Session H : Content and Media

H1 The Implementation of smart home system based on 3G and ZigBee Topology
LIU DAN, Gwang Jun Kim, Dae Hyon Kim, Chang Soo Jang (Chonnam National Univ. Yeosu)
Jin Gwang Koh(Sunchon National Univ.), Hang Kon Kim(Catholic Univ.)

H2 Post Processing of Watershed Transform Segmentation for Extraction of Border Object
Faliu Yi, In Kyu Moon (Chosun Univ.)

H3 Edge Refinment of Upsampled Depth Image Using Joint Bilateral Filtering
Do Young Kim, Sung Yeol Kim, Yo Sung Ho (GIST)

H4 Object Segmentation Based on Automatic Rectangle Estimation for GrabCut
Kang Han Oh, In Seop Na, Soo Hyung Kim, A Ran Oh (Chonnam National Univ.)

H5 Jigsaw Puzzle Solving by Feature Matching
Jeong Hwan Kim, Guee Sang Lee (Chonnam National Univ.)

H6 Smart Media Advertising in Korea: Current Situation, User Acceptability and Outlook
Sung Ho Park, Joon Seub Cha (Honam Univ.)

H7 Prediction Method by Protein Secondary Structure using Cluster Merging
Lu Zhao, Ngyuen-Quang Phuoc, Sung Ryul Kim (Konkuk Univ.)

H8 Implementation of Scanning Parallel DWT for High Speed Compression in JPEG 2000
Jong Bin Park, Yalin Wu, Ki Sun Jeong, Dong Sun Park (Chonbuk National Univ.)
Sook Yoon(Mokpo National Univ.)

H9 Visual Touch Input Device for Operating the Remote Monitor
Myung Hwan Tark, Yeon Seok Lee, Young Hoon Joo (Kunsan National Univ.)

H10 A Robust Matching Algorithm of 3D Images Obtained by White-light Scanning Interferometry
Ki Mun So, Il Kwon Moon, In Ho Ra, Young Hoon Joo (Kunsan National Univ.)

H11 Multi-copter Plane for DTV Field Strength Measurement(#1656)
Hyung Do Park, Dae Jin Kim (Chonnam National Univ.)

H12 Design of Micropayment Model Based on NFC and LBS to Reinvigorate Traditional Markets
Byung Rae Cha(GIST), Dae Kyu Kim(Ajantech Ltd.), Hyung Jong Kim (Honam Univ.),
Young Il Kim (Honam Univ.)

H13 Sharing and Use of Scientific Data on a National Basis
Sang Hwan Lee, Tae Jung Kim, Sang Ho Lee, Hyung Seon Park, Sun Tae Kim,
Kyong Seok Park, Jin Seop Shin (KISTI)

H14 Real-Time Face Detection to Measure Phone-to-Face Distance on Smart Phone
Jae Won Lee, Sung Hoon Hong (Chonnam National Univ.)

H15 Color Improvement of Retinex Image Using Maximum Color Difference Signal Table
Jae Won Lee, Sung Hoon Hong (Chonnam National Univ.)

H16 Development of Automotive Media Streaming Device with MOST Network System
Sang Yub Lee, Hyo Sub Choi, Chul Dong Lee (KETI), Byung Chul Kim (MDS technology)

H17 Wireless Connectivity of Automotive Media Service based on MOST Network System
Sang Yub Lee, Sang Hyun Park, Soo Young Min (KETI)

H18 A smart system design for preventing broadcast contents copy
Byoung Dai Mun(Dongha-Tech), Se Ill Choi, Joon Seub Cha (Honam Univ.)

H19 SmartWork as viewed through cultural lense : An empirical investigation of Korean company
Kyung Jin Cha (KeiMyung Univ.), Joon Seub Cha (Honam Univ.), Hee Jin Lee (Yonsei Univ.)

H20 Teaching Chinese College Students Business English in Korea: a Multimedia-aided Syllabus Design
Wan Qing Cheng, Seog Ju Chang (Honam Univ.)

Edge Refinement of Up-sampled Depth Images Using Joint Bilateral Filtering

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***Abstract*—In this paper, we propose a new method to refine edge information of the up-sampled depth image. After a low-resolution depth image is enhanced by its corresponding color image using joint bilateral filtering, the edge extracted from the depth image is interpolated. Then, the bi-linearly interpolated depth image is refined using the edge map. Experiments show that the proposed method outperforms the M-3DVC method in terms of the quality of the depth data and synthesized virtual view.**

***Index Terms*— depth map, edge refinement, morphological operation, view synthesis, edge up-sampling**

I. INTRODUCTION

Recently, the ISO/IEC JTC1/SC29/WG11 Moving Picture Experts Group has started a new standardization of three-dimensional video coding (3DVC) [1]. The input data for 3DVC are 2-view or 3-view video-plus-depth images [2].

At the encoder of 3DVC, the depth image is down-sampled to a low resolution and coded to utilize a transmission bandwidth efficiently. At the decoder, the transmitted depth image is up-sampled to the original resolution and used to synthesize virtual views. Thus, the quality of the decoded depth image is degraded by resolution loss and coding errors during depth data compression.

In particular, edge information of the decoded depth image becomes weak and unmatched with that of its corresponding color image. Consequently, inaccurate depth edge data decrease the quality of synthesized virtual views. In this paper, we propose a new method to restore edge information in the up-sampled depth image using joint bilateral filtering (JBF) [3].

II. JOINT BILATERAL FILTERING

For edge matching between a depth image and its color image, we employ the concept of JBF [4]. Formally, a depth value $D(x,y)$ at the position (x, y) is computed by JBF as follows:

$$D(x,y) = \arg\min_{d \in \vec{d}_p} \frac{\sum_u \sum_v W(u,v) \cdot C(u,v)}{\sum_u \sum_v W(u,v)} \quad (1)$$

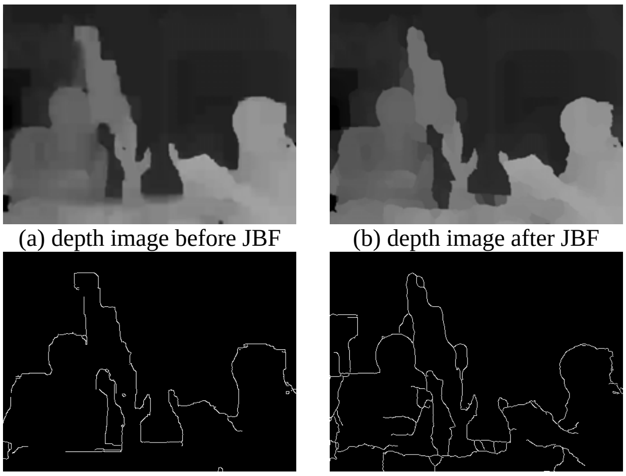
where $W(u,v)$ is the kernel weighting function, and $C(u,v)$ is the cost function. $W(u,v)$ and $C(u,v)$ are represented by

$$W(u,v) = \exp\left(-\frac{\left\|I(x,y), I(u,v)\right\|^2}{2\sigma_R^2}\right) \cdot \exp\left(-\frac{(x-u)^2 + (y-v)^2}{2r^2}\right) \quad (2)$$

$$C(u,v,d) = \min(\lambda, |D(u,v) - d|) \quad (3)$$

$W(u,v)$ is composed of intensity and spatial weighting functions; these weighting functions are usually modeled by the Gaussian function. σ_R and r are smoothing parameters of intensity and spatial weighting functions, respectively. Eq. (3) is a truncated linear model to allow for depth discontinuities and λ is a constant to reject outliers [3].

The center pixel is substituted by one of $\vec{d}_p = \{D(x\text{-}1,y), D(x,y\text{-}1), D(x, y), D(x+1,y), D(x,y+1)\}$ by Eq. (1) among its neighboring pixels. As shown in Fig. 1, we can enhance the depth image and obtain a refined edge map by applying JBF to the decoded depth image.



(a) depth image before JBF (b) depth image after JBF
(c) depth edges before JBF (d) depth edges after JBF
Fig. 1: Depth images/edges before and after applying JBF

III. PROPOSED EDGE REFINMENT

After acquiring a refined depth edge map E_L in Fig. 1(d), we convert E_L to a high-resolution edge map E_H using a 3D warping operation. Fig. 2(a) shows the warped edge map E_H. To create a one-pixel-width edge contour map E_C from E_H, we carry out dilation and erosion operations in the row, as shown in Fig. 2(b) and Fig. 2(c).

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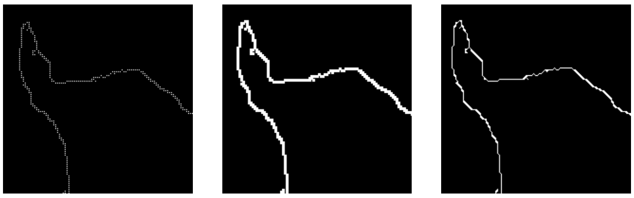


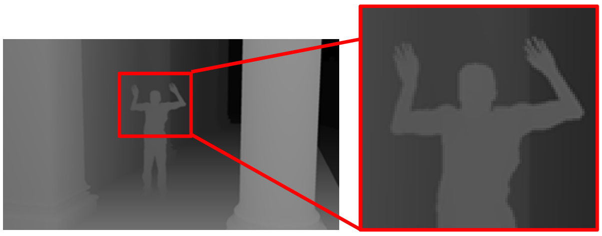
(a) warped edge (b) edge dilation (c) edge erosion

Fig. 2: Process to generate the edge contour map.

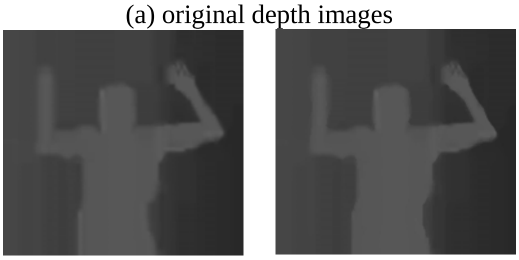
Then, the low-resolution depth image is up-sampled by bilinear interpolation. Note that bilinear interpolation usually makes depth data near edges become continuous. In order to restore depth edges, the proposed method refers to the high-resolution edge contour map E_C during depth up-sampling. Fig. 3 shows depth data discretization based on E_C.

Fig. 3: Depth data discretization

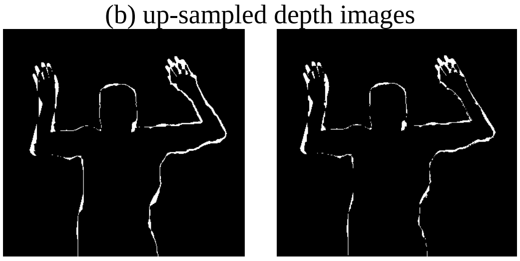
IV. EXPERIMENTAL RESULTS



(a) original depth images



(b) up-sampled depth images



(c) difference images

Fig. 4: Comparison of depth images

To evaluate the performance of the proposed method, we have tested with the *Undo-Dancer* test sequence in the 3DVC condition. Then, the proposed method is compared to the MPEG 3DVC depth up-sampling method (M-3DVC). For an objective assessment, PSNR measurement based on the ground-truth depth data was used.

Fig. 4 shows the ground-truth depth image (Fig. 4(a)) and results of the comparative methods. The left image in Fig. 4(b) is the result by M-3DVC and the right one is generated by the proposed method. As shown in Fig. 4(c), our method reduces resolution loss and coding errors more effectively than M-3DVC by refining depth edges.

Table I shows the BD-PSNR of the proposed method and the M-3DVC method. The average PSNR of the proposed method is higher than M-3DVC by 0.25 dB.

Table I: PSNR Gain

Sequence	Proposed(dB)	M-3DVC(dB)
Undo_Dancer	37.47	37.22

In order to assess improvement of the quality of virtual views, we generated virtual views using the depth images up-sampled by the proposed method and M-3DVC. As shown in Table II, the bit rate of the proposed method is reduced by 7.39 %, while increasing the PSNR gain by 0.22 dB relative to M-3DVC.

Table II: Virtual View Synthesis

Sequence	BD-Rate(%)	BD-PSNR(dB)
Undo_Dancer	-7.39	0.22

V. CONCLUSIONS

In this paper, we proposed an edge refinement method to improve the quality of up-sampled depth images. Based on a video-plus-depth provided by the MPEG 3DV, the average PSNR gain of the proposed method was higher than the MPEG 3DVC method by 0.22 dB. Furthermore, in terms of the image quality of virtual view synthesis, experimental results indicate that our method is more efficient than the MPEG 3DVC method.

ACKNOWLEDGEMENT

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