Tele-Handshake: A Cooperative Shared Haptic Virtual Environment

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Abstract

A cooperative shared haptic virtual environment, where the users can kinesthetically interact and simultaneously feel each other, is beneficial for many VR simulations. We have implemented a tele-handshake system that enables the participants to shake hands over a network and feel each other's pushing concurrently. A client-server architecture has been used with a specific implementation to meet the requirements of the haptic device. The users were able to feel each other simultaneously and shake their hands in an intuitive way. An objective evaluation based on force feedback was conducted. The results showed that the force feeling induced at the remote site was very close to that felt at the remote site. Also, a subjective evaluation based on a rating questionnaire is described. The results prove that the feeling was instant without any perceptible delay.

1. Introduction

The ability to feel objects in a shared virtual environment simultaneously can markedly enhance the effectiveness of many VR applications. Haptic cooperative virtual environments, where the users can simultaneously manipulate and haptically feel the same object, is potentially beneficial and in some cases could be indispensable. It could be useful for training as in, for example, virtual surgical simulators where the team performs on the same real patient; all the other members perceive each team member interaction with the patient directly, when dealing with the patient's tissue, or indirectly because of the collisions in the limited workspace. Virtual surgical simulators offer the possibility of training surgeons without risking casualties [1] [2] [3]. However, the interaction feeling and its effect should be provided to make sure that the perceptual experience in the virtual world corresponds to that in the real world, otherwise the training would be useless, if not dangerous. Another use of a haptically cooperative environment is in entertainment, which would allow the participants to kinesthetically interact with each other. This adds a new dimension of enjoyment and brings us one step closer to more realistic interactivity. Moreover, there will be a great benefit from such kinesthetic interaction in some sports training systems, especially the kind of multi-players sports that include direct contact between the players such as boxing, sumo wrestling, and football. The resulting virtual training system has the potential to be more realistic and efficient. In addition, there are many advantages of multi-hand manipulation that can be realized from daily life. More precise manipulation can be achieved using both hands [4]. Also, the manipulation with both hands is more efficient than one hand as has been mentioned by some ergonomic studies [5].

Buttolo et al. [6] proposed an architecture for shared haptic virtual environments where they pointed out the difference between collaborative and cooperative virtual environments. The collaborative environment is a sharing environment, in which the users take turns in manipulating the virtual object. Meanwhile, the cooperative environment is an interacting one, in which the users can simultaneously modify the same virtual object. According to these definitions most of the cooperative haptic environments that have been proposed in the last few years fall under the banner of collaborative haptic environments, as all of them cannot support simultaneous kinesthetic interaction between the participants. Takemura and Kishino [7] have built a cooperative environment using a virtual workspace by combining a head tracking display and a data glove. However, the users are not allowed to simultaneously alter the status of the virtual world. In other words, they cannot grasp the same object and manipulate it at the same time. They used what they called mutual exclusion to avoid simultaneous manipulation of the same object. In the shared virtual environment proposed by Buttolo et al. [8], one user at time, the active operator, is allowed to modify and feel the force from the environment.

Meanwhile, the other users watch the interaction but cannot modify or touch the object.

Kinesthetically linking remote users acting on the same object is a great challenge as any latency in the haptic rendering loop could bring the whole system to instability. The delay should not be more than 5-10 ms to accomplish a stable interaction with a stiff virtual object. Handshaking is a good example of simultaneous kinesthetic interaction, therefore, it is an important task to be implemented and tested. It represents a highly demanding task for concurrent interaction and quick instant feeling. As a result, achieving a rich, instant and realistic haptic sensation during tele-handshake would be an indicator for the possibility of implementing a high-quality cooperative haptic virtual environment. Another reason could be a social one related to our life communication protocol where every greeting, farewell, meeting or agreement starts and ends with handshake. Therefore, representing a handshake in any haptic cooperative virtual environment will encourage a more intuitive and natural interaction.

This paper describes a tele-handshake system with haptic sensation over the Internet. An implementation of a shared cooperative haptic virtual environment where the users, at distant sites, can shake hands and feel each other simultaneously. An architecture for kinesthetic cooperative haptic interaction in a shared virtual environment is proposed. An experiment and evaluation of the proposed system are described.

2. The experimental system

The system consists of two connected stations in client-server mode. Each machine is connected to the haptic device by which the users interact inside the virtual space, and the graphic device to display the virtual environment to the users is as shown in Figure 1. The users from different locations come to meet each other inside the virtual meeting space, which is a 3D spacious room with two graphic arms representing each user's hand as can be seen from Figure 2. PHANToM from SensAble Technologies, Inc. was used as the haptic device to represent the force feedback to the subjects [9]. The participants were asked to enter the virtual meeting space in which they can observe each other's movement, then to shake hands as naturally as they usually do in real life. The force feedback was acquired from each site to evaluate the haptic sensation provided by the local and the remote location. Figures 3 and 4 show a snapshot of the experimental environment at each site during a real tele-handshake session.

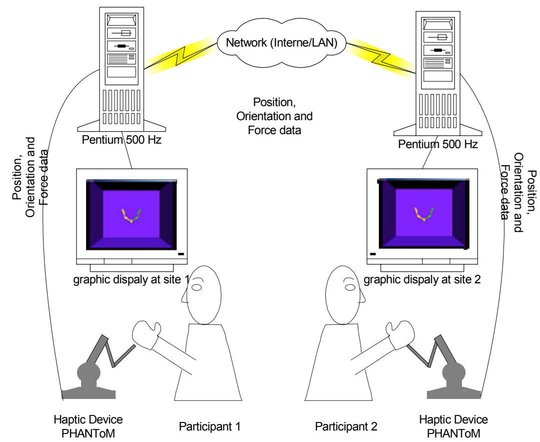

Figure 1. Diagram of the tele-handshake system

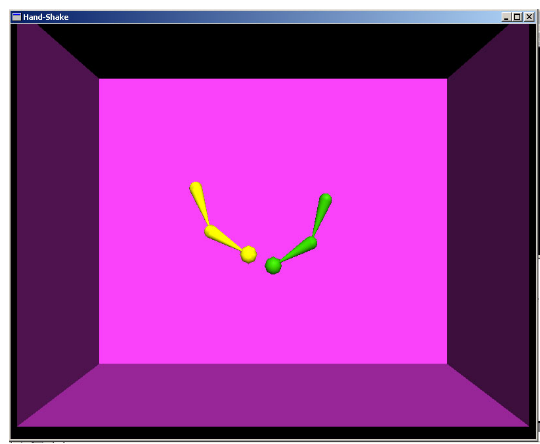

Figure 2. The virtual environment (virtual meeting space)

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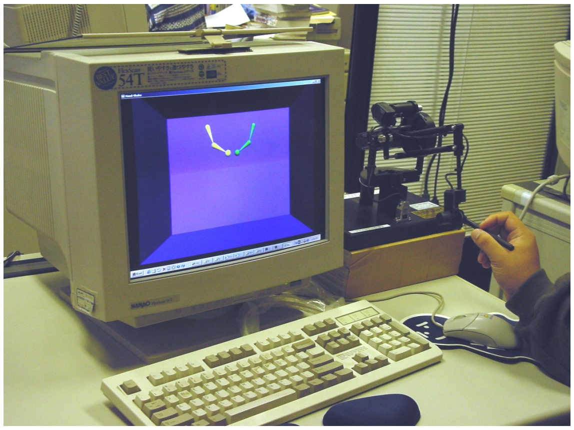

Figure 3. The experimental environment at site 1

Figure 4. The experimental environment at site 2

3. The tele-handshake system architecture

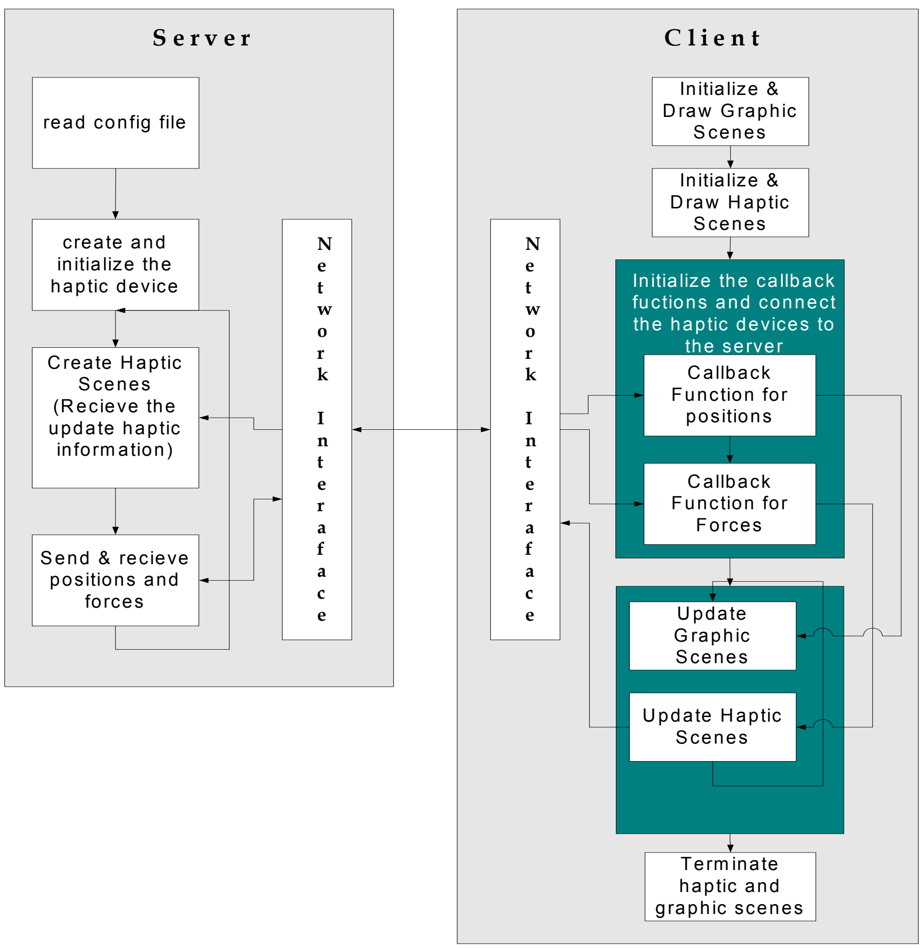

Figure 5. The system architecture

The architecture can be described as a client-server structure as can be seen from Figure 5. The system that has been used to implement the tele-handshake consists of two machines at different locations.

The server program and client program are running concurrently at each site at the same time. The server program is responsible for initiating the haptic device and passing force and position information to the client side. The client program is the application code, which initiates and draws the graphic and haptic scenes, then establishes the communication channel with the server to receive the data from the haptic device using callback mechanism. This mechanism passes only the new state information for the nodes in the haptic scene from the server side to the client side. This technique saves traversing all the nodes in the scene checking for any changes. After that, the haptic and graphic scenes are updated according to the new state information that was received from the server side.

4. Results and evaluations

4.1 Objective evaluation

Linking haptic devices over the network is a great challenge because of the small delay requirements and the high update rate required for haptic rendering. A 1000 Hz update rate was suggested by Buttolo and his colleagues to create the feeling of stiff surfaces and to prevent unwanted sudden forces [10]. Using the above architecture enabled us to meet these demands over the network. By keeping the haptic process running on the server side at a high update rate. Meanwhile, the graphic process was running at the client side and exchanging the necessary information with the haptic process, which are usually forces and positions that can be transferred efficiently through the current Internet network.

To evaluate the system we compare between the force feedback provided to the local client, who is connected to his haptic device on the local machine, and the forces provided to the remote client that is connected to the haptic device on the remote machine. Therefore, it was sufficient to obtain the forces from the local side and those from the remote side, and compare them to quantity the haptic sensation provided at each site.

The forces in the x and z directions from the remote site could provide up to 87% of the forces at the local site. Meanwhile, the forces in the y direction were up to 92% of that at the local site as can be seen from Figure 6. The results reflect the nature of the handshake task since we usually intend to shake the partner’s hand up and down in the y direction.

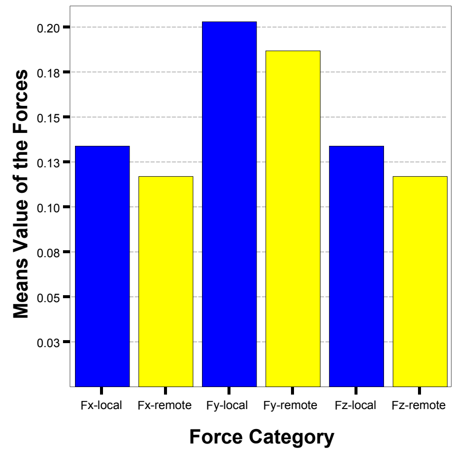

Figure 6. The local and remote force feedback evaluation

4.2 Subjective evaluation

Evaluating human interaction with any VR simulation, in general, and haptic VR simulation in particular is a complex task since there are many factors that cannot be considered. We used a simple subjective evaluation using a rating questionnaire to show to what extent the system could deliver a convincing feeling and what kind of features have been conveyed to the users. Ten subjects were asked to fill out the questionnaire shown in Table 1.

Table 1. Questionnaire rating the feel of the simulation

Convincing feeling	1–2–3–4–5–6–7	Unconvincing
Intuitive manipulation	1–2–3–4–5–6–7	Unnatural manipulation
Satisfied with the interface	1–2–3–4–5–6–7	Dissatisfied
Instant feeling of forces	1–2–3–4–5–6–7	Slow (delayed)
Haptic sense consistent with the visual sense	1–2–3–4–5–6–7	Inconsistence

As can be seen from Figure 7, the subjects thought that the system could deliver an instant feeling without any noticeable delay. Moreover, the haptic sensation was consistent with the visual sensation, up to 95%. The interface was not fully satisfactory because the Phantom is more like grabbing a pen than whole-hand grasp as in real handshake situation; only 70% of satisfaction with the interface has been expressed. This might explain why the subjects were partially convinced with the feeling and the intuitiveness of manipulation. They were up to 62% convinced with the stimulated feeling compared with the real-life handshake's feeling.

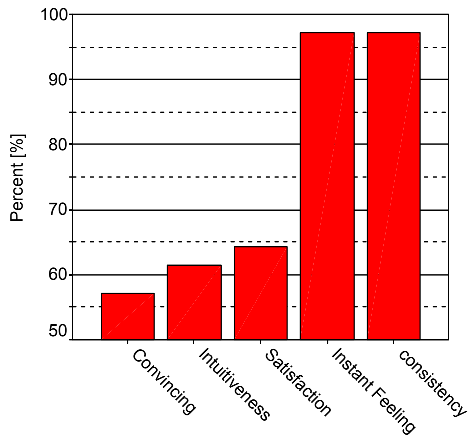

Figure 7. Subjective evaluation according to the rating questionnaire

5. Conclusions

In this paper we described a system for tele-handshake over the Internet. A client-server architecture was used to connect the users with their haptic device. Moreover, a callback mechanism was used to communicate the haptic data between the server and their clients. As a result, there is a reduction in traffic since only relevant changes are communicated.

The participants at different locations could enter the virtual space meeting and shake hands and feel each other instantly. The system, at the remote side, could provide up to 92% of the force feeling induced at the local side, which makes using the haptic devices over the network applicable and efficient. The feeling, as has been described by the subjects, was instant without perceptible delay.

The subjects expressed their desire to have the same experience but with the ability to use the whole hand, because that would deliver a more satisfactory and realistic feeling. Nevertheless, this would open up a new dimension of direct human contact and interaction over the network. The ability to touch and feel others far away would definitely start a new era in human communication and would give us access to the development of new applications over the Internet that previously only existed in our imagination.

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