Decision on Compression Ratios for Real-Time Transfer of Ultrasound Sequences

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ABSTRACT

The need for video diagnosis in medicine has been increased and real-time transfer of digital video will be an important component in PACS and telemedicine. But, Network environment has certain limitations that the required throughput can not satisfy quality of service (QoS). MPEG-4 ratified as a moving video standard by the ISO/IEC provides very efficient video coding covering the various ranges of low bit-rate in network environment.

We implemented MPEG-4 CODEC (coder/decoder) and applied various compression ratios to moving ultrasound images. These images were displayed in random order on a client monitor passed through network. Radiologists determined subjective opinion scores for evaluating clinically acceptable image quality and then these were statistically processed in the t-Test method. Moreover the MPEG-4 decoded images were quantitatively analyzed by computing peak signal-to-noise ratio (PSNR) to objectively evaluate image quality. The bit-rate to maintain clinically acceptable image quality was up to 0.8Mbps. We successfully implemented the adaptive throughput or bit-rate relative to the image quality of ultrasound sequences used MPEG-4 that can be applied for diagnostic performance in real-time.

Keywords: real-time transfer, ultrasound sequences, MPEG-4, t-Test, peak signal-to-noise ratio (PSNR)

1. INTRODUCTION

MPEG-4 video aims at providing standardized core technologies allowing efficient storage, transmission and manipulation of video data in multimedia environments. In order to achieve this goal in medicine, rather than a solution for very low bit-rate applications, image quality issues for diagnosis are prior so that every effort must be made to optimize MPEG lossy process to accomplish the delicate balance between bandwidth availability and quality of the resultant material. The required throughput for ultrasound sequence is about size 640 * 480 pixel * 8 bits/pixel * 3 channel (Y, C_r and C_b) * 30 frame/s ≈ 221.2 Mbits/s. It is not possible for real-time transfer across current networks. Therefore, the data has to be compressed before transmission. We performed the standardized MPEG-4 video for compression of ultrasound data and decided compression ratios for real-time transfer using the methods of t-Test and PSNR.

2. MATERIALS AND METHODS

2.1. MPEG-4 Video and Bit-rates Control

An important phase of the MPEG-4 video standardization process is that of development of a verification model (VM). The VM has been completely defined to encoding as well as decoding algorithm and consisted of tools and algorithms that offered as reference to assess the achievement of MPEG-4 video. We followed MPEG-4 VM version 18.0.

Ultrasound sequences were acquired from an ultrasound system (SonoAce 6600, Medison Inc., Korea). The output from the S-VHS signal was digitized through an ATI video capture card. The size of this sequence was 12 frames at 640 * 480 pixels and 8 bits per pixel. The sequences, originally in RGB format, were converted to 4:2:0 YC_bC_r format to make them compatible with the encoders and then encoded as MPEG-4 bit streams. These data were decoded on the local client passed through networks.

The transmission of MPEG-4 encoders was designed to utilize constant bit-rate (CBR) channels. CBR MPEG-4 is achieved by using a rate control buffer called the video buffer verifier (VBV). Information is taken out of the buffer at a constant rate specified by the user and a source rate algorithm is used to minimize the likelihood of buffer underflow or overflow. The source rate control algorithm uses the buffer fullness as feedback to control the buffer quantizer scale. So the encoder varies the quality of the encoded video to maintain a constant rate. Quantization is to divide the resulting coefficients of macroblocks after discrete cosine transform (DCT) by quantizer value. Therefore lower bit-rates control is achieved to increase the quantization step in this process. That is, the DCT coefficients are divided by bigger value so that sort coded words are assigned. In result, entire bit rates are decreased and then we can acquire a smaller file size.

2.2. Subjective and Objective Evaluation of Image Quality

MPEG-4 arose from a need to have a scalable standard supporting a wide bandwidth range from streaming video at <64 Kbps, suitable for Internet applications, to 4 Mbps for higher-bandwidth video needs. But the relationship between bit-rate and quality is not linear. For that reason, the final end is to achieve the best quality to be capable of real-time transfer for a given available bandwidth, presuming that there should be no degradation or influence on quality of the MPEG data in transmission of a digital system.

Ultrasound video scenes generated from several video sequences at compressed bit-rates of 0.4 – 1.2Mbps at intervals of 0.1Mbps. The overall length of video scenes was 142 seconds and each test scene is of 9 seconds duration, with 2 seconds rest. Radiologist experienced in ultrasonography determined subjective mean opinion scores using the single stimulus continuous quality evaluation methods (SSCQE). For the assessment of image quality, single stimulus methods are rated on the quality scale of 1 to 5. The terms of quality on the high score mean: excellent, good, fair, poor and bad. We used a paired sample t-Test to evaluate the image quality relative to compression ratio. The results of t-Test were analyzed using SPSS 9.0 statistics software (SPSS Inc, Chicago, USA).

In video coding, the root-mean-squared error (RMSE) and peak signal-to-noise ratio (PSNR) is widely used as a measure of distortion. These metrics are popular largely because of their analytical tractability. The PSNR of the intensity of each frame of the compressed sequence as compared with each frame of the original was calculated.

3. RESULT

t-Test Analysis and PSNR Comparison

We implemented full-time network performance testing so that determined the manageable bandwidth for real-time transfer. In the worst case, the minimum compressed bit-rate of 1.2 Mbps can steadily transfer the moving ultrasound images in real time even for current network system (10/100 Mbps Ethernet environments) at Yonsei University Medical Center (YUMC).

The paired samples t-Test for evaluating image quality was used to compare the quality of the original and reconstructed images, and to compute the differences between the mean values of the original and the reconstructed image quality assessment. Table 1 shows the results of the paired sample t-Test obtained in the evaluation of image quality. These results indicated that the t-value (≈ 1.148) was relatively small at the bit-rate of 0.8 Mbps and that little differences were found between the quality of the original and reconstructed images above 0.8 Mbps bit-rate, at the 99% confidence level (p-value>0.01). The t-Test showed that there was a significant difference between the original and reconstructed images at the bit-rate of 0.6 Mbps (p-value<0.01).

Figure 1 and 2 shows the PSNR (in dB) of luminance (Y) for the decoding of ultrasound sequences at 0.4, 0.6, 0.8, 1.0 and 1.2 Mbps and 24 frames. As shown by figure 1 and 2, the PSNR waveform displayed oscillations of approximately 10 dB in magnitude about their means. The PSNR waveform of sequences coded into 0.8 Mbps was approximately 0.5 dB upper than those coded into lower bit-rates and are neck and neck comparing with higher bit-rates.

4. CONCLUSION

The network may demand a lower bit-rate in order to guarantee service to subscribers while the encoder may simultaneously demand a high bit-rate in order to encode a difficult piece of video. As far as real-time transmission of live video is concerned, it is a priority to reduce a bit-rate as small as possible within the allowable limits of a quality. MPEG-4 is expected to play a large part as a multimedia in medicine for consulting in other location. At the same time, the capability of archiving the MPEG-4 coded ultrasound sequences is fairly available in any other standards-based PACS system. In this study, there was a strong correlation between subjective and objective evaluation and these results suggested that the bit-rates of compressed video up to 0.8 Mbps enable to transfer ultrasound video in real-time without critically adverse effects on clinical diagnostic performance.

Table 1. The t-Test results of subjective evaluation paired with original samples.

		Paired Differences						
					99% Confidence Interval of the Difference			
	Mean	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	p-Value
Original – 0.4 Mbps	4.769 2.308	2.462	0.776	0.215	1.804	3.119	11.433	0.000
Original – 0.5 Mbps	4.769 2.385	2.385	0.768	0.213	1.734	3.035	11.196	0.000
Original – 0.6 Mbps	4.769 2.385	2.385	0.5064	0.140	1.956	2.814	16.979	0.000
Original – 0.7 Mbps	4.769 3.231	1.539	0.776	0.215	0.881	2.196	7.146	0.000
Original – 0.8 Mbps	4.769 4.539	0.231	0.7250	0.201	–0.383	0.845	1.148	0.273
Original – 0.9 Mbps	4.769 4.539	0.231	0.599	0.166	–0.277	0.738	1.389	0.190
Original – 1.0 Mbps	4.769 4.692	7.692E-02	0.641	0.178	–0.466	0.620	0.433	0.673
Original – 1.1 Mbps	4.769 4.692	7.692E-02	0.641	0.178	–0.466	0.620	0.433	0.673
Original – 1.2 Mbps	4.769 4.692	7.692E-02	0.7596	0.2107	–0.567	0.720	0.365	0.721

Figure 1. Luminance (Y) PSNR for 0.4 and 0.6 Mbps comparing with 0.8 Mbps over 24 frames.

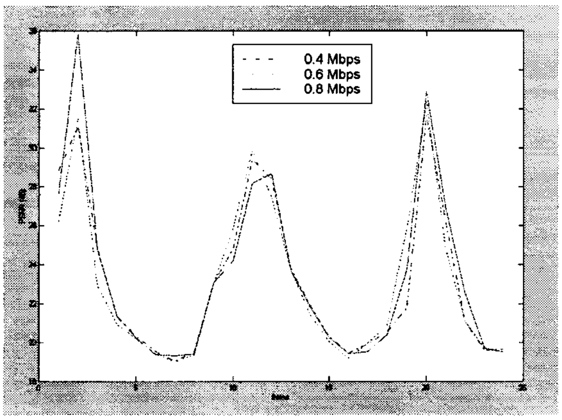
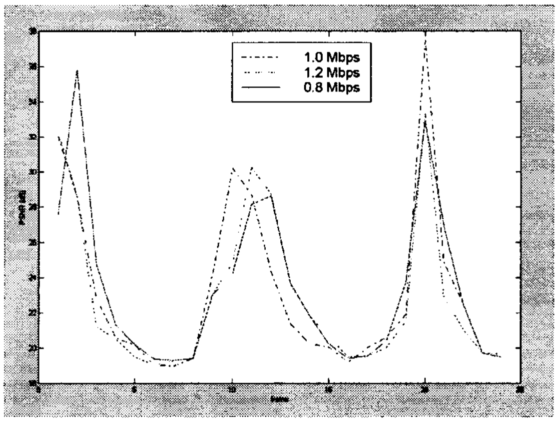


Figure 2. Luminance (Y) PSNR for 1.0 and 1.2 Mbps comparing with 0.8 Mbps over 24 frames.



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