A Low-Complexity Metric for the Estimation of Perceived Chrominance Sub-Sampling Errors in Screen Content Images

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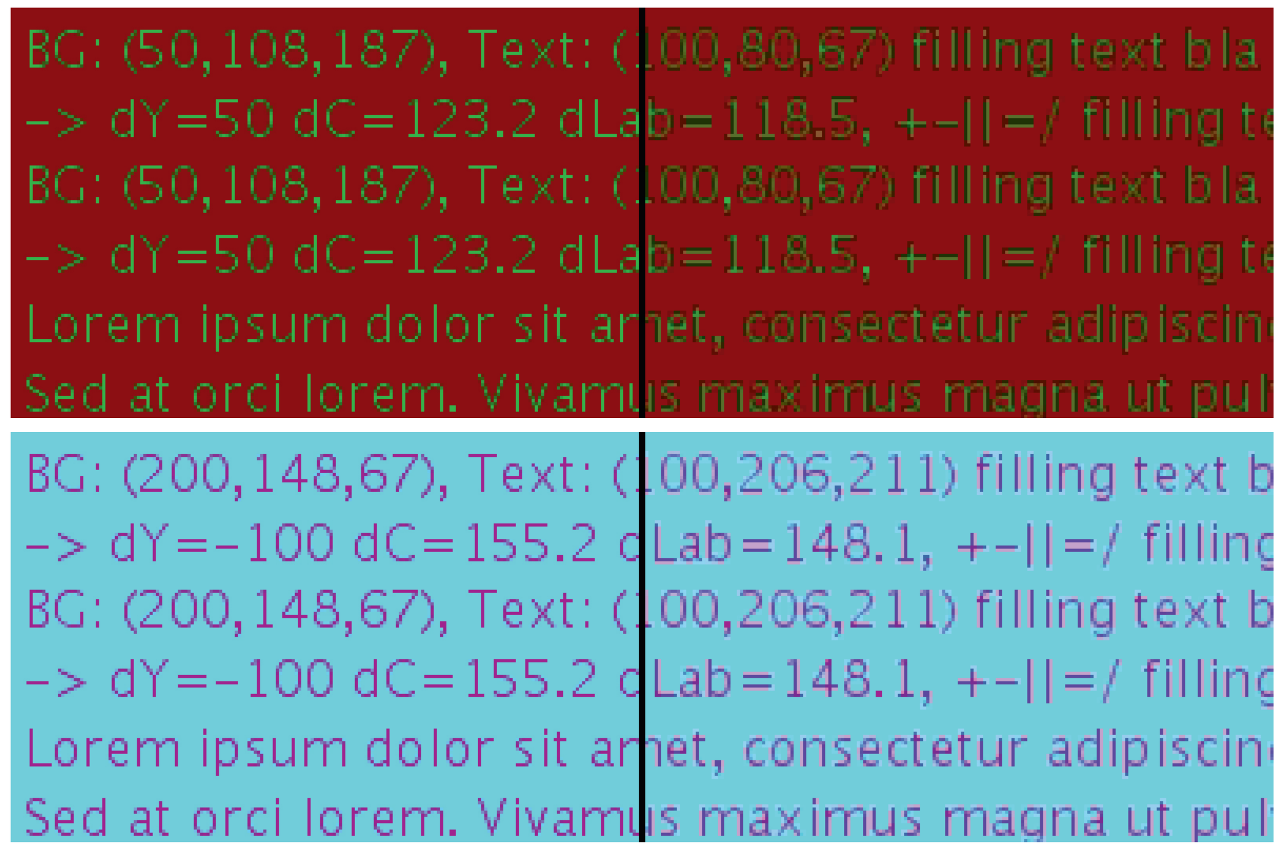
1. Introduction

- **Screen sharing** is a popular feature in web conferencing and remote desktop applications
- Commonly used basic profiles of video codecs typically utilize the YCbCr color space involving **4:2:0 chrominance sub-sampling**, introducing **visually disturbing artifacts** for screen content



- **Proposal: Perceived Chrominance Sub-sampling Error (PCSE) metric** for automatic detection of visually disturbing artifacts
- **Subjectively evaluated screen content image data set created**, which is employed for the performance evaluation

2. Perceived Chrominance Sub-Sampling Error (PCSE)

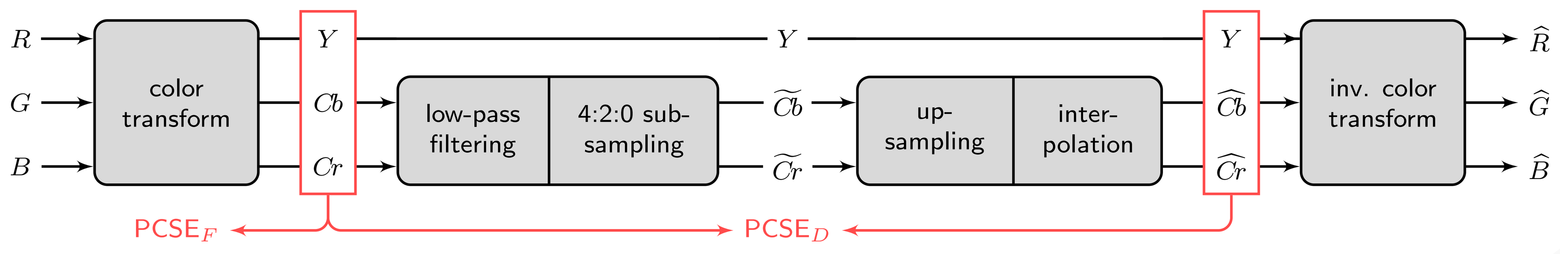


Figure: *Color space conversion steps for transmitting RGB data in the 4:2:0 sub-sampled YCbCr format $Y\widetilde{Cb}\widetilde{Cr}$. The transmission channel, including encoding and decoding, is omitted for simplicity.*

- 4:2:0 chrominance sub-sampling artifacts are caused by missing high frequency components (sharpness) in the up-sampled image
- Pixel-wise sharpness for certain color channel:

$$S[\boldsymbol{i}] = S[x,y] = \sqrt{G_x[x,y]^2 + G_y[x,y]^2}$$

- Sobel operators for gradients $G_x[x,y]$ and $G_y[x,y]$
- Computed for Y, Cb, and Cr plane: $S_Y[\boldsymbol{i}]$, $S_{Cb}[\boldsymbol{i}]$, and $S_{Cr}[\boldsymbol{i}]$

Pixel-based artifacts forecast using the 4:4:4 image

$$\text{PCSE}_F[\boldsymbol{i}] = 1 - \frac{S_Y[\boldsymbol{i}]^2}{S_Y[\boldsymbol{i}]^2 + S_{Cb}[\boldsymbol{i}]^2 + S_{Cr}[\boldsymbol{i}]^2}$$

Pixel-based full-reference artifact detection

- Incorporate the reconstructed image $Y\widehat{Cb}\widehat{Cr}$
- Higher precision of perceived error estimate expected

$$\text{PCSE}_D[\boldsymbol{i}] = 1 - \frac{S_Y[\boldsymbol{i}]^2 + S_{\widehat{Cb}}[\boldsymbol{i}]^2 + S_{\widehat{Cr}}[\boldsymbol{i}]^2}{S_Y[\boldsymbol{i}]^2 + S_{Cb}[\boldsymbol{i}]^2 + S_{Cr}[\boldsymbol{i}]^2}$$

From pixel-based to image PCSE

- Condense the PCSE image to a single value:

$$\overline{\text{PCSE}}_F = \frac{1}{\|\text{PCSE}_F[\boldsymbol{i}]\|_0} \sum_{\boldsymbol{i}} \text{PCSE}_F[\boldsymbol{i}]$$

- Exception: $\overline{\text{PCSE}}_F = 0$ for the case that $\|\text{PCSE}_F[\boldsymbol{i}]\|_0 = 0$
- Analogously from $\text{PCSE}_D[\boldsymbol{i}]$ to $\overline{\text{PCSE}}_D$

3. Subjectively Evaluated Test Set

Test images creation

- Selected $Y/Cb/Cr$ combinations leading to 18 different colors
- Images: specific text color on monochromatic background
- 224 test images labeled as good or excellent (see examples in 1. Introduction)

Subjective test

- Absolute Category Rating (ACR)
- 10 subjects (partly experts)
- Focus on text quality, disregarding color difference
- Averaged rating per image: Mean Opinion Score (MOS)

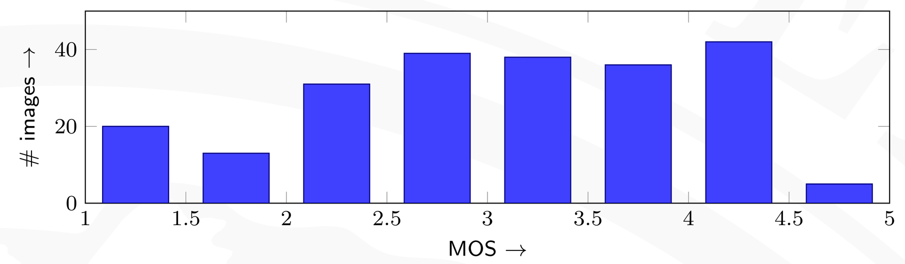


Figure: *Histogram of MOS values.*

4. Experimental Results

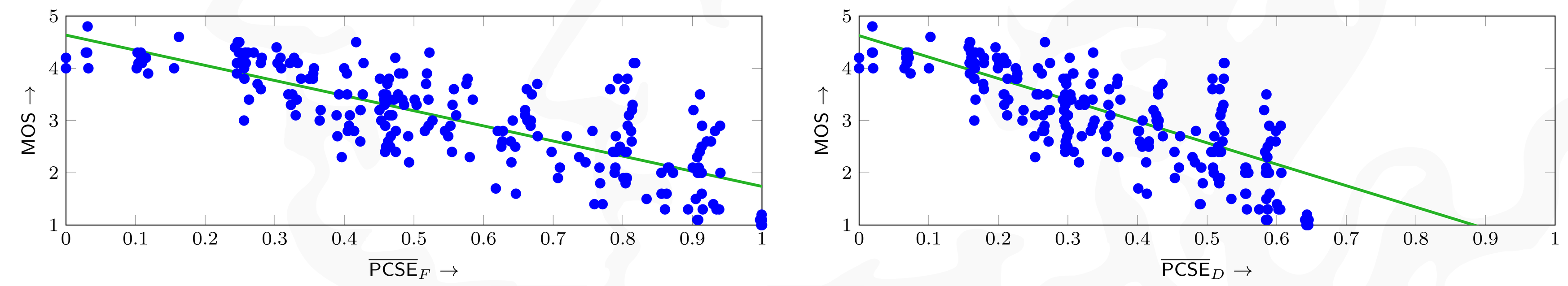


Figure: *Scatter plots of the $\overline{\text{PCSE}}_F$ and the $\overline{\text{PCSE}}_D$ against the MOS values with the least squares regression lines in green.*

Performance metrics:

- Pearson Linear Correlation Coefficient (PLCC)
- Spearman Rank-Order Correlation Coefficient (SROCC)
- Root Mean Squared Error (RMSE)

	MSE	PSNR	SSIM	$\overline{\text{PCSE}}_F$	$\overline{\text{PCSE}}_D$
PLCC	-0.3995	0.4642	0.4512	-0.7937	-0.7943
SROCC	-0.5202	0.5116	0.4533	-0.7852	-0.7857
RMSE	0.8730	0.8422	0.8499	0.5793	0.5786

No significant performance changes by ...

- alternative filter kernels for the gradient computation
- different weightings of the luminance and the chrominance components

5. Conclusions and Outlook

Conclusions

- PCSE metrics for measuring the perceived artifact level of chrominance sub-sampling errors in screen content images
- Significantly outperforming conventional image quality metrics MSE, PSNR, and SSIM

Outlook

- Specific coding or pre-/post-processing techniques for artifact reduction in affected image regions

ICIP 2017