Empirical Study of User Perception Behavior for Mobile Streaming*

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ABSTRACT

The objective of this study is to examine the effect of indivual factors over human perception behavior and to determine the right set of parameters which effectively exploit the underlying network and system capacity while maximizing the QoS perceived by the user. For the comprehensive test, we examine three different types of video clips: *news*, *drama* and *sport game*. From each of the original video clip, we vary the encoding factors as follows: *playback rate(384Kbits/sec and 1.5Mbits/sec)*, *frame rate(5 frames/sec, 15 frames/sec, and 25 frames/sec)* and *spatial resolution(176x244 and 320x240)*. We performed extensive user experiment. We particularly focus on video streaming in mobile wireless environment where playback rate and screen size are relatively small. The analysis result reveals that out of three encoding factors, *frame rate* is the most influential factor. Spatial resolution does not make significant difference on QoS for three video categories in our test settings. Playback rate results in noticeable difference in QoS. However, the analysis on the survey result suggests that the improvement on QoS obtained by quadrupling the playback rate (from 384Kbits/sec to 1.5 Mbits/sec) may not be justifiable particularly when the screen size is small.

Keywords

QoS, Multimedia, Video, Streaming, Empirical Study

1. INTRODUCTION

1.1 Motivation

Video compression technology is one of the most important constituents which make the on-line multimedia service possible. The most popular approach in compressing a video is to exploit the scene difference between the successive frames. We need to determine a number of factors when compressing a video clip: playback rate, frame rate and spatial resolution. These three factors are orthogonal to each other. We believe that these factors contribute to the user perceivable QoS in different ways. Henceforth, it is very important to provide the right set of parameters in compressing a video to maximize the QoS perceived by the user while minimizing the resource requirement in supporting the playback of given compressed video. Aligned with this theme, we focus our effort on finding out the influence of each compression parameters.

We expect wide spread usage broadband wireless network service, e.g. public wireless LAN(IEEE 802.11b) or 4G mobile wireless network in the foreseeable future. The bandwidth capacity of these network technology enables the end user to enjoy video streaming service online. For the video playback, we identify the major difference between mobile wireless environment and wired one as follows: (i) the available bandwidth and (ii) the size of screen. We carefully believe that the impact of three compression parameters may change dependent upon the maximum screen size, the available bandwidth, etc. For example, we may not be able to identify the difference between spatial resolution of $1024x768$ and $640x480$ when the video is to be displayed on 2 inch LCD screen. We tailor the domain of interest for mobile wireless environment where the available bandwidth is relatively low and screen size is relatively small.

Quality of Service is the degree of satisfaction to fulfill the requirement such as reliability, maintainability, safety, and etc [2, 4]. In this work, we focus on the user centric QoS analysis [1, 5]. The user centric QoS analysis is to examine the human perception behavior. It begins with very simple idea. If there are several services, then users are tend to prefer particular service to the other and these particular preferences are based on the rules or patterns. If we can identify the rules or patterns, these can be used to improve QoS perceived by user while minimizing the resource consumption. In this paper, our effort is focused on determining the encoding parameters which improves the QoS in the most significant way.

1.2 Related Works

Apteker et al [6] examines the effect of frame rate over QoS. In this experiment, eight video clips are categorized based upon temporal nature of the data and importance of auditory and visual components. The subjects were 60 undergraduate

*This work is funded by KOSEF through statistical Research Center for Complex System.

students. The subjects performed spelling checks situated in multi-task environment while they evaluate the video clips. The result is that a higher level of frame rate is an important factor for user QoS. Ghinea et al [3] categorized a number of video clips, e.g. action video, drama and etc., based upon the frame rate: 25fps, 15fps and 5fps. The subjects are 10 adults. They found that a certain relationship exists between the frame rate and video category. For example, in an action movie video clip, people do not acknowledge the difference in frame rates. Another interesting finding in this experiment is that people tend to collect more information from the scene with the slower frame rate. The subjects are asked about the contents of video clip. With lower frame rates, people get more correct answers.

Our work distinguishes itself from the preceding ones in a number of ways. None of the preceding works address the relative effectiveness of the compression parameters over perceivable QoS. For the comprehensive analysis, we categorize the videos into three sets depending on the inter-frame dependency and perform the user experiment to determine which set of knobs are the most significant factor in each category. The contribution of this work lies in the fact that we provide the practical guideline in authoring the video title which can maximize the user perceivable QoS while minimizing the resource requirement for resource stringent environment such as mobile wireless network.

2. EXPERIMENT SETUP

The video clips, which is used in the experiment, encoded by MPEG-2 coding scheme. To examine the effectiveness of individual compression parameters, we generate a number of MPEG-2 files from the same video clips using different combinations of compression parameters: frame size(or spatial resolution), frame rate, and playback bandwidth. We do not consider the packet loss in our experiment, which needs to be dealt with in separate context [7].

We use three video clips; *news*, *drama* and *sports*. ¿From each video clip, we generate twelve compressed files using different combination of compression parameters. Encoding parameters in our experiment were *frame rate*, *frame size(or spatial resolution)* and *playback bandwidth*. The frame rates that we used are 384 Kbits/sec and 1.5 Mbits/sec. For choosing the the network bandwidth, we consider the 3G mobile wireless network environment(e.g. IMT-2000). IMT-2000 service has bandwidth restriction. It provides 144kbits/sec, 384 kbits/sec and 2 Mbits/sec for fast speed moving, slow speed moving and non moving object, respectively. We use 384Kbits/sec and 1.5Mbits/sec compression rate, respectively. In mobile environment, the user cannot avoid the limitation in screen size. Most mobile devices are made for portability, which makes the devices small. Due to this reason, the spatial resolution is chosen to be SIF(Source Input Format: 320×240 pixel resolution) and QCIF(Quarter Common Intermediate Format: 176×144 pixel resolution). We vary the frame rates to 5, 15 and 25 frames per second. There are total of twelve different combination of encoding parameters: two frame sizes, two playback bandwidths and three frame rates.

The test is performed in completely blind manner. User do not have knowledge on the compression parameters of each video clips. To avoid any regularity, twelve compressed video files for individual video are shuffled randomly. The subjects watch total of 36 video clips in order of news, drama and sports category. Each video clip is 20 second long. The experiment proceeds on playing a video clip for 20 seconds leaving 20 seconds for evaluation. The subjects were 86 EE/CS major graduate and undergraduate students. They were asked to rate the QoS of each video with quality scale from 1(*very bad*) to 5(*excellent*). Table 1 illustrates the survey form.

3. ANALYSIS OF EXPERIMENT DATA

3.1 Synopsis: ANOVA

We use ANOVA test in analyzing the data and SAS package is used. The ANOVA stands for ANalysis Of VAriance and it is used to compare the means of more than two independent groups. Let us explain the brief procedure of the ANOVA. First, we made null hypotheses that the comparisons of independent groups are all the same, and alternative hypotheses are not all the same. If the number of groups is k, null hypotheses is $H_0 : u_1 = u_2 = \cdots = u_k$ and alternative hypotheses is H_a. The ANOVA test is performed in an ANOVA table. The test statistic is F-test with $k-1$ and $N-k$ degrees of freedom, where N is the total number of subjects and k is the number of groups. A low p-value for this test indicates the evidence to reject the null hypothesis in favor of the alternative. In other words, there is evidence that at least one pair of means is not equal. In this experiment frame size, frame rate and bandwidth are independent groups that make k as 3, and N should be 12 for 12 video clips. The critical p-value for accepting or rejecting null hypothesis is set to 0.05. The ANOVA test performed twice. The first test is to find out what the most important factor is for user perception in each category of video clips. The second test is to discover, if one factor is fixed which factor is the most significant one in affecting user perception.

3.2 Determining the most significant factor

We first examine the effectiveness of individual compression parameters in news video clip. The analysis result shows that the user notices the changes in each factors, i.e. frame size, frame rate and bandwidth. In our analysis, F values of frame size, frame rates(frames/sec) and bandwidth compared to Pr are all less than 0.05. This means that null hypothesis is not acceptable and again this means that all three factors contributes to user preceivable QoS. Among the three, frame rate category has the smallest $Pr > F$ value. This implies that frame rate is the most influential factor over QoS. Even though frame rate is shown to be the most salient factor, the quality improvement from 5 frames/sec to 15 frames/sec may be different from the improvement we can get by increasing the frame rate from 15 frames/sec to 25 frames/sec. We examine this issue in further detail via t-test. Table 3 illustrates the result of t-test. The t-test is performed using LSD(Least Significant Difference). If the mean values of two groups differ by more than LSD, they are practically two different groups. The mean values for 25fps, 15fps and 5fps in Table 3 are 327.50, 315.00 and 217.25, respectively. The difference of mean value between 25fps and 15fps is 12.50, which is less than LSD value, 31.65. This result implies that people does not perceive the difference between 25frames/sec playback and 15frames/sec playback. Meanwhile, the mean value difference between 15frames/sec and 5frames/sec is bigger than LSD of 31.65. From this, we can conclude that changing the

Table 1: Survey Form

The quality scale (Video Clip Evaluation)

	1:very bad		2:not very good		3:fair enough	4:good	5:excellent
Clip No.	1	2	3	4	5	If you feel that this video clip is not very good, please let us know which factors make you feel that way.	

(a) news (b) drama (c) sports

Figure 1: Video clips used in the experiment

frame rate from 5 frames/sec to 15 frames/sec makes noticeable improvement on QoS. We conjecture that this is due to nature of news video clip. Since news video clip does not have dynamic changes in consecutive frames, frame rate beyond a certain threshold value does not make significant quality difference on scene. To be discussed later, this does not hold for drama and football game where the scene changes more dynamically.

In drama category, the analysis result show that frame rate and bandwidth are the two knobs which affect the user perceivable QoS. Users do not seem to notice the quality difference among different frame sizes. As in case of news, frame rate is shown to be the most influential factor. It is interesting to see that the result of t-test for drama is different from the result of t-test for the news category. In drama, user recognizes the quality difference among all three frame rates, i.e. 25 frames/sec, 15 frames/sec, and 5 frames/sec. The test result from the sports category exhibits the similar characteristics with the test result of drama. The frame rate and bandwidth are the significant factor and the frame rate is the most influential factor. The t-test result is also similar to the result of the drama category.

The ANOVA analysis suggests that the frame rate is the most influential factor in all three video clips. It is quite surprising to see that the frame rate is shown to be even more influential than the playback rate. It implies that it may not be worth supplying high playback rate streaming service particularly when the screen size is small. Frame size(or spatial resolution) does not carry significant meaning.

3.3 Reducing the degree of Freedom

In this section, we examine the impact of two factors while fixing the value of one factor. In the news category, when we fix the spatial resolution to either QCIF or SIF, bandwidth becomes *insignificant* factor for user perception. People do not notice the difference between the bandwidth of 384kbps and 1500kbps. Meanwhile, frame rate is still influential factor. When we fix the frame rate to one of 5 fps, 15fps, or 25 fps, the analysis result shows that neither the bandwidth nor the frame size is influential factor. It is interesting to see how the bandwidth affects the user perception behavior. When the bandwidth is 384Kbits/sec, user does not notice the quality changes in different combination of frame size and frame rate combination. We conjecture that with 384 Kbits/sec playback, the information contained in the scene is not sufficiently good enough to enable the user to differentiate the quality among different combination of frame sizes and frame rates. On the other hand, when bandwidth is 1.5Mbits/sec, user notice the quality difference among different combinations of frame sizes and frame rates. In 1.5 MBits/sec playback, frame rate is still more influential than frame size.

In the drama category, only the frame rate is effective parameter when we fix the frame size. When the frame rate is 5 frames/sec or 15 frames/sec, the analysis results shows that none of the parameters are influential. When the frame rate is 25 frames/sec, playback bandwidth is the only influential factor. When we fix the bandwidth, frame rate is the only influential factor.

In the sports category, fixing the spatial resolution yields different result from the other two categories. When the size is fixed to QCIF, the analysis result show that neither playback bandwidth nor frame rate affects the QoS of the video. It implies that when the screen size is *very* small, i.e. resolution is coarse, changes in playback rate or frame rate does not have significant implication on user perceivable QoS. However, when the resolution becomes finer or the screen size becomes larger, both frame rate and playback bandwidth affect the user perceivable QoS in more dominant way. This is

Table 2: Summary of ANOVA analysis

Category	Score	DF	ANOVA SS	Mean Square	F Value	Pr > F
news	Size	1	3780.7	3780.7	7.03	0.0328
	fps	2	29155.1	14577.5	27.12	0.0005
	bandwidth	1	3366.7	3366.7	6.26	0.0408
drama	Size	1	616.3	616.3	4.94	0.0617
	fps	2	82563.5	41281.7	330.57	<.0001
	bandwidth	1	2028.0	2028.0	16.24	0.0050
sports	Size	1	705.3	705.3	1.21	0.3076
	fps	2	48833.1	24416.5	41.90	0.0001
	bandwidth	1	9075.0	9075.0	15.57	0.0056

Table 3: Summary of t-Tests (LSD)

	news, LSD=31.7				drama, LSD=15.3				sports, LSD = 29.9			
	Group	Mean	N	value	Group	Mean	N	value	Group	Mean	N	value
Resolution	A	304.33	6	SIF	A	262.167	6	SIF	A	236.00	6	SIF
	B	268.83	6	QCIF	A	247.833	6	QCIF	A	220.67	6	QCIF
Frame Rate	A	327.50	4	25	A	323.250	4	25	A	294.75	4	25
	A	315.00	4	15	B	303.500	4	15	B	248.00	4	15
	B	217.25	4	5	C	138.250	4	5	C	142.25	4	5
Bandwidth	A	303.33	6	1500	A	268.000	6	1500	A	255.83	6	1500
	B	269.83	6	384	B	242.000	6	384	B	200.83	6	384

because as the screen size becomes larger, subjects recgonize the finer details of what is shown on the screen. When the resolution is set to SIF, frame rate is more influential factor than than bandwidth. When the frame rate is fixed to 5 fps and 15 fps, neither size nor bandwidth is effective. When the frame rate is 25 fps, subjects recognize the changes in resolution as well as the changes in the bandwidth. When bandwidth is fixed as 384kbps, neither frame size nor frame rate is significant. When the bandwidth is 1500kbps, both size and frame rate become effective parameters. The frame rate is more influential than the frame size.

4. DISCUSSION

In this work, we performed the extensive user experiment to investigate the effect of three compression parameters: playback rate, frame rate, and spatial resolution. The objective of this work is to identify the right set of compression parameters which can effectively exploit the underlying network and system resources in maximizing the user perceivable QoS. We particularly focus on resource stringent environment where the network bandwidth and user screen are relatively small. We found that frame rate is the most significant factor in user perceivable QoS. It even dominates the effect of the playback rate. We also examine the effect of each parameters while fixing one dimension. When the resolution is low, the analysis of survey results reveals that increasing the frame rate or playback bandwidth does not deliver any significant improvement on user perceivable QoS. This carries important implication especially in mobile wireless streaming environment. It is unlikely that the mobile terminal is equipped with high resolution display device. Thus in this environment, it may not be worth servicing higher bandwidth stream since users do not seem to recognize the quality difference between 384 Kbits/sec stream and 1.5 Mbits/sec stream. Since the frame rate is directly related to the computational overhead of decoder, it may not be desirable to increase the frame rate more than necessary especially when the client terminal is mobile handheld device with low-speed low-power CPU. When the file contains the relatively static material, increasing the frame rate result in marginal improvement on QoS. The novelty of this work lies in the fact that we provide the practical guideline on *which knob to turn in compressing a video?* to effectively exploit the underlying resources while maximizing the user perceivable QoS.

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