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Title	**Influence of views and depth compression onto quality of synthesized views**
Sub group	**Video**
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1 Introduction

In the document, transmission of two views together with corresponding depth maps is considered. It is assumed that both view video as well as the respective depth maps are compressed. Subjective and objective quality of synthesized views derived from the compressed reference views and the compressed depth maps is studied. Estimated are the values of quantization steps and bitrates needed for views and depth maps in order to obtain good quality of synthesized views.

The document summarizes the results of experiments described in papers [7] and [8].

2 The idea of experiments

In the experiments, quality of synthesized view B' is estimated using original view B as a reference (Fig. 1).

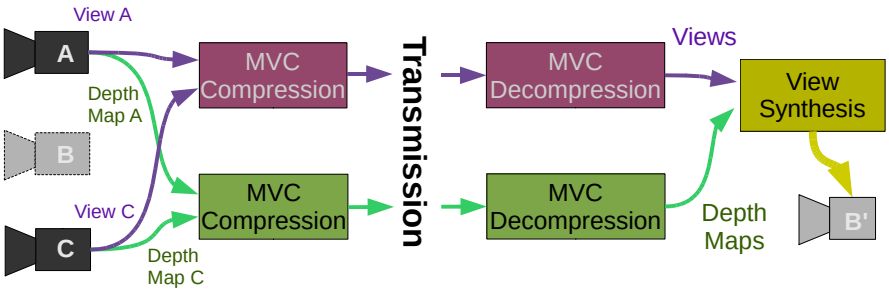

Figure 1. Test setup.

The coding experiments use MVC codec for both video and depth map compression.Video synthesis is performed using VSRS.

In order to reduce bitrate allocated to the depth maps, decimated version may be used. For comparison, both original depth maps as well as their decimated versions have been compressed. Objective and subjective quality of synthesized views have been assessed for various bitrates of depth map and view video bitstreams.

The depth map quality can be kept relatively low. Compression of depth maps faces different problems than compression of views, since depth maps have different properties and there are different requirements for depth map compression. Depth maps contain less information in general (less abundant texture, only one component), but it is important to preserve some features unchanged (like absolute values and sharp edges).

Quality of synthesized view depends on both quality of video and depth map. In order to evaluate the influence of compression an experiment was conducted, where synthesized views were compared to the original view.

In real-life systems synthesized view is presented directly to the user. Thus, it has to be as similar to the real view as possible. Therefore quality of the synthesized view should be measured with respect to the original view from a real camera.

3 Experiment details

Views from cameras A and C (Fig. 1) are compressed with several different quantization parameter index (QP) values. Similarly, depth maps are also compressed with several different quantization parameter indices for depth compression (QD – to differentiate it from quantization parameter index for a view). Quality of synthesized view B' is measured in terms of PSNR using as a reference real camera view B. Three test sequences - Book Arrival, Pantomime and Newspaper were used. Original views (camera A and C in Fig. 1) and synthesized views are specified in Table 1.

Table 1. Positions of the cameras used in experiments.

Data set	Original pair (A and C)	Synthesized view (B)
Book Arrival	7 and 10	8
Pantomime	38 and 41	39
Newspaper	3 and 6	4

Moreover, quality of synthesized views have been examined also for compression of decimated (Fig. 2) depth maps. Test setup was the same as previously, but depth maps were decimated before compression and upsampled after decompression prior to view synthesis process.

The results are presented as functions of total bitrate as well as functions of bitrate ratio

$$bitrate\ ratio = \frac{depth\ map\ bitrate}{view\ bitrate + depth\ map\ bitrate}. \quad (1)$$

Quality of synthesized view was assessed using luminance PSNR calculated with respect to original view from the real camera, i.e. by pixel-by-pixel comparison of video B' and B (Fig. 1).

For comparison purposes, quality of views synthesized using uncompressed views and depth maps are given in Table 2.

Table 2. Values of PSNR for views synthesized using uncompressed views and depth maps.

Data set	PSNR using uncompressed data [dB]	PSNR using uncompressed data (depth maps decimated with factor 2) [dB]
Book Arrival	36.1787	36.1865
Pantomime	35.5908	35.6526
Newspaper	29.2191	29.3317

In order to verify the PSNR results, some subjective tests have been performed. A single-stimulus test was conducted with 15 spectators and the quality was rated from 5 ("imperceptible artifacts") to 0 ("very bad with annoying artifacts"). The original video from actual real camera was used as hidden reference.

The experiments were conducted using the following software: VSRS version 3, DERS version 3, JMVC version 3.

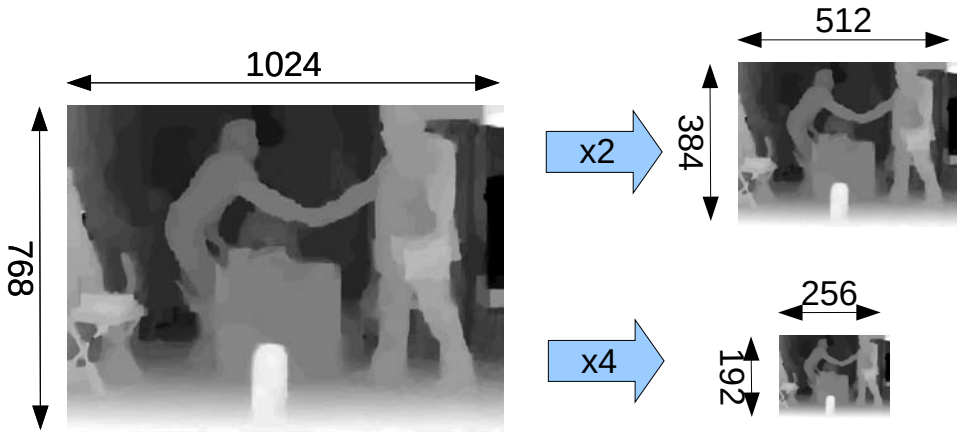

Figure 2. Decimation of the depth maps.

4 Results for non decimated depth maps – objective tests

The results obtained using the setup shown above are presented in the following graphs. Quantization parameter index (QP) used for view compression for each line on the figures below is given. Moving along each line corresponds to changing depth quantization parameter index QD. Every point on the line corresponds to a different quantization parameter index used for depth compression (QD).

Book Arrival:

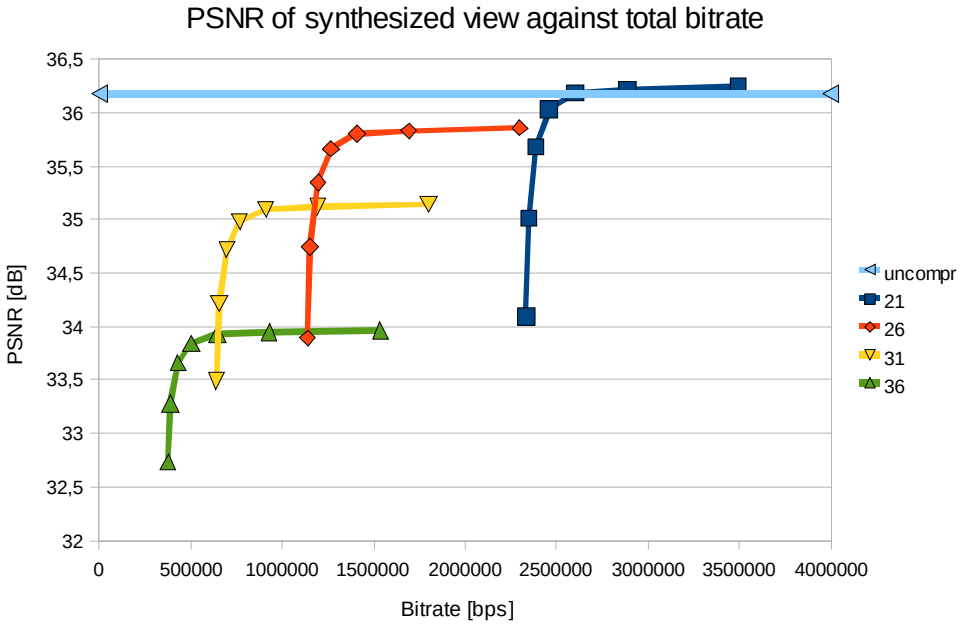

Figure 3. Results for Book Arrival sequence – PSNR of synthesized view against total bitrate. The individual lines correspond to QP values 21,26,31,36. The points on each line correspond to QD values from 21 to 51 (from right to left).

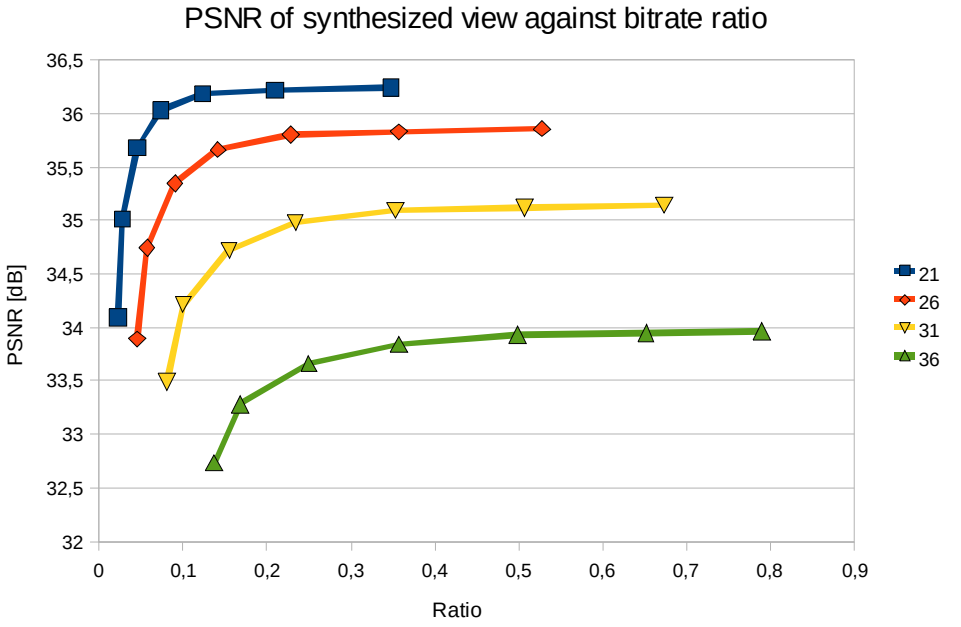

Figure 4. Results for Book Arrival sequence – PSNR of synthesized view against bitrate ratio (Eq. 1).The individual lines correspond to QP values 21,26,31,36. The points on each line correspond to QD values from 21 to 51 (from right to left).

Pantomime:

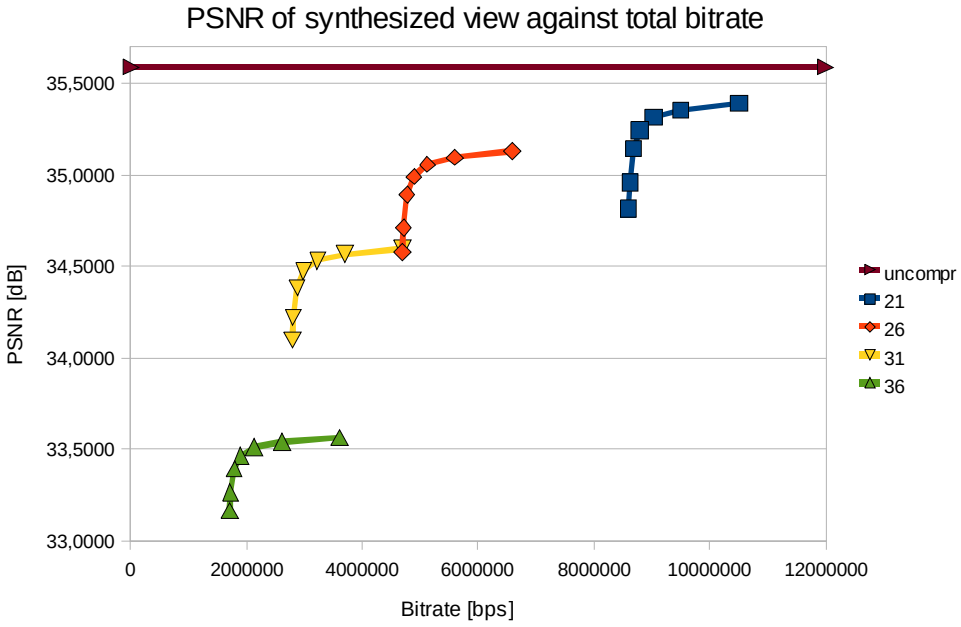

Figure 5. Results for Pantomime sequence – PSNR of synthesized view against total bitrate. The individual lines correspond to QP values 21,26,31,36. The points on each line correspond to QD values from 21 to 51 (from right to left).

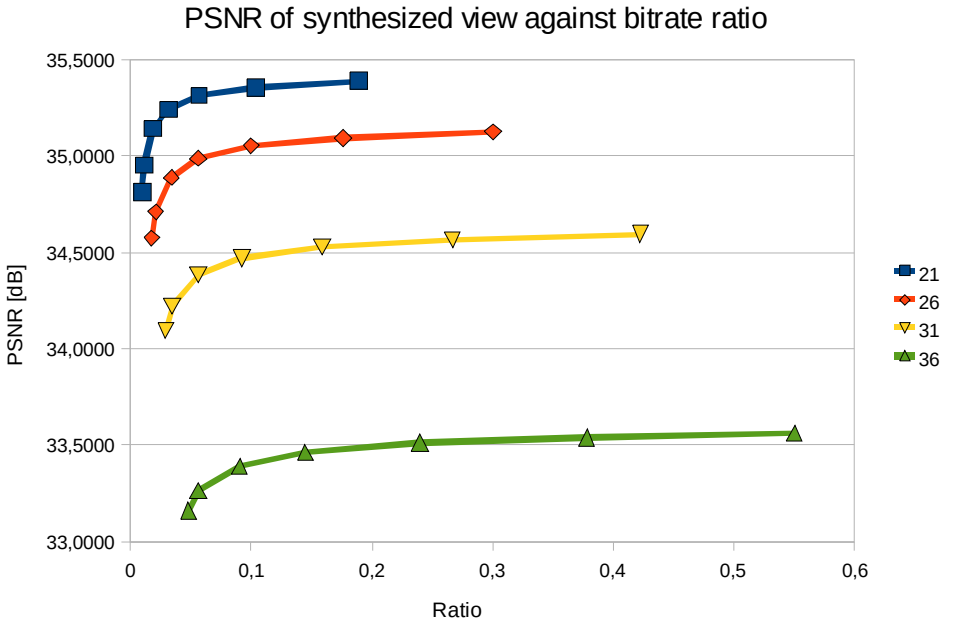

Figure 6. Results for Pantomime sequence – PSNR of synthesized view against bitrate ratio (Eq. 1).The individual lines correspond to QP values 21,26,31,36. The points on each line correspond to QD values from 21 to 51 (from right to left).

Newspaper:

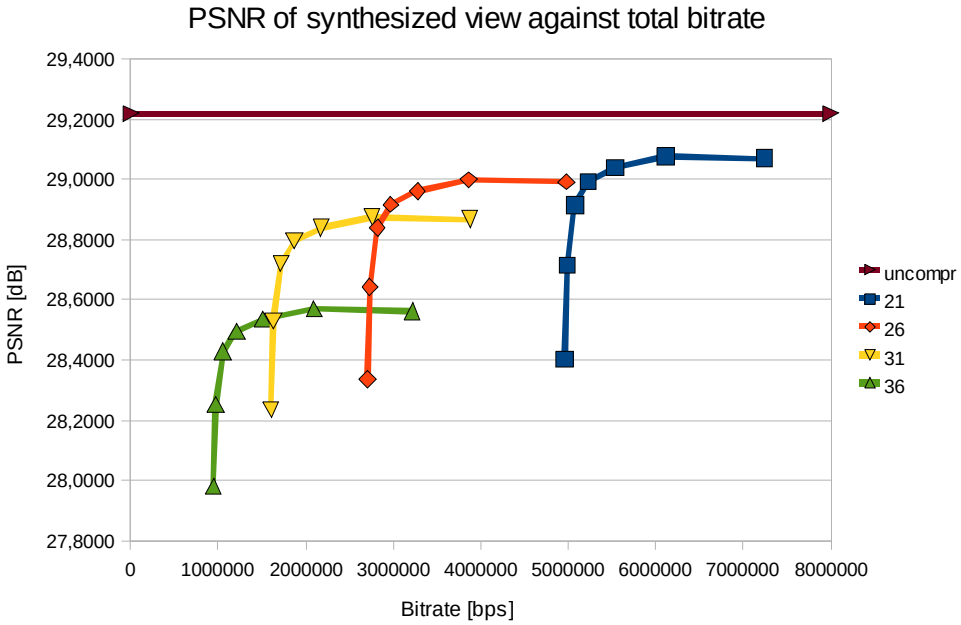

Figure 7. Results for Newspaper sequence – PSNR of synthesized view against total bitrate. The individual lines correspond to QP values 21,26,31,36. The points on each line correspond to QD values from 21 to 51 (from right to left).

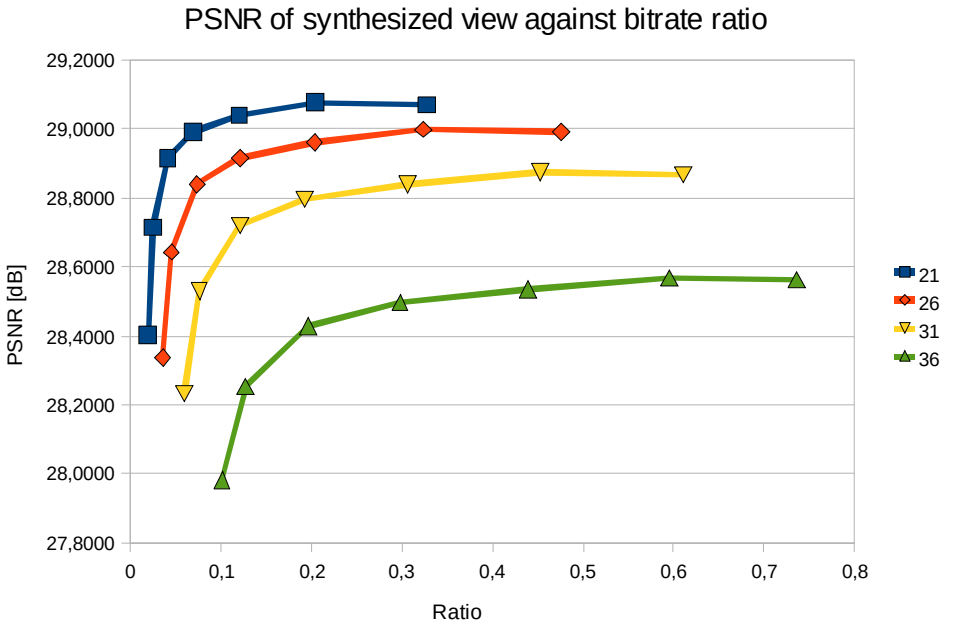

Figure 8. Results for Newspaper sequence – PSNR of synthesized view against bitrate ratio (Eq. 1).The individual lines correspond to QP values 21,26,31,36. The points on each line correspond to QD values from 21 to 51 (from right to left).

5 Results with original depth maps – subjective tests

Subjective tests were performed using Book Arrival sequence in order to confirm conclusions from objective quality tests. 95% confidence interval was used for data presentation.

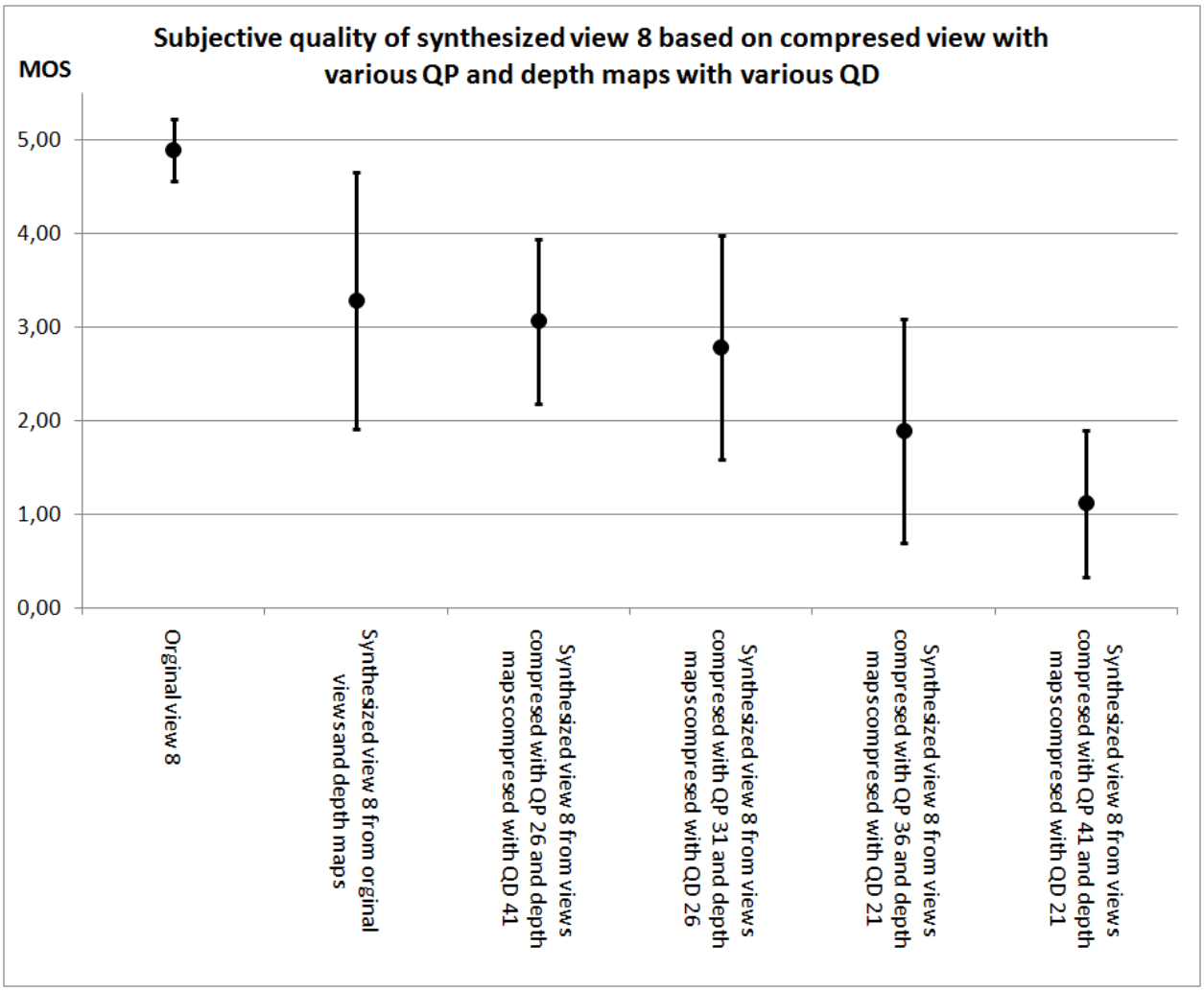

Figure 9. Subjective results for Book Arrival sequence. Various QP and QD.

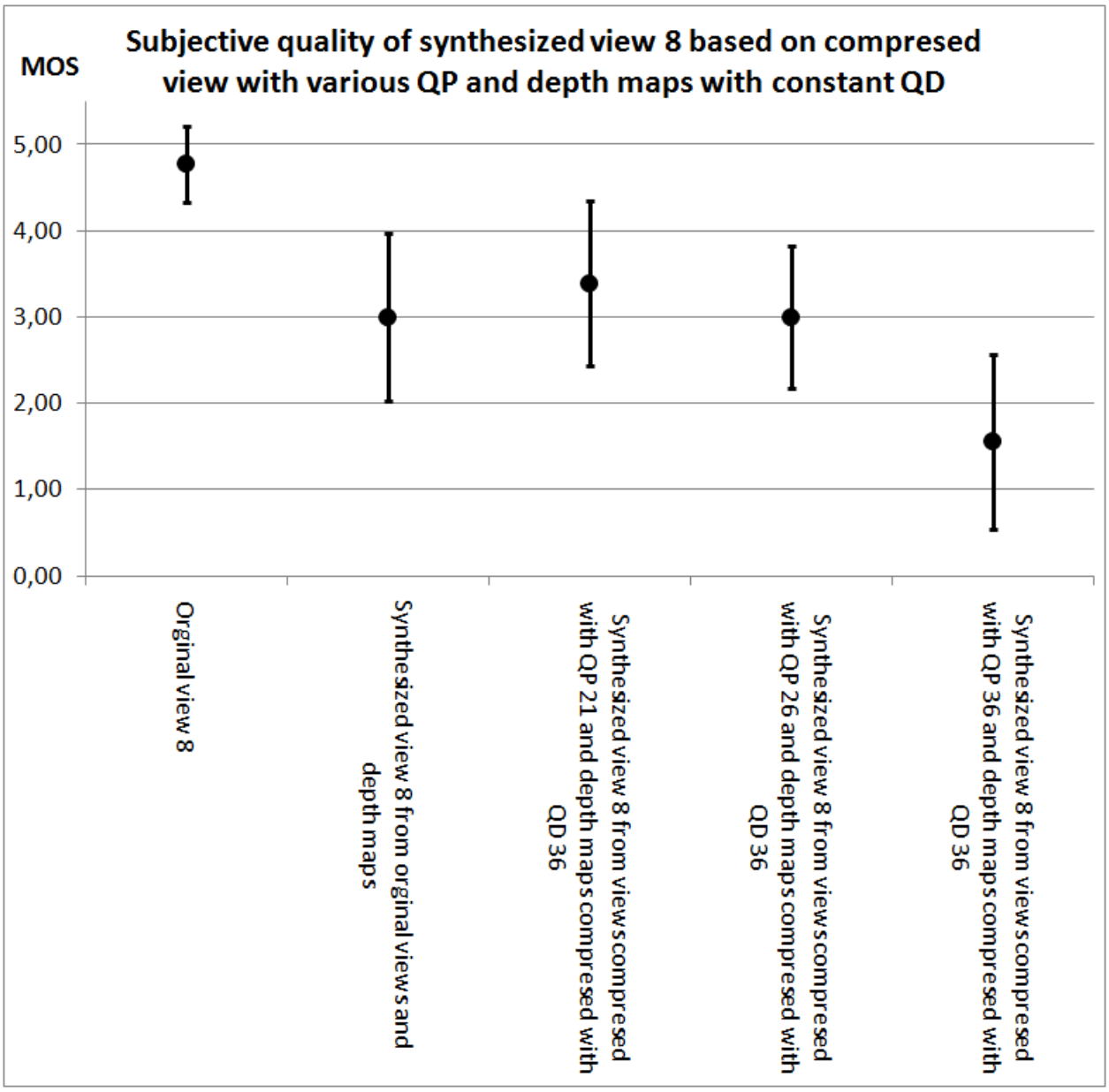

Figure 10. Subjective results for Book Arrival sequence. Variable QP and constant QD.

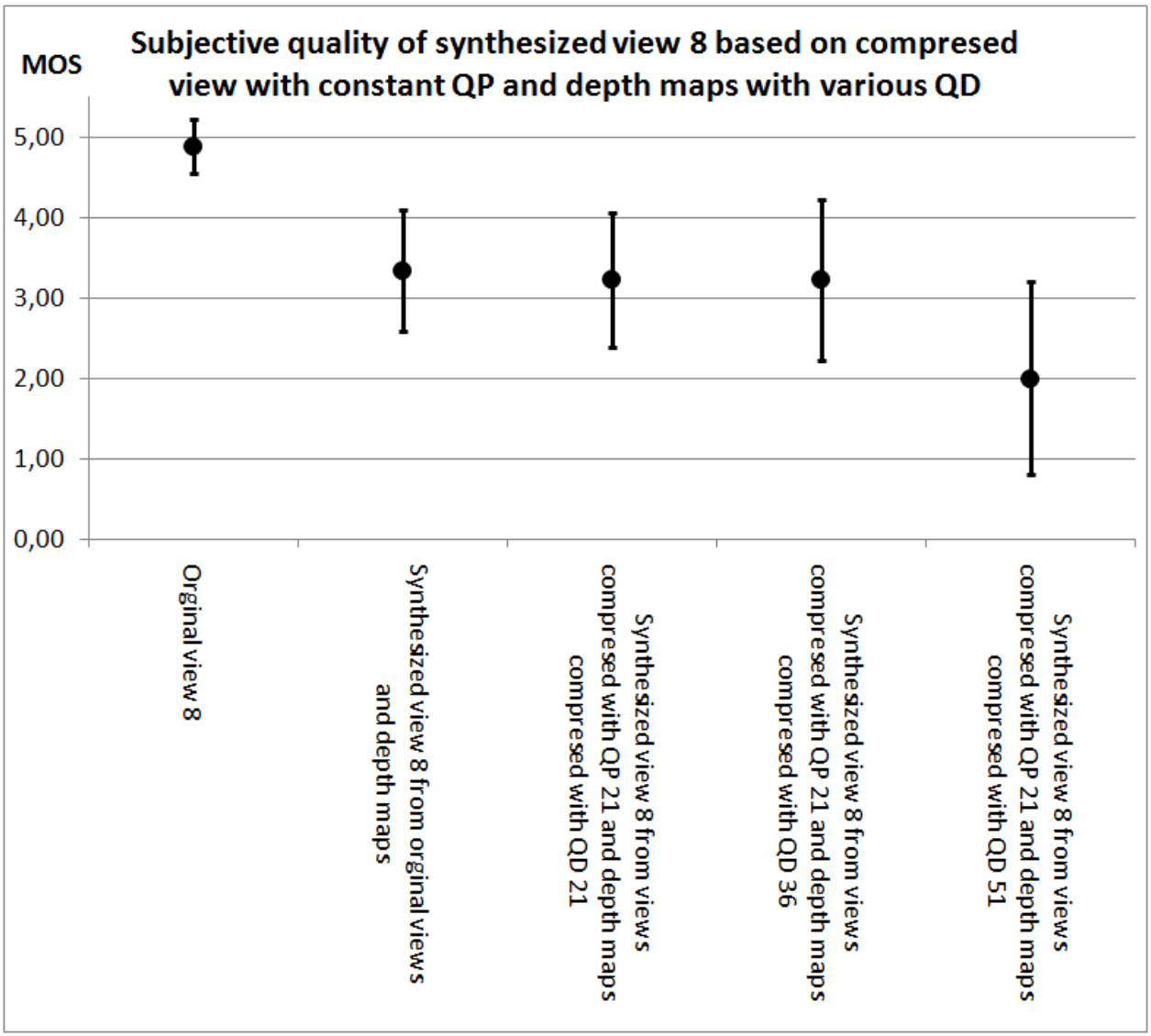

Figure 11. Subjective results for Book Arrival sequence. Constant QP and variable QD.

The results presented above are compliant with the results obtained using objective measure and therefore confirm conclusions drawn from objective results. View quality has much bigger influence on synthesis quality than depth map quality. Moreover, for a certain range of depth map quality there is no change in synthesized view quality.

6 Results with decimated depth maps – objective tests

Obtained results are presented in graphs below. There is a noticeable improvement when comparing cases for depth maps decimated by a factor of two. Decimation by a factor of four causes a decrease of view synthesis quality in the range of higher ratios of bitstream allocation between views and depth maps.

Book Arrival:

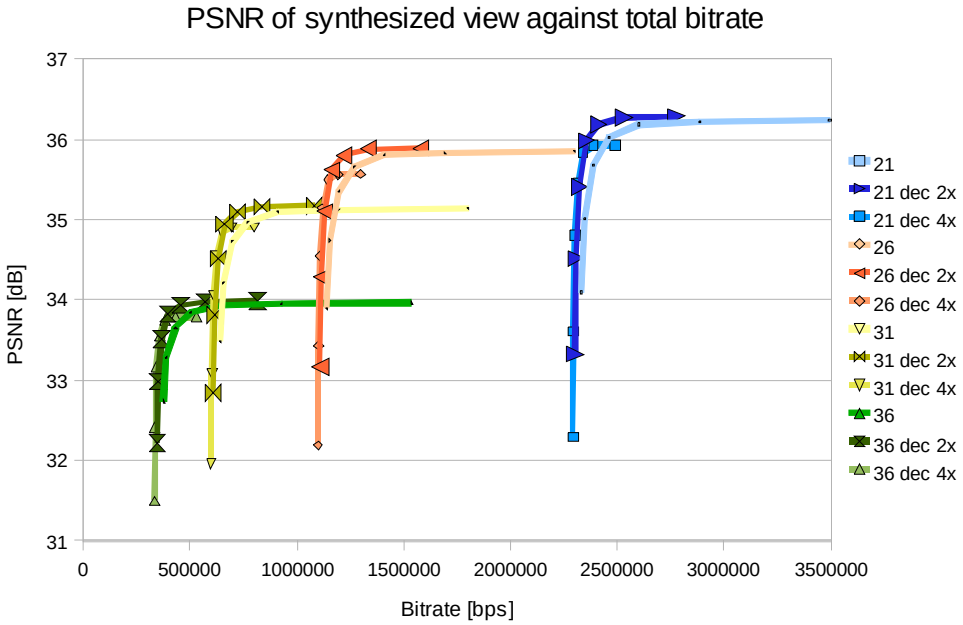

Figure 12. Results for Book Arrival sequence – PSNR of synthesized view against total bitrate. The individual lines correspond to QP values 21,26,31,36. The points on each line correspond to QD values from 21 to 51 (from right to left).

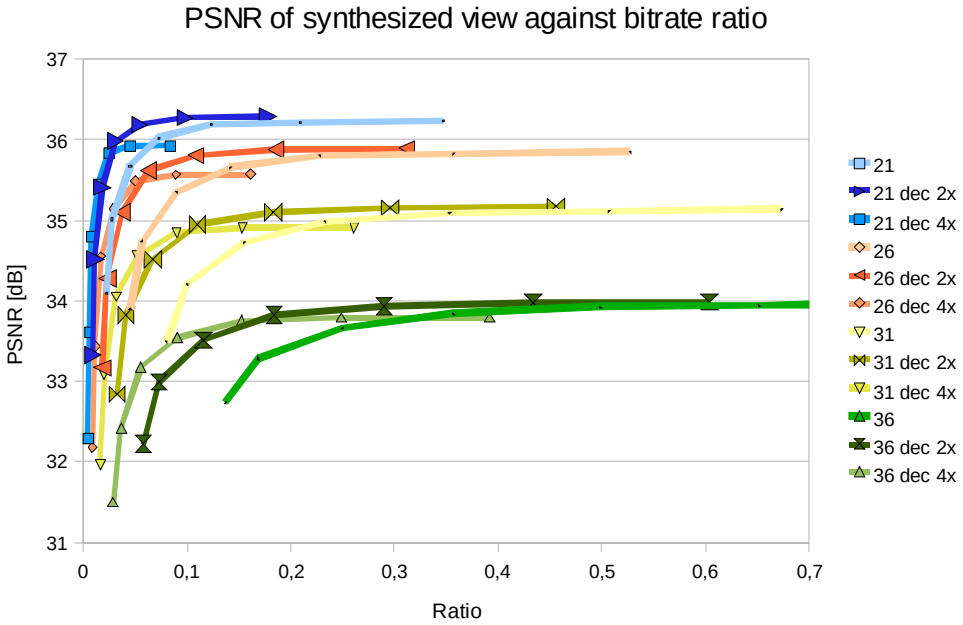

Figure 13. Results for Book Arrival sequence – PSNR of synthesized view against bitrate ratio (Eq. 1).The individual lines correspond to QP values 21,26,31,36. The points on each line correspond to QD values from 21 to 51 (from right to left).

Pantomime:

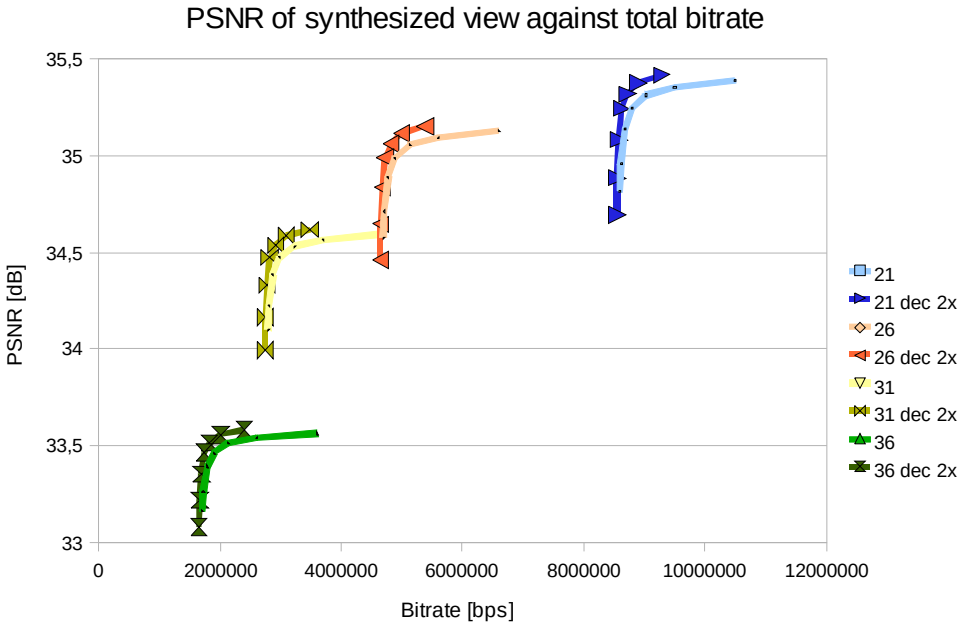

Figure 14. Results for Pantomime sequence – PSNR of synthesized view against total bitrate.The individual lines correspond to QP values 21,26,31,36. The points on each line correspond to QD values from 21 to 51 (from right to left).

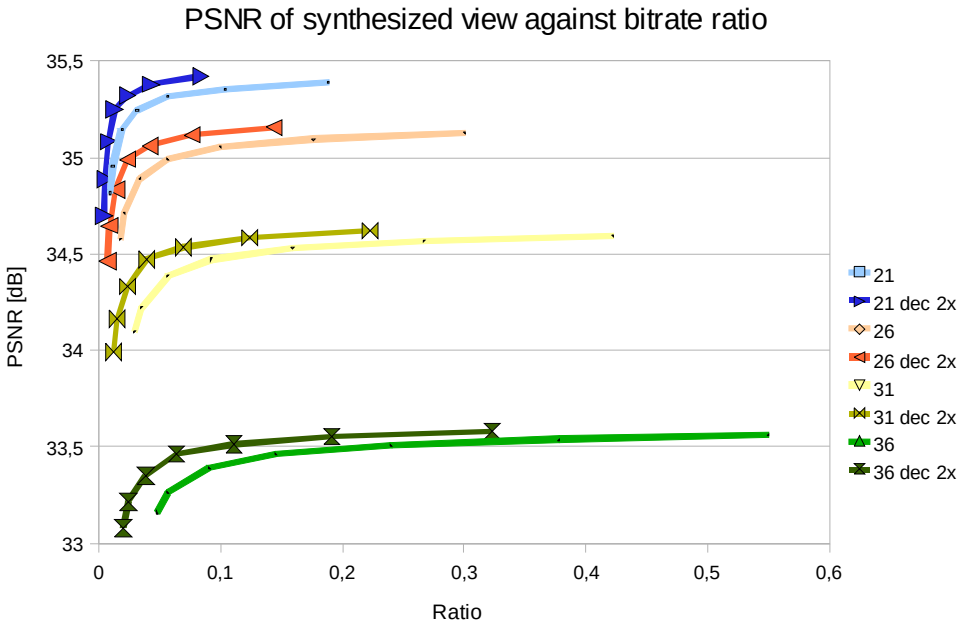

Figure 15. Results for Pantomime sequence – PSNR of synthesized view against bitrate ratio (Eq. 1).The individual lines correspond to QP values 21,26,31,36. The points on each line correspond to QD values from 21 to 51 (from right to left).

Newspaper:

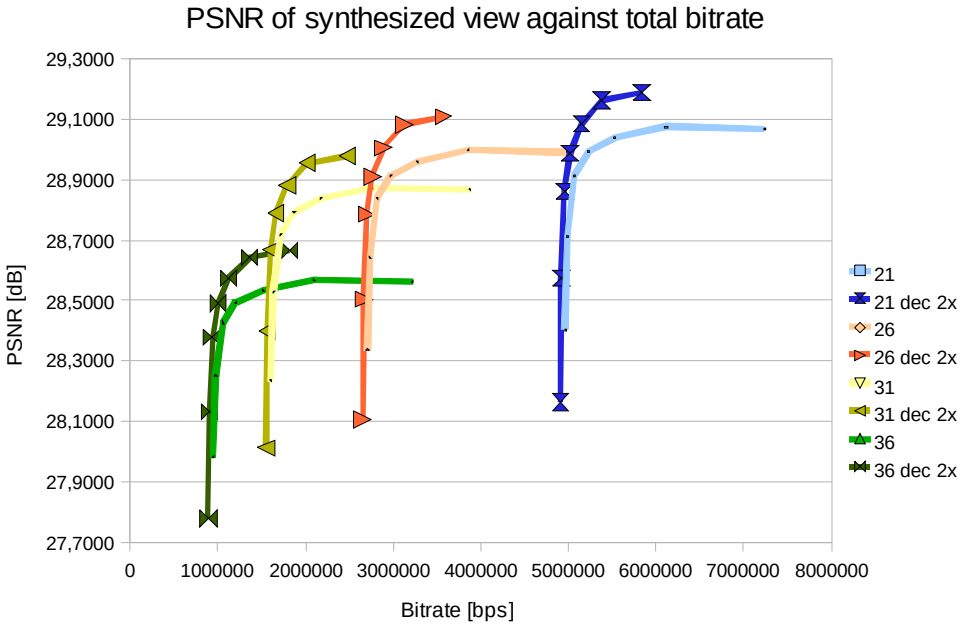

Figure 16. Results for Newspaper sequence – PSNR of synthesized view against total bitrate. The individual lines correspond to QP values 21,26,31,36. The points on each line correspond to QD values from 21 to 51 (from right to left).

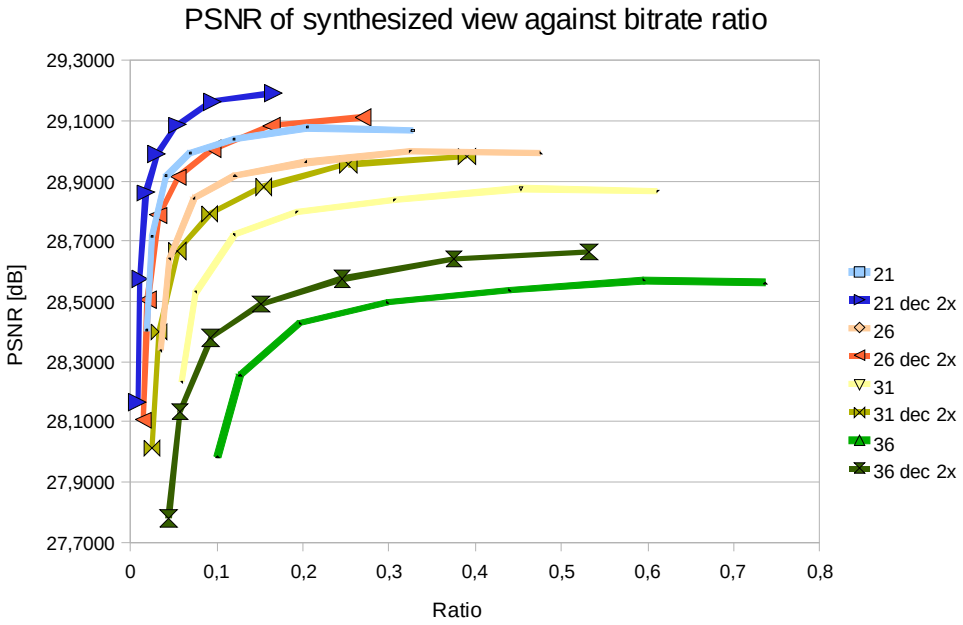

Figure 17. Results for Newspaper sequence – PSNR of synthesized view against bitrate ratio (Eq. 1).The individual lines correspond to QP values 21,26,31,36. The points on each line correspond to QD values from 21 to 51 (from right to left).

7 Conclusions

Depth quantization parameter index QD has negligible (less than 0.2 dB decrease) impact on synthesized view quality as long its value is smaller than the following threshold estimated from the experiments

$$Threshold\ QD = 49 - 0.005 \cdot (76 - QP)^2 \quad (2)$$

It can be concluded that for high- and medium-quality depth map compression, synthesized view quality is independent from depth map bitrate. For higher reference view quality (QP≤21), the quality of synthesized views is approximately the same as that for uncompressed views, PSNR differences being less than 0.2 dB and sometimes even outperform results for uncompressed data. The above mentioned results have been verified by subjective quality assessment for synthesized views.

Experiments also show that MVC codec can be successfully used as a depth map compression tool. Although not optimized for this purpose it is good and readily available solution. For useful quality of views, even bitrate ratios below 30% can provide acceptable quality. Depth bitrate for depth map should be between 10% and 30% of total bitrate for original depth maps and from 5% to 20% for decimated depth maps. For QP less than 21 and QD less than given ThresholdQD (2), significant loss of quality in synthesized views is caused rather by imperfect depth estimation and view synthesis. Below the abovementioned values, further increase of view and depth bitrate does not improve synthesized view quality.

Final conclusions from the experiments are the following:

- it is possible to transmit the depth maps using MVC codec with sufficient quality,
- view quality is much more important than depth quality in terms of synthesized view quality,
- depth bitrate can be kept as low as 5 - 20 % of total bitrate without significant loss of synthesized view quality (for decimated depth map),
- for a certain range of values of quantization parameter index for depth compression (QD) , no change of synthesized view quality is noticeable,
- higher compression rate with comparable quality can be obtained by decimating the depth map by a factor of 2.

8 Recommendations

We recommend to consider usage of decimated depth map in future depth map coding experiments.

9 Acknowledgement

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10 References

[1] "Description of Exploration Experiments in 3D Video Coding" MPEG 2008/W10173, Busan, Korea, October 2008.

[2] Yo-Sung Ho, Eun-Kyung Lee, and Cheon Lee "Multiview Video Test Sequence and Camera Parameters", ISO/IEC JTC1/SC29/WG11, MPEG 2008/M15419, Archamps, France, April 2008.
[3] M. Tanimoto, T. Fujii, N. Fukushima, "1D Parallel Test Sequences for MPEG-FTV", ISO/IEC JTC1/SC29/WG11 MPEG2008/M15378, Archamps, France, April 2008.
[4] M. Tanimoto, T. Fujii, K. Suzuki, N. Fukushima, Y. Mori, "Reference Softwares for Depth Estimation and View Synthesis", ISO/IEC JTC1/SC29/WG11 MPEG 2008/M15377, Archamps, France, April 2008.
[5] Sang-Beom Lee, Yo-Sung Ho, "Enhancement of Temporal Consistency for Multi-view Depth Map Estimation", ISO/IEC JTC1/SC29/WG11 MPEG 2008/M15594, Hannover, Germany, July 2008.
[6] I. Feldmann, M. Mueller, F. Zilly, R. Tanger, K. Mueller, A. Smolic, P. Kauff, T. Wiegand, "HHI Test Material for 3D Video", ISO/IEC JTC1/SC29/WG11 MPEG 2008/M15413, Archamps, France, April 2008.
[7] K. Klimaszewski, K. Wegner, M. Domański "Distortions of synthesized views caused by compression of views and depth maps", 2009 3DTV-Conference: The True Vision Capture, Transmission and Display of 3D Video, Potsdam, Germany, 04-06 May 2009.
[8] K. Klimaszewski, K. Wegner, "Wpływ kompresji obrazów i map głębi na syntezę widoków w systemie wielowidokowym", Przegląd telekomunikacyjny 6/2009, p.380, June 2009 (in Polish)