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Camera Characterisation Based on Skin-Tone Colours for Rock Art Recording †

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Abstract: Image-based characterisation offers accurate results for colour recording in cultural heritage documentation tasks. Although numerous researches are focused on improving either the mathematical model used or the workflow technical details, in this paper we propose the use of selected skin-tone colours instead of the full colour checker dataset. Even though the two datasets yield good colourimetric results, an improvement is observed when using the skin-tone samples. The results reveal two key aspects in the characterisation procedure, specifically the number of samples and the use of training data near the chromatic range of the scene used in the characterisation procedure itself.

Keywords: camera characterisation; CIE; colour specification; colourimetry; rock art

1. Introduction

Accurate colour recording is a priority task in heritage documentation [1–3]. Although the use of digital images has undergone remarkable advance in 3D modelling in the last decades, a rigorous setup and treatment is still necessary in order to collect colour information in a precise way [4]. A common and acceptable approach is the digital camera characterisation procedure, which basically provides a numeric framework to report image colour in a physically-based, device-independent colour space. Numerous studies seek to improve specific steps of the characterisation workflow, such as the optimal mathematical model [5–7].

In this paper, we propose the use of skin-tone patches from the reference colour checker as an alternative to using the whole colour chart. The characterisation approach with skin-tone colours allows the reduction of the training sample size and improves the adjustment to the chromatic range of the scene. In addition, the computing time required for model training is lower that in the regular approach with all colour patches.

We tested the methodology on a set of prehistoric rock art painting scenes captured with different digital cameras. Motifs in the images belong to the main scene from the "Cova Civil" shelter in Castelló (Spain), which is part of a UNESCO World Heritage Site list since 1998. Graphic and numeric results obtained for the characterised images allow us to confirm that this approach is a suitable alternative for carrying out the characterisation of digital cameras.

2. Materials and Methods

2.1. Datasets

Two different datasets are required in order to carry out the image-based characterisation. The first one is the colour data recorded by the camera sensor. Thus, we should consider the proper selection of the digital camera used for the photographic data acquisition as a key starting point. In this study, we used the Sigma SD15, a Single Lens Reflex (SLR) camera with the FoveonX3© full colour sensor. Our images were taken in raw format, in order to avoid any preprocessing operations in the image.

The images have to include a colour chart as a colourimetric reference. The X-rite ColorChecker SG, with 140 colour patches, is one of the most widely used in image colour correction (Figure 1a). The second dataset consits of the CIE XYZ coordinates for each individual patch in the colour chart. Those coordinates are obtained by direct spectrophotometer measurements (Konica Minolta CM-600d), following the Commission Internationale de l'Éclairage (CIE) recommendations, fundamentally the 2º standard observer and the D65 illuminant [8].

(**a**) (**b**) (**c**)

Figure 1. (**a**) Original Sigma SD15 raw (viewed as TIFF). (**b**) ColorChecker (140 patches) characterised image. (**c**) Skin-tone (31 patches) characterised image.

2.2. Camera Characterisation

A camera sensor usually records colour data in a device-dependent colour space, such as the well-know RGB. However, the device-dependent nature of RGB data makes them unsuitable for rigorous colorimetric purposes. Thus, image-based characterisation has the goal of transforming device-dependent original data into an independent colour space, such as the XYZ space developed by the CIE [9]. By means of the characterisation, we establish the mathematical relationship between the original RGB data and the output CIE XYZ data. Previous studies show that good results can be obtained using second-order polynomial models in rock art paintings documentation [10].

We applied the characterisation using the 140 patches of the colour chart (ColorChecker dataset), and compared the ColorChecker results with other three additional characterisations based on three subsets of the whole colour chart. We name those three subsets 'skin-tone' datasets which are defined with 17 (primary colours and skin-tone), 28 (skin-tone and grey) and 31 patches (primary colour, skin-tone and grey). The specific patch IDs are: primary colours (E4, F4, G4), skin-tone (D7, E7, F7, G7, H7, 51 I7, J7, D8, E8, F8, G8, H8, I8, J8), and grey (E5, F5, G5, H5, I5, J5, E6, F6, G6, H6, I6, J6, K6, K7).

All computations, including colourimetric and image processing, were done with our own software, named pyColourimetry, which was developed for previous colour experiments [11].

3. Results

3.1. Residuals and ΔE^*_{ab}

The best results for the image-based characterisation were found for the 31 skin-tone dataset. Table 1 shows the residuals in CIE XYZ and ΔE^*_{ab} colour differences after the second-order polynomial fit using the ColorChecker and skin-tone datasets respectively. The ΔE^*_{ab} colour difference was computed using well-known CIE formulae [8].

Table 1. Residuals (CIE XYZ units) and ΔE^*_{ab} (CIELAB units) after camera characterisation.

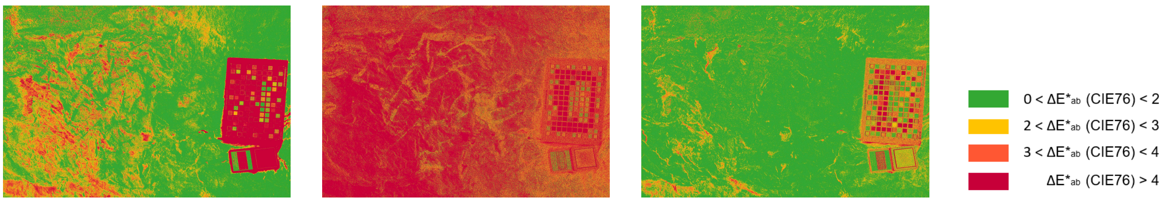
Residual	Color Checker Dataset			Skin-Tone Dataset		
	Max.	**Mean**	**Min**	**Max.**	**Mean**	**Min**
CIE X	6.499	0.033	−12.328	2.311	0.017	−3.427
CIE Y	7.255	0.042	−12.218	1.878	0.012	−2.519
CIE Z	4.923	0.046	−14.814	1.436	0.011	−1.283
ΔE^*_{ab}	11.728	2.985	0.518	4.173	1.761	0.348

3.2. Output sRGB Images after Camera Characterisation

Common display devices do not support imaging in CIE XYZ format. In order to view the output images after the characterisation procedure, a final transformation between the CIE XYZ and sRGB colour spaces is required [10]. Figure 1b,c. shows the output sRGB images obtained using the whole ColorChecker and the 31 skin-tone dataset as training datasets.

3.3. ΔE^*_{ab} Mapping Images

A quick way to validate the methodology proposed in this paper is by means of the ΔE^*_{ab} mapping images between the different datasets used for the model training. We set the ColorChecker dataset (140 patches) sRGB image as the reference, and computed the ΔE^*_{ab} between the 17-, 28- and 31-patch images respectively. Figure 2 displays the ΔE^*_{ab} mapping images.



(**a**) (**b**) (**c**)

Figure 2. ΔE^*_{ab} Mapping Images (**a**) 140 vs. 17 patches. (**b**) 140 vs. 28 patches. (**c**) 140 vs. 31 patches.

4. Discussion

Camera characterisation is a suitable methodology for cultural heritage documentation techniques. For a detailed description of the methodology, formulation and software we further recommend the reader to examine our previous articles published about the camera characterisation procedure [10,11].

We obtained satisfactory results regardless of the data used in the characterisation (whole ColorChecker or skin-tone datasets). The mean ΔE^*_{ab} colour differences values were less than 4 units for both training datasets (Table 1). It is hard for the observer to perceive visual differences between the output sRGB images from both models (compare Figure 1b with Figure 1c.).

Nevertheless, better results were found for the skin-tone dataset, with lower residuals and ΔE^*_{ab} values (Table 1). It is worth noting the differences in the ΔE^*_{ab} mapping images displayed in Figure 2. We can conclude that using a subset of 17 patches (primary and skin-tone samples) we can obtain good and acceptable results. Furthermore, the result is improved using the skin-tone dataset, which increases the number of patches from 17 to 31. Figure 2c. shows the predominant green colour (ΔE^*_{ab} less than 2 units), however, Figure 2b. shows quite a different behaviour with higher ΔE^*_{ab} values and red colours. These results clearly show that an increase in the number of sample patches does not intrinsically imply an improvement in the fitness of the output sRGB characterised image.

5. Conclusions

The image-based characterisation procedure is a suitable approach for accurate colour measurement in cultural heritage documentation techniques. This study shows the relevance of considering not only the sample size, but also the training samples used for the mathematical modelling during the process. Better results are obtained using sample data near the chromatic range of the scene. Future research lines will determine the optimal number of patches that should be used for the camera characterisation in a more specific way in order to improve the colourimetric results.

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References

1. Korytkowski, P.; Olejnik-Krugly, A. Precise capture of colors in cultural heritage digitization. *Color Res. Appl.* **2017**, *42*, 333–336.
2. Boochs, F.; Bentkowska-Kafel, A.; Degrigny, C.; Karaszewski, M.; Karmacharya, A.; Kato, Z.; Picollo, M.; Sitnik, R.; Trémeau, A.; Tsiafaki, D.; et al. Colour and Space in Cultural Heritage: Key Questions in 3D Optical Documentation of Material Culture for Conservation, Study and Preservation. *Int. J. Herit. Digit. Era* **2014**, *3*, 11–24.
3. Ruiz, J.F.; Pereira, J. The colours of rock art. Analysis of colour recording and communication systems in rock art research. *J. Archaeol. Sci.* **2014**, *50*, 338–349.
4. Iturbe, A.; Cachero, R.; Cañal, D.; Martos, A. Digitalización de cuevas con arte paleolítico parietal de Bizkaia. Análisis científico y divulgación mediante nuevas técnicas de visualización. *Virtual Archaeol. Rev.* **2018**, *9*, 57–65.
5. Finlayson, G.; Mackiewicz, M.; Hurlbert, A. Color Correction Using Root-Polynomial Regression. *IEEE Trans. Image Process.* **2015**, *24*, 1460–1470.
6. Bianco, S.; Gasparini, F.; Russo, A.; Schettini, R. A New Method for RGB to XYZ Transformation Based on Pattern Search Optimization. *IEEE Trans. Consum. Electron.* **2007**, *53*, 1020–1028.
7. Cheung, V.; Westland, S.; Connah, D.; Ripamonti, C. A comparative study of the characterisation of colour cameras by means of neural networks and polynomial transforms. *Color. Technol.* **2004**, *120*, 19–25.
8. Commission Internationale de l'Éclairage. *CIE 15:2004 Colorimetry*, 3rd ed.; CIE Central Bureau: Vienna, Austria, 2004; pp. 1–72.
9. Westland, S.; Ripamonti, C.; Cheung, V. Characterisation of Cameras. In *Computational Colour Science Using MATLAB®*, 2nd ed.; John Wiley & Sons, Inc.: Hoboken, NJ, USA; Publishing House: Chichester, UK, 2012; pp. 143–157.
10. Molada-Tebar, A.; Lerma, J.L.; Marqués-Mateu, Á. Camera characterization for improving color archaeological documentation. *Color Res. Appl.* **2018**, *43*, 47–57.
11. Molada-Tebar, A.; Lerma, J.L.; Marqués-Mateu, Á. Software development for colourimetric and spectral data processiong: PyColourimetry. In Proceedings of the 1st Congress in Geomatics Engineering—CIGeo, Valencia, Spain, 5–6 July, 2017; Volume 1, pp. 48–53.