Influences of Network Delay on Will Transmission with Haptic Sensation in Collaborative Work

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Outline

- Background
- Purpose
- Collaborative work
- Assessment systems
- Assessment methods
- Assessment results
- Conclusions and future work
Background

Research of collaborative work in distributed virtual environments using haptic sensation has become active. We can expect to achieve communication with higher sense of reality and improve work efficiency greatly.

Network delay and packet loss

- When haptic sensation is transmitted through a network.
- QoE (Quality of Experience) may seriously be degraded.

Example of distributed virtual environments

It is necessary to investigate the influences of network delay on QoE.
The influence of network delay on will transmission with haptic sensation in a 3-D virtual space was investigated by QoE assessment.

Two users lift and move an object cooperatively so as not to drop the object in the virtual space. Their own wills about the movement directions are transmitted to each other by haptic interface devices.
Purpose (2/2)

Problem

The influence of network delay on the will transmission with haptic sensation in a real space has not been investigated so far.

This work

- We deal with collaborative work in which two users move a pencil collaboratively toward a target by using haptic interface devices (i.e., haptic sensation) in a real space.
- We make a comparison between the work in real space and the work in virtual space subjectively and objectively by QoE assessment.
Two users move a pencil collaboratively toward a target along the lattice by using haptic interface devices (i.e., haptic sensation).

When the users move the pencil to the target as which a coin is used, they are asked to move the pencil along one of the shortest routes. The speed of movement is constant (2 second on a side).

After the pencil reaches the target, the target is replaced at a randomly-selected adjacent intersection.
At the intersections where the users need to determine the pencil’s movement direction, they decide the movement direction randomly.

They try to transmit their wills about the pencil’s movement directions to each other by haptics.

- If one user can know the other’s will (the movement of pencil), he/she follows the will.
- Otherwise, he/she moves the pencil based on his/her own will.
Collaborative work (virtual space) (1/3)

Server

Network

Client

Haptic interface device (Geomagic Touch)
Collaborative work (virtual space) (2/3)

- Two users lift and move an object together and move to the target by haptic interface devices.
- When the users move the object to eliminate the target, they are asked to move the object along one of the shortest routes.
- When the target is contained by the object, it disappears and then appears at a randomly-selected intersection.
Collaborative work (virtual space) (3/3)

- At the intersections where the users need to determine the object’s movement direction, they decide the movement direction randomly.
- They try to transmit their wills to each other by haptics.

- If one user can know the other’s will (the movement of object), he/she follows the will.
- Otherwise, he/she moves the object based on his/her own will.
The network emulator (NIST Net) generates an additional constant delay for each packet transmitted between the two terminals.

Assessment system (real space)

Transmission rate

Haptic media: 1000 MU/s
Video: 30 MU/s

Transport protocol: UDP
The network emulator (NIST Net) generates an additional constant delay for each packet transmitted between the two terminals.
Assessment methods (1/6)

Work contents

• After passing each intersection at which the subjects need to transmit their wills, each subject is asked to stop moving in the middle of the two neighboring intersections.
• Tell whether he/she can know the other’s will, specify the will if he/she can know it, and tell his/her own will as well.

Constant delay

Real space : 0 ms through 500 ms
Virtual space : 0 ms through 180 ms
We select the constant delay in random order for each pair of subjects.

The subjects were 20 persons whose ages were between 21 and 29.
Subjective assessments

Before the assessments, each pair of subjects practices the work on the condition that there is no constant delay for about 5 minutes.

- After the practice, they are asked to do the collaborative work once on the condition that there is no constant delay.
- The quality at this time is the standard in the subjective assessment.
Assessment methods (3/6)

Work in real space

- The operability of PHANToM
- Transmissibility of wills (whether their own wills can be transmitted correctly to each other.)
- Interactivity (difference in time between one’s own movement and partner’s movement.)
- Comprehensive quality (the weighted sum of the operability, transmissibility, and interactivity.)

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Imperceptible</td>
</tr>
<tr>
<td>4</td>
<td>Perceptible, but not annoying</td>
</tr>
<tr>
<td>3</td>
<td>Slightly annoying</td>
</tr>
<tr>
<td>2</td>
<td>Annoying</td>
</tr>
<tr>
<td>1</td>
<td>Very annoying</td>
</tr>
</tbody>
</table>

We obtained the mean opinion score (MOS)

Each test’s time : 80 seconds
Total time : 1 hour
Work in virtual space

- **The operability of PHANToM**
- **Transmissibility of wills** (whether their own wills can be transmitted correctly to each other.)
- **Comprehensive quality** (the weighted sum of the operability and transmissibility.)

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We obtained the *mean opinion score* (MOS)

Each test’s time : 80 seconds    Total time : 30 minutes
Objective assessment (real space)

- The average number of times that the pencil arrives at the position of the target
- The average number of passed intersections at which the subjects needed to transmit their wills
- The average number of intersections at which one thought that he/she knew the other’s will
- The average number of intersections at which one could know the other’s will accurately
- The percentage of questions answered correctly (defined as the average number of intersections at which one could know the other’s will accurately divided by the average number of passed intersections at which the subjects needed to transmit their wills)
Objective assessment (virtual space)

- The average number of eliminated targets
- The average number of passed intersections at which the subjects needed to transmit their wills
- The average number of intersections at which one thought that he/she knew the other’s will
- The average number of intersections at which one could know the other’s will accurately
- The percentage of questions answered correctly (defined as the average number of intersections at which one could know the other’s will accurately divided by the average number of passed intersections at which the subjects needed to transmit their wills)
Assessment results (1/6)

Constant delay (ms)

Operability of PHANToM
Transmissibility of wills
Interactivity
Comprehensive quality

*MOS*


I 95% confidence interval

Real space

3.5 *2
Assessment results (2/6)

Average number of times that pencil arrives at position of target object

Constant delay (ms)

I 95% confidence interval

Real space
Assessment results (3/6)

Percentage of questions answered correctly (%)

Real space

I 95% confidence interval

Constant delay (ms)
Assessment results (4/6)

Assessment results (5/6)

I 95% confidence interval

Virtual space

Constant delay (ms)

Average number of eliminated targets

0 20 40 60 80 100 120 140 160 180

0 2 4 6 8 10 12 14 16 18
Assessment results (6/6)

Percentage of questions answered correctly (%)

Virtual space

I 95% confidence interval

Constant delay (ms)
Conclusions

We investigated the influences of network delay on will transmission in collaborative work where two users transmit their wills to each other by using haptic sensation in a real space and in a virtual space.

- The MOS values of the operability, transmissibility of wills, interactivity, and comprehensive quality become smaller as the network delay increases.
- The deterioration in QoE is allowable, when the network delay is smaller than about 300 ms in the real space, and when the network delay is smaller than about 40 ms in the virtual space.
Future work

- Investigation of the accuracy of work with haptic sensation excluding work which transmits wills about movement direction (for example, one user tries to stop the movement of the other user).