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Aruna Thakur, Chaunsi Gao, Andreas Larsson, Peter Parnes

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The Effects of Frame-rate and Image Quality on Perceived Video Quality in Videoconferencing

Aruna Thakur[1], Chaunsi Gao[2], Andreas Larsson[3], and Peter Parnes[1]

[1]CDT
Division of Software Engineering
Department of Computer Science and Electrical Engineering
Luleå University of Technology
971 87 Luleå
+46 920 910 00
aruna,peter @cdt.luth.se,

[2]Division of Industrial Ergonomics
Department of Human Work Sciences
Luleå University of Technology
Chuansi.Gao@arb.luth.se

[3]Department of Computer Aided Design
Department of Mechanical Enggineering
Luleå University of Technology
Andreas.Larsson@cad.luth.se

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Abstract

This report discusses the effect of frame-rate and image quality on the perceived video quality in a specific videoconferencing application (MarratechPro). Subjects with various videoconferencing experiences took part in four experiments wherein they gave their opinions on the quality of video upon the variations in frame-rate and image quality. The results of the experiments showed that the subjects preferred high frame rate over high image quality , under the condition of limited bandwidth.

Keywords

Bandwidth, Frame Rate, Image Quality, Video Conferencing, Video Quality.

Introduction

As corporations and organisations tend to become more and more globalised, the need for long-distance communication has also increased. Previously, telephones and facsimile machines made a big impact in this area, but as projects and project groups grow more complex, the medium of communication need to evolve to meet the higher demands. Desktop videoconferencing is a communication system, including both video and audio connection, which has proved useful for communication among a group of people that are separated by geographical distances. Its popularity lies in the growth of the Internet, which has helped in connecting people at remote geographical locations. Using such a system, the participants are able to hear each other talk, while at the same time see them in real-time video on the computer screen.

Videoconferencing over the Internet has emerged as a cheap alternative to similar services, previously offered by telephone companies, such as room-based videoconference systems or the AT&T Picture phone [1]. It is an application comprising of several sub-applications, like audio, video, chat, whiteboard, etc. All these applications send and receive information via a control bus. These applications are still in developmental stage and a lot of work has to be done in order to satisfy the end user by providing better quality of video, clarity of audio, etc. Recent developments in compression schemes, together with increasing bandwidth availability and the implementation of multicast routing have had a large positive impact on the possibilities of conducting videoconference sessions that meet users' expectation in terms of audio and video quality [2]. Presently a large number of video conferencing tools, for example *vic*, *nv* and *ivs* are commercially available in the market. All these and many others take the advantage of hardware and software codecs (CODer-dECoder). While the hardware codecs provide better perceptual quality software codecs are cheaper and easier to use.

In spite of several advantages enjoyed by videoconference, there are some bottlenecks, partly due to the growing population of Internet users and partly due to technical constraints like bandwidth availability.

This report tries to look at and explain the dependence of perceptual quality of video on frame rate and image quality and suggests ways for improving the video quality. For the study a commercially available video conferencing tool, called as *Marratech Pro,* was studied.

Bandwidth

Bandwidth is the capacity of network link. It is the number of bits transmitted or received via the link. If the bandwidth is increased, more information can be transmitted at a higher speed. However, in the case of video conferencing the bandwidth gets shared among many participants in a session.

Packet loss

The information (audio, video, text, etc.) is transmitted over the Internet in the form of packets. During transmission some of these packets may get lost, corrupted, disordered or delayed. This leads to poor video quality.

Network Congestion

When a network is heavily loaded the congestion may occur at the bottlenecks in the bandwidth. Under such a condition some packets may get dropped or delayed.

Buffer Capacity

At the receiving and transmitting ends of the system and at network interfaces the data is temporarily stored in buffers. At times these buffers may overflow resulting in some of the packets getting dropped.

Frame-rate

The moving pictures that are seen are actually a sequence of frames transmitted at a certain speed. The speed of projection in terms of the number of frames per second is called the frame-rate. Slow frame-rate results in jerkiness in the motion of the object and the fast frame rate results in large data transmission.

Isaacs et al. [3] noted that video transmission at 4 fps could be “distracting” and result in loss of audio-video synchronisation. Watson and Sasse [2] also found that the perception of audio-video synchronisation was impaired if the frame-rate was lower than 5 fps. Kies et al. [4] performed a study of video quality in videoconferencing and reported that various levels of video quality did not affect understanding in a distance education situation, but it did affect users’ satisfaction with the system. These authors recommend a frame rate of 6 fps or more. Bruce [5] suggested that at least 17 fps were required in order to convey enough dynamic facial information.

Pappas and Hinds [6] found that subjects often stated that the speaker's movements were more important than spatial clarity. They also concluded that 5 fps to be the critical level below which video quality became highly objectionable.

Image quality

There are many factors that influence the users perception of video quality, some of which have been chosen to file under the *image quality* category. Gili et al. [7] identified seven key variables to be colour, brightness, background stability, and speed in image reassembling, outline definition, “dirty window”, and the mosaic/blocking effect. The image quality used in this report does not have a unit, but more the image quality means more finer details sent with every macro block and frame. The maximum value of image quality used in the MarratechPro tool, is 25 FPS (frames per second).

Quality of video

It is the perceived quality of video. That is how the video looks to the end user, better video quality means a clear picture.

MarratechPro

Marratech is a vigorous and growing Internet company. This company deals with the e-meeting through Internet. MarratecPro (mpro) [11] is a video conferencing tool, where people located at different geographical locations can meet together at a common virtual corridor. The video conferencing tool comprises of applications like White Board (wb), by which the users can interact by writing and drawing on a common wb. Video and audio can also be sent and received. Distance learning can be done by using this tool. At present the mpro tool provides some controls, which sender can use for transmitting and receiving audio and video, Apart from that, there are few tools which helps to reduce and increase the bandwidth, the frames sent per second, and the image quality.

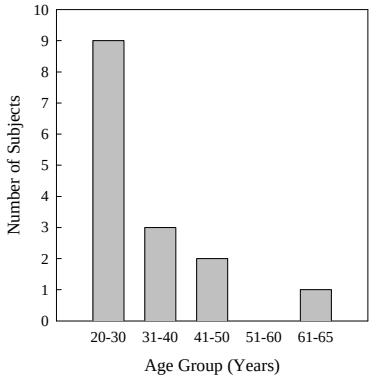

Figure 1: Age distribution of subjects

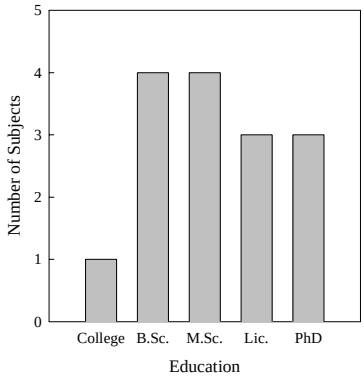

Figure 2: Education of subjects

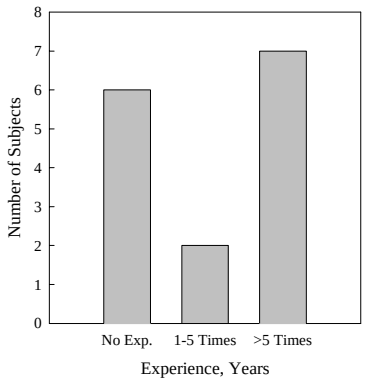

Figure3: Experience of subjects using video conferencing tools

Experimental Procedure

Participants

Fifteen university employee volunteers (12 males, 3 females) from three different departments (Computer Science, Mechanical Engineering and Human Work Sciences) participated in the experiment. The description of subjects is shown in Figure1, 2 and 3. Education of the subjects ranged from 2 years college education to Ph.D. level. Subjects' experience in video conferencing ranged from no experience to more than 5-year experience using video conferencing tools. However, all subjects have had experience of watching videos on Internet.

Tasks

Subjects were asked to watch four video recordings (50 seconds each). After each session, subjects were asked to rate the overall video quality including image clarity and body movement. Audio was muted in the experiment.

Experimental hypotheses

The hypothesis was that users preferred higher frame-rate to higher image quality. Hence, it was assumed that users, given a fixed bandwidth, would prioritise consistent video flow rather than high quality images.

Experimental Design

Independent variables were frame rate (fps) and image quality (IQ). Bandwidth (128 kbps) and packet loss (1%) were kept constant throughout the experiments. There were 2 x 2 = 4 experimental conditions, i.e., 4 experimental sessions were recorded (Table 1).

Experimental Session	Bandwidth (Kbps)	Packet Loss (%)	Frame Rate (Fps)	Image Quality
I	128	1	8	8
II	128	1	8	18
III	128	1	18	8
IV	128	1	18	18

Table 1 Settings of four video recordings

Two extra recordings were also tested by all 15 subjects which were

- 700 bandwidth, 1% packet loss, 21 frame rate, 26 image quality.
- 1024 bandwidth, 1% packet loss, 25 frame rate, 30 image quality.

All the experiments were done at a constant packet drop of 1%. The reason for selecting 1% was to simulate “real” real network situation. It was found that the packet loss in the range of 0-1% was considered good, 1-5% was acceptable, 4-6% the video was irritating but was understandable to the subject, 5-12% was poor and greater than 12 % was bad [10]. In the present study the stress was more on parameters like FPS, and IQ, hence, the packet loss was kept low and constant.

Experimental Procedure

Basic introduction to the Marratech Edu 2.2/Pro software was given to the subjects before presenting the videos. Using pre-recorded videos a controlled videoconference was simulated. The order of playing the videos was randomised in order to reduce biased opinions of the subjects. Each session was presented to subjects respectively. After each session, subjects were presented the seven-point rating scale for overall video quality and satisfaction as used in video conferencing and distance learning. There was one experimenter beside the subject to observe the session. Post session interviews were also conducted to note general impressions of the videos seen.

Measures

Rating scale: In this study, seven-point rating scales were used for the overall video quality and satisfaction, i.e., for video quality, 1 - very good, 7 - very bad, for satisfaction, 1 - strongly satisfied, 7 - strongly dissatisfied.

Observation and post session interview: during each session, experimenter was present, observed and administrated the procedure. Post session interview was also conducted with regard to user's general impressions of using Marratech as a video conferencing tool. Users' comments were manually written.

Data analysis

Statistical package SPSS was used to analyse the data collected in the experiment. Analysis of variance was conducted to test the statistical significance.

Results

Subjective ratings of overall video quality

Results of subjective ratings of overall video quality are shown in Table 2 and Figures 4 & 5. According to the rating scale described earlier, the higher the rating score / histogram shows the worse the video quality perceived by users. That is, at 128 kbps when the frames rate and quality were 8 then the perceived quality was the worst one. Where as at FPS 18 and IQ 18 the perceived quality was rated at a much higher satisfaction level.

Frame rate and Image quality	Mean	Std Deviation	N
F8_Q8	5.8000	1.4736	15
F8_Q18	5.1000	1.5337	15
F18_Q8	4.8000	1.2071	15
F18_Q18	4.1000	0.9612	15

Table 2: Descriptive Statistics of overall video quality

F-test showed that there was no significant interaction effect between frame rate and image quality ($p>0.05$). However, video qualities were significantly different between two frame rate levels ($p=0.005$), i.e., better video quality was perceived at FR18 than at FR8, and two image quality levels ($p=0.002$), i.e., better overall video quality was perceived at IQ18 than at IQ 8. Multiple Paired Comparisons showed that the overall video qualities were not significantly different between F8_Q18 and F18_Q8 ($p=0.413$).

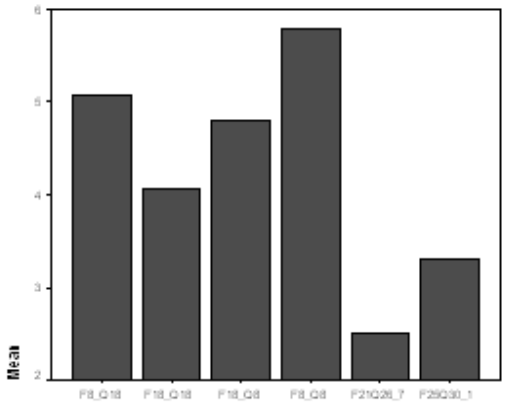

Figure 4. Mean scores of overall video quality

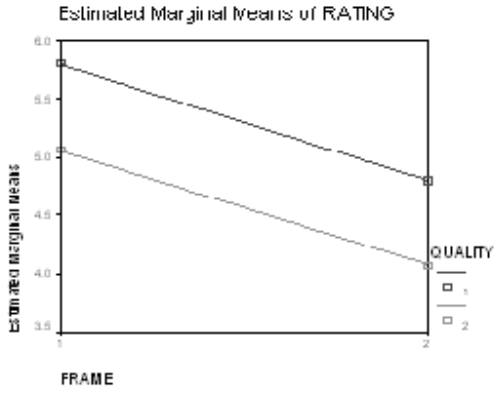

Figure 5. Profile plots of estimated mean scores of video quality ratings

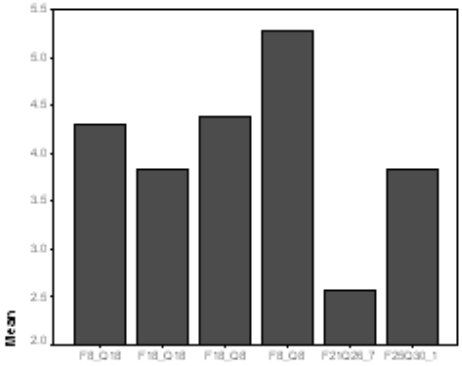

Figure 6: Mean scores of user satisfaction

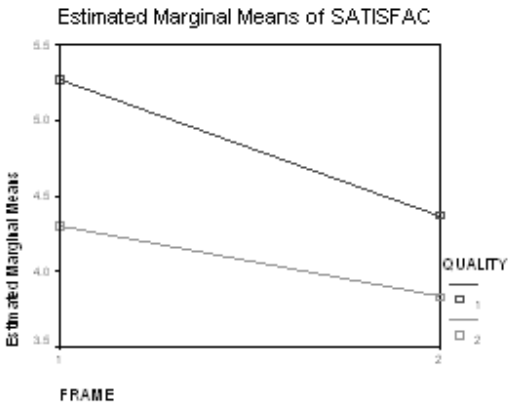

Figure 7. Profile plots of estimated mean scores of user satisfaction

User satisfaction

Results of user satisfaction with the videos are shown in Figure 6 and 7.

F-test showed that there was no significant interaction effect between frame rate and image quality ($p=0.216$). However, video qualities were significantly different between two frame rate levels ($p=0.048$) and two image quality levels ($p=0.000$).

Multiple paired comparisons showed that users were significantly dissatisfied with 8FR and 8IQ video ($p<0.05$). As shown in figure 6 the users were more satisfied when the FPS was 18 and IQ was also 18 at 128 kbps.

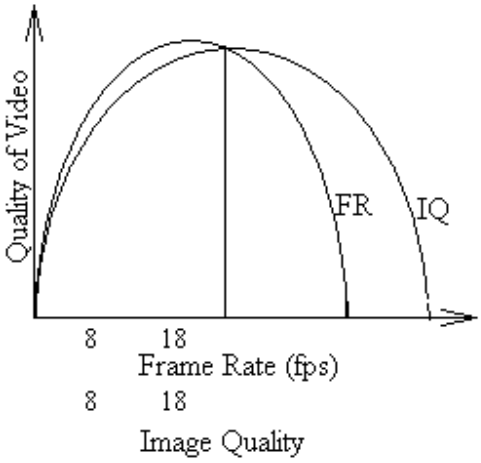

Figure 8: Schematic diagram showing relationship of IQ and Frame rate on the quality of video.

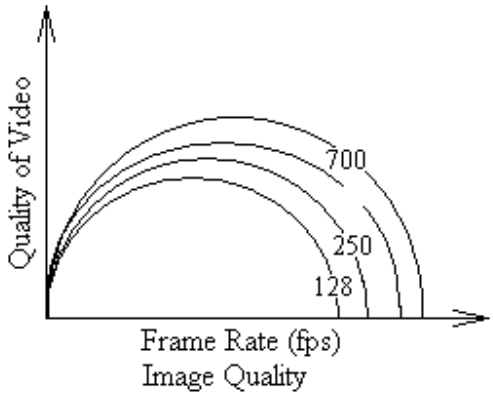

Figure 9: Conceptual Diagram of the effect of Bandwidth (kbps), Image Quality and Frame rate on the quality of video

Discussion

In a T.V. transmission images are transmitted at a rate of 30 fps. This frame rate is required to achieve good video quality without any jerkiness in the movement. In the present Internet network, where the bandwidth of 128 Kbps [ISDN] is more common for private users, conditions do not permit such high frame rates, hence, rate of 5-20 are more common.

Figure 8 shows schematically the dependency of perceptual quality of video on frame rate and image quality. As the frame-rate was increased the video becomes clearer and the movements became smoother. In the experiments when the frame rate was increased from 8 to 18 fps the quality became better since the points were on the left side of the curve. This increase in quality is brought about by an increase in load on the network. At a certain rate the load may become so high that the network may not be able to handle it. This would result in congestion and packet drops leading to poor video quality. The right hand side of the curve represents this. There is a point where the frame rate is optimum that would give the best video quality.

The image quality (IQ) has similar effect on the quality of video. When the image quality was increased from 8 to 18 there was a marked improvement in the quality of video. Again this improvement was brought about by the increased load on network. In the study the network was under utilised hence the quality improved. It may be expected that with further increase in the image quality the video quality may start decreasing because of problems arising during the transmission through the congested network.

Since, both – frame rate and image quality – show a similar behaviour, i.e., increase in video quality and load on the network with increase in the value it may be expected that there would be an optimum values for both these parameters. The values would depend upon the bandwidth. It may also be expected that with the increase in bandwidth the quality of video would increase. This is shown schematically in Figure 9.

Further experiments need to be carried out to prove the hypotheses proposed in this discussion.

Conclusions

From the limited number of experiments carried out it was seen that for a given bandwidth, better video quality is obtained by increasing the frame rate than by increasing the image quality.

Suggestions for Future Work

More experiments should be carried out to study in detail the effect of frame rate, image quality and bandwidth on the quality of video.

Acknowledgement

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