QoE Assessment of Sense of Presence in Networked Virtual Environment with Haptic and Auditory Senses: Influence of Network Delay

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Outline

- Background
- Purpose
- Networked Haptic Drum System
- Assessment Method
- Assessment Results
- Conclusions and Future Work
Recently a number of researchers have been paying attention to multi-sensory communications. By handling the multiple senses such as vision, auditory sensation, olfaction, and haptic sensation together, we can improve the sense of presence. It is important to assess how largely the sense of presence is improved. There are many researches on effects of visual and auditory senses on the sense of presence.
Meaning of Sense of Presence


The sense of presence has polysemy and multidimensionality[1].

- Meanings: “Feeling as if you were there” in a dictionary, evocative feeling, and so on.
- Four factors: Evaluation, stringency, activity, and mechanical property.

When we assess the sense of presence, we need to clarify what kinds of aspects of the sense should be assessed.
We assessed the sense of presence for remote ikebana with haptic and olfactory senses and a fruit harvesting game with haptic, olfactory, and auditory senses in order to clarify effects of sensory stimuli on the sense of presence[2].

Assessment Method

- The rating scale method and Semantic Differential (SD) technique are used together.
- The relation between results of the rating scale method and those of the SD technique is examined by multiple regression analysis.

We demonstrated that contributions of the sensory stimuli depend on the applications.
Purpose

Problems

- It is not clear that we can employ our assessment method to examine influences of network delay on Quality of Experience (QoE) in terms of the sense of presence.
- The influences are not sufficiently clear.

This Work

We investigate the influences of network delay on QoE in terms of the sense of presence in a networked haptic drum system [3] by using our assessment method.

Networked Haptic Drum System

- Two users play drum performance in a 3D virtual space.
- A user (teacher) remotely controls the other user’s (student’s) drumsticks.

Terminal 1

Haptic interface device (Geomagic Touch)

Network

Terminal 2
To investigate the influences of network delay on QoE in terms of the sense of presence

Our Assessment Method

- The rating scale method and Semantic Differential (SD) technique are used together.
- The relation between results of the rating scale method and those of the SD technique is examined by multiple regression analysis.
A pair of subjects (subjects 1 and 2) played a drum set.

Subject 1 remotely controlled subject 2’s drumsticks.

Subject 1 actively played the drum set freely (called the *active mode* here) for one minute, and subject 2 just held the device styli (the *passive mode*).

Subjects 1 and 2 judged the sense of presence for constant delays in the active and passive modes, respectively.

**Constant delay**

- 0ms, 50ms 100ms, 150ms
- We presented the four constant delay in random order for each pair of subjects.
A pair of subjects (subjects 1 and 2) played a drum set.

Subject 1 remotely controlled subject 2’s drumsticks.

Subject 1 actively played the drum set freely (called the *active mode* here) for one minute, and subject 2 just held the device.

Subjects 1 and 2 judged the sense of presence on four constant delays in the active and passive modes, respectively.

Constant delay

- 0 ms, 50 ms, 100 ms, 150 ms
- We presented the four constant delays in random order for each pair of subjects.

- Two terminals are connected to each other through a network emulator.
- The network emulator is used to generate a constant delay for each packet transmitted between the terminals.
Assessment Method (3/5)

Rating scale method

We defined the sense of presence.

- Feeling as if you were there.
- Feeling the sense of immersive.
- Feeling as if you were carrying out drum performance.
- Feeling that you remotely control the other user’s drumsticks (your drumsticks are remotely controlled by the other user’s ones).

<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 **Mean Opinion Score (MOS)** by averaging scores of all the subjects.
Each subject provided answers to our questions about how much applicable to 36 adjective pairs by using the bipolar five-grade scales.

We performed the factor analysis for scores of the SD technique.

<table>
<thead>
<tr>
<th>very applicable</th>
<th>applicable</th>
<th>neither applicable nor inapplicable</th>
<th>applicable</th>
<th>very applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>good</td>
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<td>likable</td>
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</tbody>
</table>
The number of subjects (men and women) whose ages were between 21 and 24 was 36.

Total assessment time per pair of subjects was about fifty minutes.

Multiple Regression Analysis

We examined the relation between the results of factor analysis and the scores of the rating scale method by multiple regression analysis.
The MOS values of sense of presence deteriorate as the constant delay increases. The reaction force increases depending on the constant delay[3].
Evaluation & Operability factor (Factor 1)

- The nine adjective pairs fit into the “evaluation” dimension[^4] advocated by Osgood.
  
  "natural - unnatural,“ “common - extraordinary,“
  “reasonable - unreasonable,“ “pleasant - unpleasant,“
  “friendly - unfriendly,“ “likeable - dislikeable,“ “good - bad,“
  “realistic - unrealistic,“ and “enjoyable - agonizing”

- The six adjective pairs compose the “operability” factor[^2].
  
  “stable - unstable,” “smooth - sharp,” “delicate - rugged,“
  “relaxed - tense,” “continuous - discontinuous,”
  and “overall - divisional”

Activity factor (Factor 2)

- The four adjective pairs have the meaning of activity\(^4\) of the semantic space.

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Potency factor (Factor 3)

- The three adjective pairs have the meaning of potency\(^4\) of the semantic space.
  
  "strong - weak," "heavy - light," and "big - small"

- The remaining adjective pair ("powerful - watery") is somewhat related to the potency.

The subscales are the average scores of the adjective pairs of the four conditions for each factor.
The subscales are the average scores of the adjective pairs of the four conditions for each factor.

The subscales of the active and passive modes in Factors 1 and 2 have a tendency to deteriorate as the constant delay increases.
The subscales of the passive mode hardly depend on the constant delay, and those of the active mode increase as the constant delay becomes larger.

Because the reaction force in the active mode increases more largely than that in the passive mode as the constant delay increases.
Equation

\[ V_{\text{score}} = 2.710 F_1 - 0.744 F_3 + 3.959 \]

- **\( V_{\text{score}} \):** Estimated score of the rating scale method
- **\( F_1, F_3 \):** Average subscales of Factors 1 and 3

Contribution rate adjusted for degrees of freedom: 0.927

The largest degradation factor of the sense of presence caused by the network delay is \( F_1 \) ("evaluation & operability").
Equation

\[ V_{\text{score}} = 2.710F_1 - 0.744F_3 + 3.959 \]

- **\( V_{\text{score}} \):** Estimated score of the rating scale method
- **\( F_1, F_3 \):** Average subscales of Factors 1 and 3

We can suppose that “operability” factor has largely influences on “evaluation” factor.

The largest degradation factor of the sense of presence caused by the network delay is \( F_1 \) (“evaluation & operability”).
We assessed the operability of the haptic interface device in the networked haptic drum system by QoE assessment.

The MOS values of the operability are almost the same as that of the sense of presence.

The largest degradation factor caused by the network delay is the operability in networked haptic drum system.
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The MOS values of the operability are almost the same as that of the sense of presence.

Our assessment method is effective in QoE assessment about the sense of presence.
Conclusions

We investigated the influences of network delay on QoE in terms of the sense of presence in a networked haptic drum system by using our assessment method.

- The largest degradation factor caused by the network delay is the operability in the networked haptic drum system.
- Our assessment method is effective in QoE assessment about the sense of presence.
Future Work

- We will investigate influences of network delay, delay jitter, and packet loss on the sense of presence for other applications.
- We will examine effects of QoS (Quality of Service) control such as the adaptive reaction force control [5] on the sense of presence.