Optimal Configuration of SVC for Satellite Broadcasting Service with Ku/Ka Bands

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Abstract

The study investigated the optimal configuration of SVC (Scalable Video Coding) to apply to the satellite broadcasting service, and compared the performance of the SVC with that of the AVC (Advanced Video Coding). To get the optimal configuration, we analyzed the optimal bit rate allocation between the layers and the optimal scalability which requires the least bit rate for the required PSNR for various kinds of contents using JSVM. As a result of investigation, we found that the optimal bit rate allocation occurs when the bit rate of the base layer is minimum, and the spatial scalability shows the best performance. The performance of SVC is similar to that of AVC for spatial scalability, but it depends on contents.

1. Introduction

The optimal configuration of scalable video coding (SVC) to apply to the satellite broadcasting service with Ku/Ka bands is investigated. The Ka band is a good spectrum resource for the new broadcasting service, but it has a rain fading problem. The Ka band signal is highly attenuated under the heavy rain environment. To overcome the problem, the scheme to combine the Ka band with the Ku band is considered. The Ku band is more robust to rain fading than the Ka band, and the more important data can be transmitted through the Ku band, and the other data through the Ka band. The SVC can be employed to transport two levels of data with two layers: a base layer and an enhancement layer.

In applying the SVC to the satellite broadcasting service, we are trying to find the optimal configuration of the SVC. We want to investigate the optimum bit rate allocation between layers, the scalability having the best performance, and the performance of the SVC with respect to the AVC.

The paper is organized as follows. Section 2 illustrates the problem formulation and the configuration of JSVM software. Section presents the optimal bit rate allocation of SVC, and the compares the performance of SVC with that of AVC.

2. Problem formulation

2.1 Problem formulation

The system description for the study is illustrated in Figure 1.

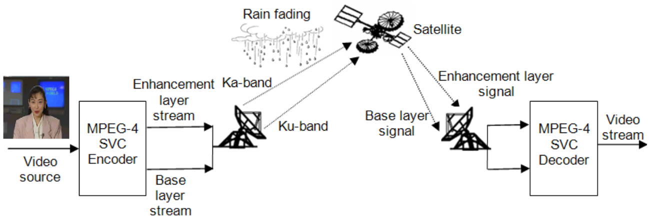

Figure 1. System description.

The video source is input to the SVC encoder, and each layered signal (the base layer or the enhancement layer signal) is transmitted through an independent RF channel having Ku or Ka band separately. The Ku band signal is more robust than the Ka band signal, and it conveys more important data. To make the Ku band signal more robust, we may use more robust modulation and channel coding schemes.

In configuring the SVC encoder, we are trying to find the optimal bit rate allocation between layers. We are also trying to find the best scalability having the best performance. We are also trying to find the SVC configuration having the nearest performance to that of AVC.

2.2 JSVM Software Configuration

To analyze the performance of SVC, we used the JSVM software of version 9.19.7. For configuration of JSVM, the Lagrangian multiplier employed for motion estimation and mode decision is controlled via a mode quantization parameter (MQP). Additional parameter required for configuration is residual quantization parameter (RQP). In the research, we will encode several CIF sequences in different scalability modes with GOP=32.

A. *Spatial Scalability*

The encoder is similar to the single-layer coding because there is not quality refinement slices (Q>0). The difference from the single-layer coding is that the mode decision for each layer considers the additional SVC macroblock modes with inter-layer prediction in addition to the regular H.264/AVC modes. The Lagrangian multiplier is determined depending on the layer quantizer QP (MQP=RQP). Proper choice of QP parameter depends on the target bit rate.

B. *SNR scalability*

There is quality refinement slices (Q>0), and we should notice about the MQP and RQP values to find which MQP and RQP values meet the target bit rate at the best quality. Normally, for quality scalability with one quality refinement layer, MQP=RQP-2 has shown to provide the best result. RQP parameter equals to the QP parameter [2].

3. Optimal Bit rate Allocation in SVC

The simulation results provide the bit rate allocation between base and enhancement layers. A comparison of the SVC performance for temporal, spatial and quality scalability is presented. SVC is also compared to the H.264/AVC at the same quality.

3.1 Simulation Environments

Seven test sequences were selected for the evaluation. Three CIF sequences (Football, Foreman, Mobile) are well-known and used in the development of video codec for long time. The others are Ice, City, Crew and Harbor sequences which have different motion characteristics and texture complexity.

Table I shows the characteristics of motion and texture complexity for each sequence.

Table I. Characteristics of test sequences.

Motion / Texture Complexity	Slow	Medium	High
Low	Ice	Crew	X
Medium	City	Foreman	Football
High	Mobile	Harbour	X

3.2 Optimal Bit rate Allocation

Figures 2-8 show the simulation results for AVC and SVC coding at the optimal bit rate.

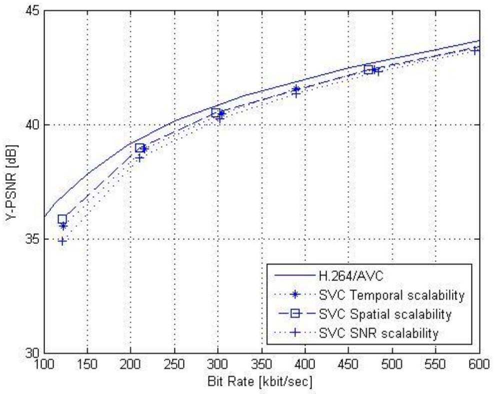

Figure 2. R-D performance of SVC coding (City).

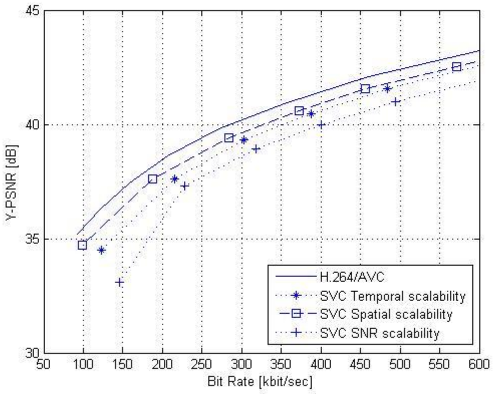

Figure 3. R-D performance of SVC coding (Crew).

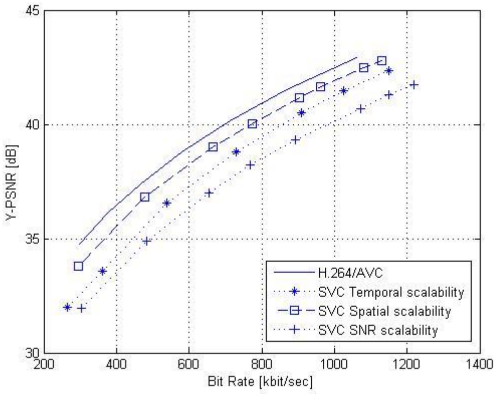

Figure 4. R-D performance of SVC coding (Football).

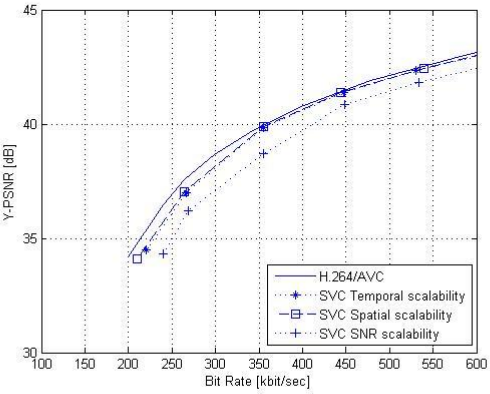

Figure 5. R-D performance of SVC coding (foreman).

Figures 2-8 show rate-distortion results for the temporal/spatial/quality scalabilities of SVC and AVC at the optimal bit rate of base layer for seven test sequences. The optimal bit rate for the base layer is found to be the smallest possible bit rate or the highest quantization parameter value of the base layer. The results are also compared with AVC single layer coding with hierarchical B-pictures.

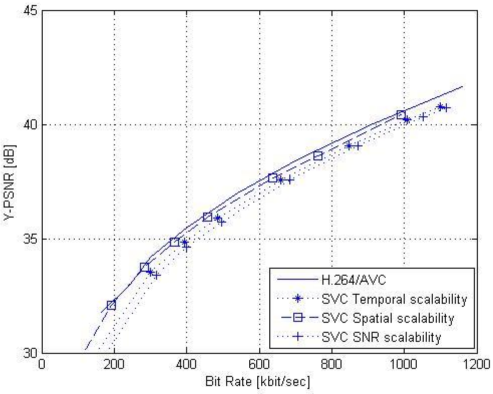

Figure 6. R-D performance of SVC coding (harbor).

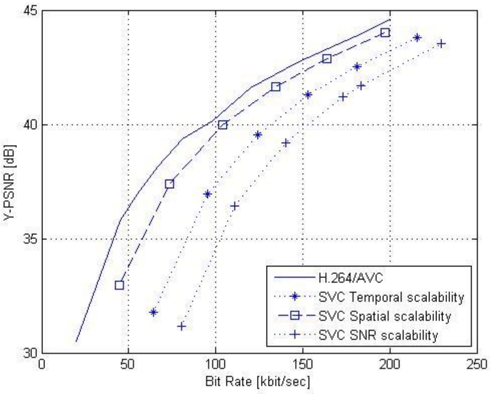

Figure 7. R-D performance of SVC coding (ice).

Considering each scalability, the spatial scalability performance is better than the others. The SNR scalability has the worst performance. Especially, the SNR scalability in the contents which has high motion is much worse than the other cases. This happens because the GOP size of 32 is not reasonable. By choosing the lower GOP size, we can get the better rate-distortion performance. Besides, it can be seen that all scalability performance in City sequence coding is nearly the same.

It can be found that the rate-distortion performance for the spatial scalability is closest to the rate-distortion performance of the single layer codec. Generally, it can be seen that the R-D performance for AVC coding has a slight difference to the SVC coding and it is not too much except contents which have high or slow motion or low texture.

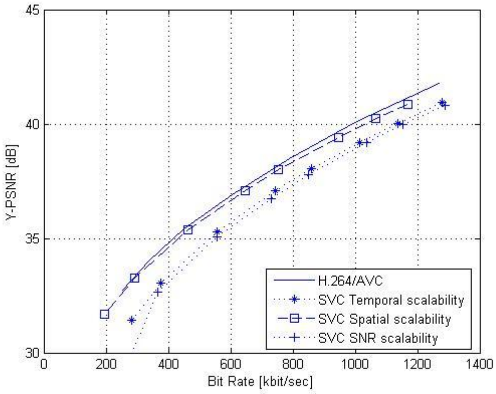

Figure 8. R-D performance of SVC coding (mobile).

Finally, it can be seen that the difference between AVC and SVC will be different depending on contents. The performances of SVC with the spatial scalability for the contents having high texture or medium texture and medium motion are very close to the AVC performance. A drop of about 0.2dB in PSNR or slightly 10% rate increase can be observed.

3.3 Performance of SVC and AVC

The relative efficiency of the SVC to AVC at PSNR=C (dB) is defined as in Eq. 1.

$$\alpha_C = \frac{r_S - r_A}{r_A} \times 100\ (\%) \tag{1}$$

r_A : Bit rate for AVC, r_S : Bit rate for SVC

Tables II-IV show the relative efficiency of SVC to have the same PSNR as AVC for temporal, spatial and quality scalabilities. The performance of the SVC is compared with that of the AVC though the relative efficiency as defined in Eq. 1.

Table II. Relative Efficiency of SVC to have the same PSNR as AVC (temporal scalability).

Test sequence	r_b (kbps)	$\alpha_{35}(\%)$	$\alpha_{40}(\%)$
Ice	34	107.5	40.2
City	33	27.5	66.2
Mobile	100	30.5	15.0
Crew	32	55.5	60.0
Foreman	26	4.5	1.4
Harbor	30	10.4	10.7
Football	85	53.3	22.9

Table III. Relative Efficiency of SVC to have the same PSNR as AVC (spatial scalability)

Test sequence	r_b (kbps)	$\alpha_{35}(\%)$	$\alpha_{40}(\%)$
Ice	14	45.0	15.2
City	30	25.0	62.5
Mobile	18	4.9	1.5
Crew	10	22.2	13.8
Foreman	24	2.3	1.4
Harbor	10	7.7	8.6
Football	26	20.0	11.4

It can be seen that the percentage of additional bit rate for SVC to have the same PSNR (35/40dB) as AVC for spatial scalability is the smallest for all test contents, while the percentage of additional bit rate for SNR scalability is the biggest.

Table IV. Relative Efficiency of SVC to have the same PSNR as AVC (SNR scalability).

Test sequence	r_b (kbps)	$\alpha_{35}(\%)$	$\alpha_{40}(\%)$
Ice	50	160.0	65.2
City	30	40.0	71.8
Mobile	100	34.1	16.5
Crew	49	100.0	37.9
Foreman	27	20.4	15.5
Harbor	45	16.0	11.8
Football	130	60.0	41.4

On the other hand, for each different contents, the percentage of additional bit rate for SVC to have the same PSNR (35/40dB) as AVC must be different. The less texture contents have, the more percentage of additional for SVC to have the same PSNR (35/40dB) as AVC is needed. Besides, for contents which have the slow motion, the percentage of additional for SVC to have the same PSNR (35/40dB) as AVC is small. It is less than the high motion cases.

4. Conclusion

The efficiency in coding for temporal, spatial and SNR scalability strongly depends on the choice of quantization parameter and the bit rate of base layer. It has been generally observed that spatial scalability performs better than the others at the optimal bit rate allocation between base and enhancement layers. By choosing a proper bit rate for base layer, we can get the better R-D performance SVC coding and it will be closer to the performance of AVC coding. Although scalable coding still comes at some costs in terms of bit rate or quality, the gap between SVC and AVC single layer coding can be small at the optimal bit allocation between base and enhancement layers.

References

[1] ISO/IEC 14496-10 and ITU-T Rec.H.264: “Advanced Video Coding”, 2003.

[2] Mathias Wien, H.Schwarz, Tobias Oelbaum, “Performance Analysis of SVC”, IEEE Transactions On Circuit and Systems For Video Teachnology, Vol.17, No.9, September 2007.

[3] Thomas Wiegand, Ludovic Noblet, Fabrizio Rovatio, “Scalable Video Coding for IPTV Services”, IEEE Transactions on Broadcasting, Vol.55, No.2, June 2009.