connecting geographically distributed resources in four sites: an MEG device in the AIST, PC clusters in Osaka University and Nanyang Technological University, and user terminals (windows PCs) in the Baltimore Convention Center in the United States. Fig. 2 illustrates the structure of the experimental system.

RESULTS AND DISCUSSION

MEG measurement, real-time data transfer, data analysis, and visualization of the results were carried out successfully by the developed system.

The experiment demonstrated in this study revealed the potential of Grid computing for MEG by allowing large-scale analyses through a collaboration of people at data acquisition sites and analysis sites. It enables high-speed and low-cost data analyses. It is also significant that the experiment has drawn a

roadmap for remote-diagnoses by the clinical experts in distant locations, and for experiments involving geographically distributed researchers. These results have been accomplished by designing and implementing an experimental environment using Grid computing technologies, which enable us to build a large-scale but low-cost computing infrastructure from pre-existing resources.

The experiment is a first step toward a collaborative environment for MEG data analysis. We still need to improve the performance of various analysis methods by Grid computing and we also must develop a database system for sharing information, such as setting the parameters of analysis programs.

ACKNOWLEDGEMENTS

This study was supported by the IT-program of the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT). This product includes software developed by and/or derived from the Globus project (<http://www.globus.org>).

REFERENCES

Foster I, Kesselman C. The grid 2: Blueprint for a new computing infrastructure. 2nd ed. San Francisco (CA): Morgan Kaufmann Publishers; 2004.

Hyvarinen A, Oja E, Karhunen J. Independent component analysis. New York: John Wiley & Sons; 2001.

Kaishima T, Mizuno-Matsumoto Y, Date S, Shimojo S. The experience and practice of developing a brain functional analysis system using ICA on a Grid environment. Proceedings of the 7th Asian Computing Science Conference (ASIAN'02); 2002 Dec 4-6; Hanoi, Vietnam. London: Springer-Verlag; 2002. p. 98-109.

Mizuno-Matsumoto Y, Tamura S, Sato Y, Zoroofi RA, Date S, Tabuchi Y, Shinosaki K, Ukai S, Ishii R, Inoue K, Tatsumi H, Kadobayashi Y, Shimojo S, Takeda M, Miyahara H. Propagation of epileptiform discharges using wavelet-cross correlation analysis in MEG. Medical Imaging Technology 2002;18(1):61-70.

The Globus Alliance. Available at: <http://www.globus.org>. Presented May 26, 2004.