The Influences of Network Issues on Haptic Collaboration in Shared Virtual Environments

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Abstract

There is currently much discussion of Quality of Service (QoS) measurements at the network level of real-time multimedia services.

The presence of a network brings up a number of issues. In case of visual or auditory interaction, the effect of such issues have been treated by many researchers and the effective countermeasure have been proposed. However, little is known about the relationship between network issues and networked haptic interfaces in virtual environments(VEs). Our researches aim at investigating and clarifying the above issue and constructing more robust haptic interaction system to realize network-based shared virtual environments(Net-SVEs) under realistic network conditions - from the end-user's point of view. For this purpose, we have designed some experiments to investigate the influence of network delay on multiuser haptic collaboration system through subjective and objective assessment by users. This paper shows the results of the relation between QoS and network delay on haptic Net-VEs.

1 Introduction

The number of real-time multimedia applications over network has been increasing steadily, and with it, to measure and assess Quality of Service (QoS) are becoming more and more important. There has been a surge in literture addressing QoS issues. But the emphasis has been on the QoS of conventional "one-directional" multimedia(i.e, visual and auditory. Farthermore, most of them focus on QoS issues at the network level, rather than from the end-user's point of view. Since it is the end-user who will determine whether a service or application is a success, it is vital to carry out subjective assessment of the multimedia quality delivered through these.

2 Network Issues on Haptic Interacition

Network issues that is, delay, jitter (variation of delay), reliability, or bandwidth may cause severe deterioration of stability or performance of the system. They are unavoidable in realistic network environments, so need to be discussed carefully. In this section, we discuss these issues focused on network latency and communication architecture.

2.1 Network Latency and Force Feedback

In networked remote haptic interaction in Virtual Environments(VEs), delay may cause not only time lag between human operation and force feedback, but system instability like an excessive rebound or vibration of reaction force. As regards impedance display(sensing motion and producing force)like PHANToM, interaction force between haptic device end point and virtual object is calculated based on Spring-dumper model. Reaction force is generated in proportion to the depth of a PHANToM cursor in a virtual object and the relative velocity between a cursor and a object. Without delay between haptic display and VEs , reaction force calculated in VEs is output to haptic device instantly, but when there is some delay, a time lag between generating and outputting reaction force occurs. For this time lag, haptic end point might penetrate deeper in a virtual object till it is pushed back by reaction force. By the time the force feedback arrives haptic display, the penetration have already increased, so large forces are generated. This effect is felt as a rebound or vibration of a haptic display by users.

Differences of delay time between each users in SVEs is also troublesome. Network states - including delay time - in each client are not the same in many cases.

This may cause inconsistency of collaboration.

2.2 Communication Architectures

Generally, we can choose various communication architectures to realize SVEs, for example, client-server or peer-to-peer, or a mixture of them and so on. They have different features respectively, so we need to choose more suitable ones considering of the overall system along with their advantages and disadvantages.

Suppose the simplest case of Peer-to-peer architecture. In this case, all clients have whole SVEs information independently, and required data to be transmitted is only PHANToM position information. In this architecture, to guarantee consistency of SVEs on condition that exists fixed delay, we only have to delay timing that local PHANToM position is displayed to the maximum delay time of all the peer-to-peer connection. This method provides absolute consistency for SVEs without excess penetrating. However, as an increase of a number of clients the connections become complex, besides each client requires a high machine power to calculate all SVEs . In the client-server architecture, a required machine power of each client is lower and connections are simpler than peer-to-peer. Moreover, by managing SVEs in a central server it can keep consistency of collaboration. But the differences of delay may cause inconsistency of collaboration.

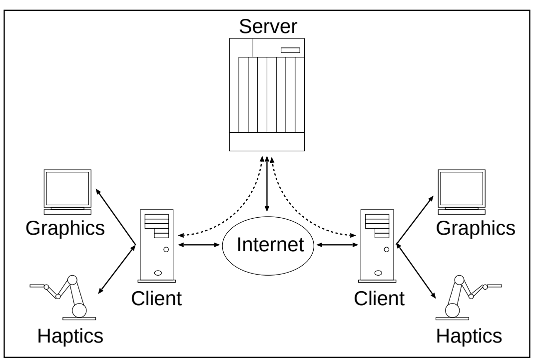

Figure 1: Client-Server Model of Net-SVEs

3 Design of System

In consideration of the issues described in previous section, we designed a prototype of network-based haptic collaboration system for subjective and objective assessment.

This time, we adopted Client-Server architecture for network-based haptic collaboration system. In this architecture, physical simulation or management of entity state are processed at a central server almost all together in order to keep consistency of collaboration. Details of each part of the system are provided below.

3.1 Control Design

To avoid generation of excess reaction force, it is calculated at each client. In Figure 2 , Fe, the force calculated in a server, is applied to VEs managed by the server, and Fm, the force calculated in clients, is applied to haptic display. A server transmits information of object surface state which is contacting to server PHANToM position, to each client. Each client calculates the reaction force based on interaction between the contact object state from the server, and client PHANToM position.

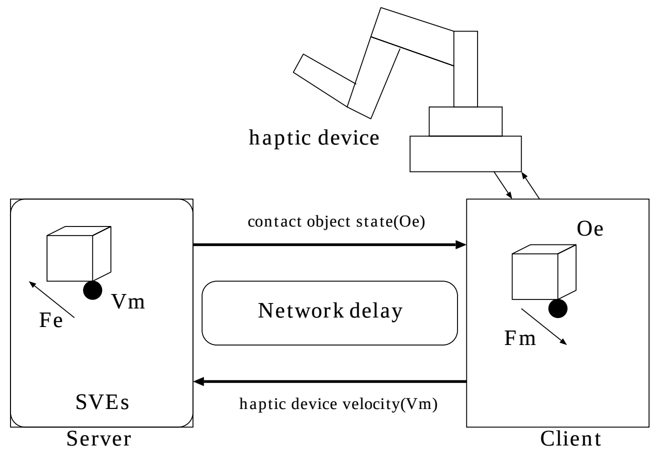

Figure 2: Control Design for haptic net-VEs

3.2 System Specification

- Server
  PLATFORM :Windows NT4.0
  CPU :PentiumIII 600MHz
  RAM :128MB SDRAM
  NIC(10/100BASE-TX):3COM 3C905B-J-TX
- Clients
  PLATFORM :Windows NT4.0
  CPU :PentiumIII 850MHz
  RAM :512MB SDRAM
  Display-Adapter:ELSA Gloria-XXL with 3D shutter glasses
  Force Device :PHANToM PREMIUM 3.0L
  NIC(10/100BASE-TX):3COM 3C905B-J-TX

4 Experiments

4.1 Experimental Overview

In the experiments, the users perform a task along with a particular rule in a VE. Network delay from

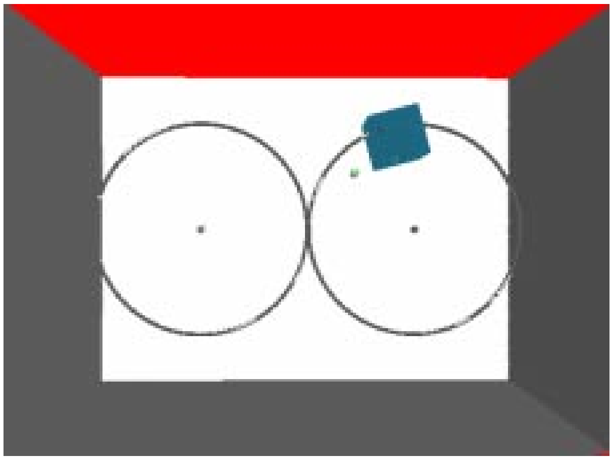

Figure 3: A View of the Experiments in SVEs : Users manipulate a dynamic cube in order that the moving target is always within the cube in collaboration. The target moves along the two circles at 30 seconds per cycle.

the server to each user is changed arbitrarily and independently, and the deterioration of performance is measured. We characterized the system performance as Quality of Service(QoS). QoS is measured by both subjective and objective(quantitative) assessment. Our experiment are designed for both single-user and multi-user system. At present, single-user experiment has always conducted.

4.2 Experimental Design

A task of both experiments is the same, except motion constraint of virtual dynamic object.

In VEs(Figure 3), there is a small moving target. Users manipulate a dynamic cube in order that the target is always within the cube. The target moves along the two circles at 30 seconds per cycle. We constrained the motion of the object on the 2-Dementional plane, to control the difficulty of this task.

4.2.1 Experiment1(single-user)

As preparation, we have experimented on networked single-user haptic operative system in a VE - without collaboration. This is aim to investigate the influence of delay on a sense of operation of virtual object in client-server architecture. The dynamic cube does not rotate in the single-user VE, so a user lifts up and moves the cube by supporting the bottom surface.

4.2.2 Experiment2(multi-user)

Based on the results of an experiment1, we implemented networked multi-user collaborative system in a SVE. This aims to investigate the influence of difference of delay between each client on a sense of accomplishment of a task. In case of multi-player system, the cube behaves as rigidbody, so users must nip and manipulate cube in collaboration as keeping the balance.

4.3 Assessment Methodology

4.3.1 Subjective Assessment

Since there are no recommendation of haptic quality assessment methodology, we adopted the method of assessing quality of image[1]. In this case, comparisons to reference conditions (i.e.no network delay) are made using the double-stimulus continuous quality scale (DSCQS) and the double stimulus impairment scale (DSIS). The scale of both methods, 5-point quality scale and impairment scale are defined at Table1.

A Subjective quality is assessed based on, "controlablity of the object"(using DSIS), "a feeling of touch to the object"(using DSCQS), and"a sense of fulfillment of the collaborative task"(using DSIS, multi-user only).

Table 1: 5-point opinion scale

Score	Impairment Scale	Quality Scale
5	Imperceptible	Excellent
4	Perceptible, but not annoying	Good
3	Slightly annoying	Fair
2	Annoying	Poor
1	Very annoying	Bad

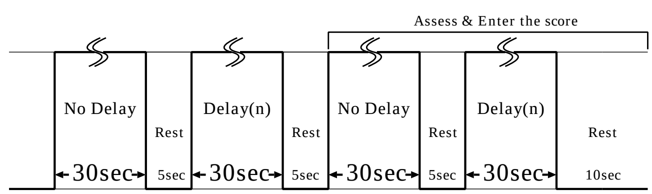

Figure 4: Presentation method of assessment

4.3.2 Objective Assessment

A quantitative(objective) measures for the "the performance of the task" was derived from how long time users could keep a moving target within the cube.

5 Results

The Experimental results are shown below. They are not reliable enough statistically, but indicate tendencies of the effects of delay on QoS in networked haptic interaction in a VE. Single-user experimental results are shown in Figure5-7. They indicate an allowable rate of delay are around 60ms in the system.

Conculusions

This paper reports the prototype experimental system design and implementation for investigating the influence of network delay on QoS of haptic interaction in SVEs, and shows the experimental results. The multi-user experiment is being conducted now, and the results will be shown in the near future.

ACKNOWLDGEMENT

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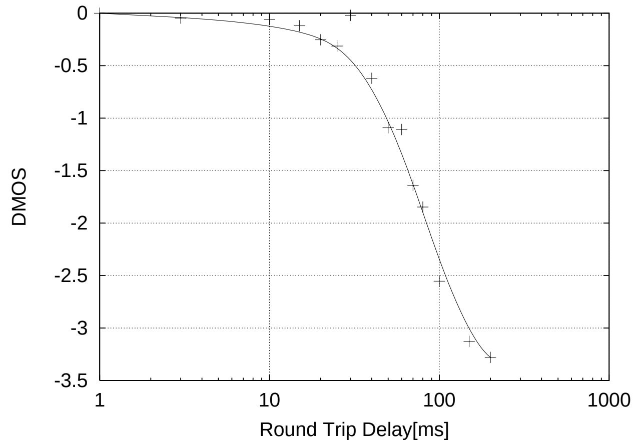

Figure 5: Controlability of the object – Delay(single-user)

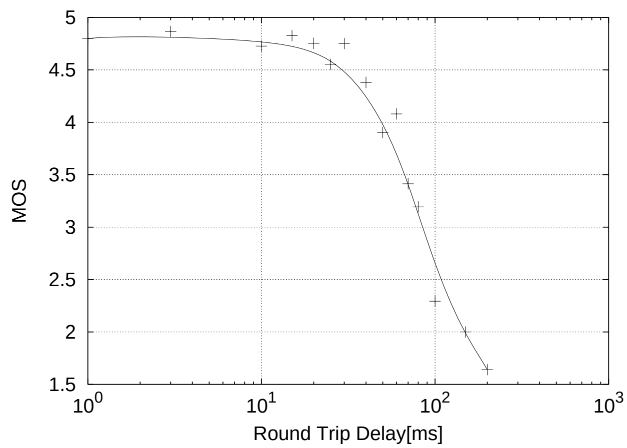

Figure 6: a feeling of touch to the object - Delay(single-user)

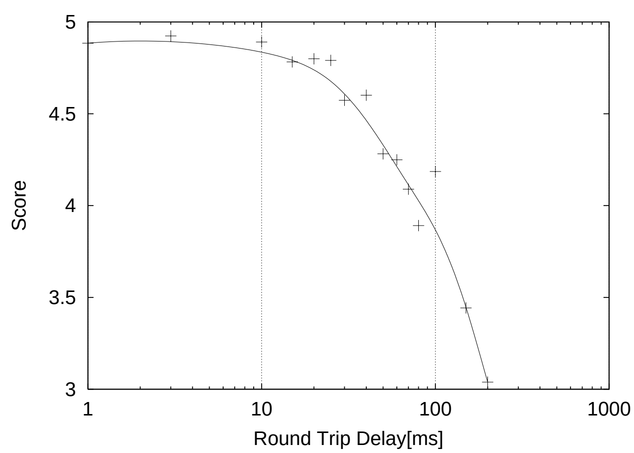

Figure 7: Performance of the task – Delay(single-user)