Influences of Network Latency on Interactivity in Networked Rock-Paper-Scissors

Yousuke Hashimoto
Department of Computer Science and Engineering
Graduate School of Engineering
Nagoya Institute of Technology
Nagoya 466-8555, Japan
hashiyou@mcl.elcom.nitech.ac.jp

Yutaka Ishibashi
Department of Computer Science and Engineering
Graduate School of Engineering
Nagoya Institute of Technology
Nagoya 466-8555, Japan
ishibasi@nitech.ac.jp

ABSTRACT

This paper investigates the influences of network latency on the interactivity in rock-paper-scissors which two users do over a network by using live voice and video. By subjective assessment, we have assessed the interactivity in two cases. In one case, only one of the two users (referred to as the caller here) says, "Rock, paper, scissors, go!" and then both users try to show rock, paper, or scissors at the same time. In the other case, the two try to say, "Rock, paper, scissors, go!" simultaneously after one of them (i.e., the caller) has said, "Here we go," and then they try to pick rock, paper, or scissors at the same time. Assessment results show that the mean opinion score (MOS) of the caller tends to decrease as the network latency becomes larger in both cases. The MOS of the other user hardly depends on the network latency.

Categories and Subject Descriptors

H.4.3 [**Information Systems Applications**]: Communications Applications—*Computer conferencing, teleconferencing, and videoconferencing*; H.5 [**Information Interfaces and Presentation**]: Multimedia Information Systems

General Terms

Human Factors, Performance, Experimentation

Keywords

Rock-paper-scissors, Network latency, Interactivity, Voice, Video

1. INTRODUCTION

In live voice and video communications [1], we can enjoy chats and sometimes play games such as fastest fingers first and rock-paper-scissors. The interactivity and fairness among users are very important in such chats and games [2]. However, when we transmit the live voice and video streams over a network like the Internet, the interactivity and fairness among users may seriously be damaged owing to the network latency.

In [2], the authors investigate the influences of the difference in network latency among terminals on the perception of fairness in a name-guessing task like fastest fingers first by subjective assessment. They show that most of subjects perceive unfairness when the difference in network latency between two terminals exceeds approximately 100 ms. They also examine the influence of the difference in packet loss rate on the perception of fairness. However, they do not examine the influence on the interactivity. They further need to handle tasks different from the name-guessing task like fastest fingers first.

In networked real-time games such as networked shooting games and networked racing games, the interactivity has extensively been studied [3]–[7]. It is well known that the maximum allowable delay is roughly 100 ms (for example, see [3] or [8]). However, how stringent delay constraints are required seems to be dependent on what we do over a network.

This paper deals with rock-paper-scissors which two users do over a network by using live voice and video (called *networked rock-paper-scissors* in this paper) as one of networked real-time games which have stringent delay constraints. We subjectively assess the interactivity between the two users in the networked rock-paper-scissors. We also investigate the influences of network latency on the interactivity.

The rest of this paper is organized as follows. Section 2 outlines the networked rock-paper-scissors, and Section 3 describes our experimental system. The subjective assessment method is explained in Section 4, and assessment results are presented in Section 5. Section 6 concludes the paper.

2. NETWORKED ROCK-PAPER-SCISSORS

Here we suppose that two users do rock-paper-scissors over a network by using live voice and video in the following two cases: *One-way case* and *two-way case* in terms of priming

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(a) The caller says, "Rock, paper, scissors, go!"

(b) The caller and the other user show scissors and paper, respectively.

Figure 1: Displayed images in the one-way case.

(i.e., calling out and motion before showing rock, paper, or scissors). In the one-way case, only one (referred to as the *caller* here) of the two users says, "Rock, paper, scissors, go!" (in Japanese) (see Fig. 1 (a)), and then both users try to show rock, paper, or scissors at the same time (Fig. 1 (b)). In the two-way case, after one (i.e., the caller) of the two has said, "Here we go" (in Japanese) (Fig. 2 (a)), they try to say, "Rock, paper, scissors, go!" simultaneously (Fig. 2 (b)). Then, they try to pick rock, paper, or scissors at the same time (Fig. 2 (c)).

It should be noted that in rock-paper-scissors, rock is stronger than scissors, which are stronger than paper, but rock is weaker than paper. Thus, in Fig. 1 (b), the user picking scissors wins at networked rock-paper-scissors. The user showing paper wins in Fig. 2 (c).

The reason why we handle the two cases is as follows. It seems to be more difficult to adjust the timing between the two users in the two-way case than in the one-way case. We should examine the influence of the difference in difficulty of timing adjustment on the interactivity. Also, we actually do rock-paper-scissors in such ways.

3. EXPERIMENTAL SYSTEM

As shown in Fig. 3, two terminals (i.e., *terminals 1* and *2*) are connected to each other through a network emulator (NIST Net [9]) by using 100BASE-T cables. Each terminal (CPU: Pentium4 processor at 2.8 GHz, RAM: 512 Mbytes) has a headset with a microphone and a video camera. The terminal inputs voice samples (PCM, the bit rate: 64 kbps) as a voice *media unit* (*MU*), which is an information unit for capturing and transmission, every 20 ms. It also inputs a video picture (MPEG1, GOP: I, the image size: 253×189 pixels, the average bit rate: 922 kbps) as a video MU every 33 ms.

Each MU input at a terminal is transmitted to the other terminal by UDP. Each terminal outputs the MU on receiving it. NIST Net is employed to generate a constant additional delay for each MU transmitted in both directions between the two terminals. The constant additional delay in one direction is set to the same as that in the other direction in this paper.

We measured the average MU delay, which is defined as the average time from the moment a terminal starts to capture an MU until the instant the MU is output at the other terminal. When the constant additional delay is zero, the average MU delays of voice and video were around 30.4 ms and 39.8 ms, respectively.

4. SUBJECTIVE ASSESSMENT METHOD

For subjective assessment, we have enhanced the double-stimulus method in ITU-R BT.500-10 [10], which is a recommendation for subjective assessment of television pictures. At first, ten pairs of subjects (i.e., twenty subjects) whose ages were between 21 and 23 took part in the subjective assessment in the one-way case. One subject of each pair acted as the user (i.e., the caller) saying, "Rock, paper, scissors, go!" The other subject of the pair acted as the other user. Next, they swapped their roles with each other.

In the two-way case, one of each pair acted as the user (the caller) saying, "Here we go," and the other of the pair did as the other user. Then, they also swapped their roles as in the one-way case.

In each test, each subject did rock-paper-scissors several times for 10 seconds on the condition that there was no

(a) The caller says, "Here we go."

(b) The two users say, "Rock, paper, scissors, go!"

(c) The caller and the other user show rock and paper, respectively.

Figure 2: Displayed images in the two-way case.

Table 1: Five-grade impairment scale for deterioration owing to network latency.

Score	Description
5	Imperceptible
4	Perceptible, but not annoying
3	Slightly annoying
2	Annoying
1	Very annoying

additional delay, and then the subject did for the same duration by generating constant additional delays. The subject could do rock-paper-scissors around five to seven times for the duration in the experiment.

The subjects were asked to base their judgments in terms of wording used to define the subjective scale (see Table 1). Each subject gave a score from 1 through 5 to each test to obtain the *mean opinion score* (*MOS*) [10].

The number of stimuli per subject is 16 in each of the one-way and two-way cases. The total time per subject was around 8 minutes in each case.

5. ASSESSMENT RESULTS

In this section, we first show the assessment results in the one-way case. Next, the assessment results in the two-way case are presented.

5.1 One-way case

We plot the MOS values of the caller and the other user as a function of the constant additional delay in the one-way case in Fig. 4. We also display the 95 % confidence intervals in the figure.

In Fig. 4, we see that as the constant additional delay becomes larger, the MOS value of the caller tends to decrease; especially, when the constant additional delay exceeds around 60 ms, the MOS value largely decreases; the value becomes less than three when the delay exceeds about 80 ms. The MOS value of the other user hardly depends on the constant additional delay. This means that the user does not perceive any deterioration in the interactivity. This is because the user just adjusts his/her timing of motion to the caller's timing while hearing voice and watching video; thus, he/she does not perceive any latency. In contrast, the caller experiences the round-trip delay before hearing/seeing the other user's reaction after priming.

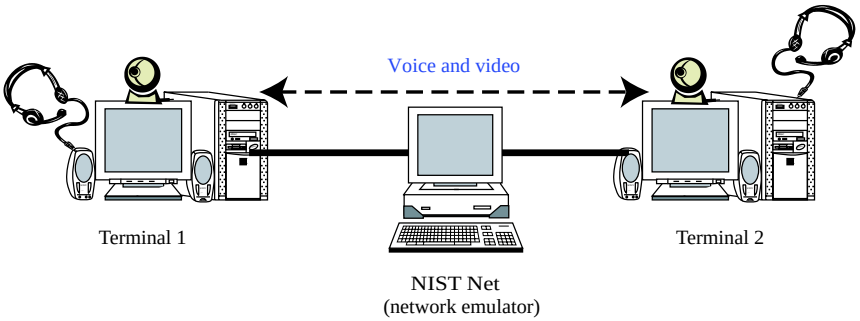

Figure 3: Configuration of the experimental system.

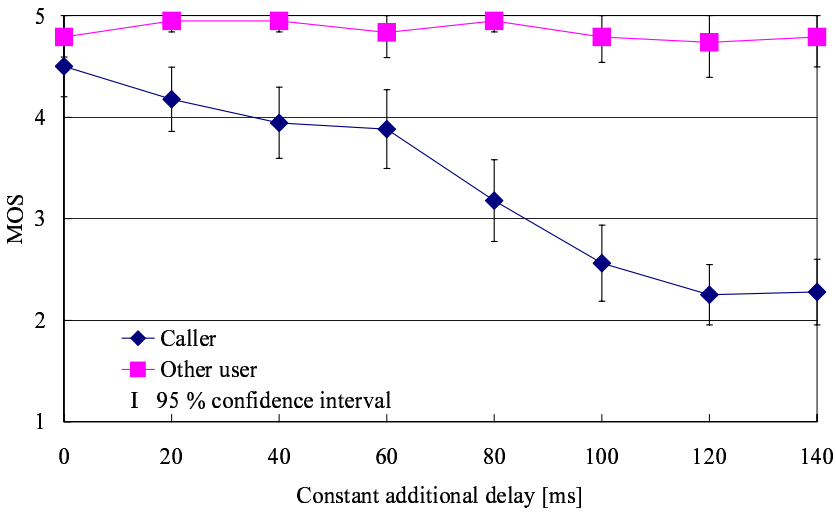

Figure 4: MOS versus constant additional delay in the one-way case.

5.2 Two-way case

We show the MOS values versus the constant additional delay in the two-way case in Fig. 5, where we plot the 95 % confidence intervals.

From Fig. 5, we can notice almost the same tendency as that in Fig. 4. That is, the MOS value of the caller tends to decrease as the constant additional delay becomes larger; the MOS value of the other user is hardly dependent on the constant additional delay.

However, in Fig. 5, the MOS value of the caller largely decreases when the constant additional delay exceeds around 100 ms; the MOS value becomes less than three. The value of 100 ms is larger than 60 ms, which is the corresponding value in Fig. 4. The reason is closely related to the average MU delays of 30.4 ms and 39.8 ms (see Section 3); the delays damage the interactivity of the two-way case more largely than that of the one-way case even if the constant additional delay is zero. Thus, we cannot perceive the deterioration in the interactivity in the two-way case more largely than in the one-way case.

6. CONCLUSIONS

This paper dealt with networked rock-paper-scissors which two users do over a network by using live voice and video. By subjective assessment, we investigated the influences of network latency on the interactivity of the networked rock-paper-scissors in the one-way and two-way cases. The two-way case differs from the one-way case in priming; that is, only one user says, "Rock, paper, scissors, go!" in the one-way case, but both users try to say that simultaneously in the two-way case.

As a result, we found that the MOS value of the caller tends to decrease as the network latency becomes larger in both cases; the MOS value of the other user hardly depends on the network latency. The network latency in the one-way case influences the interactivity more largely than that in the two-way case.

As the next step of our research, we will examine the influ-

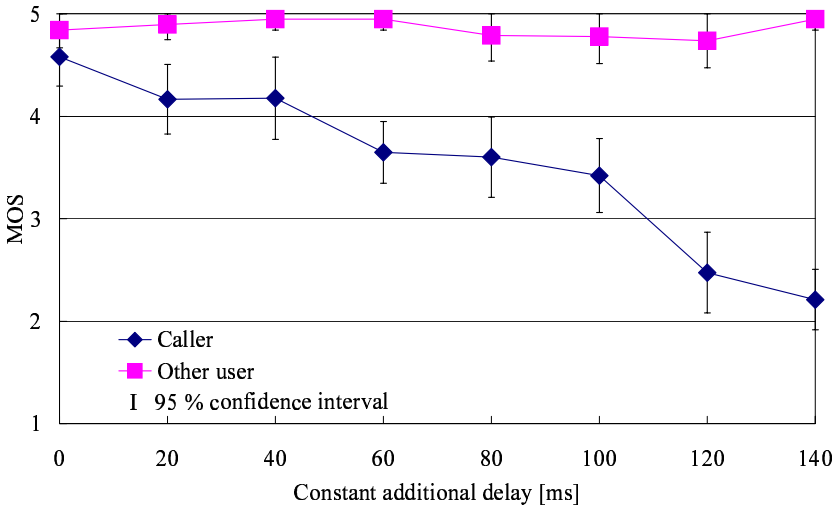

Figure 5: MOS versus constant additional delay in the two-way case.

ences of the network latency jitter on the interactivity and those of the difference in the network latency and packet loss on the fairness among users. We also plan to study group (or inter-destination) synchronization control [11], which adjusts the output timing among terminals, by taking advantage of the results obtained in this paper.

7. ACKNOWLEDGMENT

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8. REFERENCES

[1] F. Gong. Multipoint audio and video control for packet-based multimedia conferencing. In *Proceedings of ACM Multimedia*, pages 425–432, October 1994.

[2] Y. Ishibashi, M. Nagasaka, and N. Fujiyoshi. Subjective assessment of fairness among users in multipoint communications. In *Proceedings of ACM SIGCHI ACE*, June 2006.

[3] L. Pantel and L. C. Wolf. On the impact of delay on real-time multiplayer games. In *Proceedings of NOSSDAV*, pages 23–29, May 2002.

[4] C. Schaefer, T. Enderes, H. Ritter, and M. Zitterbart. Subjective quality assessment for multiplayer real-time games. In *Proceedings of ACM NetGames*, pages 74–78, April 2002.

[5] T. Beigbeder, R. Coughlan, C. Lusher, J. Plunkett, E. Agu, and M. Claypool. The effects of loss and latency on user performance in Unreal Tournament 2003. In *Proceedings of ACM NetGames*, August 2004.

[6] P. Quax, P. Monsieurs, W. Lamotte, D. D. Vleeschauwer, and N. Degrande. Objective and subjective evaluation of influence of small amounts of delay and jitter on a recent first person shooter game. In *Proceedings of ACM NetGames*, August 2004.

[7] G. J. Armitage. An experimental estimation of latency sensitivity in multiplayer Quake 3. In *Proceedings of IEEE ICON*, September 2003.

[8] Y. Ishibashi and S. Tasaka. Causality and media synchronization control for networked multimedia games: Centralized versus distributed. In *Proceedings of ACM NetGames*, pages 34–43, May 2003.

[9] M. Carson and D. Santay. NIST Net - A Linux-based network emulation tool. *ACM SIGCOMM Computer Communication Review*, 33(3):111–126, July 2003.

[10] ITU-R BT.500-10. Method for subjective assessment of the quality of television pictures. International Telecommunication Union, March 2000.

[11] Y. Ishibashi and S. Tasaka. A group synchronization mechanism for live media in multicast communications. In *Conference Record of IEEE GLOBECOM*, pages 746–752, November 1997.