# QoE Enhancement by GUI for Threshold Selection in the QoE-Based Video Output Scheme SCS


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***Abstract*—This paper makes multidimensional QoE comparisons of GUIs for threshold selection in the QoE-based video output scheme SCS in audio-video IP transmission. SCS switches between error concealment and frame skipping by comparing the ratio of video slice loss in a video frame with a threshold value. For the purpose of adapting SCS to individual users' inclination, we need to create some appropriate threshold selection interfaces and give the option to select a threshold value to the user. We propose two new interfaces: a slide bar method (choosing a threshold value by a slide bar), and a two mode method (selection of one out of two modes by two buttons). In the latter, a threshold value is set according to the mode. To assess QoE multidimensionally, we conducted subjective experiments on four methods: the conventional error concealment method (100% method), a previously proposed interface called the radio button method (selecting a threshold value by four radio buttons) and the two new interfaces. As a result, we observe that the two new interfaces can achieve higher overall audiovisual QoE than the conventional 100% method and the radio button method. In addition, we show that the slide bar method achieves the highest controllability whereas it imposes a burden on the user and that the two mode method imposes the lightest burden on the user among the three interfaces while it provides high QoE.**



***Keywords*-QoE, SCS, Error Concealment, Frame Skipping, GUI**


## I. INTRODUCTION

Audio-video transmission is an important ingredient of multimedia application services on IP networks. IP networks basically offer best-effort services. *QoS (Quality of Service)* for audio-video transmission may deteriorate because of packet loss, delay and delay jitter. This leads to the degradation of *QoE (Quality of Experience)* [1], which is the ultimate target of the service offering. Therefore, we need some technique to enhance QoE.

In audio-video streaming services, which are now very popular, some types of quality control improve the output quality as shown in Fig. 1 where the media receiver informs the media sender of the quality-level requested by the user. For example, DASH (Dynamic Adaptive Streaming over HTTP) introduced in [2] provides fine tuning control of QoE by feedback of client information. However, feedback control methods like this have two problems. One is response delay caused by feedback control, and the other is increase in the network traffic.

In order to enhance QoE for audio-video IP transmission, Tasaka *et al.* propose a video output scheme called *SCS (Switching between error Concealment and frame Skipping)* in [3]. Video error concealment is a method to interpolate lost video slices due to packet drop with other information of the video stream. However, the spatial quality of the error-concealed video degrades compared to the original one since the method cannot perfectly interpolate the lost information. In addition, there is a problem that the degradation propagates to the succeeding frame in a unit of GOP (Group of Pictures). On the other hand, frame skipping is a method which does not output video frames with lost slices. The method keeps the spatial quality of the output video original, while it degrades the temporal quality because of skipped frames. Error concealment, frame skipping, and SCS, which utilize the first and second methods, can control video output quality only at the media receiver. Thus, we have no problem associated with the feedback control because SCS does not need feedback information to the media sender as illustrated in Fig. 2.

As another quality control method, H.264/SVC (Scalable Video Coding) [4] is available for video streaming services. SVC provides a video encoding solution for integration of multiple resolutions, frame rates and SNRs. Thus, the media sender can seamlessly decrease an amount of video data in case of network congestion. The media receiver can also select the decoded video quality of streaming services considering the terminal capabilities. Objective QoE evaluation with SVC is conducted in [5] and [6]. We can utilize a combination of SCS and SVC.

Laghari *et al.* point out that we need to consider business aspects to provide a rich QoE model in [7]. SCS can be implemented at low cost because it is just a matter of the receiver only. This also validates the adoption of SCS as a method of quality control in terms of business aspects.

SCS utilizes the opposite features of error concealment and frame skipping; i.e., it is based on the trade-off relation

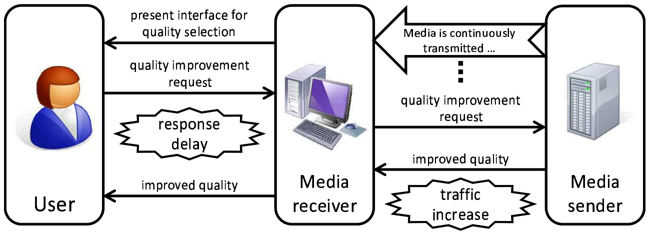


Figure 1. quality control with feedback

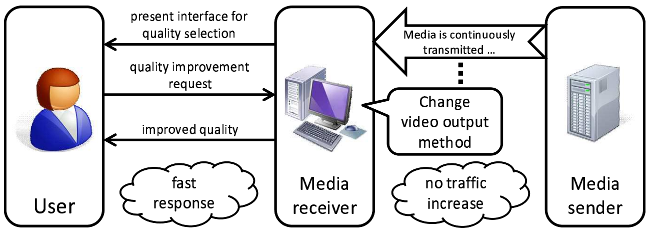


Figure 2. quality control with SCS

between video spatial quality and temporal quality to maximize QoE. SCS defines the error concealment ratio ($R_c$) [%] as the ratio of the number of lost video slices to the total number of slices in a frame and introduces a threshold value $T_h$ [%]. When $R_c$ is larger than $T_h$ in a video frame, the video frame is skipped, i.e., *frame skipping*. When an I frame with $R_c \leq T_h$ comes out, the output scheme is switched to error concealment. We then see that an appropriate selection of the $T_h$ value maximizes QoE.

To increase the effectiveness of SCS, we need to adopt some appropriate threshold setting methods [8]. In [8], Tasaka and Hirashima propose the *table lookup method* and the *user selection method* by GUI; they compare the two proposed methods with the *QoE estimation method* [3] and the conventional error concealment method. They demonstrate that the first three methods achieve higher QoE than the conventional error concealment method by experiment.

In [8], the user selection method achieves the highest QoE of all the methods. It enables the user to select a threshold value optionally to adapt SCS to individual users' inclination. If the user conducts the optional threshold selection, however, it can be a burden on the user; also, if the threshold selection is inappropriate, the video output quality degrades. Consequently, we have to devise some appropriate GUIs which achieve high QoE while imposing a light burden on the user.

In [9], Eronen and Vuorimaa propose and evaluate two user interfaces for digital television. They conclude that navigation is considered a part of the functionality and content, and it cannot be designed independently from the two. It means that user interfaces affect evaluation of the functionality and content. From this result, we also confirm that the user selection method for SCS also needs appropriate interfaces for the threshold selection.

The novelty of this paper is two-fold: proposal of two new interfaces for the threshold selection, and multidimensional QoE comparisons of four methods for the threshold selection. The new threshold selection interfaces are the *slide bar method* and the *two mode method*. We compare the two new interfaces with the *100% method* (i.e., $T_h$=100%), which is equivalent to the conventional error concealment method, and the *radio button method*, which is previously proposed in [8], in terms of overall audiovisual subjective quality. In addition, we assess four QoE measures of the interfaces: *burden*, *usability*, *selectability* and *controllability*.

The remainder of the paper is organized as follows. Section II introduces the threshold selection interfaces. Section III describes an experimental method. Section IV presents experimental results. Section V concludes the paper.

## II. Threshold Selection Interfaces

We explain the three interfaces for threshold selection used in the experiment. Note that change of the threshold value is not mandatory but optional; if the user does not change the threshold value at all, it remains at the default value, which is set according to the content type and picture pattern.

**radio button method [8]**

The user selects one out of multiple threshold values. Fig. 3 illustrates the interface. This method does not present threshold values explicitly but provides comments on the meanings of the buttons. The user clicks a radio button by referring to the comments.

**slide bar method**

Fig. 4 indicates the interface for the slide bar method. The user can choose a threshold value by a unit of one percent. He/She clicks the pinch of the slide bar and moves it up or down to control the threshold value. This interface displays the threshold value selected by the user as shown in Fig. 4.

**two mode method**

As shown in Fig. 5, the user with this method switches the output mode between two modes: "smooth video flow" and "good picture quality" to control video output quality. A media receiver (MR) sets a threshold value according to both the mode the user has selected and the degree of network congestion. The MR calculates the slice arriving ratio to estimate the degree of network congestion in 1 second intervals. The slice arriving ratio is defined as the ratio of the number of received slices to the number of sent slices.

## III. Experiment

### A. Experimental network

Fig. 6 illustrates the experimental network. The network consists of two routers and four PC's which are used as a media sender (MS), a media receiver (MR), a Web server (WS) and a Web client (WC). The two routers are Cisco 2811 by

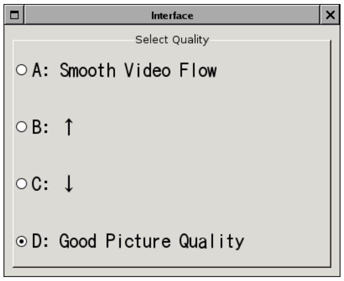


Figure 3. radio button method

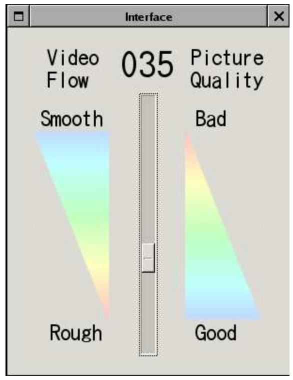


Figure 4. slide bar method

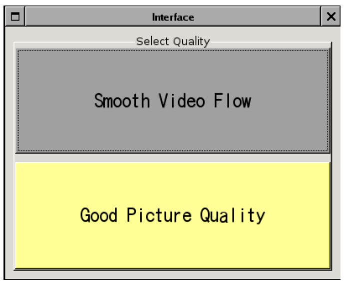


Figure 5. two mode method

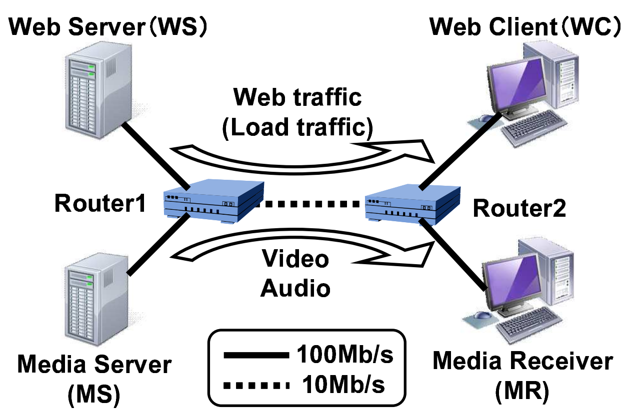


Figure 6. system configuration

Cisco Systems. The links between a terminal and a router are full duplex Ethernet channels of 100 Mb/s. The link between the two routers is a full duplex Ethernet channel of 10 Mb/s. The MS transmits an audio stream and the corresponding video stream, which are transferred as two separate streams with RTP/UDP, to the MR. The WS sends the load traffic with HTTP/TCP generated by *WebStone 2.5* [10], which is a web server benchmark tool, to the WC. The MR carries out playout buffering of 1 second to absorb delay jitter. We do not perform inter-stream synchronization control between audio and video.

Tables I and II show the specification of video used in the experiment and that of audio, respectively. *MU (Media Unit)* in these tables represents the information unit for transfer between the application layers. We define a video MU as a video frame and an audio MU as audio samples for 20 ms. We utilize H.264/MPEG-4 AVC reference software JM17.2 [11] for video encoding; we do not adopt FMO (Flexible Macroblock Ordering). As the number of P frames in the picture pattern increases, the video temporal quality is more degraded with frame skipping. This is because once a P frame is dropped, all the succeeding P frames cannot be decoded. To clarify effects on QoE by the difference of the GOP length, we adopt three picture patterns: I, IPPPP and IPPPPPPPPPPPPPP (I+14P's).

In the experiment, we select two content types: *sport* and *music video* referring to the final report of VQEG [12]. Sport is the same content as sport used in [13]; it is a soccer game. In the music video, a woman is singing a song with a slow tempo; it is the same as music video in [13].

Table III shows the average bit rate and TI value of each video. The TI value is an index of the degree of video motion. It is specified by ITU-T Rec. P.910 [14]. As the value increases, the video motion becomes larger. Note that SCS does not use the TI value.

For video error concealment, we utilize *Frame Copy* (to a P frame) and the interpolation from neighboring mac-

Table I
VIDEO SPECIFICATION

| | |
|---|---|
| Coding method | H.264/AVC (JM17.2) |
| Image size [pixel] | 320 × 240 |
| Number of slices in a frame | 15 |
| Average MU rate [MU/s] | 30 |
| Picture pattern | I, IPPPP, IPPPPPPPPPPPPPP (I+14P's) |
| Playing time [s] | 60 |

Table II
AUDIO SPECIFICATION

| | |
|---|---|
| Coding method | Linear PCM |
| Sampling rate [Hz] | 24000 |
| Quantization bit rate [bit] | 16 |
| Number of channels | 1 (mono) |
| Average MU rate [MU/s] | 50 |
| Average bit rate [kb/s] | 384 |
| Playing time [s] | 60 |

Table III
VIDEO BIT RATE AND TI VALUE FOR EACH CONTENT

| Content type | GOP | Average bit rate [kb/s] | TI value |
|---|---|---|---|
| sport | I | 3045.73 | 16.405 |
| | IPPPP | 1657.77 | |
| | I+14P's | 1436.26 | |
| music video | I | 1812.20 | 3.287 |
| | IPPPP | 526.09 | |
| | I+14P's | 325.68 | |

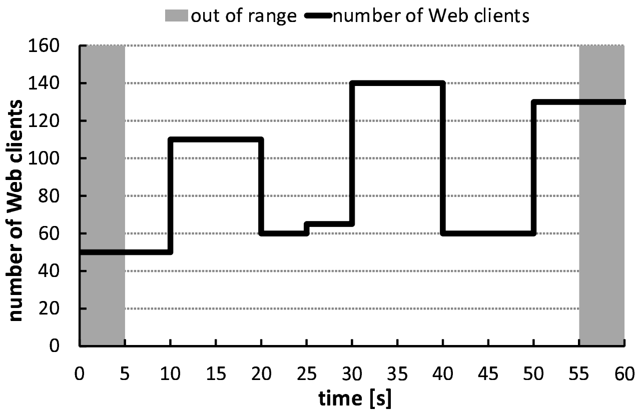


Figure 7. traffic pattern

Table IV
THRESHOLD SETTING TABLE FOR THE TWO MODE METHOD

| mode | slice arriving ratio $A$ [%] | | |
|---|---|---|---|
| | $A \geq 96$ | $90 \leq A < 96$ | $A < 90$ |
| smooth video flow | 20% | 40% | 100% |
| good picture quality | 0% | 20% | 40% |

Table V
DEFAULT THRESHOLD VALUE OR MODE FOR EACH INTERFACE

| content | GOP | radio button | slide bar | two mode |
|---|---|---|---|---|
| sport | I | 0% | 0% | good picture quality |
| | IPPPP | 20% | 20% | good picture quality |
| | I+14P's | 100% | 100% | smooth video flow |
| music video | I | 0% | 0% | good picture quality |
| | IPPPP | 40% | 40% | smooth video flow |
| | I+14P's | 100% | 100% | smooth video flow |

roblocks (to an I frame) of JM16.2, which is used for video decoding.

We adopt a time-varying traffic pattern in Fig. 7; this reflects a current trend of Internet traffic, which is increase in the percentage of video distribution [15]. It causes bursts of the traffic by a large amount of data transmissions in a short term. This pattern represents a feature of the burst and is the same as traffic 2 used in [13].

In the experiment, we remove the first 5 seconds from the scope of the assessment because a subject may not have been ready for the assessment. In addition, the last 5 seconds are out of range because of losing logs at the end of playing.

### B. *Implementation of threshold selection interfaces*

In this experiment, we utilize the conventional error concealment method (100% method) and the threshold selection interfaces defined in Section II. The implementation for each interface is as follows.

**(1) 100% method**

This method always sets a constant threshold value of 100%. It means pure error concealment, which is commonly used in video decoding.

**(2) radio button method**

The user selects one out of four threshold values: 100%, 40%, 20% and 0%. Buttons A, B, C and D in Fig. 3 correspond to the threshold values of 100%, 40%, 20% and 0%, respectively. This GUI is the same as the interface of the user selection method in [8] and [13].

**(3) slide bar method**

The user sets a threshold value by a unit of one percent through the GUI of Fig. 4. When the user moves up the pinch of the slide bar, the threshold value gets higher. In this experiment, the picture output quality takes 16 levels because we split a video frame into 15 video slices.

**(4) two mode method**

The user selects one out of two modes "smooth video flow" and "good picture quality" in real time. The MR calculates the slice arriving ratio, which is denoted by $A$, to estimate the degree of network congestion and sets a threshold value referring to Table IV. How to set boundaries of the slice arriving ratio categories depends on the content type. Assembling the reference tables for a variety of content types is future work.

For each threshold selection interface, the default threshold value or mode is set according to Table V. We have constructed the table by referring to the results of [3], [8] and [13].

### C. *QoE assessment experiment*

In total we have 24 objects to be evaluated because of the two contents, three picture patterns for each content, and four threshold setting methods. An evaluation object corresponds to an output audiovisual flow in an experimental run.

The procedure of this experiment is as follows.

**Step 1:** The original audio and video are presented to the subject.

**Step 2 (except for the 100% method):** Checking an evaluation object, the subject selects a threshold value. It should be noted again that selecting a threshold value by GUI is not mandatory but optional; if the subject does not want to select a threshold value, it is kept at the default value, which is set automatically according to the content and GOP at the start of the session.

**Step 3 (except for the 100% method):** The subject makes *interface evaluation*, which means evaluation of the threshold selection interface with scales in Table VI. In these scales, score 5 represents the most positive term (the right-hand side one in each scale in Table VI), while score 1 means the most negative term. Score 3 is neutral.

**Step 4:** The subject continuously evaluates the audiovisual quality by using *DCR (Degradation Category Rating)* [14] with the following *five-level impairment scale*: "the impairment is imperceptible" assigned score 5, "perceptible, but not annoying" 4, "slightly annoying" 3, "annoying" 2, and "very annoying" 1. Note that score 5 means the best quality,

Table VI
QoE SCALES FOR INTERFACE EVALUATION

| | | |
|---|---|---|
| **burden** : A burden on you using this interface is ... | | |
| heavy | 1 2 3 4 5 | light |
| **usability** : This interface is ... | | |
| awkward | 1 2 3 4 5 | friendly |
| **selectability** : Selecting the threshold value is ... | | |
| hard | 1 2 3 4 5 | easy |
| **controllability** : Can you control video output quality at will? | | |
| No | 1 2 3 4 5 | Yes |

while score 1 is the worst. The evaluation is conducted by pushing a numerical key from among 1 to 5 of a keypad in real time. The subject updates the score by pushing a key when his/her evaluation changes because of degradation of audiovisual quality. At this time, the MR samples the subject's score at intervals of 0.5 seconds.

**Step 5:** Repeat from Step 2 to Step 4 until the subject finishes all evaluation.

As the QoE metric, we adopt the *psychological scale* [16]. The psychological scale is the *interval scale* in psychometric theory, while the most popular QoE metric MOS (Mean Opinion Score) is the *ordinal scale*. It means that the psychological scale can represent human subjectivity more accurately than MOS.

We carry out subjective experiment with the *method of successive categories*. Each subject first gives a score (e.g., an integer between 5 and 1) to the interface or the audio-video stream output at MR; this step is called the *rating-scale method*[1]. Then, we apply the *law of categorical judgement* to the scores to obtain the interval scale of an evaluation object. We further conduct Mosteller's test [17] to confirm the goodness of fit for the obtained scale. Once the goodness of fit has been confirmed, we use the interval scale as the psychological scale. See [16] for more detail.

The number of the subjects is 65: 27 Japanese males and 38 Japanese females. Their age ranged from 18 through 47: 16 females in their teens, 27 males and 12 females in their twenties, 3 females in their thirties and 7 females in their forties. It took about 60 minutes for a subject to evaluate all the audiovisual streams. In general, at least 15 subjects should participate in a viewing test [14]. Therefore, the number of the subjects is enough to obtain confident data.

## IV. Experimental Results

In this section, we present the psychological scale calculated from the result of the subjective experiment.

### A. Psychological scale

With respect to the assessment of burden, usability and selectability, we have found that the test with a significance level of 0.05 cannot reject the hypothesis that the observed value equals the calculated one. Consequently, we utilize the interval scale as the psychological scale.

Regarding the assessment of the overall audiovisual subjective quality and controllability, we saw that the test with a significance level of 0.05 can reject the hypothesis. For the overall audiovisual subjective quality, we define a *stimulus* as an audio-video stream output at MR for 0.5 seconds out of the 60 seconds. The number of the stimuli is 2424: 24 objects to be evaluated and 101 evaluation sampling between 5 and 55 seconds. In the evaluation of the controllability, an audio-video stream for the 60 seconds is regarded as a stimulus. The number of the stimuli for the controllability evaluation is 24 because of the 24 objects to be evaluated. Then, we removed stimuli which give large errors in Mosteller's test. Removing 314 stimuli in the overall audiovisual subjective quality evaluation and a single stimulus in the controllability evaluation, we saw that the hypothesis cannot be rejected. Consequently, we utilize the interval scale as the psychological scale. Since we can select an arbitrary origin in an interval scale, we set the minimum value of the psychological scales to unity for each evaluation.

Figs. 8 through 13 indicate the psychological scale of the overall audiovisual subjective quality. The abscissa in the figures represents the playing time, and the ordinate shows the psychological scale and the number of Web clients. Straight broken lines parallel to the abscissa represent the lower boundaries of the categories. Note that the results removed by the Mosteller's test are not plotted in the figures.

Fig. 14 shows the average of the psychological scale over time in the overall audiovisual subjective quality.

Figs. 15 through 18 present the result of the psychological scales in the interface evaluation.

### B. Consideration on overall audiovisual QoE

We show the result of the QoE assessment for each picture pattern to clarify effects of the difference in the GOP length on QoE.

**picture pattern: I**

In Figs. 8 and 9, we see that the methods with which the user can select a threshold value achieve higher QoE than the 100% method. The same result is also observed in Fig. 14. Frame skipping does not greatly degrade the temporal quality in the case of short GOP video. Since the 100% method cannot apply frame skipping to the video output scheme, it causes low QoE.

**picture pattern: IPPPP**

As we see in Figs. 10 and 11, the result is similar to that of picture pattern I. However, the degradation of the temporal quality becomes larger as the number of P frames increases. Therefore, the difference in QoE between the 100% method and the other methods is small compared with the case of picture pattern I.

[1]MOS is just the arithmetic average of the scores over all the subjects.

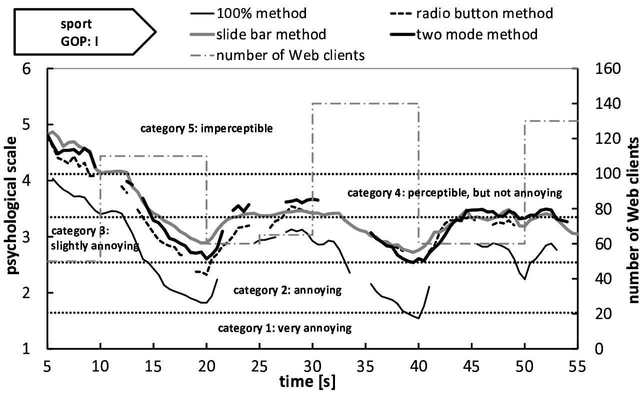


Figure 8. psychological scale of overall quality (sport, I)

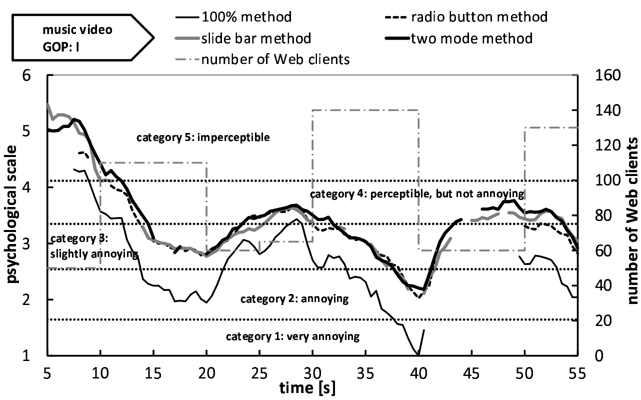


Figure 9. psychological scale of overall quality (music video, I)

Since the music video in this paper is a content with small video motion, improvement of the spatial quality by frame skipping achieves higher QoE than that of the temporal quality by error concealment. Therefore, QoE of the 100% method, which employs error concealment only, is lower than that of the other methods (see Fig. 11). Since the sport is a content with large video motion, the degradation of the temporal quality by frame skipping badly affects QoE. Consequently, Fig. 10 reveals that the difference in QoE between the 100% method and the other methods is small compared with the case of music video (Fig. 11).

**picture pattern: I+14P's**

In Figs. 12, 13 and 14, the difference in QoE between the threshold selection interfaces is small compared with the cases of picture patterns I and IPPPP. QoE of the four threshold selection methods is almost the same in sport. In music video, on the other hand, the three threshold selection interfaces achieve higher QoE than the 100% method. This result is similar to that of picture pattern IPPPP.

**result of overall subjective quality assessment**

Fig. 14 shows that the slide bar method and the two mode method for music video achieve higher QoE than the radio button method. For sport, the slide bar method accomplishes high QoE. The slide bar method enables the user to control video output quality finely. The two mode method sets an appropriate threshold value on the basis of the degree of network congestion; this decreases the user's selection error.

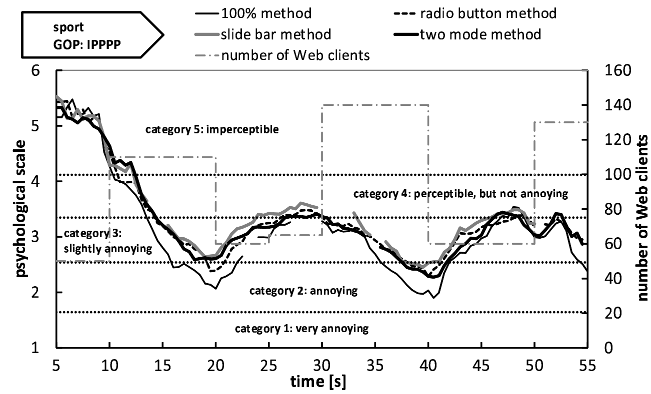


Figure 10. psychological scale of overall quality (sport, IPPPP)

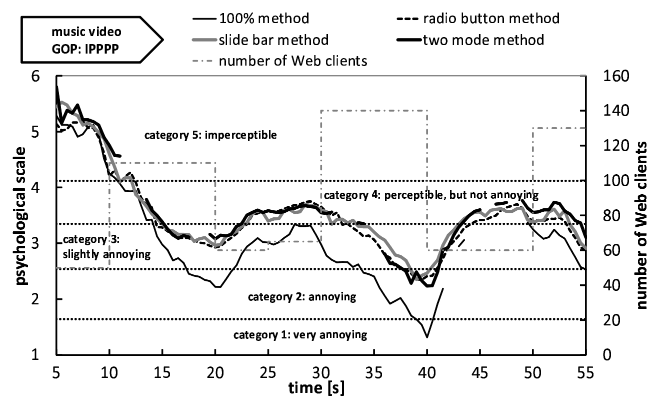


Figure 11. psychological scale of overall quality (music video, IPPPP)

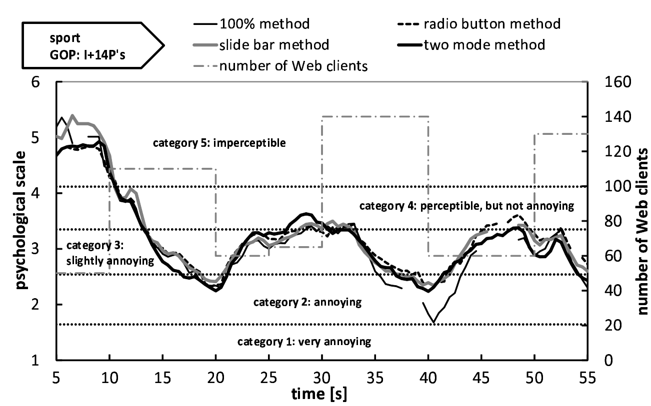


Figure 12. psychological scale of overall quality (sport, I+14P's)

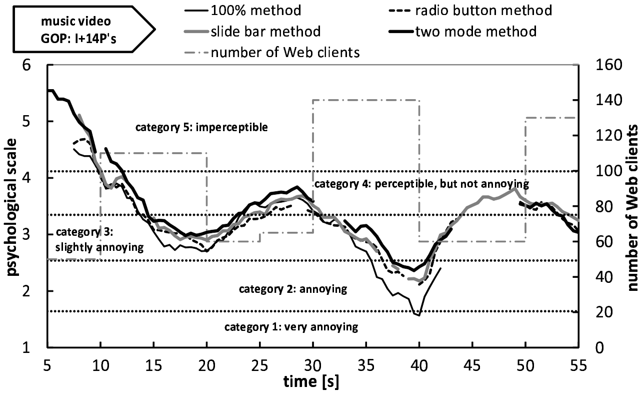


Figure 13. psychological scale of overall quality (music video, I+14P's)

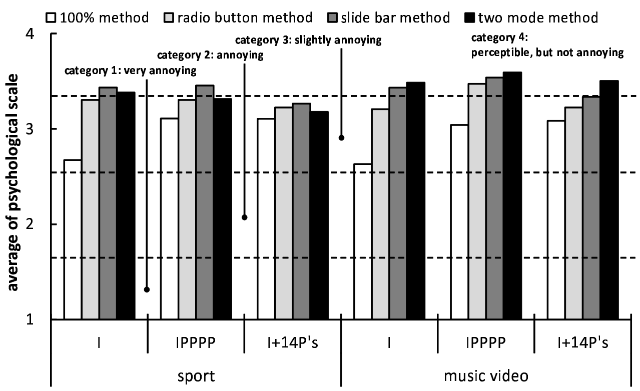


Figure 14. psychological scale of overall quality (average)

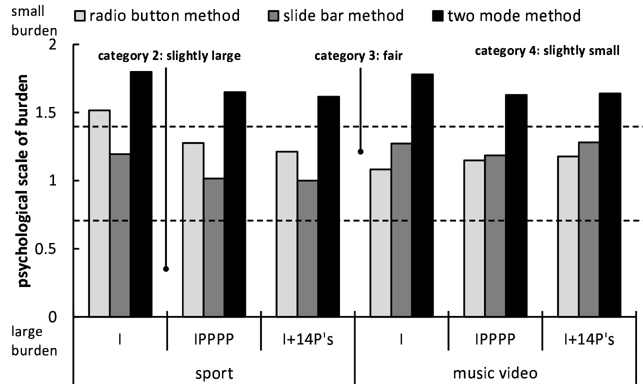


Figure 15. psychological scale of burden

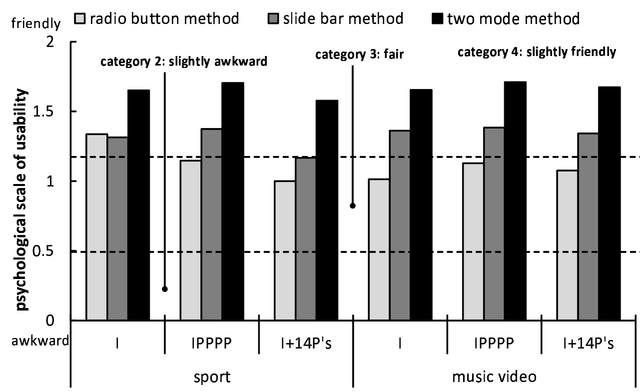


Figure 16. psychological scale of usability

### C. Consideration on QoE of interface evaluation

Fig. 15 indicates that the two mode method imposes a lighter burden on the user than the other interfaces. This is because the two mode method is easy to control the video quality; that is, there are only two buttons. In addition, Figs. 16 and 17 show that the radio button method and the slide bar method are hard to select an appropriate threshold value compared with the two mode method.

In Fig. 18, we observe that the user with the slide bar method can control the video output quality most freely. This is because the slide bar method can continuously change the threshold value. On the other hand, the controllability of the two mode method is lower than that of the others since the two mode method automatically sets the threshold value on the basis of the network congestion. For example, even if the user selects the good picture quality mode, the spatial quality may degrade because a threshold value of 40% is set under high load traffic (i.e., small values of $A$) as seen in Table IV.

### D. Comparison of the threshold selection interfaces

The user can select the threshold value easily to a certain extent with the radio button method, but the method is inferior to the slide bar method and the two mode method in terms of overall QoE. The slide bar method enables us to control the video output quality at will (Fig. 18) and achieves high overall QoE (Fig. 14). However, the slide bar method is hard to select an appropriate threshold value (Fig. 17) and imposes a burden on the user (Fig. 15). The two mode method can achieve high overall QoE (Fig. 14), and it has a lighter burden on the user (Fig. 15), while the user cannot control the video output quality at will (Fig. 18).

From the above results, we can say that the two mode method is an appropriate choice in terms of both overall QoE and the burden on the user. Note that most users are concerned about whether the burden on them is light or not.

## V. Conclusions

In this paper, we proposed two new threshold selection interfaces of SCS. As a result of the multidimensional subjective experiment, the slide bar method and the two mode method can achieve higher QoE than the previously

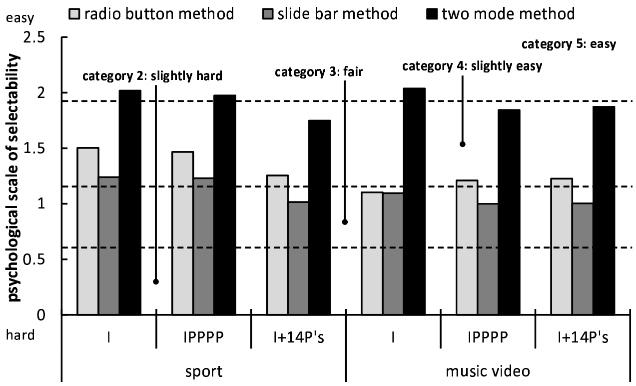


Figure 17. psychological scale of selectability

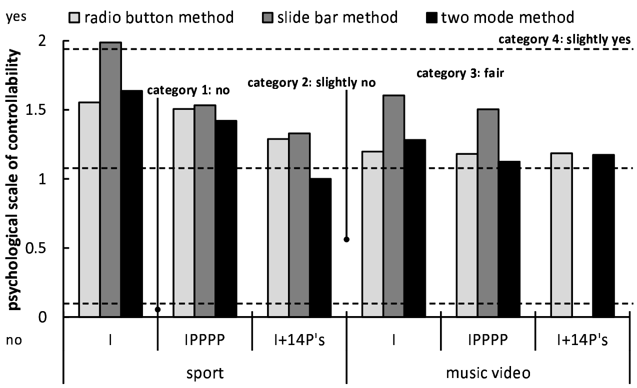


Figure 18. psychological scale of controllability

proposed radio button method and the conventional pure error concealment (100%) method. In addition, we observed that the slide bar method achieves higher controllability than the radio button method, and that the two mode method imposes a lighter burden on the user compared with the radio button method. We concluded that the two mode method is an appropriate choice for threshold selection in SCS since the method accomplished high overall audiovisual QoE and a light burden on the user.

If we appropriately set boundaries of the slice arriving ratio categories and the corresponding threshold value in the two mode method, we can achieve higher QoE with the method. As future work, we will study how to set these parameters.

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