Source	**Poznań University of Technology (PUT), Poznań, Poland**
Status	**Input**
Title	**[MPEG-I Visual] Color refinement method for Immersive Video**
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1   Introduction

This document presents a technical description of the proposed color refinement method for immersive video purposes. The proposed method allows to significantly improve temporal and inter-view consistency of color characteristics of input views.

The method was used to refine the IntelFrog sequence [M51561].

2   Overview of the proposed method

The proposed color refinement method consists of two techniques. In the first one, all views are processed independently in order to equalize their color characteristics over time. Then, color characteristics of all views are unified.

2.1   Temporal consistency improvement

The temporal consistency improvement technique can be divided into three main steps.

In the first step, the background (with highly reduced resolution) for the input view is calculated. At first, the input view is decimated 16 times in both directions (without any filtering, simply by removing another 15 samples). For each pixel of reduced input view the vector containing color values from all frames is created. Then, for each pixel the median value is calculated (separately for each color component). Despite containing also some parts of the foreground objects, the resulting image is called "background" in order to keep the simplicity of the description.

Next two steps are performed independently for all frames of the sequence.

In the second step, a global color difference between background and frame i is calculated. The global color difference is calculated as an average difference for each color component between background and frame i. Each pixel of ith frame of reduced input view is compared to colocated pixel of the background. If the difference is smaller than the fixed threshold (10% of color range for Y, 5% for both chromas) for all 3 color components, it is assumed, that both pixels represent the same object and the difference is caused by temporally changing color characteristics. In this case, analyzed pixel is taken into account when calculating global color difference. Otherwise, it is omitted.

In the third step, the previously calculated global color difference is subtracted from the color component values for all pixels of ith frame of a full resolution input view.

2.2 *Inter-view consistency improvement*

The second technique used in the proposed color refinement method is an extension of PUT/ETRI CE-5 proposal [M48092]. The inter-view consistency improvement is performed on temporally improved views.

The global color difference between points projected from two real views is calculated as the average difference (averaged for the entire image) between color component projected from one view and color component projected from the second one. The algorithm is performed separately for Y, C_b and C_r color components. In order to equalize colors of points projected from any real view i, the global color difference between view i and reference view (the view acquired by closest real camera to the virtual one) is subtracted from color component values projected from view i.

At first, the reference view is chosen. In our proposal, the most central view is chosen as a reference one. Then, each real view is projected to the position of the reference view. All real views are processed separately.

In the second step, YC_bC_r values of every pixel of the reference view are compared to YC_bC_r values of collocated pixel reprojected from the real view. Each color component is processed in the same way, so below we described processing for one component (e.g. Y).

The differences are aggregated separately for 3 equal ranges of Y intensity: [0, 341), [341, 683) and [683, 1023]. Then, the summarized difference for each range is divided by number of pixels with Y value in that range. At the end of this step, we obtain 3 global color differences for each color component.

In the next step, all pixels in the real, non-reference views are modified by subtracting proper global color difference. In order to avoid color artifacts for pixels with color value close to range boundaries, range overlapping for mean ratios adding was applied: all Y values within an overlap are modified using a weighted average of two global color differences.

In order to reduce the possibility of flickering when common area of the scene visible in reference and corrected view, the global color differences are filtered using simple IIR filter. Each global color difference for frame i is modified using:

$$GCD'_{c,r}(i) = GCD_{c,r}(i-1) \cdot w_{prev} + GCD'_{c,r}(i) \cdot \left(1 - w_{prev}\right),$$

where $GCD'_{c,r}(i)$ is the global color difference (for frame i, color component c and intensity range r) after filtering and w_{prev} is the weight for $GCD'_{c,r}$ of the previous frame. Weight w_{prev} was set to 0.5.

3   Results

The proposed color refinement method was tested on two natural multiview test sequences: SE (IntelFrog) and SL (PoznanFencing) [W18789]. Input textures for SL were the ones in CTC, thus already color-corrected using [M47170].

In order to present inter-view consistency, refined views were used as input for TMIV3.0. A comparison with the A17 anchor is presented in Fig. 1.

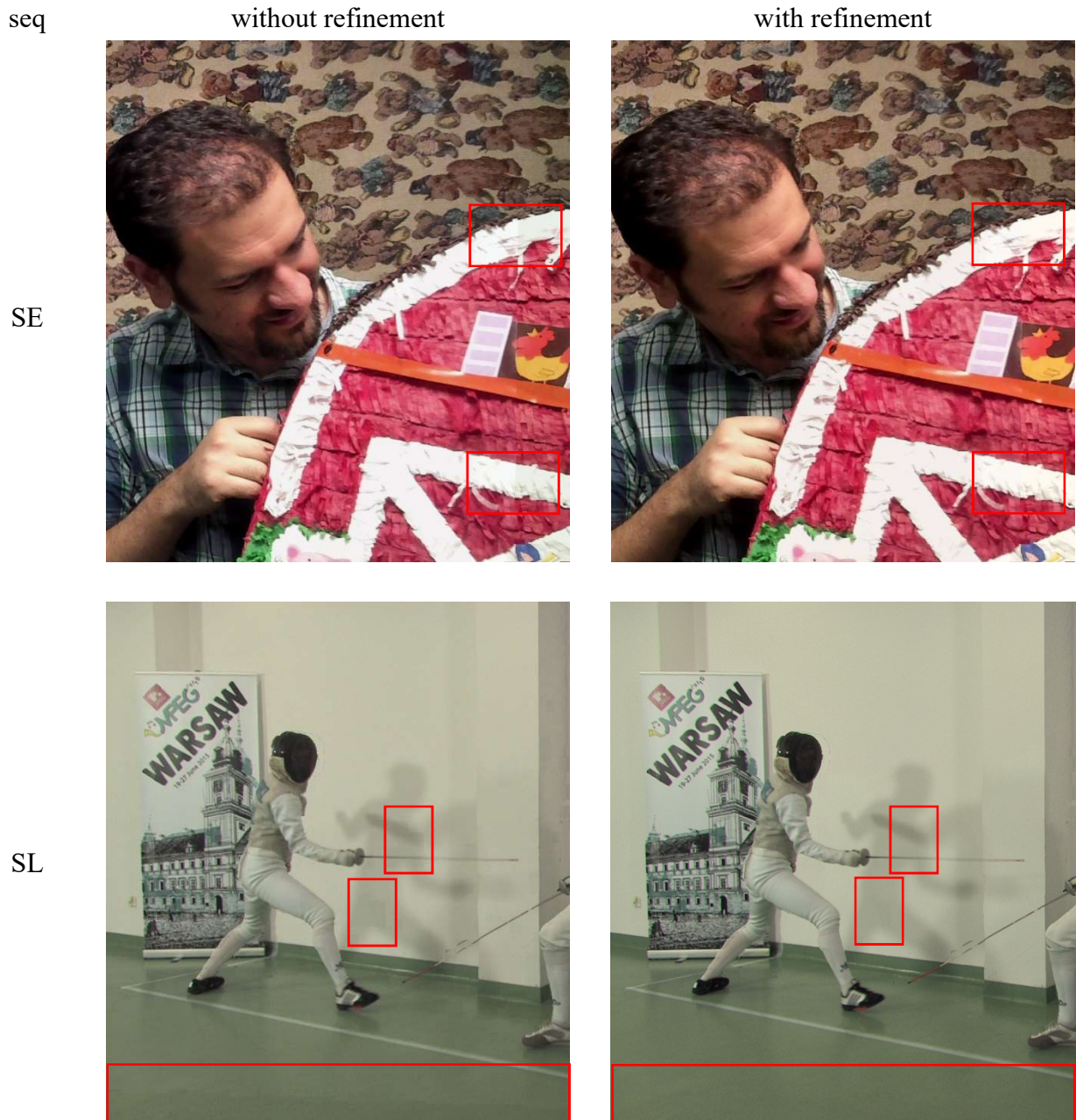| seq	without refinement	with refinement
SE		
SL		

Fig. 1. Virtual views synthesized using original input views and refined ones.

The differences can be spotted e.g. on wall and floor in PoznanFencing and right side of the house in the IntelFrog sequence.

In Fig. 2 the temporal consistency of a single view is presented. The blue line represents mean value (averaged within one 64×64 block of background – area without movement) of color component before refinement. The same value, but after color refinement, is presented by orange line.
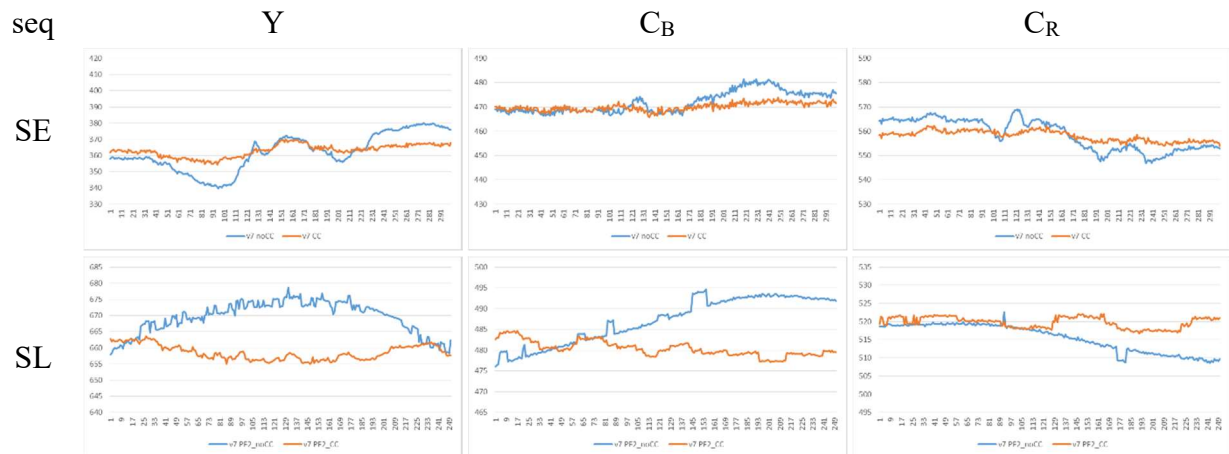
seq	Y	C_B	C_R

Fig. 2. Y, C_B, C_R color component changes over time. Blue line: before refinement, orange: after.

4 Recommendations

We recommend this software to become MPEG reference software for color refinement.

5 Acknowledgment

6 References

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[M48092]   A. Dziembowski, D. Mieloch, M. Domański, G. Lee, "PUT/ETRI Response to Immersive Video CE-5: Depth and color refinement", ISO/IEC JTC1/SC29/WG11 MPEG/M48092, July 2019, Göteborg, Sweden.

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