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Title: Implementation of Boundary Noise Removal for View Synthesis
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1. Introduction

This document reports the results of synthesized image using boundary noise removal on 'VSRS (View Synthesis Reference Software)'. In the last Busan meeting, we volunteered to implement the boundary noise removal algorithm on view synthesis software of Nagoya University [1][2]. We changed the name of algorithm from 'boundary noise processing' to 'boundary noise removal' because the changed name is more representative of the algorithm [3]. We look through the implemented algorithm in the next chapter; then, the result and analysis are represented.

2. Boundary Noise Removal Method

As already described in our last proposal, we have developed the algorithm in order to remove boundary noise caused by estimation error around depth discontinuity [3]. Figure 1 shows an example of boundary noise. If the synthesized intermediate image contains boundary noise, a user may feel discomfort from it. If the depth estimation is perfect, we don't need this algorithm, but due to the disocclusion problem, we need this tool.

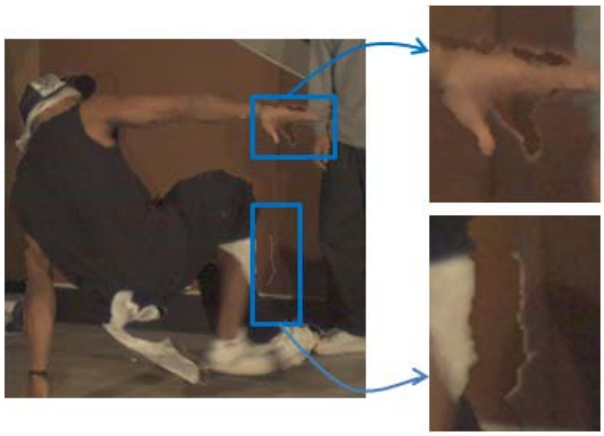


Fig. 1. Example of Boundary Noise

We focused on the fact that the boundary noise is located near to the boundary of objects. Hence, we detect the newly exposed region, and determine a boundary contour neighboring to background. After that, as we illustrated in Fig. 2, we determine a target area supposed to include the boundary noise. It is painted with gray color in the figure.

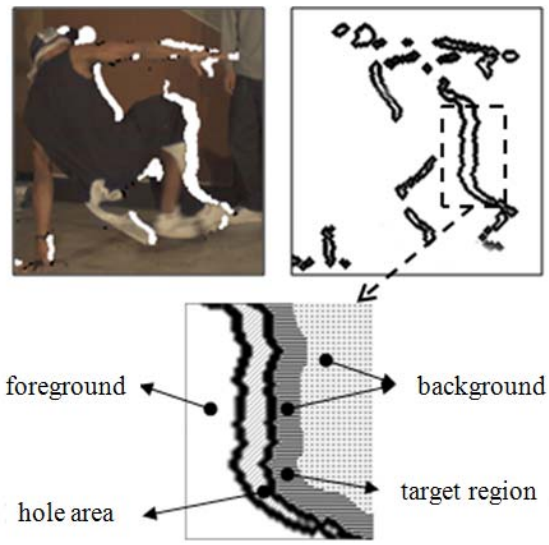


Fig. 2. Background Boundary Contour and target Region

The target region is adjacent region of background. In the next step, we find the corresponding information of the target region at the other reference image. Since we are using multi-view video, the alternative texture information exists in the other reference view. We can find the corresponding texture data along the background contour as alternative information. By guiding the background contour, we copy the alternative information from the other synthesized images. Replacing the data of the target region with the alternative data gives us a final synthesized image as shown in Fig. 3.

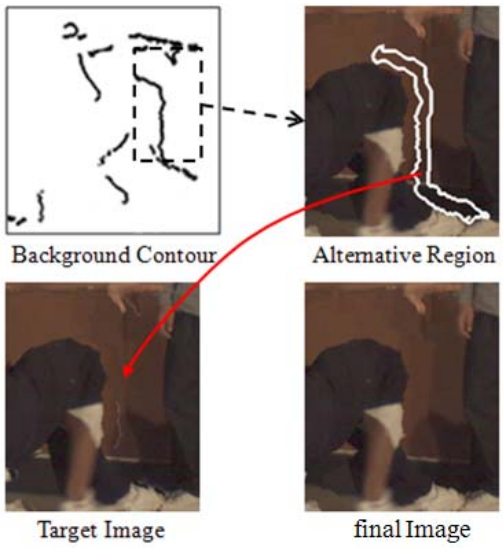


Fig. 3. Boundary Filtering

3. Experimental Results

3.1. Obtaining Depth Map using 'DERS'

After implementing the algorithm onto 'VSRS' provided by Nagoya University, we have tested all 3DV sequences using the updated software. The configuration file for each sequence is based on the files which are distributed on November 12, 2009 on the SVN server. The version of depth estimation software is 'DERS' distributed on January 19, 2009. Since the 'sub-pel precision' algorithm performs better than 'full-pel precision', we used 'sub-pel' for all sequences.

3.2. Result of Synthesized Images

We used the subjective quality evaluation method for the proposed method. The main part of the algorithm is detecting background region and replacing them with alternative texture data from the other view. It means that the objective measure such as PSNR is hard to use for the proposed algorithm. Practically, when we calculate the PSNR values for all synthesized image with original image, the delta PSNR between the previous and the proposed is close to zero as presented in Table 1.

Table 1. Comparison of average PSNR values on synthesized images

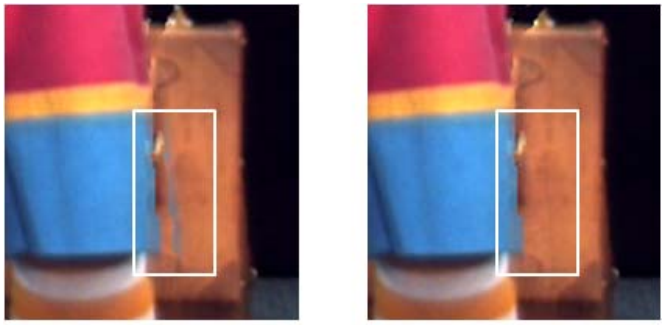
	Previous		Proposed		delta PSNR	
	Left	Right	Left	Right	Left	Right
Book_arrival	34.399	35.569	34.336	35.498	0.063	0.071
Door_Flowers	36.128	36.265	36.074	36.190	0.054	0.075
Leaving_laptop	36.040	36.176	35.967	36.066	0.073	0.110
Alt_Moabit	35.135	35.402	35.148	35.402	-0.013	0.000
Dog	31.127	28.144	31.127	28.136	0.000	0.008
Pantomime	35.786	32.963	35.793	32.979	-0.007	-0.017
Champagne_tower	28.766	23.386	29.172	23.563	-0.406	-0.176
Lovebird1	31.159	29.763	31.193	29.763	-0.034	0.000
Lovebird2	34.467	29.949	34.248	29.716	0.219	0.232
Newspaper	28.044	30.099	28.061	30.055	-0.017	0.045

As we mentioned above, we focused on the subjective quality measurement. Figure 4 is one example of noise removed image 'Lovebird1' sequence has wide disparity range because actors come close to the camera. It means that the boundary noise noticeably occurs as the actors come. You can easily see the boundary noise around his shoulder. However, by using the proposed algorithm, we could remove the noise from the background.

Original 'VSRS' Updated 'VSRS'

Fig. 4. Results of 'Lovebird1'

Another example on 'Pantomime' sequence is shown in Fig. 5. Fractions of trousers are located on the bag in the left image. On the other hand, there is no noise on the bag in the right image which is processed image.



Original 'VSRS' Updated 'VSRS'

Fig. 5. Results of 'Pantomime'

The considered problem on view synthesis is caused by depth estimation error around depth discontinuity. In other words, if the depth estimation performs well on that region, boundary noise would not occur. Therefore, the proposed algorithm is worthy when the depth range is wide and a scene has many objects. Practically, it is hard to see the effectiveness on HHI sequences because the moving objects are located at the backside of the scene. It is that there is small depth difference on the moving objects between views.

Since 3DV considers various scene conditions, we need to consider the boundary noise that would occur in many cases in order to prevent generating annoying artifacts on the synthesized images. As a conclusion, we propose this algorithm should included on the view synthesis reference software.

4. Conclusion

We have explained the results of view synthesis using the implemented algorithm on the 'VSRS'. The tested depth map is based on the results of EE provided by MPEG SVN server. The implemented algorithm is boundary noise removal which reduces boundary noise caused by depth estimation error on the depth discontinuity region. As a result, we confirmed that the boundary noise have been removed from the synthesized image. Since the implemented algorithm is proposed in order to prevent annoying artifacts on the

synthesized image for various 3DV conditions, we cannot see the effectiveness of it when the input sequence has small depth range. To make general tool of view synthesis, we propose that the boundary noise removal algorithm should be included in the view synthesis reference software.

5. Acknowledgements

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6. References

[1] ISO/IEC JTC1/SC29/WG11 “View Synthesis Tools for 3D Video,” M15851, October 2008.

[2] ISO/IEC JTC1/SC29/WG11 “Boundary Filtering on Synthesized Images for 3D Video,” m15597, July 2008.

[3] ISO/IEC JTC1/SC29/WG11 “Description of Exploration Experiments in 3D Video Coding,” N9991, July 2008