1. INTRODUCTION A number of papers handling haptic media have been published so far [1]-[4]. When we transmit haptic media over a network, the output quality of haptic media may seriously be degraded owing to network latency and packet loss [1], [2]. In [1], Kim et al. carry out an experiment on international connection between Massachusetts and London for collaborative work with haptic interface devices. Also, in [2], Nishino et al. conduct an experiment between Japan and Korea for a remote instruction system with haptic interface devices that enables students to learn an instructor’s skills interactively. However, the influences of network latency and packet loss have not necessarily been investigated sufficiently.

In this paper, we make an experiment on international connection between Japan and Korea or Greece for work in which a user lifts and moves a virtual object in a 3-D virtual space. The size of the virtual space is the same as the workspace size of PHANToM (i.e., width: 160 mm, height: 120 mm, depth: 70 mm). A user lifts and moves a rigid cube (the length of each side is 1/4 of the height of the virtual space) as an object by using a cursor so that the cube contains a target which revolves along a circular orbit at a constant velocity. The cursor moves in the virtual space when the user manipulates the stylus of PHANToM with his/her hand. A radius of the orbit is 30 mm, and the target is a sphere whose diameter is equal to the length of each side of the cube.

2. WORK DESCRIPTIONS We use the PHANToM Omni (referred to as PHANToM here) as a haptic interface device. Figure 1 shows a displayed image of the virtual space in the work. The size of the virtual space is the same as the workspace size of PHANToM (i.e., width: 160 mm, height: 120 mm, depth: 70 mm). A user lifts and moves a rigid cube (the length of each side is 1/4 of the height of the virtual space) as an object by using a cursor so that the cube contains a target which revolves along a circular orbit at a constant velocity. The cursor moves in the virtual space when the user manipulates the stylus of PHANToM with his/her hand. A radius of the orbit is 30 mm, and the target is a sphere whose diameter is equal to the length of each side of the cube.

3. EXPERIMENTAL SYSTEM As shown in Fig. 2, our experimental system consists of a server in Korea (CPU: Pentium4 3.8 GHz, RAM: 1 GB, OS: Windows XP) or Greece (CPU: Xeon 3.2 GHz 3.2 GHz (2 processors), RAM: 4 GB, OS: Windows Server 2008) and a client in Japan (CPU: Pentium4 2.8 GHz, RAM: 512 MB, OS: Windows XP). The server and client are connected to each other through the Internet.

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4. EXPERIMENTAL METHOD In the experiment, we adopt Skipping [3] as an intra-stream synchronization algorithm. Skipping outputs only the latest arrived MU at each point of output time (i.e., every millisecond); therefore, it skips obsolete MUs. As a performance measure, we employ the average distance between cube and target [3]. This measure is defined as the mean distance between the centers of the cube and target. Small values of the average distance indicate that the cube follows the target precisely; this signifies that the efficiency of the work is high.

The experiment was carried out at 0, 6, 11, 15, and 19 o’clock of Japan standard time. At each time, we made the experiment ten times for each of Korea and Greece. The measurement time of each experimental run was 30 seconds.

5. EXPERIMENTAL RESULTS We show the average distance between cube and target only at 0 o’clock in Fig. 3, where we plot the 95% confidence intervals. This is because there was no large difference in the average distance between 0 o’clock and the other times. For comparison, we also show the average distance in the case where we set the server as well as the client in NIT campus in Fig. 3.

From Fig. 3, we see that the average distance between Japan and Greece is the largest; that between Japan and Korea is the second largest. To investigate the reason, we measured the average and standard deviation of network latency and the packet loss rate by transmitting 3,000 ICMP packets at each above-mentioned time. The average network latency denotes the average value of round-trip time of the ICMP packets. The average and standard deviation of network latency and the packet loss rate between Japan and Korea were 27.01 ms, 0.19 ms, and 0.02%, respectively. Those between Japan and Greece were 331.10 ms, 6.30 ms, and 1.53%, respectively. We also examined the number of hops. There were 11 hops between Japan and Korea and 26 hops between Japan and Greece. In the case of NIT campus, no ICMP packets were lost. The number of hops was 1, and the average network latency was smaller than 1 ms.

In addition, we conducted an experiment on international connection between Japan and Korea for a remote haptic calligraphy system [4]. As a result, there was almost no degradation owing to the network latency and packet loss. The average and standard deviation of network latency and the packet loss rate were 27.23 ms, 0.34 ms, and 0.03%, respectively.

As the next step of our research, we need to make experiments on international connection for other types of work.

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