Development of problem solving environment system for Grid and its applications

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学位論文要旨

With the improvement of computer technologies and the expansion of network bandwidth, the concept of Grid has been born to satisfy the requirement to use many kinds of heterogeneous computer resources like one single computer system. However, even if Grid environment could be realized, there exists still very high hurdle to overcome: namely how to *develop* applications of this environment to real scientific and engineering problems. Two problem solving environments (PSE) for Grid: PIV-WL and CyberGRIP have been developed and applied to fluid phenomena and massive design simulation.

As there has existed few success story in Grid applications so far, this should be largely noted as a success story that shows concrete effect in Grid application. Further, it is indicated that collaborative research environment and CyberGRIP might have a by-product: by using these, we could transcend barriers between organizations of intra-company and inter-companies, the border of countries, etc., and change our present research and work style.

1. Computation and Grid

For nearly 40 years the marvelous march of computation progress has been linked to "Moore's Law", which refers to the doubling of chip performance about every 18 months. Further, the advance of network according to "Guilder's Law", which refers to the doubling of network band width every 9 months, is expected to contribute computation progress. As a result, at present, people can get computer power and network band width needed for computation. However, practically, people can not easily make use of such information technology (IT) resources as they want from anywhere. This is because IT resources belong to university, national laboratory, company, or organizations all over the world, and people must designate most suitable IT resource to make it possible to accomplish their computation. Namely, people must make use of each IT resource by paying their attention on the following points under security policy of each organization:

1) if IT resource can deal with their computation or not,

2) where its IT resource is

3) what characteristic such as performance or operating system of its IT resource are.

This is a very high hurdle to overcome for making use of IT resources through internet.

In order to overcome this hurdle, the concept of "Grid" was born in the United States in the middle of 1990s. This is the concept coming from "Power Grid" of electric power supply. The intention of Grid is to develop an environment which makes it possible for people to use necessary computing power without awareness of the locations and characteristic of computer resources all over the world only by accessing a thin client computer to a network port, as if people can use necessary electric power by inserting a plug into a wall socket.

The Grid has a structure of four layers: infrastructure layer which consists of computer systems, network equipments, experimental instruments, etc., common services (or Grid middleware) layer to hide many heterogeneous IT resources, programming tools and problem solving environment (PSE) layer which enables people to develop applications on Grid, and application layer which consists of data-intensive computing, high throughput computing, collaborative computing, distributed computing and on-demand computing. Most of researches related to Grid have been devoted to Grid middleware. There are two famous Grid middleware. Globus toolkit is developed by Globus team and used mainly in the United States. Globus toolkit has resource management, information service, and data management under security function. However, Globus toolkit has disadvantages that a number of ports must be opened dynamically when people wishes to use Grid environment beyond firewall. Globus toolkit does not support Windows platform, but only UNIX platform. Therefore, job status can not be monitored on Windows personal computer (PC). The other Grid middleware is UNICORE developed by Fujitsu Laboratories of Europe(FLE) and is used mainly in European Union. The UNICORE consists of four components: UNICORE client to generate jobs, Gateway which is an access point to all resources on UNICORE, network job supervisor (NJS), and target system interface (TSI). In the case of UNICORE, it is easier to use beyond firewall than in the case of Globus toolkit. The UNICORE has been ported to Windows PC platform by us under assistance of FLE.

2. Collaborative Research Environment for Particle Image Velocimetry (PIV)

One of the most important issues of research about Grid is to apply Grid middleware to real scientific and engineering problems. The purpose of my research is to develop PSE systems using UNICORE, apply them to real problems and create some success stories of Grid. Grid applications classify into the following three categories: computational grid for virtualization of computational power, data grid for virtualization of many kinds of distributed data bases and file systems, and access grid to realize collaborative research environment on internet. Among these three, access grid and high throughput computing in computational grid are challenged in this dissertation.

Particle image velocimetry (PIV) is one of the most important experimental methods for fluid flow studies, which is made all over the world. Unfortunately, fluid flow researchers have no their own PIV collaborative research environment which makes it easy for them to use high performance computer, large scale storage, and advanced visualization computer for such calculations as velocity vector, kinetic energy and digital image processing. Further, PIV is extending from two dimensional to three dimensional experiments in response to their needs of higher accuracy. An collaborative research environment has been developed, which makes it possible PIV researchers to publish their own data, to retrieve where the useful data are, and to exchange PIV information each other through internet. This environment could release PIV researchers from having their own high performance computer, large scale storage, and advanced visualization computer at their sites. From the point of view of Grid, this is to develop real application of access Grid.

The access Grid, PIV web laboratory (PIV-WL) has been developed step by step. At first, the PSE system called PIV web visualization (PIV-WV) was developed using Globus toolkit, programming language Java and Java Servlet. This system has "Grid portal" which enables researchers to view the visualization resources on the network as a unified whole. It combines "two dimensional Korea Maritime University - PIV (KMU-PIV)" as PIV software on visualization server in KMU with a nonlinear video editing system in Kanazawa University (KU). Therefore, PIV researchers have not to have their own powerful visualization computer with advanced computer graphics (CG) package at their site.

With an evolution of PIV experiment from two dimensional to three dimensional measurements, an increase of PIV applications, and rapid change of PIV technique, PIV researchers wish to have environment for PIV collaborative research using powerful computer resources. According to this demand, computer resources such as high speed computer, large capacity storage devices, and advanced visualization system are needed for reducing the central processing unit (CPU) time to compute many velocity vectors distributed in three dimensional space and to visualize the images of physical quantities with advanced CG technique. Thus, the PIV-WV has been extended to PIV collaborative research environment called PIV-WL, using remote real time image processing (R2TIP) system which is newly developed using visualization package "Amira", remote control software "VNC (virtual network computing)", and a web camera. The R2TIP is available under multi-user environment. To avoid two disadvantages of Globus toolkit mentioned before, UNICORE has been used for the development of PIV-WL. One access method called "Pallas client" by graphical user interface (GUI) has been available thus far. The new interface is needed to make use of computer resources flexibly: UNICORE application program interface (API) and broker has been developed. The PIV-WL developed on UNICORE using UNICORE API, broker, and Java language includes three dimensional stereo KMU-PIV, Grid portal, data base, animation server with Amira, and client PC. The portal server makes it possible for researchers to input the instructions to use the resources of PIV-WL. All related data obtained from PIV experiments are stored in data base system, and search engine of data base helps researchers who wish to search the data stored in data base system.

The PIV-WL has been used to analyze flow characteristics of delta wing of a jet fighter. The turbulence kinetic energy of the delta wing with leading edge extension (LEX) has been compared with the energy of the delta wing without LEX. The PIV-WL has shown that one with LEX is more effective for reducing turbulence kinetic energy than one without LEX. The PIV-WL has been tested by accessing animation server at KU from Texas Agriculture and Manufacturing University (TAMU), KMU, etc. It has been shown that researchers can manipulate animation server freely transcending borders between countries. Moreover, we have visualized the results of micro test section of couette flow experiment made by TAMU.

3. High Throughput Computing using Cyber GRid Innovation Platform (CyberGRIP)

High throughput computing is known to be useful in such simulations as computer aided design (CAD), financial engineering, etc., where massive simulations play an important role. It is quite difficult for any private enterprises to purchase such expensive high performance computer as supercomputer under the recent economic slump. On the other hand, private enterprises make poor use of their computing power of their servers and PCs. There are mainly two reasons for this poor usage: the first is that servers and PCs are purchased for their particular applications by each department or section and it is necessary to transcend barrier of vertical organization in a company. The second is that it is technically cumbersome to develop a cluster system with servers and PCs and to use its cluster system. It is expected that there is a possibility that Grid technology might shed light on the problem.

For making a significant improvement over high throughput computing, a PSE has been developed.

To execute massive simulations efficiently, there are two issues. One is to realize the system to make it possible to submit massive jobs efficiently without considering the status, performance, operating system and etc. of computational resources and the situations of jobs under executing. The other is to develop the mechanism to be able to utilize all computational resources efficiently as much as possible. To solve these issues, we have developed a PSE named cyber Grid innovation platform (CyberGRIP) for high throughput computing.

In CyberGRIP, UNICORE has not been used as middleware for Windows PC from the following reasons: requested smaller memory size than UNICORE, easier to install on Windows PC than UNICORE. Therefore, we did not apply UNICORE for CyberGRIP.

The CyberGRIP consists of mainly three parts: organic job controller (OJC) for controlling jobs, Grid resource manager (GRM) for monitoring the status of computational resources and submitting jobs after deciding most suitable resource for submitted jobs, and Grid mediator for Windows (GMW) using in office for ordinary works to make it possible to execute jobs by using surplus CPU power. For the server resources based on Solaris or Linux, Condor is installed, so that jobs can be submitted through GRM. The OJC consists of web portal, viewer interface, interpreter for OJC script, inventory database, local script interpreter, job submit part and interface part for outer batch job environment. When the user would like to submit jobs, the user access web portal and the user activates OJC interpreter by submitting OJC scripts prepared beforehand by the user, binary files such as simulation programs and etc. through browser. OJC analyzes OJC script described by user, and submits jobs to GRM one after another according to the results of analysis. The user designates the ranks of jobs as additional information on web portal when the user submits jobs. When the job is submitted from OJC, GRM decides the most suitable computational resource to execute the job referring this rank information, and submits the job to Condor or GMW (server). The level of jobs can be categorized into five ranks according to the load of job execution. On GMW (PC), the priority of jobs submitted by the user is set up automatically as lowest level on Windows operation system, so that the owner of PC continues to use PC without any disturbances and any awareness that the jobs are running as background jobs.

We have developed tools to enable us to develop Grid environment in which the user can submit their jobs not only to Solaris and Linux servers, but also Windows PC used for office works. Namely, we have realized the virtualization of computational environment incorporating not only Solaris and Linux servers, but also Windows PC.

Although the CyberGRIP is a PSE to execute efficiently massive simulations, CyberGRIP is not always suitable for any kinds of simulations. In the case of the parallel computations which require large volume of communications between cells for computations such as the simulations using molecular dynamics method and to solve Navier-Stokes equations, it should be adopted the computational system which nodes are connected with high speed network such as PC cluster. This PSE is useful for the simulations which are based on Monte Carlo method or which are able to be divided into small calculations under the conditions such as time, space or conditions.

With the recent high performance of mobile terminal, the developers of this domain encounter the high level issues which are too difficult to solve. Especially, one of the main factors is the existence of radio wave. The states of radio wave change largely according to such air conditions as the route of transmission which depends on geographic conditions and natural phenomena. Therefore it is necessary to do massive simulations to generate various conditions of transmission for development of mobile communication system. The CyberGRIP was used to improve the efficiency of the design of mobile communication system. As a result, it has been shown that we can reduce the simulation turn-around-time for the design of mobile communication system (exchange system for oversea market) to one fourth, and to cut down man-power necessary for setting parameter and controlling jobs on one fourth. As there has existed few success stories in Grid applications so far, this should be largely noted as a success story that shows concrete effect in Grid application.

4. Conclusions and Future Plans

I have developed two systems of PSE on Grid. The first is on demand computing system by using Grid common service tool "UNICORE", programming language Java, and some server systems. This system is applied to fluid flow research as PIV-WL with PIV server based on "three dimensional stereo KMU-PIV" developed by Korea Maritime University, Grid portal, broker, database, animation server based on "Amira" developed by ZIB, and client PC. I have realized practical use of PIV-WL for the analysis of flow field. Thus, I could establish the basic global collaborative research environment for the research of flow field by means of international cooperation with Korea Maritime University, Texas A&M University, Konrad-Zuse-Zentrum für Informationstechnik Berlinve (ZIB) and Kanazawa University.

Concerning CAD-Grid System based on CyberGRIP, it has been shown that, when used with CyberGRIP, we can reduce the both of simulation turn-around time and manpower of the design for mobile communication system to one fourth. As there has existed few success stories in Grid applications so far, this should be largely noted as a success story that shows concrete effect in Grid application. In near future, I am going to extend the application domain not only for mobile communication system, but also for logic simulation of LSI, noise simulation and the simulation for the analysis of electromagnetism.

Further, it is indicated that PIV-WL and CyberGRIP might have a by-product: by using these, we could transcend barriers between organizations of intra-company and inter-companies, the border of countries, etc., and change our present research and work style.

The PIV-WL and CyberGRIP are expected to extend their applications not only PIV or development of mobile communication system, respectively, but also other applications domain such as material design, the analysis of electromagnetism and so on.

学位論文審査結果の要旨

平成16年1月30日に口頭発表、その後に学位論文審査委員会を開催し、慎重審議の結果以下の通り判定した。なお、口頭発表における質疑を最終試験に代えるものとした。

近年、複数の異質なコンピュータ資源をあたかもひとつのコンピュータシステムとして利用するためにグリッドという概念が生まれたが、実際に適用するにはアプリケーションに適した問題解決環境 Problem Solving Environment（PSE）の開発が課題である。本論文では、流体の協調研究のための PSE である PIV Web Laboratory（PIV-WL）を開発し、航空機のデルタ翼の上の流体現象の解明やマイクロテストセクション中の Couette 流の観測のために大変有効であることを検証した。この開発において韓国海洋大学、ベルリンツーゼ情報技術研究所、Texas A&M 大学と連携し、流体研究における国際協調研究基盤を実現した。また企業内の IT 資源を有効活用して大量計算を効率的に実行するため PSE として CyberGRIP を開発し、シミュレーション時間と工数をともに4分の1に削減出来ることを示した。これまでグリッドを活用した成功事例が数少ない中で、この成果は注目すべき貴重な事例である。さらに PEV-WL および CyberGRIP により組織間、企業間、国家間の壁を取り除き、新たな研究スタイルやワークスタイルを実現した。

以上の研究成果は、学術的価値が国際的レベルにあり、流体解析およびグリッドへの貢献度は高く、本論文は博士（理学）に値するものと判定した。