Evaluation of 3D Data Service Based on Depth Image Based Rendering over T-DMB

Youngjin Oh[1], Kwanghee Jung[1], Joong Kyu Kim[1],Gwangsoon Lee[2],
Hyun Lee[2], Namho Hur[2], and Jinwoong Kim[2]

[1]School of Information and Communication Engineering, Sungkyunkwan University,
Suwon 440-746, Republic of Korea
[2]Electronics and Telecommunications Research Institute
161, Gajeong-dong, Yuseong-gu, Daejeon, 305-350, Republic of Korea
E-mail: [1]isotopic@skku.edu, jkkim@skku.edu

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Abstract: 3D data service over Terrestrial-Digital Multimedia Broadcasting (T-DMB) is very attractive because the single user environment of T-DMB is suitable to glassless 3D viewing. However, the bit budget for transmission of additional 3D data over T-DMB is very limited with 32Kbps through data service channel. To overcome this limited condition, Depth-Image-Based-Rendering (DIBR) can be applied, because corresponding depth sequence is only additionally needed to current T-DMB and this can be compressed effectively. Therefore, in this paper, we evaluate 3D data service based on DIBR over T-DMB. Evaluation mainly consists of two experiments. One is to evaluate the coding efficiency of depth sequences and the other is to measure the subjective quality and percived depth of auto-stereosopic image generated by DIBR with coded depth sequence. Therefore, we evaluate the possibility of transmitted depth image through data service channel that transmission rate is 32Kbps. Evaluation results show that DIBR can efficiently be utilized for 3D data service over T-DMB. However, it is also shown that the development of some techniques such as the depth preprocessing is required for the improvement of image quality.

1. Introduction

Three-dimensional television (3DTV) is regarded as the next logical development towards a more natural and life-like visual home entertainment experience. Proponents of 3D-TV have argued that it will bring the viewer a whole new experience, a fundamental change in the character of the image [1]. Especially, these expectations of 3DTV can be realized efficiently in T-DMB because the single user environment of T-DMB is suitable to glassless 3D viewing.

The latest developed T-DMB based 3D data service is the structure which transmits the left/right images to the terminal and synthesizes these two images. But there are some problems to supply the 3D data service over T-DMB. Transmitter should transmit the two (left/right) color images to construct an auto-stereoscopic image, which makes the system to be inefficient. And the limited capacity of transmission line is not proper to transmit two color images. To solve these problems, 'Advanced Three-Dimensional Television System Technologies' (ATTEST) project in Europe has selected DIBR.

DIBR is defined as the process of synthesizing "virtual" views of a real-world scene from still or moving images and associated depth information[2]. In general, a depth image contains depth information as just 8bit-gray level for each pixel. Therefore, by using DIBR, it is possible to transmit additional 3D data with higher coding efficiency than traditional methods. This advantage of DIBR shows that DIBR is very suitable for 3D service over T-DMB with the very limited data rate. However, this possibility of DIBR must be evaluated for various aspects because the depth sequence must be compressed under 32Kbps to be transmitted through data service channel of T-DMB.

Therefore, we evaluate 3D data service based on DIBR over T-DMB by considering three aspects of the coding efficiency, the auto-stereoscopic image quality and the perceived depth.

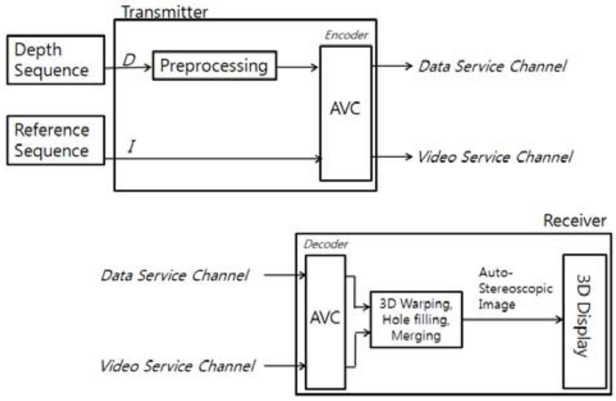
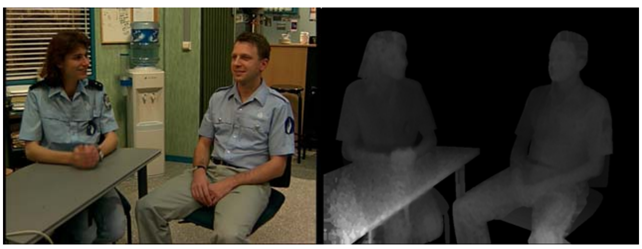


Figure 1. Block diagram of the DIBR technique.

This paper is organized as follows. In section 2, the coding efficiency of depth sequences over T-DMB is evaluated. In section 3, a subjective test for the perceived depth and quality of auto-stereoscopic image is conducted. Finally, a conclusion is made in section 4.

2. Coding efficiency

In this section, we measure the coding efficiency of three depth sequences over T-DMB. 3D data service over T-DMB can be served as two mode of stream mode and packet mode. Here, we assume the scenario that the associated depth information are first encoded and then transmitted through stream mode data path. Because stream mode must provide a constant data rate of 32Kbps, we check whether depth sequences have reasonable coding efficiency at lower bitrates than 32Kbps. For the experiment, version JM12.4 of the H.264/AVC reference software has been used[5]. The frame rate of each sequence is 15 frame per second and each frame size is 320x240 pixels.



(a) (b)

Figure 2. Reference image(a) and Depth image(b) of the 'interview' sequence.

(a) (b)

Figure 3. Reference image(a) and Depth image(b) of the 'orbi' sequence.

(a) (b)

Figure 4. Reference image(a) and Depth image(b) of the 'ballet' sequence.

Figure 2, figure 3 and figure 4 show examples of three test sequences. 'interview' sequence and 'orbi' sequence[2] are used by ATTEST(Advanced Three-Dimensional Television System Technologies), and 'ballet' sequence[6] is provided by Microsoft Research. We use the each sequence by downsampling with 320x240 size for T-DMB environment. Figure 5 shows rate-distortion curves for each sequence. All three curves show that H.264/AVC achieves reasonable PSNR values over about 35dB at 32Kbps. Especially, notice that H.264/AVC coding of the 'interview' depth sequence at 30.695Kbps leads to PSNR of 41.986dB, 'orbi' depth sequence at 19.848Kbps leads to PSNR of 38.14dB and 'ballet' depth image at 22.986Kbps leads to PSNR of 34.179dB. This result shows that the transmission of depth information over T-DMB could be possible to achieve the reasonable coding efficiency. However, it is somewhat rash to determine the possibility of 3D data service with just the analysis of the coding efficiency. Therefore, we conduct an additional test for the perceived depth and the quality of the auto-stereoscopic images made by interlacing virtual views which are synthesized by DIBR in section 3.

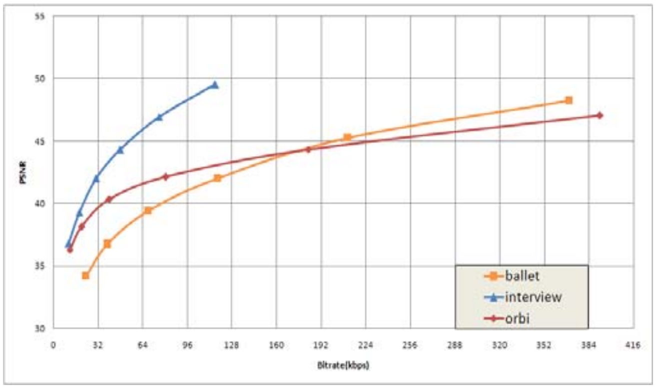


Figure 5. Coding result shown as rate-distortion curves over a range of bitrates

3. Perceived Depth and Image Quality

In this section, we assess the perceived depth and the quality of auto-stereoscopic images made by interlacing virtual views (left/right) which are synthesized by DIBR using transmitted reference and depth sequence. For the this test, 'interview' and 'ballet' sequence are selected. As a subjective assessment method, we adopt the standard ITU-R BT.500-10 recommendation, so-called DSCQS (Double-Stimulus continuous Quality-Scale)[3], which is the representative one of subjective tests with adequate assessment methods and perceptual factors [4].

In the DSCQS, observers access the overall image quality and the perceived depth in a pair of the reference sequence and the test sequence presented separately in time. The configuration of each test sequence is shown in table 1.

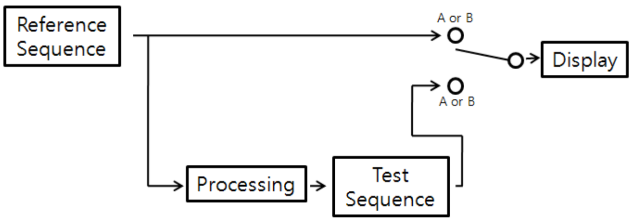
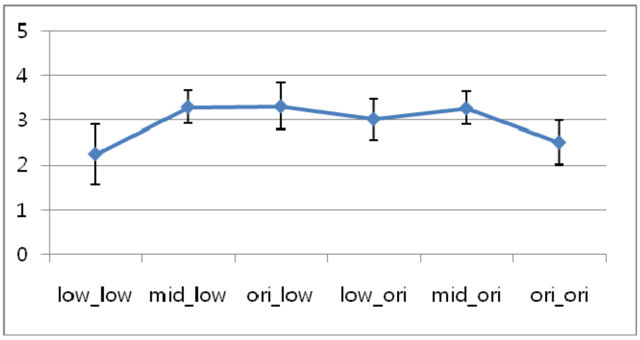


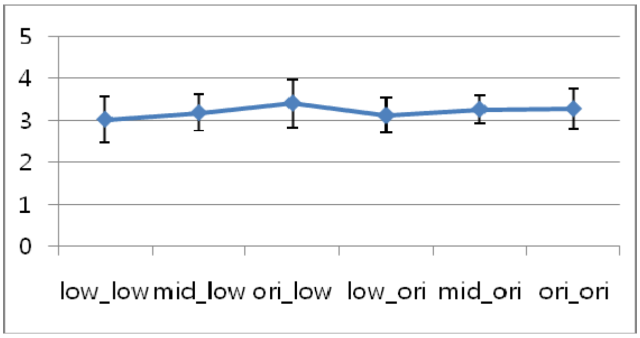
Figure 6. Test system of DSCQS

Reference image	Depth image	Test sequence
Non coded	Non coded	ori_ori (reference sequence)
Non coded	coded	ori_low
Coded around 140Kbps~330Kbps	Non coded	mid_ori
Coded around 140Kbps~330Kbps	coded	mid_low
Coded close 512Kbps	Non coded	low_ori
Coded close 512Kbps	coded	low_low

Table 1. 3D video sequence for subjective test.



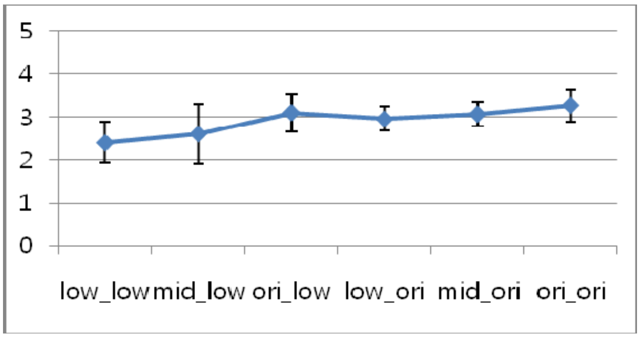
(a)



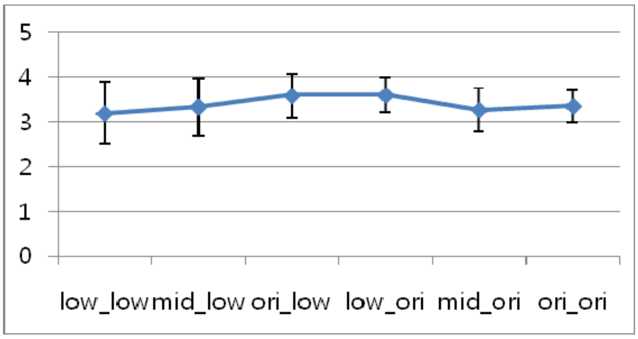
(b)

Figure 7. Result score and error bars for (a) quality and (b) perceived depth of the 'interview' sequence

As you can see in figure 7 (a), in case of 'interview' sequence, quality scores of 'ori_ori' are higher than them of 'low_low'. Quality scores of 'ori_ori' are 3.2 and quality scores of 'low_low' are 3.0. As fallow the result, the score difference is only 0.2. Moreover, relatively high scores are achieved when either depth sequence or reference sequence is coded. As you can see in figure 7 (b), scores of the perceived depth are almost same for all test sequence. Score of 'ori_ori' is 2.50 and score of 'low_low' is 2.23. This result shows that all test sequence have almost same perceived depth when the coded depth sequence has PSNR value over 30dB. So coding of depth sequence doesn't almost have influence for the perceived depth.



(a)



(b)

Figure 8. Result score and error bars for (a) quality and (b) perceived depth of the 'ballet' sequence

As you can see in figure 8, the results of 'ballet' sequence are similar to them of 'interview' sequence. In figure 8 (a), quality scores of 'ori_ori' are also higher than them of 'low_low'. Quality scores of 'ori_ori' are 3.26 and quality scores of 'low_low' are 2.4. Score difference is bigger than the 'interview' sequence. Especially, it is clear that using coded depth sequences(low_low, mid_low, ori_ori) makes lower quility of auto-stereoscopic images than using non-coded depth sequence(low_ori, mid_ori, ori_ori). Additionally, this result shows that coding of depth sequence has more influence on the quility of auto-steoscopic sequence than coding of reference sequence. As you can see in figure 8(b), scores of the perceived depth are almost same for all test sequences. Score of 'ori_ori' is 3.34 and score of 'low_low' is 3.18. This result shows that all test sequences have almost same perceived depth when the coded depth sequences have PSNR value over 30dB similarly 'interview' sequence. According to these results of the subjective test, when the coded depth sequence has PSNR value over 30dB, it dosen't almost have influence for the perceived depth. However, coded depth sequence has more influence on the quality of auto-stereoscopic sequence than perceived depth of auto-stereoscopic sequence. From this analysis, we can see that it's possible to provide efficient 3D service using DIBR over T-DMB if the quality of auto-sterescopic image is improved .

4. Conclusion

In this paper, we have evaluated 3D data service based on DIBR over T-DMB. Overall, two experiments were conducted. First, we evaluated the coding efficiency of depth sequences. A rate-distortion curve for each sequence shows that the depth sequence can be transmitted with the reasonable quality over 35dB at lower bitrates than 32Kbps. This result was supported by results of the following experiment. In the second experiment, the subjective test for the perceived depth and the image quality was conducted. Results showed that the compression of depth information had more effect on the image quality than the depth perception. These results propose the research strategic for improving 3D data service based on DIBR over T-DMB. For example, preprocessing of depth information such as adaptive smoothing could ellevate the image quality of coded depth sequence.

Acknowledgment

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