COOPERATIVE TELEOPERATION TASK IN VIRTUAL ENVIRONMENT
Influence of Visual Aids and Oral Communication

Sehat Ullah, Samir Otmane and Malik Mallem

IBISC Laboratory, University of Evry, 40 rue de Pelvoux, Evry, France

Paul Richard

LISA Laboratory, University of Angers, 62 av Notre Dame du Lac, France

Keywords: CVEs, Cooperative teleoperation, Parallel robots, SPIDAR, Human performance, Multimodal feedback.

Abstract: Cooperative virtual environments, where users simultaneously manipulate objects, is one of the subfields of Collaborative virtual environments (CVEs). In this paper we simulate the use of two string based parallel robots in cooperative teleoperation task, Two users setting on separate machines connected through local network operate each robot. In addition, the article presents the use of sensory feedback (i.e shadow, arrows and oral communication) and investigates their effects on cooperation, presence and users performance. Ten volunteers subject had to cooperatively perform a peg-in-hole task. Results revealed that shadow has a significant effect on task execution while arrows and oral communication not only increase users performance but also enhance the sense of presence and awareness. Our investigations will help in the development of teleoperation systems for cooperative assembly, surgical training and rehabilitation systems.

1 INTRODUCTION

A CVE is a computer generated world that enables people in local/remote locations to interact with synthetic objects and representations of other participants within it. The applications of such environments are in military training, telepresence, collaborative design and engineering and entertainment. Interaction in CVE may take one of the following form (Otto et al., 2006): Asynchronous: It is the sequential manipulation of distinct or same attributes of an object, for example a person changes an object position, then another person paints it. Another example is, if a person moves an object to a place, then another person moves it further.

Synchronous: It is the concurrent manipulation of distinct or the same attributes of an object, for example a person is holding an object while another person is painting it, or when two or many people lift or displace a heavy object together.

In order to carry out a cooperative task efficiently, the participants need to feel the presence and actions of others and have means of communication with each other. The communication may be verbal or non verbal such as pointing to, looking at or even through gestures or facial expressions. We implement the VE designed for cooperative work in replicated architecture and seek solution to network load/latency and consistency in unique way. Similarly to make cooperative work easier and intuitive we augment the environment with audio and visual aids. Moreover we investigate the effect of these sensory feedback on user performance in a peg-in-hole task.

This section is followed by the related work, Section 3 describes the proposed system. Section 4 discusses the experiment and results analysis. Section 5 is dedicated to conclusion future work.

2 RELATED WORK

A lot of work has already been done in the field of CVE, for example MASSIVE provides a collaborative environment for teleconferencing (Greenhalgh and Benford, 1995). Most of this collaborative work is pertinent to the general software sketch and the underlying network architecture (Chastine et al., 2005; Shirmohammadi and Georganas, 2001). Basdogan et al. have investigated the role of force feedback in cooperative task. They connected two monitors

and haptic devices to a single machine (Basdogan et al., 2001). Similarly, Eva-lotta et al. have reported the effect of force feedback over presence, awareness and task performance in a CVE. They connected two monitors and haptic devices to a single host (Sall-nas et al., 2000). Other important works that support the cooperative manipulation of objects in a VE include (Jordan et al., 2002; Alhalabi and Horiguchi, 2001) but all theses systems require heavy data exchange between two nodes to keep them consistent.

Visual and auditory substitution has already been used both in single user VR and teleoperation systems to provide pseudohaptic feedback. The sensory substitution may be used as a redundant cue, due to lack of appropriate haptic device or to avoid the possible instabilities in case of real force feedback (Richard et al., 1996).

3 DESCRIPTION OF THE SYSTEM

We present our system that enables two remote users(connected via LAN), to cooperatively manipulate virtual objects using string based parallel robots in the VE. In addition we present the use of visual (shadow and arrows) aids and oral communication to facilitate the cooperative manipulation.
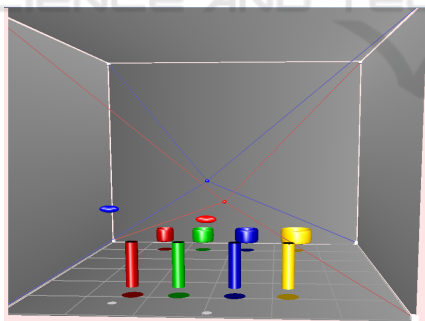

Figure 1: Illustration of the virtual environment.

The VE for cooperative manipulation has a simple cubic structure, consisting of three walls, floor and ceiling. Furthermore the VE contains four cylinders each with a distinct color and standing lengthwise in a line. In front of each cylinder at some distance there is a torus with same color. We have modeled two SP-IDAR (3DOF) to be used as robots (Richard et al., 2006)(see figure 1). At each corners of the cube a motor for one of the SPIDAR has been placed. The end effectors of the SPIDARs have been represented by two spheres of distinct color. Each end effector
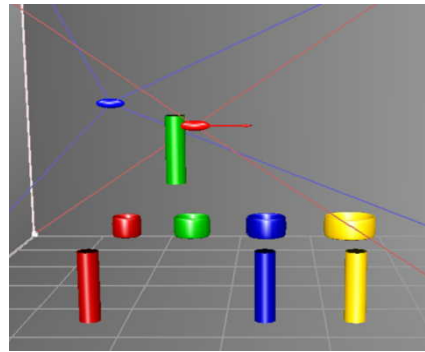

Figure 2: Illustration of the appearance of arrow.

uses 4 wires (same in color) for connection with its corresponding motors.

We use two spheres which are identic in size but different in colors (one is red and the other is blue) to represent the two users. Each pointer controls the movements of an end effector. Once a pointer collides with its corresponding end effector, the later will follow the movements of the former. In order to lift and/or transport a cylinder the red end effector will always rest on right and blue on left of the cylinder.

3.1 Use of Visual Aid and Oral Communication in Cooperative Work

Cooperative work is really a challenging research area, for example the co-presence and awareness about collaborator's actions is essential. Similarly the cooperating persons should also have some feedback to know, when they can start together, or if there is some interruption during task. For this purpose we exploit visual(arrow and shadow) feedback and oral communication.

If any user moves to touch a cylinder on its proper side, an arrow appears pointing in the opposite direction of the force applied by the end effector. The arrow indicates the collision between an end effector and cylinder. Similarly during the transportation, if any user looses control of the cylinder, his/her arrow will disappear and the cylinder will stop moving. Here the second user will just wait for the first one to come back in contact with the cylinder. It means that the two users will be aware of each other's status via arrows during task accomplishment.(see figure 2)

In order to have the knowledge of perspective positions of various objects in the VE, we make use of shadow (see figure 1) for all objects in the environment. The shadows not only give information about the two end effector's contact with cylinder but also provide feedback about the cylinder's position with
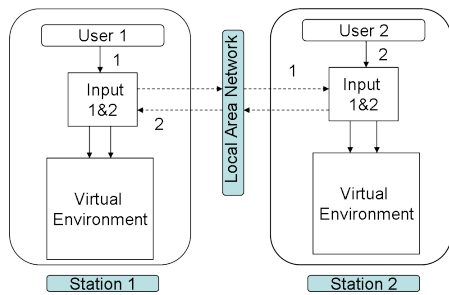
375

Figure 3: Illustration of the framework of cooperative virtual environment.

respect to its corresponding torus during transportation.

Normally human beings frequently make use of oral communication while performing a collaborative or/and cooperative task. In order to accomplish the cooperative work in a more natural manner, we include a module for oral communication in our system. For this purpose we use TeamSpeak software that allows the two users to communicate over the network using a headphone equipped with microphone (tea,).

3.2 Framework for Cooperative VE

The framework plays a very important role in the success of collaborative and/or cooperative VEs. We use a complete replicated approach and install the same copy of the VE on two different machines. As the figure 3 depicts each VR station has a module which acquires the input from the local user. This input is not only applied to the local copy of the VE, but is also sent to the remote station. It means that a single user simultaneously controls the movement of two pointers (in our case a sphere) at two different stations, so if this pointer triggers any event at one station, it is also simultaneously applied at other station. In order to have reliable and continuous bilateral streaming between the two stations, we use a peer-to-peer connection over TCP protocol. Here it is also worth mentioning that the frequently exchanged data between the two stations is the position of the two pointers where each is controlled by a user.

3.3 Experimental Setup

We installed the software on two pentium 4 type personal computers connected through Local network. Each machine had processor of 3GHZ and 1GB memory. Each system is equipped with standard graphic and sound cards. Both the systems used 24 inch plate LCD tv screen for display. Similarly each VR system is equipped with a patriot polhemus (pat,) as input

device. The software was developed using C++ and OpenGL Library.

4 EXPERIMENTATION

4.1 Procedure

Ten volunteers including five male and five female participated in the experimentations. They were master and PhD students. All the participants performed the experiment with same person who was expert of the domain and also of proposed system. They were given a pre-trial in which they experienced all feedback. The users needed to start the application on their respective machines. After the successful network connection between the two computer the user could see the two spheres (red and blue) as well as the two end effector of SPIDARs on their screens. Seeing the two spheres they were required to bring their polhemus controlled spheres in contact with their respective end effectors (i.e red+red and blue+blue). The red sphere was assigned to the expert while the subjects were in charge of the blue one. In order to pickup the cylinder the expert needs to touch it from right while the subject should rest on its left. The experiment was carried out under the following four conditions. C1= only shadow, C2= shadow + arrows, C3= shadow + arrows + oral communication, C4= No aid All the ten groups performed the experiment using distinct counter balanced combinations of the four conditions. We recorded the task completion time for each cylinder. The time counter starts for a cylinder once the two end effectors have an initial contact with it, and stops when it is properly placed in the torus.

4.2 Task

The task was to cooperatively pick up a cylinder and put it into the torus. The users were required to place all the cylinder in their corresponding toruses in a single trial. Each group performed exactly four trials under each condition. The order of selection was also the same for all groups i.e to start from the red, go on sequentially and finish at yellow.

4.3 Task Completion Time

For task completion time the ANOVA ($F_{(3,9)}= 16.02$, $p < 0.005$) is significant. Comparing the task completion time of C1 and C2, We have 30.07 sec (std 6.17) and 22.39 sec (std 3.10) respectively with a significant ANOVA. This result shows that arrow has an influence on task performance. Similarly comparing C4
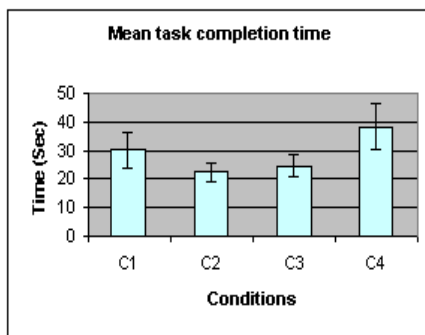
Figure 4: Task completion time under various conditions.

(mean 38.31 sec , std 7.94) with C1 also gives significant ANOVA. This indicates that only "shadow" as compare to "No aid" also increases user performance.

Now we compare the mean 22.39 sec (std 3.10) of C2 with that of C3 (24.48 sec std 3.93), the ANOVA result is not significative. It shows that users had almost the same level of performance under C2 and C3. On the other hand the comparison of C2, C3 with C4 (mean 38.31 sec , std 7.94) both have statistically significant results (see figure 4).

5 CONCLUSIONS

In this paper we simulate the use of two string based parallel robots in cooperative teleoperation task, two users setting on two separate machines connected through local network operated each robot. In addition the article proposed the use of sensory feedback (i.e shadow, arrows and oral communication) and investigated their effects on cooperation, co-presence and users performance. We observed that visual cues (arrows and shadow) and oral communication greatly helped users to cooperatively manipulate objects in the VE. These aids, specially arrows and oral communication also enabled the users to perceive each others actions. Our investigations will help in the development of teleoperation systems for cooperative assembly, surgical training and rehabilitation systems. Future work may be carried out to integrate the modality of force feedback.

REFERENCES

www.polhemus.com.

www.teamspeak.com/.

Alhalabi, M. O. and Horiguchi, S. (2001). Tele-handshake: A cooperative shared haptic virtual environment. *in Proceedings of EuroHaptics*, pages 60–64.

Basdogan, C., Ho, C.-H., Srinivasan, M. A., and Slater, M. (2001). Virtual training for a manual assembly task. In *Haptics-e*, volume 2.

Chastine, J. W., Brooks, J. C., Zhu, Y., Owen, G. S., Harrison, R. W., and Weber, I. T. (2005). Ammp-vis: a collaborative virtual environment for molecular modeling. In *VRST '05: Proceedings of the ACM symposium on Virtual reality software and technology*, pages 8–15, New York, NY, USA. ACM.

Greenhalgh, C. and Benford, S. (1995). Massive: a collaborative virtual environment for teleconferencing. *ACM Transactions on Computer Human Interaction*, 2(3):239–261.

Jordan, J., Mortensen, J., Oliveira, M., Slater, M., Tay, B. K., Kim, J., and Srinivasan, M. A. (2002). Collaboration in a mediated haptic environment. *The 5th Annual International Workshop on Presence*.

Otto, O., Roberts, D., and Wolff, R. (2006). A review on effective closely-coupled collaboration using immersive cve's. In *VRCIA '06: Proceedings of the 2006 ACM international conference on Virtual reality continuum and its applications*, pages 145–154. ACM.

Richard, P., Birebent, G., Coiffet, P., Burdea, G., Gomez, D., and Langrana, N. (1996). Effect of frame rate and force feedback on virtual object manipulation. *PRESENCE : Massachusetts Institute of Technology*, 5(1):95–108.

Richard, P., Chamaret, D., Inglese, F.-X., Lucidarme, P., and Ferrier, J.-L. (2006). Human-scale virtual environment for product design: Effect of sensory substitution. *International Journal of Virtual Reality*, 5(2):3744.

Sallnas, E.-L., Rassmus-Grohn, K., and Sjostrom, C. (2000). Supporting presence in collaborative environments by haptic force feedback. *ACM Trans. Comput.-Hum. Interact.*, 7(4):461–476.

Shirmohammadi, S. and Georganas, N. D. (2001). An end-to-end communication architecture for collaborative virtual environments. *Comput. Netw.*, 35(2-3):351–367.