An Alternative Color Difference Formula for Computing Image Difference

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Abstract

In this paper, we approach color-image-difference metrics by a Euclidean color-difference formula for small-medium color differences in log-compressed OSA-UCS space. We start from previous image-difference metrics by replacing the CIE color-difference formulae with the new one. Tests are performed on th TID database and current results show improvements in the actual state of art, making this formula the future key for image- difference metrics.

1 Introduction

The CIE published the CIELAB color space [3], with the idea of a perceptually uniform color space. In this color space it is straightforward computing the distance between two colors, by using the Euclidean distance ΔE^*_{ab}. This metrics formula has been used also for computing the difference between color images as color difference of all the pixels and averaged. The inadequateness of the original CIELAB formula was the origin of other important proposals. The British Colour Measurement Committee proposed the ΔE_{CMC} formula [6], defined on the CIELAB system. The CMC formula is today used as standard formula in industrial color control [16]. The BFD [9] formula, introduced in 1987 by Luo and Rigg, is a modification of the ΔE_{CMC} formula. It provided a correction for the CMC in the blue region [6]. In 1994, CIE proposed the ΔE_{94} [2] formula with the main intention to reduce the high complexity of the CMC formula. All these formulas (CMC, BFD and CIE94) are based on the BFD color-difference data [10] and none of them resulted completely satisfactory. The last CIE formula for small-medium color differences is the ΔE_{00} one [8], known as CIEDE2000 and based on a wider set of empirical data, known as COM10 dataset. Very recently, in 2009, a Euclidean color-difference formula for small-medium color differences in log-compressed OSA-UCS space, termed ΔE_E, has been published [11, 5]. The BFD empirical color difference data represented in the OSA-UCS space show a regularity not existing in the CIELAB space. First, this induced the authors of this formula to represent the small-medium color differences by a simple ellipsoidal equation [5], termed ΔE_{GP}, and finally to propose a proper logarithmic compression of the OSA-UCS space with a consequent reduction of the parameters and new formula, that is Euclidean and termed as ΔE_E [11]. So far in the years many different color-image-difference metrics have been proposed [12], some with the intent of measuring general image quality and some for detecting specific distortions. However, at the moment, a universal color-image-difference metric does not exist. A spatial extension to the CIELAB color-difference formula (S-CIELAB) was proposed by Zhang and Wandell [17] in 1997, introducing a spatial filter, which simulates the human visual system, as spatial pre-processing to the CIELAB color difference formula [3]. Johnson and Fairchild [7] followed the same approach but the spatial filter is implemented in the frequency domain, allowing for more precise control of the filter. In 2002 Hong and Luo [4] proposed the hue angle algorithm still based on the CIELAB color difference correcting some of the drawbacks. However, not including a spatial filtering of the image, it is unsuitable for halftone images [13, 15]. In 2008 Pedersen et al. [14] proposed two new image-difference metrics with spatial filtering simulating the human visual system. These two metrics (called SHAME and SHAME-II) apply a spatial filtering of the images similar to that used by Zhang and Wandell [17] and Johnson and Fairchild [7], before applying the hue angle measure to the filtered images.

2 A Proposal of Two New Metrics

The first metric that we propose and analyze is the simple pixel value difference but instead of using ΔE^*_{ab} formula we use ΔE_E in the Log-Compressed OSA-UCS space. The second metrics that we consider is based on the S-CIELAB developed by Johnson et al. [7]. This metric works with the following steps:

- The original and the reproduced image are converted to the opponent color space
- Afterwards they are spatially filtered
- Then they are converted to CIELAB color space
- In final a pixelwise difference is done using ΔE^*_{ab} formula, obtaining an image difference representation generally called S-CIELAB representation.

We have modified the last step changing again the ΔE^*_{ab} with the ΔE_E obtaining a different image difference representation that we call S-DEE.

3 Preliminary Results

For the evaluation of the proposed metrics we used the TID2008 database [1], which is composed by 25 original images. These images have been altered and divided into seven categories: Noise, Noise2, Safe, Hard, Simple, Exotic, Exotic2. Each category represents different kind of distortions. These two new metrics have been tested on 1700 images. Three types of correlation are computed for the results, the Pearson-product-moment-correlation coefficient, the Spearman-rank-correlation coefficient and the Kendall-tau-rank-correlation coefficient20.

Table 1: ΔE_E correlations compared to $DeltaE^*_{ab}$ ones on each category of the TID2008 database.

Dataset	Pearson correlation		Spearman correlation		Kendall correlation	
	ΔE^*_{ab}	ΔE_E	ΔE^*_{ab}	ΔE_E	ΔE^*_{ab}	ΔE_E
Noise	0.294	0.203	0.333	0.238	0.223	0.158
Noise2	0.243	0.338	0.297	0.412	0.213	0.285
Safe	0.336	0.405	0.338	0.461	0.221	0.303
Hard	0.492	0.643	0.466	0.665	0.324	0.481
Simple	0.418	0.585	0.434	0.608	0.309	0.433
Exotic	0.252	0.311	0.201	0.26	0.087	0.133
Exotic2	0.019	0.049	0.041	0.053	0.007	0.017
All	0.174	0.212	0.173	0.248	0.121	0.166

As shown in Table 1, ΔE_E performs better than ΔE^*_{ab}, excluding the noise dataset, with the same computational complexity and computational time. However either ΔE^*_{ab} and ΔE_E show a low performance considering all database set; only in the category "hard" and "simple" ΔE_E shows a reasonable result. A T-test at 5% confidence level on Spearman correlation values confirms the performance of the metric.

The simple pixelwise difference using ΔE_E performs better than the ΔE^*_{ab}, hue angle metrics but it is still worse of some others metrics previously developed. The S-DEE metric performs better than ΔE^*_{ab}, ΔE_E and hue angle metric. It performs slightly worse than S-CIELAB by Zhang et al. and S-CIELAB by Johnson et al., while it is still not efficient like SHAME-II, SSIM and UIQ.

Table 2: ΔE_E and S-DEE compared against other metrics considering all TID2008 database set.

METRICS	Pearson correlation	Spearman correlation	Kendall correlation
ΔE^*_{ab}	0.174	0.173	0.121
Hue angle	0.179	0.161	0.113
ΔE_E	0.212	0.248	0.166
S-DEE	0.443	0.456	0.335
S-CIELAB	0.476	0.482	0.354
S-CIELAB (Johnson)	0.542	0.538	0.4
SHAME	0.544	0.55	0.414
SSIM	0.547	0.653	0.437

4 Conclusion

The ΔE_E color difference formula makes improvements to the previously developed image-difference metrics and, at the moment, seems promising, but more studies must be done. Future studies will encapsulate the ΔE_E in other image difference metrics and applied to other spatial filters and evaluated on other different kind of dataset.

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