An Alternative Color Difference Formula for Computing Image Difference

Gabriele Simone
Gjovik University College, Norway
gabriele.simone@hig.no

Claudio Oleari
University of Parma, Italy
claudio.oleari@fis.unipr.it

Ivar Farup
Gjovik University College, Norway
ivar.farup@hig.no

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 the 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 \( \Delta E_{ab}^* \). 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 \( \Delta E_{CMC} \) 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 \( \Delta E_{CMC} \) formula. It provided a correction for the CMC in the blue region [6]. In 1994, CIE proposed the \( \Delta E_{94} \) [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 \( \Delta E_{00} \) 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 \( \Delta E_E \), has been published [11]. 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 \( \Delta E_{GP} \), 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 \( \Delta E_E \) [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 $\Delta E_{ab}$ formula we use $\Delta E_E$ 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 $\Delta E_{ab}$ formula, obtaining an image difference representation generally called S-CIELAB representation.

We have modified the last step changing again the $\Delta E_{ab}$ with the $\Delta E_E$ 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: $\Delta E_E$ correlations compared to $\Delta E_{ab}^*$ ones on each category of the TID2008 database.

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Pearson correlation</th>
<th>Spearman correlation</th>
<th>Kendall correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\Delta E_{ab}$</td>
<td>$\Delta E_E$</td>
<td>$\Delta E_{ab}^*$</td>
</tr>
<tr>
<td>Noise</td>
<td>0.294</td>
<td>0.238</td>
<td>0.223</td>
</tr>
<tr>
<td>Noise2</td>
<td>0.243</td>
<td>0.297</td>
<td>0.213</td>
</tr>
<tr>
<td>Safe</td>
<td>0.336</td>
<td>0.461</td>
<td>0.221</td>
</tr>
<tr>
<td>Hard</td>
<td>0.492</td>
<td>0.665</td>
<td>0.324</td>
</tr>
<tr>
<td>Simple</td>
<td>0.418</td>
<td>0.608</td>
<td>0.309</td>
</tr>
<tr>
<td>Exotic</td>
<td>0.252</td>
<td>0.26</td>
<td>0.087</td>
</tr>
<tr>
<td>Exotic2</td>
<td>0.019</td>
<td>0.053</td>
<td>0.007</td>
</tr>
<tr>
<td>All</td>
<td>0.174</td>
<td>0.121</td>
<td>0.166</td>
</tr>
</tbody>
</table>

As shown in Table 1, $\Delta E_E$ performs better than $\Delta E_{ab}^*$, excluding the noise dataset, with the same computational complexity and computational time. However either $\Delta E_{ab}^*$ and $\Delta E_E$ show a low performance considering all database set; only in the category "hard" and "simple" $\Delta E_E$ 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 $\Delta E_E$ performs better than the $\Delta E_{ab}^*$, hue angle metrics but it is still worse of some others metrics previously developed. The S-DEE metric performs better than $\Delta E_{ab}^*$, $\Delta E_E$ 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: $\Delta E_E$ and S-DEE compared against other metrics considering all TID2008 database set.

<table>
<thead>
<tr>
<th>METRICS</th>
<th>Pearson correlation</th>
<th>Spearman correlation</th>
<th>Kendall correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta_{E_E}^{ab}$</td>
<td>0.174</td>
<td>0.173</td>
<td>0.121</td>
</tr>
<tr>
<td>Hue angle</td>
<td>0.179</td>
<td>0.161</td>
<td>0.113</td>
</tr>
<tr>
<td>$\Delta E_E$</td>
<td>0.212</td>
<td>0.234</td>
<td>0.166</td>
</tr>
<tr>
<td>S-DEE</td>
<td>0.443</td>
<td>0.456</td>
<td>0.335</td>
</tr>
<tr>
<td>S-CIELAB</td>
<td>0.476</td>
<td>0.482</td>
<td>0.354</td>
</tr>
<tr>
<td>S-CIELAB (Johnson)</td>
<td>0.542</td>
<td>0.538</td>
<td>0.4</td>
</tr>
<tr>
<td>SHAME</td>
<td>0.544</td>
<td>0.55</td>
<td>0.414</td>
</tr>
<tr>
<td>SSIM</td>
<td>0.547</td>
<td>0.653</td>
<td>0.437</td>
</tr>
</tbody>
</table>

4 Conclusion

The $\Delta E_E$ 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 $\Delta E_E$ in other image difference metrics and applied to other spatial filters and evaluated on other different kind of dataset.

4.1 Acknowledgments

The authors would like to thank Marius Pedersen and Jon Yngve Hardeberg for their advice, suggestions and feedback regarding this project.

References

   difference metrics. In Bernice Rogowitz and Thrasyvoulos Pappas, editors, Human Vision and Electronic
   Imaging VIII (HVEI-08), volume 6806 of SPIE proceedings, pages 680611–1–680611–12, San Jose, USA,
   Jan 2008. SPIE.