A Feasibility Study on the Use of a Remote Supercomputer in a Collaborative Virtual Environment with Force Feedback

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Abstract: - Virtual reality technology brings numerous advantages to many different application fields and the continuous increase in computational power and network speed means that it is possible to find new methods to improve training and reduce education costs.
It is becoming feasible to realize multi-user systems via networks and interactive applications with world wide accessibility features and collaborative working without being limited in terms of location. One of the essential requirements of a realistic surgical simulator is to reproduce haptic sensations due to the interactions in the virtual environment. However, the interaction needs to be performed in real-time, since a delay between the user action and the system reaction reduces user experience. But accuracy and efficiency are two opposite requirements; in fact, increased accuracy implies higher computational time and vice versa. So, it is necessary to find a trade-off according to the application and to reduce realism in favour of the real-time interaction. In this paper a feasibility study on the use of the computational power of a remote supercomputer in a virtual reality application with force feedback is presented; the aim is verify whether real-time haptic interactions can be made in addition to a very realistic virtual environment shared among different users involved in a collaborative virtual environment application.

Key-Words: Virtual Reality, Collaborative Virtual Environment, Supercomputer, Force Feedback, Haptic Interface

1 Introduction

Virtual reality technology brings numerous advantages to different fields of application. With the continuously increasing speed of computers, surgical simulators are now being offered as a means of improving training and reducing the costs of education.
Realism and real-time interactions are the essential features for many simulations in order to be used as training systems. The realism of the simulation strictly depends on the accuracy of the virtual environment modelling and on the use of force feedback devices [1].

Therefore, the most critical issues in designing surgical simulators are accuracy, in order to generate visual and haptic sensations which are very close to reality, and efficiency, in order to obtain deformations rendered in real-time [2]. Accuracy and efficiency are two opposite requirements; in fact, increased accuracy implies higher computational time and vice versa. So, it is necessary to find a trade-off according to the application.

For some simulations, real-time visual and haptic feedbacks are more important than deformation accuracy. However, substantial differences between the real and the virtual deformations may lead to problems in learning the procedure.

In several scientific and industrial fields interaction, collaboration and communication among people are beneficial to create new ideas, to reduce the time of the training cycle and to design a high quality final product.

Collaborative Virtual Environments (CVEs) are distributed virtual reality systems which offer graphically realized, potentially infinite, digital landscapes. Within these landscapes, individuals can share information through interaction with each other and through individual and collaborative interaction with data representation [5].

In a CVE people can meet and interact with others, with agents or with virtual objects. This is very far from dedicated systems that can only be used in one location and which are designed for individual teaching without any interaction among the different users [3].

The influence of the World Wide Web as a valid Collaborative Virtual Environment medium for exchanging information and services has grown rapidly. With the great improvements in network speed, the graphic capability of computers and CPU power, it is progressively becoming feasible to realize systems used by multi-user via networks. Hence, these applications will inherit from the web its world wide accessibility feature, as well as facilitating multi-user access and collaborative working without location or time limitations [4].

The aim of this project is to apply virtual reality, computer graphics and computer networks techniques to traditional Collaborative Virtual Environment design in order to see whether it is possible to use the computational power of a remote supercomputer to build a very realistic virtual environment and to interact with this in real-time.

The idea is to obtain a new training system in which a master trains several junior colleagues (slave users) in order to improve his experience in a multi-user vision [6].

The Trainer carries out and shows the procedure to the Trainees, but also each trainee can perform the procedure; this situation is shown in Fig. 1.

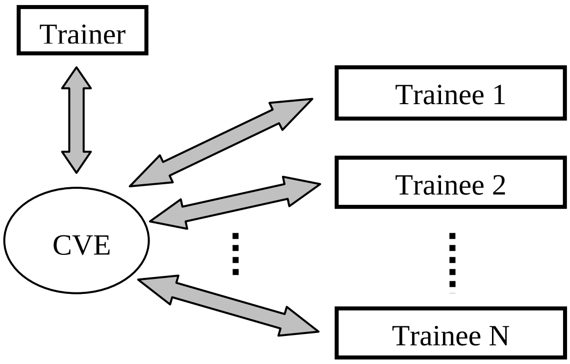

Fig. 1: Example of a CVE

The supercomputer used in this feasibility study is the Cluster Platform HP XC6000 made up of 128 Intel Itanium-2 CPUs and is located in the Center for Advanced Computational Technologies/NNL of the Salento University, Lecce. The technical specifications are reported below:

- 128 CPU Intel Itanium 2,1.4 GHz;
- 64 nodes (60 compute nodes, 4 login nodes);
- 76 HDs SCSI Ultra-320 (36GB - 15000rpm);
- 264 GByte Cumulative RAM;
- Storage Area Network EVA 3000 (720GB);
- Quadrics Elan 4 interconnection switch - fiber channel;
- GNU/Linux IA64 Operating System based on Red Hat EAS3;
- C, C++, Fortran Intel compilers.

The haptic interface used in this simulation is the PHANTOM Omni of SensAble Technologies, Inc.; the device offers 6 degrees of freedom output capabilities [7].

2 The Developed Application

In the developed application the client, provided with a haptic interface, sends to the server (supercomputer) the initial geometry of the virtual world and, during the simulation, the current position of the end-effector.

On the server side the collision detection algorithm runs and, in case of contact between end-effector and virtual objects, the force that has to replicate on the user by means of the haptic device is calculated and sent to the client.

The force feedback algorithm is based on the distance of penetration inside the body [8]. To allow to force visualization on the display, a red line which represents the force vector in the surface contact point is shown.

In Fig. 2 a possible situation of the developed application is represented.

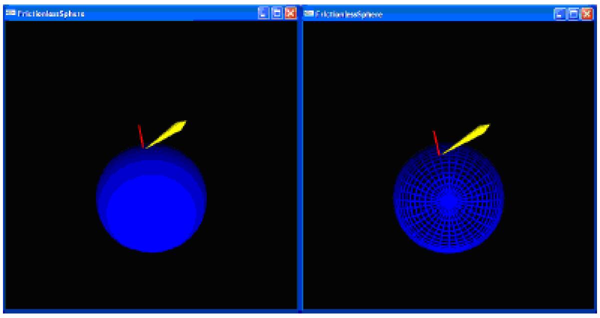

Fig. 2: Force feedback representation

3 The Test Phase

A test phase has been carried out in order to monitor the traffic network in case of TCP and UDP connections [9]. The aim is to check whether the user experience is compromised because of the delays due to the communication between client and server.

Different tests have been performed taking into account or not a possible change in the geometry of the virtual environment. In the first case, 10.000 execution times have been calculated in relation to the bandwidth; the execution time takes into account the duration necessary to send data to the server, to run the collision detection and collision response algorithms and, finally, to send the force feedback to the client.

The two graphics reported in Fig. 3 show the results of these tests; the second one highlights the execution times lower then 2 msec.

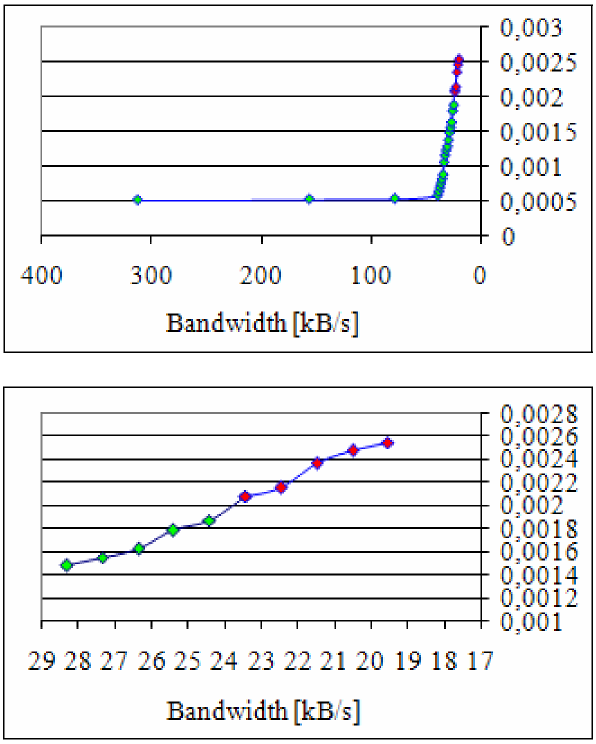

Fig. 3: Results of the tests carried out without changes in the virtual environment geometry

This test phase indicates that, with the smallest bandwidth of 25.000 b/sec, the interaction algorithms (collision detection and collision response) can run on the remote supercomputer if the virtual world is rigid and static and the collision detection algorithm is no longer then 0,131 msec.

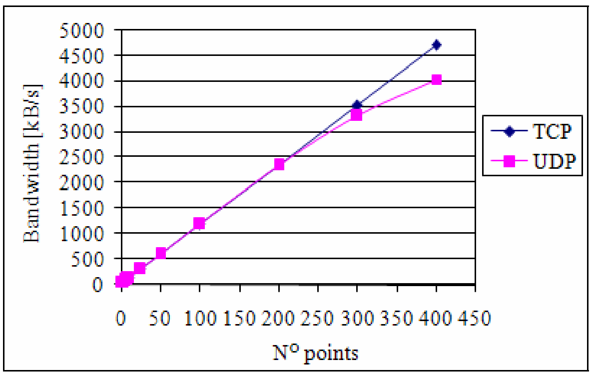

Fig. 4: Results of the tests carried out for TCP and UDP protocols with changes in the virtual environment geometry

Other tests have been carried out taking into account a possible change in the geometry of the virtual environment; the smallest required bandwidth and the execution time have been calculated in relation to sending the remote server an increasing number of mesh nodes in order to update the virtual environment when collision between virtual objects occurs.

The test results have been carried out taking into account the different transmission modalities of the TCP and UDP protocols. Fig. 4 shows the results of the tests carried out.

N° points	TCP Run time [s]	UDP Run time [s]
1	0,000398	0,000361
2	0,000422	0,000377
3	0,000430	0,000390
4	0,000450	0,000398
5	0,000461	0,000410
6	0,000475	0,000419
7	0,000490	0,000430
8	0,000501	0,000445
9	0,000526	0,000476
10	0,000553	0,000509
25	0,000833	0,000744
50	0,001213	0,001128
100	0,001462	0,001373
200	0,001644	0,001575
300	0,001842	0,001785
400	0,002072	0,001924

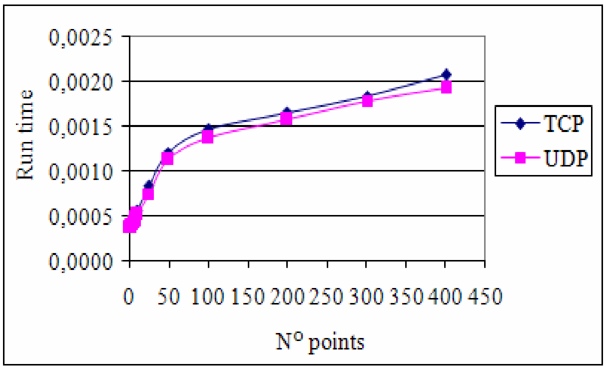

Fig. 5: Total execution times

It is possible to observe that, up to 200 nodes, the behaviour of the two transmission protocols in terms of required bandwidth is the same; due to the bigger overhead of the TCP packet (20 byte compared with 8 byte of the UDP protocol), for a larger number of nodes the TCP protocol requires a bigger bandwidth.

In addition, using the two different transmission protocols, the total execution time has been computed. The results are shown in Fig. 5.

Up to 400 nodes sent from the client to the remote supercomputer, using the UDP protocol, the total execution time remains lower then 2 msec (the updating frequency boundary of the haptic interface is 500 Hz), using the TCP protocol this limit is not respected.

These results highlight that, taking into account the time necessary to run the interaction algorithms on the server side, the execution time remains very short.

4 Conclusion

The aim of this work is to evaluate the possibility of using the computational power of a remote supercomputer in a virtual reality application with force feedback; in this way it would be possible to build a very realistic virtual environment shared among different users involved in a collaborative virtual environment application.

A client/server application has been developed and a haptic device has been used to carry out the test phase. The interaction in the virtual environment happens on the client side and uses the results of the collision detection and collision response algorithms that run on the server side (supercomputer).

To test the limits of the application, the number of nodes in the virtual environment mesh sent to the server has been increased; only in the case of a virtual environment which changes little in number of nodes and is composed from undeformable objects can this system be successfully used.

In other cases it is necessary to give up the force feedback and rely only on visual feedback.

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