

PIV Web Visualization System Toward PIV Visualization Grid

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Abstract: To visualize the simulation and experimental data, the fluid dynamics scientists and engineers have to possess a powerful visualization engine with CG package in their laboratories. We developed a Problem Solving Environment (PSE) system called "PIV Web Visualization System" to solve this obstacle, using computational grid common service tool "Globus", programming language Java and Java Servlet. This system has "Grid Portal" which enables us to view the visualization resources on the networks as a unified whole and can be accessed around the world through the Internet, and it combines PIV engine "KMU-PIV" on visualization server in Korea Maritime University with a nonlinear video editing system on Kanazawa University as a real application.

Keywords: PIV, Web visualization, Visualization grid, Computational grid, Globus.

1. Introduction

Visualization is one of the most useful methods for understanding fluid dynamics phenomena. However, several obstacles to overcome remain before fluid dynamics scientists and engineers can visualize their simulation and experimental data: they must learn computer graphics (CG) technique and how to use CG packages, and it is necessary for them to possess a powerful visualization engine with CG package in their laboratories. An attempt to solve these two former obstacles has been made (e.g., Toriyama et al., 1999) from the point of view that establishes software interface between simulation and measurement data and software package AVS(Advanced Visual Systems, Inc., 1998). Here, an approach is given to solve the latter. Computational grid technique (e.g., Foster et al., 1999) is utilized for remotely visualizing the data from the Particle Image Velocimetry (PIV) which is a

state-of-the-art quantitative flow velocity measurement technique (e.g., Lee, et al., 2000). Computational grid has the following four layers: infrastructure, common services, programming tools/problem solving environment (PSE), and applications. The purpose of this paper is to develop PSE system called PIV Web Visualization System using grid common service tool “Globus” (<http://www.globus.org>), programming language Java, and the computer system named by us Grid Portal which allows us to view the visualization resources on the networks as a unified whole. The PIV Web Visualization system combines PIV engine “KMU-PIV” (Image Information Technology Co., Ltd., 2001) on visualization server in Korea Maritime University (KMU) and a nonlinear video editing system on Kanazawa University (KU). Recently, we have enhanced some functions to be more useful for fluid dynamics scientists and engineers. In this paper, we introduce not only PIV Web Visualization system (e.g., Kadooka et al., 2002), but also enhanced functions.

2. PIV Web Visualization System

2.1 Passage to PIV Visualization Grid

The PSE system for research and development of material design using the molecular theory called “Web Molecular Simulation Support System (WMS3)” (e.g., Kobashi et al., 2001) has been already developed and tested on LAN (Local Area Network) in Kanazawa University (KU) campus. The WMS3 includes the following three subsystems: 1) network computing subsystem which makes it possible to run molecular dynamics program through LAN, 2) remote visualization subsystem using POV-Ray (<http://www.povray.org/>), AVS and Open GL (e.g., Woo et al., 1999, or <http://www.opengl.org/>), and 3) MS - Word based report subsystem. In WMS3, it is possible to use computer resources only by assigning URL. One can easily run molecular dynamics simulations on the network computer subsystem. The numerical data obtained are converted to XML (Extensible Markup Language: <http://www.xml.org>) format. The visualization is made using visualization software on server, but not on client. As a result, one can visualize and view, through a browser on client, any kind of molecular assembly. The PIV Web visualization system is an extension of this remote visualization subsystem of the WMS3 to grid visualization through web between KU and KMU.

2.2 Development of PIV Web Visualization System

Our target of this research is to realize collaborative research environment of fluid mechanics through Internet based on Grid. We tried to develop a system according to Grid Layer to solve this problem as shown in Fig. 1. Namely, infrastructure is composed by Linux and Windows. Globus Toolkit is used for service layer. As programming tool, we tried to develop a new PSE. Application layer is “KMU-PIV”.

In the development stage, we met some obstacles which we must overcome to develop this system. First of all, this system should be used by any researchers independent of their environment. However, Globus can be installed only on UNIX. The first issue is how we can access to Globus from Windows based clients. To solve this issue, we have constructed “Grid Portal” to be able to access from Windows based clients. Namely, when

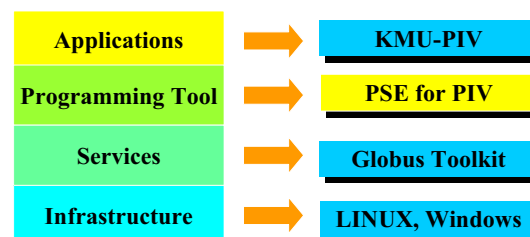


Fig. 1. Grid Layer for PIV Web Visualization.

Windows users desire to use this system, they access to Grid Portal. Then, they input the data necessary for extracting the result of PIV experiment. These data are sent automatically to Java Servlet by Java function on Web Portal. And Java Servlet sends these data to Globus. As a result, Globus is not necessarily to be installed on Client machine. In the original system, an applet was downloaded on client machine to access KMU-PIV from Web Portal. In advanced system, JSP (Java Server Page) technologies are adopted to make it easy to use.

The “KMU-PIV” is available only on Windows environment, but not on UNIX environment where Globus is available, and has no Application Program Interface (API) to make it possible to access through network, because “KMU-PIV” has been developed by Delphi on Windows as the stand-alone system for PIV experiment. The second issue is how we can embed KMU-PIV based on Windows in Globus environment. To make “KMU-PIV” engine to be embedded easily in Globus environment as it is, we have developed the “Bridge” to embed “KMU-PIV” function in Globus environment (Grid system) and the “Wrapper” to activate “KMU-PIV” program remotely using Java and Java Servlet technologies as shown Fig. 2. This Bridge sends the request of researcher to KMU-PIV and receives the extracted data by the communications between Globus and Java on Linux. In other words, Bridge works as the bridge between Globus environment and KMU-PIV.

KMU-PIV generates many animations. The third issue is easy and speedy extraction of animations generated in KMU-PIV even through narrow band. For this purpose, we have newly introduced nonlinear video editing system in our Grid environment to generate animation from many stills output by “KMU-PIV”. This system has the function to specify some image files of physical quantities which are really necessary part for the researcher. Furthermore, we constructed this animation server on Grid Portal, so that it can be extracted the animation files whenever the researcher desires to after the file has once extracted from KMU-PIV.

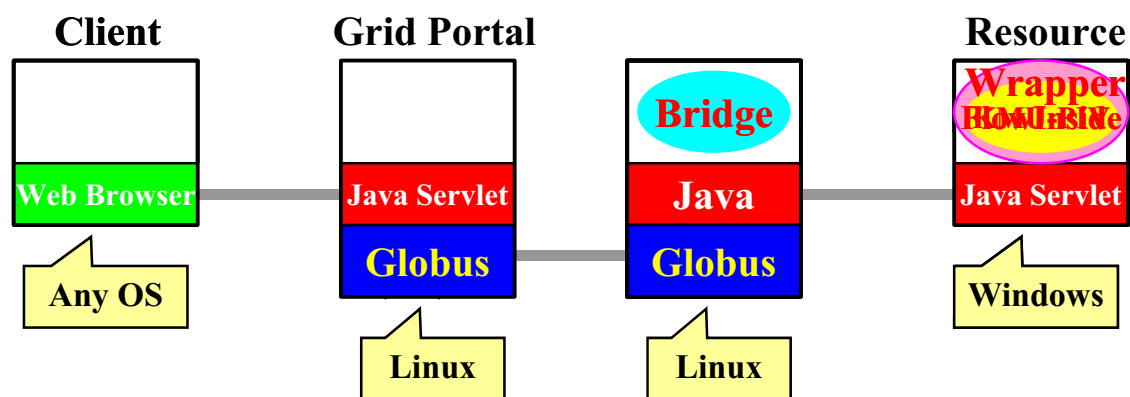


Fig. 2. How to access to KMU-PIV.

As a result, we have developed the “Grid Portal” to integrate these functions as a unified whole in our Grid environment, so that many fluid dynamics scientists and engineers can use “Grid Portal” as PIV Web Visualization System through Internet wherever PIV engine and Animation server are located on as shown Fig. 3.

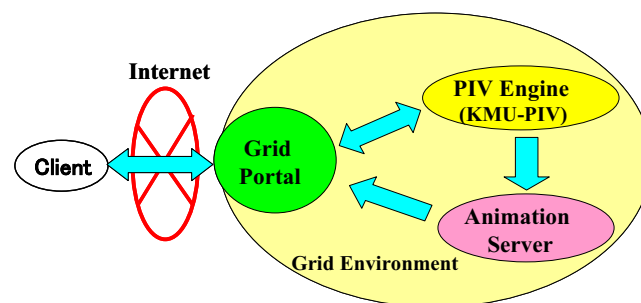


Fig. 3. PIV Web Visualization System.

2.3 Functions Realized through Grid Portal

The following four functions are prepared in this Grid System:

1) User Registration and Login on Grid Portal

The researcher or engineer can use this PIV Web Visualization System by doing user registration at once, and login for every access on Web page of Grid Portal as shown Fig. 4.

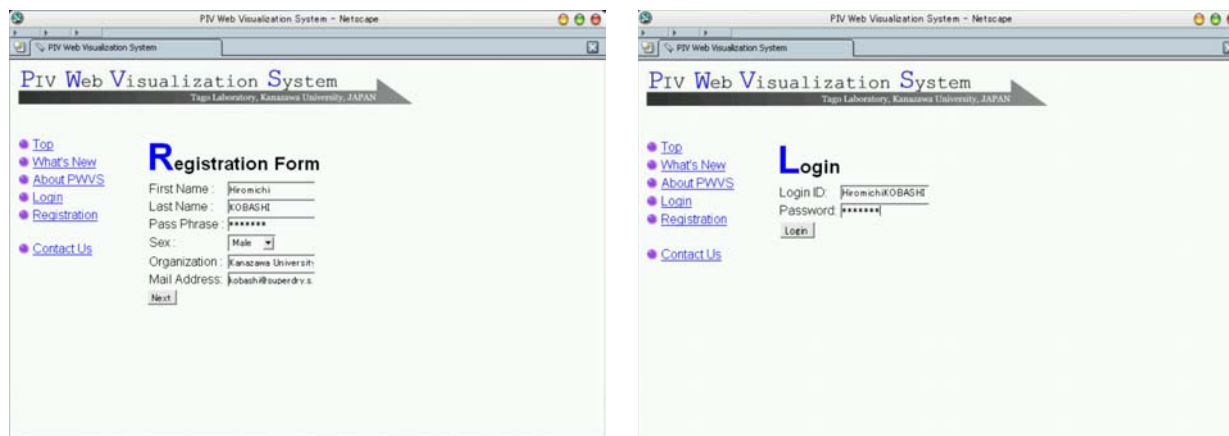


Fig. 4. User Registration and Login.

2) Extraction of PIV Images

The user can point out the results of experiments one wishes to view, thus, extract the related PIV images generated by “KMU-PIV” such as velocity vectors, kinetic energy, vorticity, turbulence intensity, etc. The examples of Web browser for pointing out are shown in Fig. 5.

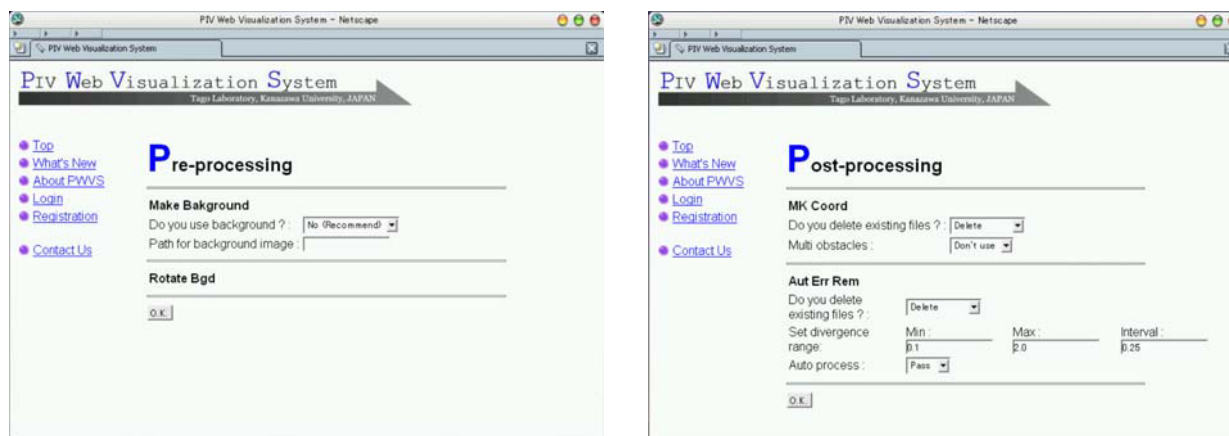


Fig. 5. Pre- and post-processing for viewing the PIV images of various physical quantities.

3) Generation of Animation of Physical Quantities

Velocity vectors and physical quantities created on PIV engine are sent to Visualization Server through Grid Portal by request of user. On this server, PIV animation is generated by using nonlinear video editing system and transported by Streaming technique, and finally can be viewed on the Web browser of the user.

4) Synchronized Visualization of Physical Quantities

In KMU-PIV engine, we can not show results of calculation of various physical quantities on display at the same time in every time step. We have developed this function on PIV Web

Visualization System. Four physical quantities are displayed according to the designation of user on Web as shown Fig. 6.

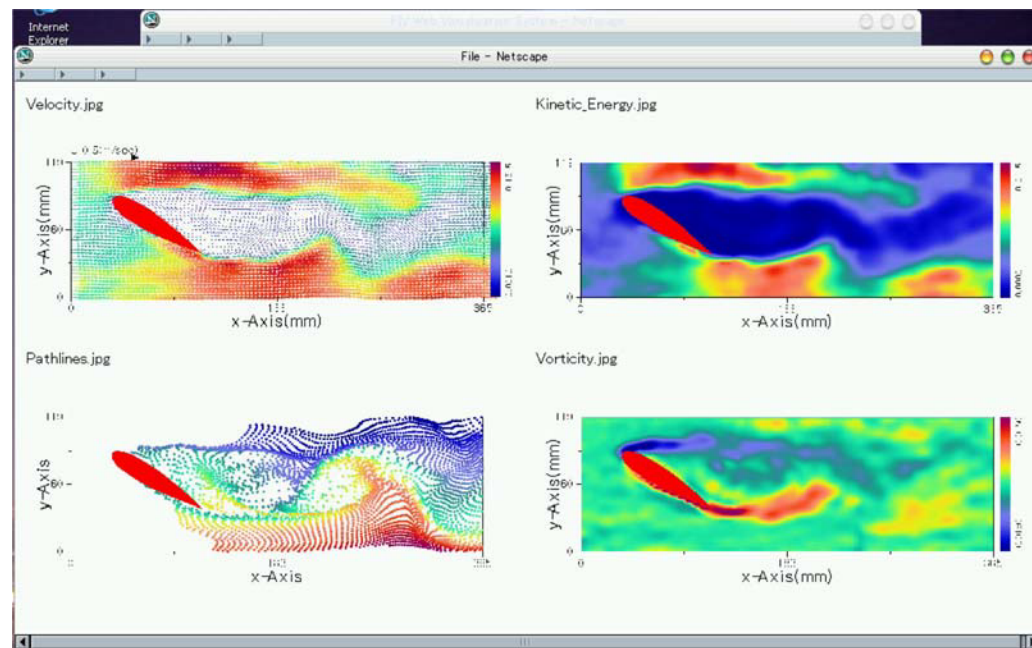


Fig. 6. Example of Synchronized Visualization.

2.4 System Configuration

We have constructed Grid Environment based on Globus in KU, and embedded “Grid Portal”, “Animation Server” and “Bridge” function in this environment. On the other hand, we have installed PIV engine and “Wrapper” function on the same Windows server in KMU. The PIV Web Visualization System has been realized by integrating these functions as shown in Fig. 7. The blue lines show Globus to Globus communication, and the red lines show the communications using Java.

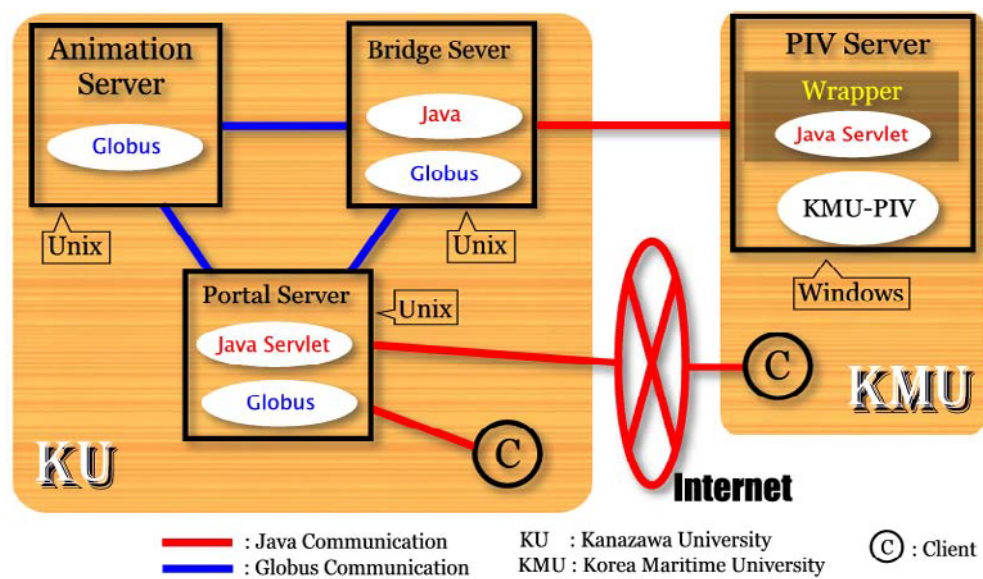


Fig. 7. PIV Web Visualization System.

In Table 1, we show the functions of each server, hardware platform, operating system and installed software on each server. We have developed PIV Web Visualization System using de fact standard technologies as shown in Table 1. It means this system is not proprietary, but has the possibility to be extended not only to KMU-PIV, but to many other PIV engines.

Table 1. Functions of Server and Client.

Site	Type	Functions	Platform	Software
KU	Portal Server	- User Authentication - WWW Server to define user interface (GUI)	- Linux Redhat 7.3 - Xeon1.5GHz x 2 - Memory: 512MBytes	- Globus Toolkit2.0 - Tomcat3.2.4 - Apache1.3.22
	Bridge Server	- Protocol Conversion between Globus Environment and Windows Platform	- Linux Redhat 7.3 - PentiumIII,866MHz x 2 - Memory: 1GBytes	- Globus Toolkit2.0 - Java2 ver.1.4 - MPEGEncode1.5b
	Animation Server	- Non-linear Video Editing - Converter from JPEG images to MPEG file - Streaming MPEG file		
KMU	Wrapper (Server)	- Execution of PIV engine - Conversion from BMP to JPEG files	- Windows - PentiumIV,1.4GHz - Memory: 512MBytes	- Tomcat3.2.4 - KMU-PIV3.0
	PIV Server	- PIV Visualization (Still images)		
KU/KMU	Client	- Access to "Grid Portal" - Presentation of the PIV image data	Any	- Web browser

2.5 How to work PIV Web Visualization System

The fluid dynamics scientists and engineers who desire to see the result of experiment by PIV engine in KU access "Grid Portal" through Internet, on which the user is authenticated the right to access this system. The user designates its request by GUI (Graphical User Interface) of Java Applet downloaded from "Grid Portal". This request is transmitted to Java Servlet of "Grid Portal", and then to "Bridge" by means of the Globus-Globus communication method. The "Bridge" communicates with "Wrapper" in KMU by Java communication method to activate PIV engine, namely "KMU-PIV", by request of user. As the response of this request, the physical quantities created on PIV engine are converted to JPEG files on "Wrapper", and sent back to "Bridge". The "Bridge" sends these data to an appropriate server in Globus environment. If user requests to extract PIV images, then these images are sent to the client as JPEG files and viewed through Web browser of this client. If a user desires to see animation of streak lines, then PIV images generated in "KMU-PIV" are sent to "Animation Server", and converted to animation (MPEG) file.

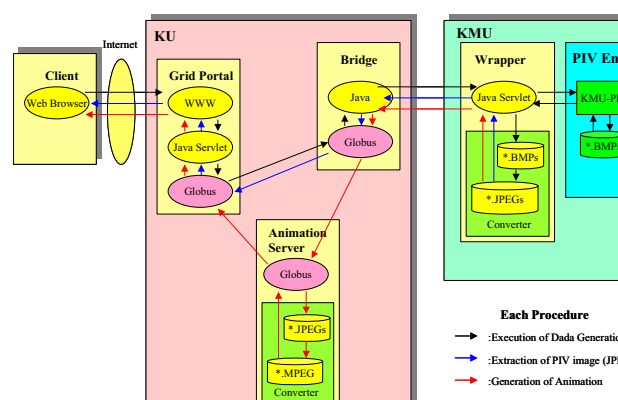


Fig. 8. How to work PIV Web Visualization System.

This animation is transmitted to the client terminal by streaming technique and is shown on Web browser having pre-installed plug-in software for MPEG decoding.

3. Results and Discussions

The velocity vector of PIV measured in two-dimensional fluid field and the physical quantities calculated by this velocity vector have been visualized remotely using PIV engine in KMU by user through Grid Portal. Figure 9 shows the example extracted by this system. As a result, it was possible for each party to use one combined powerful networked visualization resource from each client. In the next stage, we are going to develop the function by which many users will be able to access simultaneously to the same data of KMU-PIV. As a result, any fluid dynamics scientist and engineer, if he or she desires, could see the results of experiment taken by using PIV system from anywhere by accessing to "Grid Portal" through Internet, and they could discuss via on-line about the results of experiment, viewing the same data (not only still data, but animation file) in Grid environment, on all over the world. This situation is not restricted in the experimental environment using KMU-PIV, but will happen to any other experimented environment by developing interface functions, because our system has been developed on de fact standard technologies to access to KMU-PIV. In the near future, the collaborative researchers would require to seeing simultaneously the same animation as the results of PIV experiment generated in PIV Web Visualization System. We are going to prepare the function which make it possible to transmit these streaming data as one same synchronization tasks by using VNC server (<http://www.realvnc.com/>).

On the other hand, the needs for three dimensional PIV experiment are increasing rapidly day by day. To meet this expectation, however, it is clear the powerful computational resources and large scale data storages should be prepared for the fluid dynamics experiment environment. With the expansion of broadband network, we think the issue to respond to this needs could be solved by adopting Grid Technologies such as Grid Computing and Data Grid.

Our final goal is to realize the system to satisfy the above mentioned needs, by enhancing "PIV Web Visualization System".

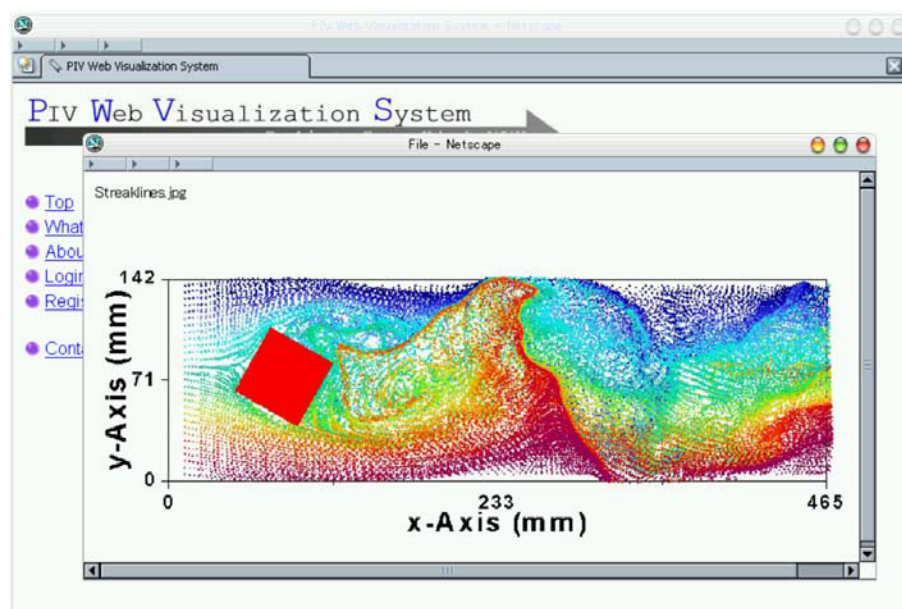


Fig. 9. Example of the result extracted by PIV Web Visualization System.

4. Conclusions

We have developed the PSE system called Advanced PIV Web Visualization System using grid common service tool “Globus”, programming language Java, and some server systems. The system is composed of PIV engine “KMU-PIV”, Grid Portal, Bridge, Wrapper, Animation servers, and client PC. It has been shown that, between KU and KMU, the PIV Web visualization system could be treated as if it were one powerful visualization computer. The volume rendering of PIV measured in three-dimensional flow field is planned by using this system. The system could be a quite useful PSE system for PIV on Grid, when used with any other networked computers in the world.

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