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Title: A Grid-enabled Scene Rendering Application
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1 Introduction

In this paper is shown a 3D image generation application, in which Grid tools have been used to improving it with certain interesting characteristics, as the possibility of run remote jobs. This type of tools provides some characteristics like uniformity, transparency, reliability, ubiquity and security [4] that are very important at distributing an application over Internet. The Globus Toolkit 2 has been the selected tool since is one of the most used and is a reference in the Grid world.

This work is an extension of the research project "VRE-Commerce: High Performance Virtual Reality Distributed Electronic Commerce: Application for the Furniture and Ceramics Industries" [1]. VRE-Commerce was an EU-funded research project, finished in March of 2002 and coordinated by the GRyCAP, which aims at developing all the necessary technology for the integration of low-cost fast synthetic image generation in electronic commerce applications.

This application gives the user the possibility of obtain 3D realistic images. To render the images the radiosity illumination algorithm [6] has been used. This algorithm obtains high realistic images, and the calculations must be done once per scene. In order to use this algorithm in a electronic commerce application, the response time must be lower than one or two minutes. This restriction makes necessary to use parallelization to obtain response times within these limits.

2 The VRE-Commerce Prototype

The two main parts of the system are the following:

- The web server and the electronic commerce system installed in it. This virtual store has an up-to-date catalogue of products and might be also connected to the company's back-office. The virtual store also contains the *Room Planner* tool.
- The computational server in charge of generating the realistic image that will be shown to the user, produced by the parallel radiosity kernel. It can be a cluster of PC's, for example.

The VRE-Commerce system is depicted in Figure 1. The client access the system by Internet using a standard browser to connect with the web server, where he will find the company product catalogue and will be able to choose those that interests to him. Later he will go to the 2D room design, *"Room Planner"*, where he will be able to place the objects previously selected, as well as to complete the room with other auxiliary objects (doors, light points...) to produce a greater realism.

Once the room has been designed, the user must select the point of view to obtain the 3D image of the room. Then he will make the request of image generation that will be sent to a CGI program located in the web server, that will be in charge to sent the request to the computational server. The application

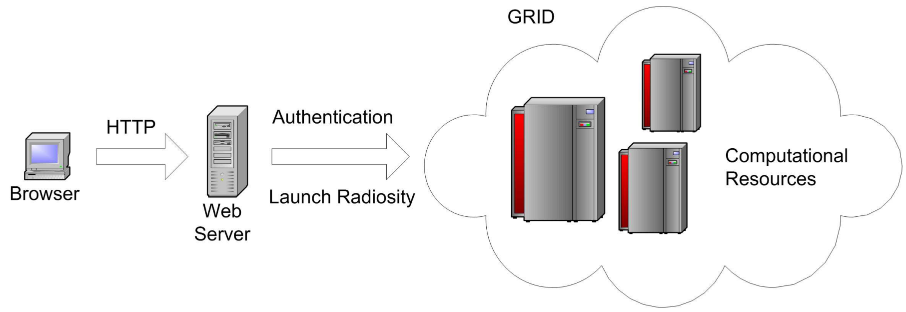

Fig. 1. VRE-Commerce System.

uses Grid tools to launch remotely the jobs to the system without worrying about the exact location where the calculation processes will be finally located.

Initially it is needed to authenticate in the Grid. Once authenticated is possible to use all the available resources, since the Grid provides the characteristic of single sign-on to all of them.

Once the request has been sent, the system is in charge to search the available resources, and launch the application in the most suitable resource. Another important characteristic would be the fault tolerance, so that the system assures that, in case of failure of some of the resources, the task would be sent in another resource, assuring therefore the work completion.

Once the job is finished, the system will notify about the conclusion and will send the result, in our case the image generated by the 3D application.

3 Prototype Implementation

In this section it is shown the implementation of the prototype, using the tool that has been selected, the Globus Toolkit 2 [3], [7]. The complete operation of the VRE-Commerce application, with the Grid elements that the Globus Toolkit 2 contributes is depicted in the Figure 2.

Initially the client connects with the virtual store located in the Web server, and makes the image generation request. When the request arrives at the Web server, a CGI program (linked with the Globus librarys), using calls of the Globus API, is in charge to make the request of launching the radiosity program to the Grid, It follows the steps described next.

3.1 Search information about Grid resources

To obtain information about the available Grid resources it has been used the MDS (Monitoring and Discovery Service) [2] available in the Globus Toolkit.

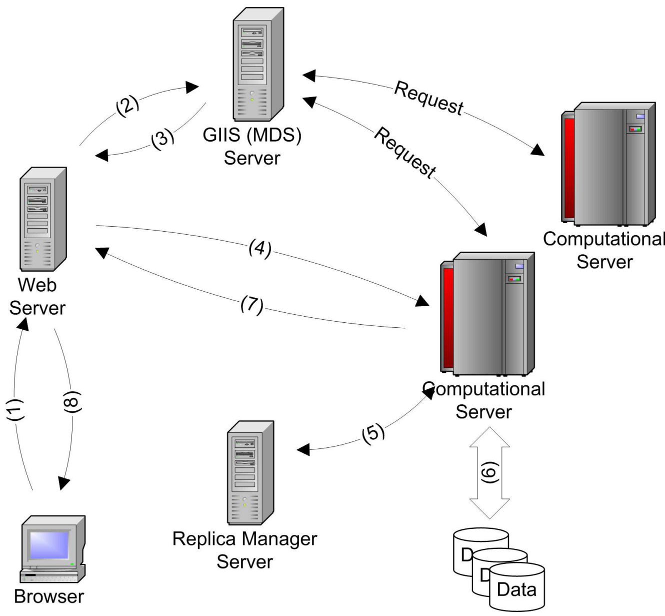

Fig. 2. VRE-Commerce scheme with Globus Toolkit 2.

To search all the available resources the program must connect with the GIIS (Grid Index Information Service) server, a part of the MDS service. The GIIS server has some Grid resources registered. This registered resources have other component of the MDS system, the GRIS (Grid Resource Information Service) server. When a somebody asks for information to a GIIS server, it connects with the GRIS server installed in the Grid resources to obtain information about the resources.

The GRIS server stores the necessary information in order to select the suitable computational server: number of CPUs, amount of memory, drive space, etc.... In that case, has been added some extra information to add more flexibility to the system. The GRIS server inform about the installation of the radiosity program in the resource, as well as the complete path the radiosity program is installed (although it would be possible to send the program to each Grid resource, it is not viable to send it due to the size and the number of files needed to work).

The CGI program uses the information provided by the GRIS server in order to select the suitable resource. The information used is the number of free nodes, always having in mind that the radiosity program must be installed.

Using this information it chooses the most suitable, as well as the number of nodes to use to launch the program. If there isn't enough free resources, the program will inform the user to wait and try later (steps 2 and 3 in the figure 2)

3.2 Launching the job

Once chosen the suitable server, the CGI program connects with the GRAM (Globus Resource Allocation Manager) server to make the request of launching the radiosity program. Before launching it is necessary to create the *proxy*, a file where the certificate and key of the Globus Grid are stored, used to authenticate within the Grid. Once authenticated, the job is launched to the remote resource (step 4 in the figure 2). In this case a PBS queue system has been used to manage the cluster usage.

Once the job has been launched, the GRAM server returns an identifier used to verify the request state, testing if it has finished. Using this identifier it is possible to stop the job.

When the job is finished the program uses the I/O functions provided by the GASS (Global Access to Secondary Storage) service to send the generated image by the radiosity program to the Web server (step 7 in the figure 2). Using this functions the CGI program can gather the image with no need of modification of the radiosity code. At last the web server will show the image in the client's web browser (step 8 in the figure 2).

3.3 Update geometrical data files

The radiosity program uses a set of files with the furniture geometrical data used in the scenes. These files belong to the different manufacturers using the application. In each computational server there are a set of local files used in the image generation. The application adds the possibility to update this files by the manufacturers, as well as to add new ones. In the ceramics case the updated files are the ceramic tiles textures.

To do it has been used other Globus component, the Replica Manager. This service is used to manage sets of files and its physical locations. Using this service a manufacturer can put in a FTP server its geometrical data files, and then register them in the Replica Manager, indicating its name and location.

The radiosity program analyzes the scene looking for the furniture or ceramic pieces used, and then, using the Replica Manager, looks for its location (a FTP server) (step 5 in the figure 2). Once obtained the location, the remote and the local files are compared, if the remote file is newer, or the local file doesn't exist, the program download it (step 6 in the figure 2).

Once verified the furniture or ceramic files, the parallel radiosity program is executed, which gives back an JPG image as a result. This image is sent to the CGI program which shows it to the client's web browser.

3.4 Component Distribution

There are many possible distributions of the system components, since one of the basic characteristics contributed to the application by the Globus Toolkit is the flexibility on the distribution of the components. To obtain better performace the components must be interconnected by means of high bandwidth networks.

In a typical configuration, the system elements would be distributed this way:

- Web Server: It would be inside the company's (furniture or ceramics) local network, or in some server located in a ISP (Internet Service Provider).
- GIIS Server (MDS): This server will act as the access point to the Grid resources. The Grid resources, although could be provided by the own manufacturing company, are usually provided by an external organization with computational resources available.
- Computational Server: The computational Grid resources will be inside the local network of the organization that provides all the Grid services (although given the Grid philosophy they could be distributed anywhere).
- Replica Manager: Usually it is in the GIIS server machine, since this machine is used as the access point to the Grid and must be well connected with all the Grid resources.
- FTP Servers: The FTP servers with the furniture geometrical data or the ceramic textures, like the web server, would be inside the company's local network, or in a ISP.

4 Results

Some tests has been made to verify the operation and the performance obtained by the global system. Four test cases has been used to measure times to verify the overload produced by the Globus components. The chosen scenes are typical examples of the scenes that can be designed with the VRE-Commerce application. The generated images are shown in Figure 3.

The times measurement is started in the moment the user push the *"Generate Image"* button in the web page, and finished when the request has been processed and the system starts to send the result image, since that time depends of the client Internet connection and should be very variable. There are several components that affect this time:

- Time consumed obtaining information about the computational server available in the Grid, contacting with Globus MDS service.
- Network time consumed by the CGI program to the shipment of the request of the radiosity algorithm in the computational server.
- Time consumed by the Globus system since it receives the request until this indeed is sent to the computational server.
- Consumed time since the execution has finalized until Globus notifies that it has finalized. This time depends on the frequency, established by Globus, of program finalization test. Globus establish this time in 30 seconds, which is a very great time, so this time has been reduced to 2 seconds (modifying the Globus source code) so that the wasted time has been reduced considerably.

– Time consumed by the program in charge of the update of the geometric data files (without including the possible shipment of these files). This time includes obtaining the files location contacting with Replica Manager, as well as the verification of the files modification date contacting with the FTP server (in the test cases in the same local network of the computational server).

Table 1. Scenes used for performance evaluation.

Scene	Polygons	Patches	Lights	Radiosity	Globus	Total
Ex. 1	2.426	28.562	2	46	12	59
Ex. 2	5.160	28.740	2	56	12	68
Ex. 3	4.908	24.372	2	60	11	71
Ex. 4	1.374	20.118	2	17	13	30

To obtain all these times separately is almost impossible, due to the intervention of different machines in the process, for that reason it will only obtain the time consumed by the radiosity program and the added time produced by the Grid functions. The time obtained for each one of the test cases in shown in Table 1, along with the initial polygon number, as well as the light number (to give an idea of the size of the problem).

The time added by the Grid part of the application is slightly greater than 10 seconds, which is a reasonable time for the response time of 1 - 2 minutes established initially in the VRE-Commerce project. Although the time consumed by Globus functions is an important percentage, it is a fixed time, so that in greater cases it will be less significant. In addition, it is possible to verify in all the test cases, the total response time always is below the initially established one.

Although, given the flexibility of the created system, it is possible to use up to 5 different machines, the tests have been made using 3 different machines, all of them within the same local network. One of the machines (the computational server) has been reused to make all the functions in which takes part Globus components.

The computational server used is a PC cluster composed by twelve IBM xSeries 330 SMP server. Each one includes:

– Two pentium III processor 866 MHz, with 256 KB cache.
– 512 MB of RAM 133 MHz.
– Ethernet 10/100 integrated.
– Ethernet Gigabit.
– S.O.: Red Hat Linux 7.1 (Seawolf), with Kernel 2.4.2-2 to multiprocessor.

The PC cluster have installed the Globus Toolkit 2.4. It is in charge of the MDS services (as much GIIS as GRIS), the Replica Manager functions, and the main function for the cluster, the computation of the parallel radiosity algorithm.

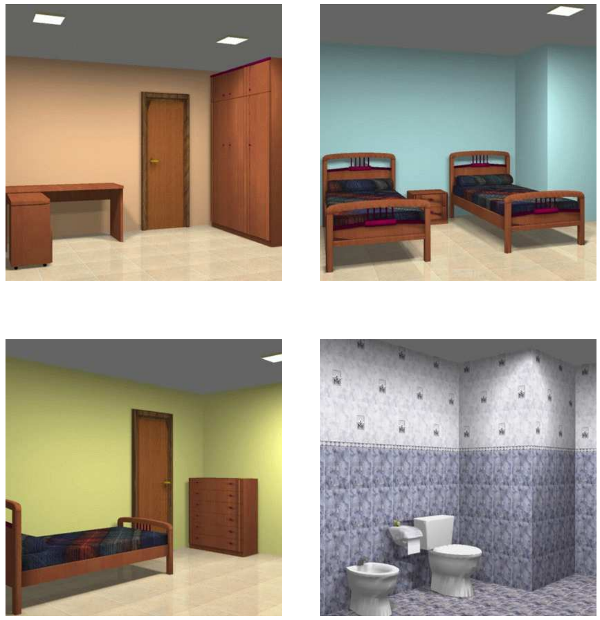

Fig. 3. Images generated in test cases.

Another machine has been used as web server, where the store catalogues, furniture and ceramics, have been stored. As tool for the development of the electronic commerce stores has been used Interchange. Interchange is an open source alternative to the commercial tools (like WebSphere of IBM used originally in the VRE-Commerce project). This tool allows the creation of virtual stores easily, in a Linux server, with the great advantage of being open source.

Finally the third machine has been used as the FTP server to store the archives, as much of the geometric data of the furniture pieces, like of the ceramics pieces.

5 Conclusions

The Grid tools provides some characteristics like uniformity, transparency, reliability, ubiquity and security that are very important at distributing an application over Internet. The Globus Toolkit 2 has been de selected tool since is one of the most used and is a reference en the Grid world.

This job continues a project consisting of an electronic commerce application with integrated virtual environment visualization, called VRE-Commerce. In this application, a parallel 3D image generation application installed in a computational server is launched from a web page. It has been used the Globus Toolkit to provide the system with all that functionality.

The system operation has been tested successfully, obtaining a system with robust behaviour towards possible network or server failures. The response times obtained, produced by the Globus tools, are reasonable for the application. The obtained times vary between 10 and 15 seconds, so the whole system obtains a response time under 60 - 120, seconds initially established as the response time limit.

The properties aported by the Grid tools to the system are:

- Scalability: it is possible to add computational servers to the system easily, so that the system automatically can use them, in a transparent way to the user.
- Fault tolerance: if some computational servers doesn't work, the system can send the request to the active ones.
- Security: the user must be authenticated to access the system, and all network data is encrypted. Although in this application there aren't confidential data, it is an interesting characteristic in other comercial application.
- The system selects the server with greater availability, so that the response time should be the shortest.
- The system can update the geometrical data of furniture and ceramic pieces.

6 Future Work

After the recent launching of the new Globus Toolkit 3, the logical extension of the system would be to migrate to the GT3 to take advantage of its new possibilities: the improvement of service GRAM with fault tolerance and mainly the possibility of adapting the application to the Grid Services of OGSA standard [5].

The use of certificates allows the possibility of making an accounting of the radiosity service uses. It would also allow to establish different execution permissions, depending on the user that access the Grid.

As much the input format as the output one could be improved in order to use a more standard and flexible format. It can be used some 3D modeling language as VRML or X3D to obtain as a result an interactive scene.

Also it would be possible to access the image generation application from standard room design applications, which already have a image generation engine that obtains low realist images, because they are thought to be used in PCs. This applications would have the possibility of generate high realistic images, launching the image generation request to the Grid radiosity application.

In order to improve the image generation, new methods of image generation could be added (as ray tracing) that could be used for another type of applications that do not need as much quality image, or that they need a faster response time. This way a more generic Grid system could be created for the synthetic 3D images generation.

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