An Experimental Study of Haptic Positional Synchronization in TCP/IP Networks

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***Abstract*—Traditional Internet is based on the best effort approach, which allow connections for peer-to-peer communications with different characteristics, such as VOIP (Voice over Internet Protocol), VoD (Video on Demand) and data transmission services. In contrast, the increasing demands for variety multimedia applications for future Internet. Therefore, all multimedia services should have Quality of Service (QoS) to support real-time data transmissions in the future Internet multimedia services. This paper presents an experimental investigation into the real-time tele-haptic operation via TCP/IP networks. The experimental results show many challenges in conducting haptic traffic over TCP/IP networks. The UDP jitter, delay and packet loss, these factors will seriously affect user experience under haptic interaction. It is because, jitter, delay and pack loss may lose the positional synchronization between master and slave haptic devices, which will cause haptic communication instability. Thus this paper describe the haptic interaction in order to compare the real-time X-position discrepancies between master and slave haptic devices as the mean opinion score (MOS) over TCP/IP networks.**

***Keywords*—PHANTOM Omni, Haptic, Packet delay, Quality of Serivce, Force Feedback**

1. INTRODUCTION

Recently, the use of interactive internet development related research the increasing human perception. For example: medical, manufacturing, and other aspects of military and their applications can be found; Doctors use the remote control for remote areas far away in the patient's medical, home care assistance old people or the disabled, spacecraft space exploration etc. These applications use the internet to interact communication has become an important part of the remote operation. These applications use the internet to interact with remote operation has become an important part. The internet force feedback system which has been paying attention many research teams, such as remote surgery provides only visual feedback is inadequate. Therefore, through tactile and force feedback presented can accurately perceive the force feedback information on the scalpel immediately reflected in the mechanical manipulation, and to achieve a more true and accurate representation of the basic needs of the remote control.

1.1. Haptic device

Haptic devices can be divided into two types, they are tactile feedback and the force feedback devices. The tactile feedback device is based on mechanical finger cots by finger touch manner to transmit touch object information [1]. The force feedback devices uses human arm movement to generate force information, so that those who feel the force feedback in remote experience.

Figure 1. PHANTOM Omni Module

In Figure 1, it shows the force feedback device which is developed by a single point SensAble haptic feedback device PHANTOM Omni [3]. The force feedback device is based on the device the freedom and the number of points of contact divided into several different types.

DOF range is typically from 1 to 6 dimensions [2] with shown on the simulation system to simulate different models and touch. PHANTOM Omni will provide between 3-6 dimension force feedbacks information [3].

1.2. Haptic Virtual Environment

In the haptic virtual environment, users can manipulate virtual objects or virtual characters and interact, such as 3D hockey computer games [4]. In addition to sharing the virtual world, distributed virtual reality (Distribute Haptic Virtual Environment: DHVEs) is more suitable for remote interactive operations, such as drilling, cutting, surgery, writing text, etc. [3]. Phantom Omni under normal circumstances in order to maintain real-time data transmission requires a higher update frequency. Therefore, it has can transfer up to 1000 packets/sec, packets contain haptic devices in virtual environments tip position and force feedback information [2]. How to quantify and applied haptic information is a great challenge to network issues.

1.3. Network losses affect for PHANTOM

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2. Analysis of Relevant Literature

From related research literature [5], the authors test the network transmission delay for haptic quality of service via wired networks. The total test time is 30 minutes, when there will be less than 100ms MOS manifestations. In [6], the connection also tested by playing virtual games when the MOS value at 130ms. These two examples were tested delay from 100ms to 130ms respectively. However, the peer-to-peer testing environments are not synchronized.

In [7], different types of haptic device have been tested to assess the haptics MOS values. The connection of video, headphones and haptic bidirectional transmission is tested in [8].

The ITU-R BT.500-11 standards [2][9][10][12] and ITU-R BT.500-12 standards [6][11] are used for MOS value to measurement haptic QoS. In [9], the experimental method use NetDisturb [13] to simulate network delay, and substitute with ITU-R P800 standard for MOS value.

However, there are no clear definition for haptic quality of service requirement from above experiments. In this study, the current experimental standards adopted by ITU-R BT.500-11 as an experimental basis, and tested in the ITU-R BT.500-11 with the peer-to-peer network environment, the resulting shows the difference between delay and feedback moving distance in real test-bed under wired network environment.

3. Test-Bed Architecture and Experiment Methods

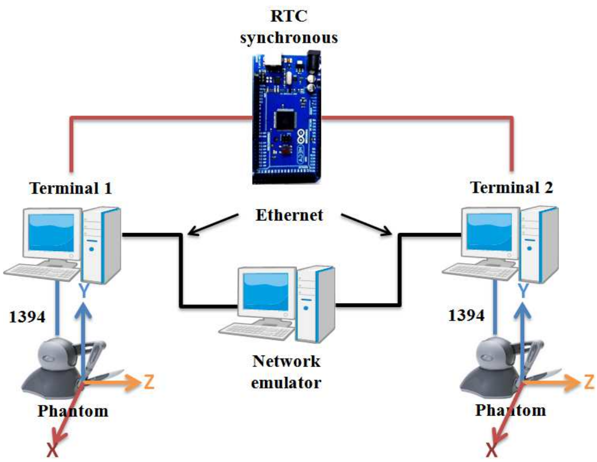

Figure 2. The architecture of Distribute Virtual Environments test-bed

Figure 2 shows the experimental design of DHVEs (Distribute Virtual Environment). Terminal 1 and Terminal 2 are communicate by UDP via a network emulator. The PHANTOM Omni devices are connected Terminal 1 and Terminal 2 by IEEE 1394 interface. In this experiment, the maximum moving distance is 10 cm. A Mirco-controller system is used as an external RTC (real-time clock) device which accuracy is milliseconds. The moving distance in Server/Client sides are recorded during the interactive connection through network emulator simulation in vary packet delay conditions.

4. EXPERIMENTAL RESULTS

This section shows the effects of peer-to-peer haptic position on X-position discrepancies when two haptic devices are performing the haptic collaboration. Positional synchronization is a major challenge in distributed networked haptic communication [14]. This becomes a challenging in our peer-to-peer architectures. The peer-to-peer architecture, position synchronization is achieved by sending the different of position data in UDP packet, which is calculated from current and previous positions from haptic device. The UDP position packet is transmitted from the local haptic device to the remote haptic device who adds this difference to its local position in order to achieve position synchronization. Thus, the testing environment of thus paper, the first haptic device (master haptic device) moves from left to right and the second haptic device (slave haptic device) follows it in the same direction. This means, two haptic devices move from left to right together at the same time without any transmission delay between them. When this force is transmitted under non-ideal network condition, it behaves differently with different transmission delay.

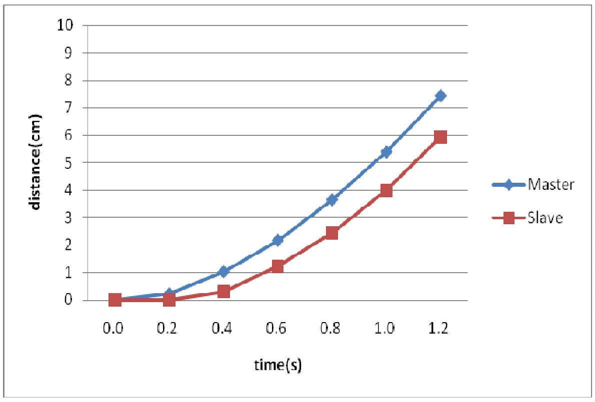

Figure 3. Haptic X-position discrepancies in the original peer-to-peer wired network

The experiment result in the original peer-to-peer wired network is shown in Figure 3. The round-trip delay time is 0.121 ms, which means there is no adding any extra packet delay from the network emulator.

The master device is moving from 0 cm X-position to 8 cm X-position within 1.2 seconds. The X-position discrepancies between master and slave devices is increased from 0 cm to 1.48 cm when 0 sec to 1.2 sec experiment time.

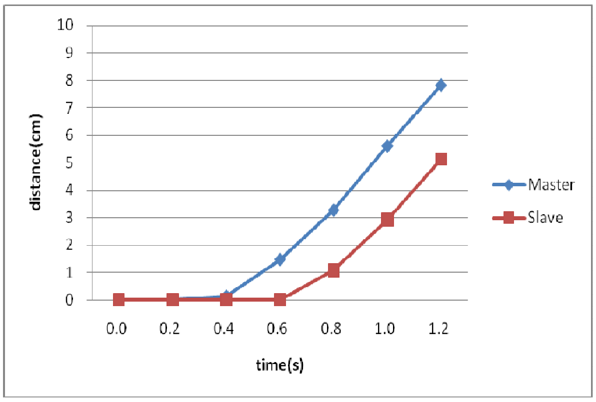

Figure 4. Haptic X-position discrepancies in adding 100MS packet delay from network emulator in the peer-to-peer wired network

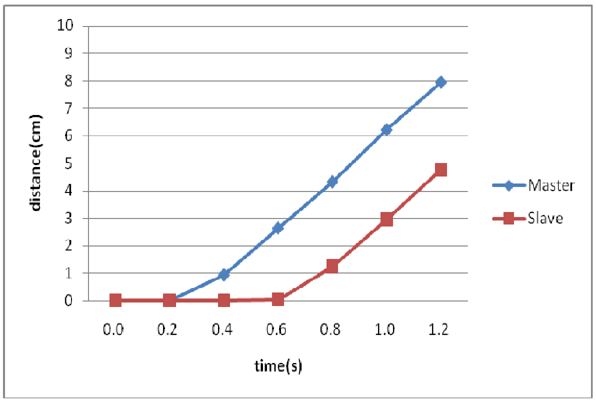

Figure 5. Haptic X-position discrepancies in adding 200MS packet delay from network emulator in the peer-to-peer wired network

Figure 4 and Figure 5 were added 100ms and 200ms packet delay through the network emulator respectively. The experimental result in Figure 5 presents the more significant X-position discrepancies between master and slave devices than the experimental result in Figure 4. It is because, the longer packet delay time will prolong the UDP position packet from local haptic device to remove haptic device. Thus, the distance error will increases due to the packet delay.

From [9], the MOS value has declined from 7 (The maximum MOS value is 7) to 3.5 when the average packet delay increases from 0 ms to 100 ms, and the MOS value will drop to 1 when the average packet delay is larger than 200ms. It is because, the longer packet delay in coordinates update would cause disconnection in the peer-to-peer haptic communication. Thus, the connection will disconnect when the average packet delay is larger than 200 ms.

5. CONCLUSION

The work presented in this paper is an experimental architecture for networked haptic interactions. Different network delay is shown to be one of major problems in the positional synchronization between master and slave haptic devices via peer-to-peer networks. It is also found to be more difficult to perform positional synchronization under the longer delay in the peer-to-peer wired network.

In this study, an experimental investigation into the real-time tele-haptic operation via peer-to-peer wired network. The experimental results show packet delay will seriously affect user experience under haptic interaction. It is because, the longer delay of UDP position packet would cause disconnection in the peer-to-peer haptic communication.

The future work will investigate the haptic force feedback in error-prone wireless network in order to compare the measured quality of real-time force feedback value as the mean opinion score (MOS) over wireless networks.

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