Joint Collaborative Team on 3D Video Coding Extension Development of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29/WG 11
1st Meeting: Stockholm, SE, 16–20 July 2012

Document: JCT2-A0060

Title:	**3D-CE3.a results on depth boundary filtering**
Status:	Input Document
Purpose:	Proposal

Author(s) or Contact(s):

Yunseok Song
Cheon Lee
Yo-Sung Ho

Tel: +82-62-715-2263
Email: ysong@gist.ac.kr
leecheon@gist.ac.kr
hoyo@gist.ac.kr

Source: Gwangju Institute of Science and Technology (GIST)

Abstract

The proposed filter aims to refine depth boundary regions to improve the quality of synthesized images. The filter is applied as post-processing of depth upsampling. Due to an unexpected memory error, 1920x1088 sequences were not tested. Synthesized gains of -2.32% and -2.59% BD-rate were achieved for deblocking (for depth) enabled/disabled. However huge decoder complexity was observed. The cross check report from Samsung indicates a match for SD sequences. In their report, when including HD sequences, synthesized gains were -3.18 and 3.53% BD-rate for deblocking enabled/disabled.

1 Introduction

This document includes a description the proposed depth boundary filtering method and its results. The filter is applied to upsampled depth data. Initially, boundary pixels are extracted and then filtered based on depth similarity, distance, and direction.

2 Depth boundary filtering

2.1 Boundary region estimation

The proposed filter targets near-boundary pixels. Boundary information is estimated by calculating gradient magnitude of each pixel. The gradient magnitude's standard deviation represents the amount of edge information. Thus, we use this as a threshold for selecting near-boundary pixels. In addition, a 3x3 mask is used to expand targets for filtering.

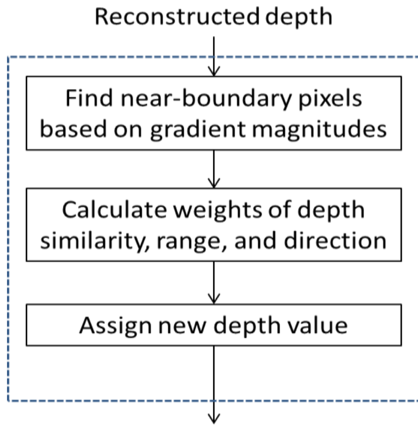


Fig. 1. Flowchart of the proposed filtering

2.2 *Weights of depth similarity, distance, and direction*

Filtering is based on three factors: depth similarity, distance, and direction. Fig.1. shows the weight position regarding the boundary pixel direction. Eq. (1) and Eq. (2) represent the weight formula for depth similarity and distance, respectively.

We assign more weights to pixels which possess depth values similar to the current pixel. In detail, we discard the pixels which are unlikely to be near the current pixel. Hence, we represent this similarity term as:

$$w\_sim_{p,q} = \exp\left(\frac{-\left|D_p - D_q\right|^2}{2\sigma^2}\right) \tag{1}$$

Unlike the range term of the bilateral filter, we apply more range weight to farther pixels. We assume that pixels farther from the boundary present less error.

$$w\_range_{p,q} = 1 - \exp\left(\frac{-\left((p_x - q_x)^2 + (p_y - q_y)^2\right)}{2\sigma^2}\right) \tag{2}$$

Regarding the direction weight, initially we define four directions: horizontal, vertical, diagonal upleft, and diagonal upright. Fig. 2 represents partitions between the defined directions. The direction weight is centered at the orthogonal direction of the boundary pixel direction. Fig. 3 shows that the direction weights in accordance to boundary directions are by strongly distributed near the orthogonal direction.

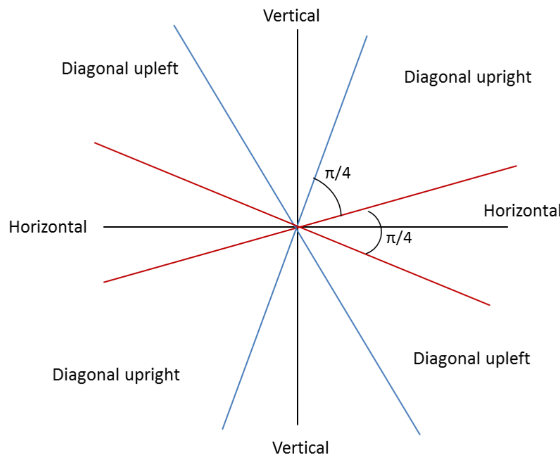
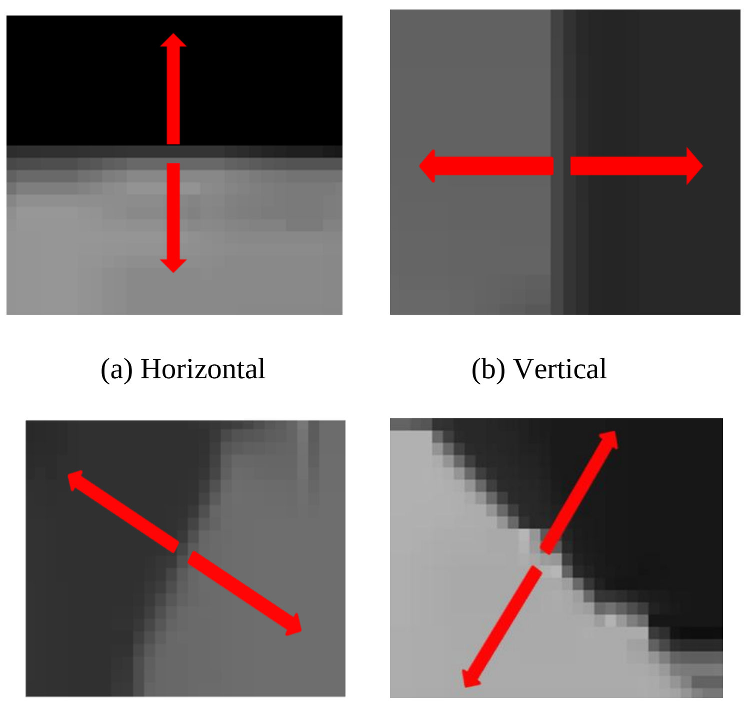


Fig. 2. Direction partitions



(a) Horizontal (b) Vertical

(c) Diagonal upright (d) Diagonal upleft

Fig. 3. Weights toward the orthogonal of boundary direction

We designed a function to assign the highest weight to the orthogonal direction. First we find the angle between the boundary direction and the orthogonal direction. Eq. (3) shows the formula. The range for angle $\theta_{p,q}$ is adjusted to keep the weight in between 0 and 1. Using Eq. (3) and a 9x9-sized window, we pre-calculate the weights as in Table 1. Weights are symmetric in respect to the boundary direction.

$$w\_direction = 1 - \cos(\theta_{p,q}), \quad 0 \le \theta_{p,q} \le \frac{\pi}{2} \tag{3}$$

Table 1. Weights for each direction

0.29	0.4	0.55	0.76	1	0.76	0.55	0.4	0.29
0.2	0.29	0.45	0.68	1	0.68	0.45	0.29	0.2
0.11	0.17	0.29	0.55	1	0.55	0.29	0.17	0.11
0.03	0.05	0.11	0.29	1	0.29	0.11	0.05	0.03
0	0	0	0	0	0	0	0	0
0.03	0.05	0.11	0.29	1	0.29	0.11	0.05	0.03
0.11	0.17	0.29	0.55	1	0.55	0.29	0.17	0.11
0.2	0.29	0.45	0.68	1	0.68	0.45	0.29	0.2
0.29	0.4	0.55	0.76	1	0.76	0.55	0.4	0.29

(a) Horizontal boundary (weight: vertical)

0.29	0.2	0.11	0.03	0	0.03	0.11	0.2	0.29
0.4	0.29	0.17	0.05	0	0.05	0.17	0.29	0.4
0.55	0.45	0.29	0.11	0	0.11	0.29	0.45	0.55
0.76	0.68	0.55	0.29	0	0.29	0.55	0.68	0.76
1	1	1	1	1	1	1	1	1
0.76	0.68	0.55	0.29	0	0.29	0.55	0.68	0.76
0.55	0.45	0.29	0.11	0	0.11	0.29	0.45	0.55
0.4	0.29	0.17	0.05	0	0.05	0.17	0.29	0.4
0.29	0.2	0.11	0.03	0	0.03	0.11	0.2	0.29

(b) Vertical boundary (weight: horizontal)

0	0.01	0.05	0.14	0.29	0.49	0.68	0.86	1
0.01	0	0.02	0.11	0.29	0.55	0.8	1	0.86
0.05	0.02	0	0.05	0.29	0.68	1	0.8	0.68
0.14	0.11	0.05	0	0.29	1	0.68	0.55	0.49
0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
0.49	0.55	0.68	1	0.29	0	0.05	0.11	0.14
0.68	0.8	1	0.68	0.29	0.05	0	0.02	0.05
0.86	1	0.8	0.55	0.29	0.11	0.02	0	0.01
1	0.86	0.68	0.49	0.29	0.14	0.05	0.01	0

(c) Diagonal Upleft boundary (weight: diagonal upright)

1	0.86	0.68	0.49	0.29	0.14	0.05	0.01	0
0.86	1	0.8	0.55	0.29	0.11	0.02	0	0.01
0.68	0.8	1	0.68	0.29	0.05	0	0.02	0.05
0.49	0.55	0.68	1	0.29	0	0.05	0.11	0.14
0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
0.14	0.11	0.05	0	0.29	1	0.68	0.55	0.49
0.05	0.02	0	0.05	0.29	0.68	1	0.8	0.68
0.01	0	0.02	0.11	0.29	0.55	0.8	1	0.86
0	0.01	0.05	0.14	0.29	0.49	0.68	0.86	1

(d) Diagonal Upright boundary (weight: diagonal upleft)

3 Simulation Results

The proposed method is implemented on 3DV-ATM (v0.4) under the common test conditions [1]. Due to an unexpected memory error, 1920x1088 sequences were not tested. Synthesized gains of -2.32% and -2.59% dBR were achieved for deblocking (for depth) enabled/disabled. About 260% decoder complexity was observed.

Table 2. Synthesis results

Sequence	Deblocking off		Deblocking on	
	BR (%)	PSNR (dB)	BR (%)	PSNR (dB)
S05	-2.01	0.09	-1.68	0.07
S06	-1.88	0.09	-1.65	0.08
S08	-3.88	0.15	-3.62	0.14
Average	-2.59	0.11	-2.32	0.10

Table 3. Complexity comparison

Sequence	Deblocking off		Deblocking on	
	Encoder time (%)	Decoder time (%)	Encoder time (%)	Decoder time (%)
S05	100.5	279.5	100.5	245.7
S06	100.5	255.3	100.4	238.3
S08	100.9	282.1	100.9	255.0
Average	100.6	272.3	100.6	246.3

4 Summary

Gains were achieved in synthesized images. However, huge decoder complexity remains as a burden. Further study would be needed.

5 Acknowledgment

This research was supported a grant "Establishing the Foundation of International Standardization for Mobile Devices and Multimedia Convergence Technology" from Improvement of Standards Technology Program funded by Korean Agency for Technology and Standards, Ministry of Knowledge Economy of Korea.

References

[1] ISO/IEC JTC1/SC29/WG11, "Common test conditions for 3DV experimentation", ISO/IEC JTC1/SC29/WG11 N12745, May 2012, Geneva, Switzerland.