Low Bandwidth Hybrid Color Compensation for Multiview View Synthesis

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Abstract— **Multiview video applications are getting emerging in the recent years by its 3D and free-view-point perception functionalities. To support smooth viewpoint switching, virtual view synthesis is required. However, the color information between each view is different due to the difference between multiview cameras. Further, the complexity and the corresponding bandwidth grow up dramatically with number of views. In order to make the real-time multiview application practical, a low bandwidth hybrid color compensation scheme is proposed in this paper. By the proposed motion propagation scheme reduces the frame-level processing times from each frame to once every six GOP. Finally, the proposed adaptive average assignment and the regularized access pattern reduce the bandwidth requirement at one frame by 45.4% with only 0.05dB quality drop.**

I. INTRODUCTION

Recently, multiview video has drawn public attention, providing viewers a complete 3D perception by its multiple-viewpoint feature. [1][2] In order to support smooth and continuous viewpoint switching, virtual view synthesis is required since it is impossible to capture video sequences from all viewpoints with infinite real cameras. In order to make the real-time multiview and 3D applications practical, MPEG-FTV group is working on virtual view synthesis since 2007. The view synthesis reference software (VSRS) is released by the MPEG-FTV group as the reference software and the research platform. [3] In virtual view synthesis field, there are design challenges are mainly from the occlusion parts in the virtual view frame. In a multiview sequence, the occlusion area can be filled by reference frames from viewpoints neighboring the target virtual viewpoint. However, since frames in different views are captured by different cameras at different locations, color/illumination information also changes between different views. Nevertheless, previously works on the color compensation are mainly targeted on the multiview video compression and cannot be adapt in view synthesis directly. In our previous work in [5], the inter-view color/illumination issue is solved by the inter-view color correspondence estimation and mirror-like material optimization. However, the additional inter-view calibration required in [5] caused another design challenge on the bandwidth consumption. Then, the linear regression needed in the inter-view color correspondence estimation also causes iterative frame-level access. In the real-time applications, these complexity results huge bandwidth consumption and thus limit's the processing ability. In order to make the real-time multi view applications practical, a low bandwidth color compensation scheme is proposed in this paper. By the proposed hybrid motion propagation scheme, the required processing time on a multiview sequence can be down to once every six GOP while the direct implementation needs performing at each frame. Then, the proposed adaptive average assignment and the regularized access pattern reduce the bandwidth requirement at each frame by 45.4% with only 0.05dB quality drop.

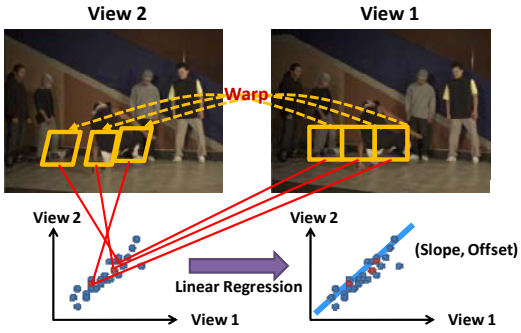

Figure 1. Proposed color compensation flow.

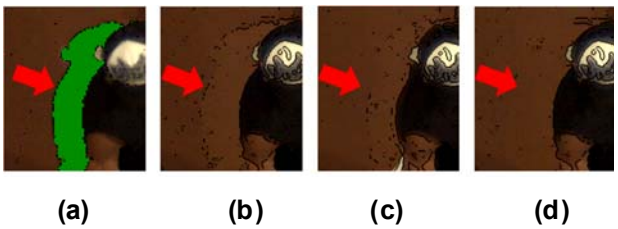

Figure 2. Color mismatch is reduced by the proposed color compensation. (a) Virtual view with un-filled occlusion, (b) occlusion filled by [4], and (c) VSRS, (d) occlusion filled with proposed color compensation. The dark lines are the edge filter result to highlight the color mismatch boundary.

The remaining of this paper is organized as follows: First, issues and previous works on color compensation are briefly reviewed in Sec. II. Second, the proposed low bandwidth schemes are introduced in Sec. III. Then, Sec. IV shows the simulation result. Finally, Sec. V concludes this paper.

II. PREKNOWDGE OF COLOR COMPENSATION

In this paper, the color compensation algorithm under analysis is mainly based on the previous works in [5]. Figure 1 shows the concept of the proposed algorithm. Since there exist color difference between each view in a multiview sequence, the virtual view cannot be blended from neighboring reference views smoothly without any calibration. In the proposed color compensation, changes of color/illumination are assumed to be linear. Then, the color correspondence between two views is estimated by first warping one view to the other. While warping, the location relationship and also the color relationship of each pixel between these two views can be found. Then, the color relationships of each pixel are taken as the data pairs in the linear regression process. The slope and offset outputted from linear regression can be used to decide the color weighting of these two reference views when the target virtual view is located between them.

Based on this flow, the color mismatch issue is solved. Figure 2 shows the subjective quality comparison between different view synthesis algorithms including the proposed algorithm. In Fig. 6, only view synthesis with proposed color compensation contains no color/illumination mismatch boundaries.

The proposed algorithm in the previous work successfully reduces the color mismatch in the multiview video. However, the computational cost and the corresponding hardware requirements, especially the bandwidth, are too large. Also, the redundant access from pixel-based warping causes irregular access and increases the bandwidth consumption.

III. Proposed Low Bandwidth Color Compensation Flow

A. Motion Propagation

In the color compensation algorithm under analysis, we found that the slope and offset between views may need not to be updated every frames. It is because that color mismatch in a multiview video is caused by different light field or different CCD configuration. Since the CCDs of each camera are fixed, only the scene-change event leads to different linear regression result. Thus, update is only required when the scene-change is happened. This largely reduces the required computation. However, in order to provide better visual quality, another mirror-like material detection is proposed in the previous work. In order to find the mirror-like materials, the color compensation should still perform every frame.

Based on the above analysis, the motion propagation scheme is proposed. Since the only reason of performing color compensation every frame is the location update requirement of the mirror-like materials, motion vector used in MVC is used here to reconstruct the location relationship between frames. That is, blocks pointed by motion vectors from the detected mirror-like materials are also seen as mirror-like materials. Under this concept, the location of mirror-like materials can be propagated frame-by-frame. However, because of the error propagation issue, update period under the motion propagation may not as long as the scene-change period and needs to periodically update.

B. Access Pattern Optimization

The proposed motion propagation works well in the general cases. However, while considering the worst case design, the required update period may be too short to maintain the performance of computation reduction. Therefore, the steady block-level bandwidth optimization is also required. In this paper, two access pattern optimization schemes in block-level are proposed. First, while looking into the color compensation scheduling, more than one pass is needed in the linear regression part. The main reason of this multi-iteration characteristic is from the average calculation. In the linear regression, the average of all data pairs is used to calculate the variance. Thus, all the data should be scanned once to find the average before the linear regression. The second optimization scheme is the regularized access pattern. Since the square access pattern is the most often used when store the frame data, the bandwidth waste can be reduced if the required access pattern is also square. In order to regularize the access pattern, the average depth of the block is used in warping instead of individual depth of each pixel. Therefore, every pixel inside the same block has the same disparity vector and the corresponding access pattern after warping can be maintained square.

TABLE I. Bandwidth And PSNR Comparison in Motion Propagation

Algorithm	PSNR (dB)
Hybrid color compen-sation	32.79 dB
+ motion propagation	32.80 dB

TABLE II. Bandwidth And PSNR Comparison in Access Pattern Optimization

Algorithm	Bandwidth Consumption	PSNR (dB)
Hybrid color compen-sation	4.4186 × (Frame Size)	32.79 dB
+ adaptive avg.	2.4186 × (Frame Size)	32.79 dB
+ regularized access	2.4102 × (Frame Size)	32.74 dB
No color compensation	N/A	32.53 dB

IV. Simulation Result

In this paper, two multiview sequences, “ballet” and “breakdancers” published by Microsoft, are taken as test sequences. Table I shows the performance of the proposed motion propagation scheme. In this paper, the GOP size is chosen as 4 and the update period is set as once every six GOPs. That is, once every 24 frames. As assuming before, there is no quality drop in this case since there is no scene-change in these two sequences.

Table II shows the bandwidth and PSNR comparison in the proposed access pattern optimization. While the adaptive average is used, the bandwidth consumption is reduced by 45.3% with nearly no quality drop. After the regularized access pattern is adopted, the bandwidth consumption can be further reduced with 0.05 dB PSNR drop. Comparing with cases without color compensation, the proposed low bandwidth method still maintains 0.21 dB PSNR gain.

V. Conclusion

In this paper, a low bandwidth color compensation scheme is proposed. By the proposed hybrid motion propagation scheme, the required processing time on a multiview sequence can be down to once every six GOP while the direct implementation needs performing at each frame. Then, the proposed adaptive average assignment and the regularized access pattern reduce the bandwidth requirement at each frame by 45.4% with only 0.05dB quality drop.

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