An extended image database for colour constancy

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We present an extended version of an image database presented in 2003, to test colour constancy and other kinds of visual and image processing algorithms. Big technology improvements have been done in the last eleven years, however the motivations to present this upgrade are not only technological. We decided to address other characteristics related to vision, like e.g. high dynamic range. Moreover, to address computer vision related problems (e.g. illuminant or reflectance estimation) we have made available a set of data regarding objects, backgrounds and illuminants used.

Received 2 July 2014; accepted 24 July 2014

Published online: 8 December 2014

Introduction

We have presented in 2003 an image database (IDB) called YACCD (Yet Another Color Constancy Database), to test color constancy and other kinds of algorithms [1, 2]. The original motivation to add another IDB to the many that were already present on the web was due to the fact that each IDB was characterised by choices that can fit or not with the algorithms to test. For example, a database of images containing a white area can be suitable for algorithms based on the White Patch approach, or alternatively, the complete absence of white areas can advantage algorithms with different approaches.

YACCD had the following characteristics:

- Different backgrounds with a wide frequency range, containing white areas but with an average reflectance close to middle gray
- A set of natural, artificial and extreme illuminants
- Images with and without casted shadows

After eleven years, we have decided to update the original database keeping the above features and introducing new ones in order to make it more suitable to test a wider variety of visual and image processing algorithms like e.g. models of human colour constancy, computational colour constancy, human vision models, HDR tone rendering, intrinsic images and other computer vision algorithms. In particular, in the new database, called YACCD2 [3, 4], we have introduced the following new features:

- Higher resolution of the images
- More recent set of illuminants
- Acquisition with newer SLR cameras
- Multiple exposures for HDR imaging
- Images available in both JPEG and RAW formats
- Each image in the database comes with information on the reflectance data, acquired at the moment on the test scenes

In digital imaging literature, two main different approaches to Colour Constancy (CC) can be found according to their goals in modeling this phenomenon: computer vision CC (CVCC, even if in some scholar works it is referred as computational CC) and human vision CC (HVCC). They have distinct goals, different kind of outcomes are expected, and different measures of performance are required.

CVCC can have three different goals: separating illuminant from reflectance, estimating objects reflectance under different illuminants, or alternatively estimating the illuminant spectral or colorimetric component [5, 6].

In HVCC, illuminant component is not totally removed; the resulting appearance shows significant departures from reflectance. These departures serve as important signatures of the underlying visual mechanisms [7-11].

Historically, CC has been formulated as the problem of adjusting colour sensation according to the illuminant. Many tests afterwards revealed that colour constancy in our vision can be better modeled as a mechanism that synthesise the appearance from the spatial distribution of the stimuli, and this mechanism has the useful advantage to discount a big part (rarely the whole) of possible colour dominant present in the scene.

CVCC kept the original formulation of the mechanism, aiming at completely discounting the illuminant or reversely estimating and/or removing the illuminant.

Both approaches introduce a sort of normalisation with regard to the illuminant but can differ in the estimated pixel output according to the use of spatial arrangement of the scene. CVCC aims at computing reflectance and HVCC aims at computing appearance.

The proposed IDB has been designed in order to support both the approaches.

In order to allow the evaluation of CVCC algorithms we have provided in the DB spectral data of the illuminants and the object reflectance, together with the colorimetric data of the arrays of radiances coming from the scene.

Table 1 reports a list of other available image datasets for similar purposes [12-28].

Lab/Dept	Author	Organisation	Ref.	Web address
The Computational Vision Lab	Brian Funt et al.	Simon Fraser Univ., CANADA	[12]	http://www.cs.sfu.ca/~colour/data/
Ucentric Systems	John A. Watlington	Maynard, MA USA	[13]	http://web.media.mit.edu/~wad/color/exp1/new/
Dep. of Psychology	David H. Brainard	Univ. of Pennsylvania USA	[14]	http://color.psych.upenn.edu/hyperspectral/
Machine Vision Group	Matti Pietikäinen	University of Oulu, FINLAND	[15, 16]	http://www.ee.oulu.fi/research/imag/color/pbfd.html
Harvard School of Eng. and Applied Sciences	A. Chakrabarti, K. Hirakawa, and T. Zickler	Cambridge, Harvard University, USA	[17, 18]	http://www.eecs.harvard.edu/~ayanc/oldcc/dbs.html
Vision Group	Peter V. Gehler	Microsoft Research, Cambridge	[19, 20]	http://people.kyb.tuebingen.mpg.de/pgehler/colour/index.html#publication
Centre de Visió per Computador	Parraga, C. A.	Universitat Autònoma de Barcelona	[21, 22]	http://www.cvc.uab.es/color_calibration/database.html
Department of Psychology	Kitaoka, A.	Ritsumeikan Univ., Kyoto, Japan	[23]	http://www.psy.ritsumei.ac.jp/~akitaoka/colorconstancy2e.html
tUL -IBBT, EDM	Ancuti, C. et al.	Hasselt University	[24 , 25]	http://research.edm.uhasselt.be/~oancuti/Underwater_CVPR_2012/
Electrical and Computer Eng. Dep.	Moghaddam, M. E.	Shahid Behehsti University	[26]	http://faculties.sbu.ac.ir/~moghaddam/index.php/main/page/11
Pattern Recognition Lab	Bleier, M. et al.	Pattern Recognition Lab	[27, 28]	http://www5.cs.fau.de/research/data/multi-illuminant-dataset/

Table 1: Image databases for colour constancy in the web.

YACCD2 content

YACCD2 database consists of two sets of images: the images in the first set comes from a low dynamic range (LDR) scene, while a high dynamic range (HDR) scene has been considered for the second set.

From the acquisition point of view, the two datasets share the following common features:

- Five light sources have been selected: a fluorescent warm, a fluorescent cold, a halogen, a fluorescent tube with a strong yellow cast, a set of blue LEDs disposed on a circular ring. For the LDR scene all five light sources have been used. For HDR scene we considered a subset of three light sources: fluorescent warm, fluorescent cold and halogen. The spectral power distributions of all the light sources are available in the DB for download. In subsection *Light sources* we provide further details on the characteristics of the light sources.
- Following the approach of the original YACCD, we have acquired the images using two different backgrounds based on a white noise pattern (see subsection *Backgrounds*).
- For both LDR and HDR scenes, we have acquired images using two different subjects: a standard 24-patches Macbeth ColorChecker™, and an object made with different coloured toy building bricks. Reflectance properties of the objects have been measured and provided with the database (see subsection *Objects*)

- For both LDR and HDR scenes, we have provided the data from the measurements taken with a colorimeter (Konica Minolta CA-2000) and the exposure values taken with a spot-meter (Konica Minolta Spot Meter F). Further details are available in subsection *Acquisition devices*.

The two LDR and HDR datasets differ in some aspects regarding the shooting setup and illumination: in the LDR scenes we have used a lighting booth, and we have also introduced in half of the images a shadow. Subsections *LDR setup characteristics* and *HDR setup characteristics* will provide a more detailed description of these aspects.

For LDR we provide to download a 3 shot bracketing set, while for HDR we provide a 7 shot bracketing set, that can be used to build a HDR image with the preferred tool/algorithm.

Considering all the parameters and possible combinations, the LDR dataset consists so far of 120 images (5 light sources, 2 subjects, 2 backgrounds, 2 shadow conditions, 3 different exposures), while the HDR dataset consists of 84 images (3 light sources, 2 subjects, 2 backgrounds, 7 different exposures).

All the images (of resolution 5184 × 3456 pixels) are provided in both JPG and CR2 (Canon RAW files) formats.

YACCD2 database is available at: http://eidomatica.di.unimi.it/index.php/research/idb/yaccd2.

YACCD2 technical details

Acquisition devices

The devices used for this project are the following:

- Canon EOS 60D camera, 18-megapixel CMOS sensor, with a Canon EF-S 17-85mm f/4-5.6 IS USM Lens. The automatic settings were disabled and the white balance set to the value 6500K for every scene. The image stabiliser has been disabled and the camera was mounted on a tripod. The pictures were saved both in RAW and JPG format.
- Konica Minolta Color Analyzer CA-2000 2D: a colour analyser that, using a CCD sensor and a set of filters, is able to measure the distribution of chromaticity and luminance of a two-dimensional scene. The output is a 980 × 980 × 3 matrix with the colorimetric data of the scene. The device has been used to measure each photographed scene. Figure 1 shows an example of CA-2000 measurement.

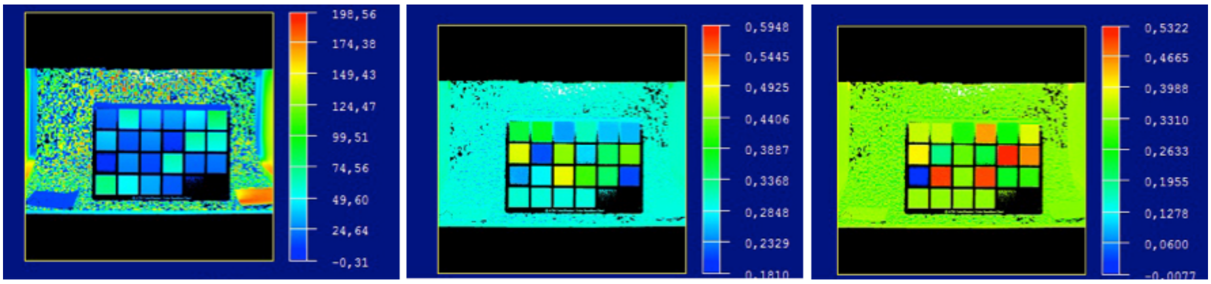


Figure 1: Example of Minolta CA-2000 measurement (Luminance channel and chromatic channels).

- Konica Minolta CL-500A Illuminance Spectrophotometer. The device was used to measure the spectrum of the light sources. It has a wavelength range from 360 to 780 nm with resolution of 1nm, which makes it useful to measure even light sources such as LEDs.

- Konica Minolta CM-2600D Spectrophotometer. The device was used to measure the reflectance colours spectrum of the chosen objects. It has a wavelength range from 360 to 740nm.
- Konica Minolta Spot Meter F, used to measure the reflected ambient light of a white and a black patch.

Light sources

The choices made for YACCD2 derives from YACCD, with some changes. We have chosen light sources easily available on the market, with moderate colour casts, together with illuminants with stronger colour casts, trying to cover different lighting conditions.

In the near future we plan to include photos taken with natural light in different conditions.

In Table 2 we have listed the light sources, while Figure 2 shows their spectral power distributions.

Label	A	B	C	D	E
Manufacturer	LEXMAN	LEXMAN	LEXMAN	PHILIPS	Low cost Consumer LED
Type	Cold Fluorescent	Warm Fluorescent	Halogen	Yellow neon	Blue LED

Table 2: Light sources considered in YACCD2.

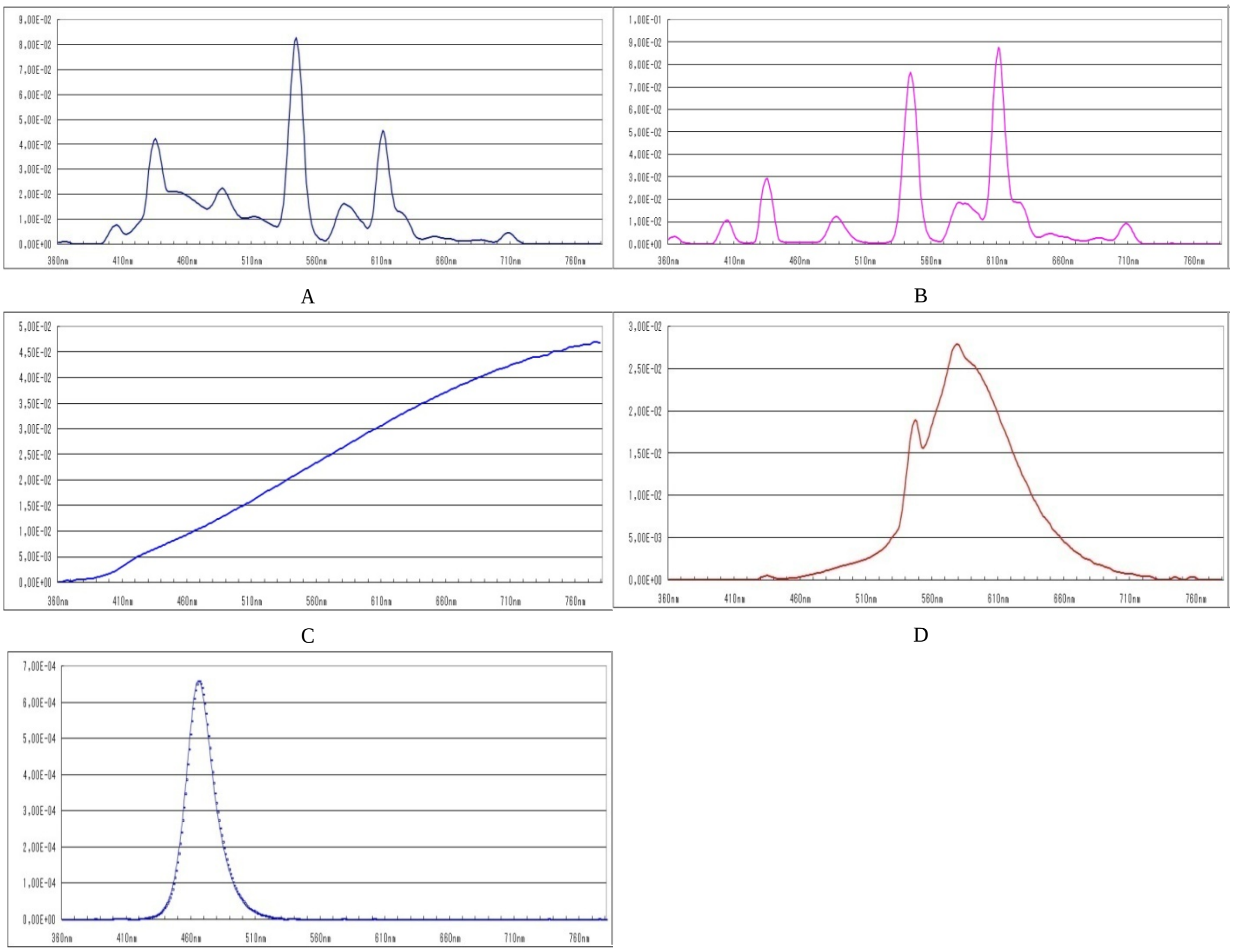


Figure 2: Spectral power distributions of the light sources listed in Table 2.

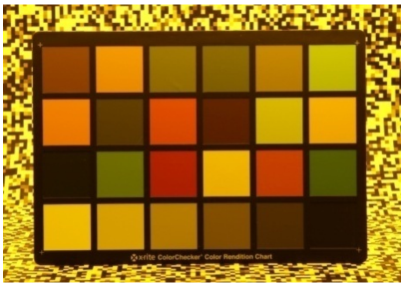
We recall that, for LDR scenes we have used all the five light sources, while in HDR scenes only the first three have been used.

In Figure 3 some example shots, using different light sources, are shown. The images are from the LDR dataset; the subject used is the Macbeth ColorChecker™.

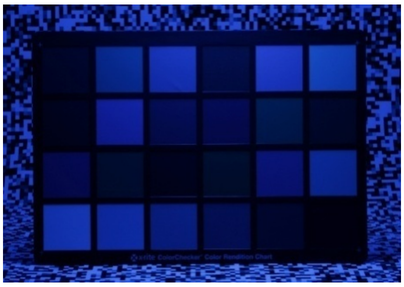
A

B

C



D



E

Figure 3: Example images showing the different colour casts introduced by the different light sources.

Backgrounds

The choice of the background is a delicate matter. Choosing a white instead of a middle gray or black background changes heavily the appearance of the colour in the scene. This can be problematic if someone aims at testing human vision colour constancy, or other properties of our vision system. Even for computational colour constancy, the presence or absence of a particular tone in the background can be a strong bias for the results (e.g. white for White Patch algorithms or grey for Grey World ones). For this reason, like in YACCD, we have adopted two different backgrounds based on white noise pattern at different spatial frequencies.

Then we have printed the images on A1 sized sheets as backgrounds for the shooting. Both backgrounds are available to be downloaded. Figure 4 shows the two backgrounds.

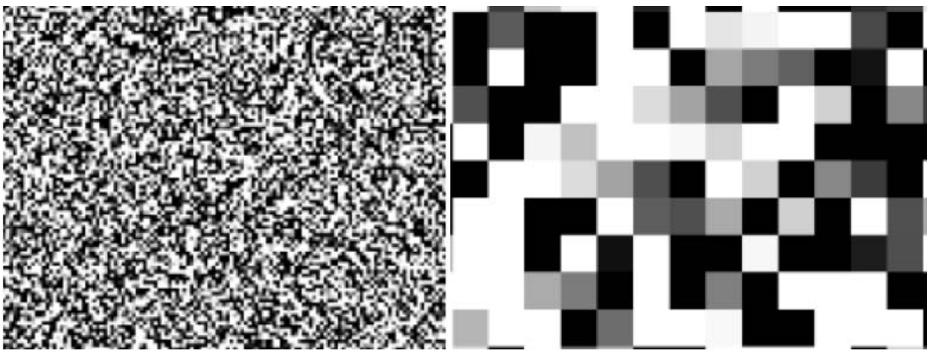


Figure 4: Gaussian pattern at different resolution.

Objects

We have selected two different subjects, with different surface properties: a 24-patches Macbeth ColorChecker™ (MCC) (January 2010 edition) and a small model built with plastic toy bricks (in the following called Shuttle). We have used two identical subjects to create contrast and shadow effects in the HDR scene (as explained in section *HDR setup characteristics*). A brief description of the chosen objects is presented in Table 3.

We have measured the reflectance of the objects (patches of the MCC, and bricks of the Shuttle) with a spectrophotometer Minolta CM-2600d (see section *Acquisition devices*).

The measures are available at the YACCD2 website, while supplementary data regarding MCC can be found on the web, e.g. [29].

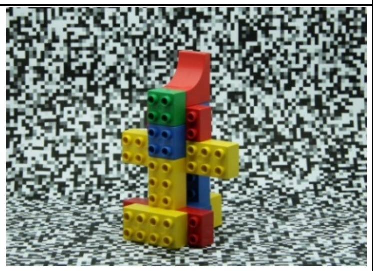
Name	**Material**	**Brief Description**	**Sample Image**
Macbeth ColorChecker™ *MCC*	Paper	The Macbeth ColorChecker™ is a calibration chart composed by 24 squares of painted samples. The material has a diffusive reflection.	
Toy *Shuttle*	Plastic	A model recreated with plastic toy bricks of different colours. The object has in most of its parts straight edges, with a curved surface on the top. The type of plastic is moderately shiny.	

Table 3: Objects used in the database.

LDR setup characteristics

For LDR scenes, we have used an acquisition setup similar to the one used in the first version of the database. In a completely dark room, we have placed a box with dimensions of 60.5 cm × 60.5 cm × 50 cm made of plywood, and internally white. On the ceiling of the box it was possible to place the light sources.

The backgrounds (see section *Backgrounds*) are placed so that they are curved between the back wall and the bottom, in order to have a continuous transition between the two orthogonal walls.

In Figure 5 it is shown the setup of the scene: the box, an object inside, one of the backgrounds, and the camera and the colorimeter placed side by side.

As in the previous database, also in YACCD2 we have shot considering two geometries of illumination for each light source: a diffuse illumination and a partially occluded one with a shadow covering part of the scene.

Figure 5: Acquisition devices and setup.

The diffuse illumination setup was achieved placing a diffuser panel between the light source and the subject, while for the second setup a half-panel was used instead of the diffuser panel, with the aim of creating a shadow on a side of the box. In Figure 6 an example of these two setups are shown. In Fig A1-A4 as shown in the appendix, the Toy Shuttle object is shown, under all the illuminants, using both the chosen backgrounds and both the illumination setups.

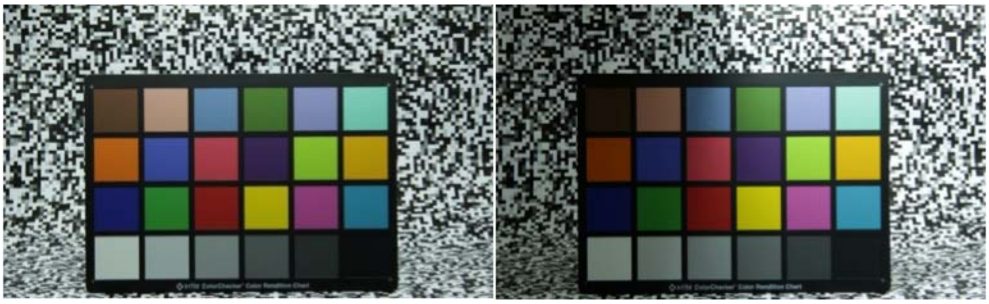


Figure 6: On the left: diffuse lighting, on the right: introduction of a shadow covering half of the scene.

HDR setup characteristics

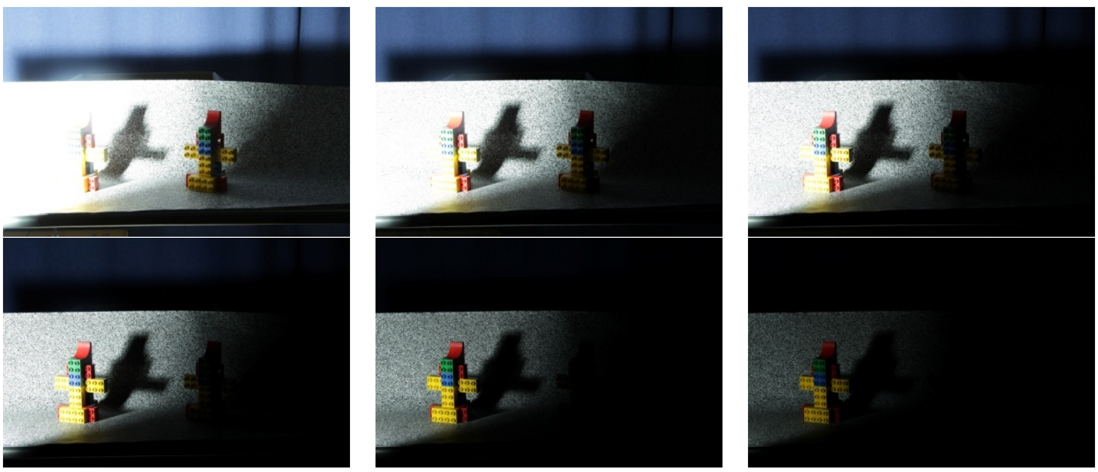


Figure 7: Six shots at increasing exposure values of one of the HDR scenes with two Shuttle objects.

The HDR scenes have not been taken in the light booth, and the diffuse panel or the half-panel for the shadows configuration were not used.

We have utilised two copies of MCC or Shuttle subjects, placed on table side by side, on the backgrounds placed in the same curved way as in the LDR scenes.

We have used the three illuminants in a directional spotlight placed on the left of the scene, and pointed towards the left object, leaving the right one in the shadow, as visible in Figure 7.

For each combination of light sources/objects/backgrounds seven bracketing shots at 1 EV increasing exposure values were taken in order to cover the full dynamic range of the scene.

The camera and the colorimeter were placed in the same way as in the LDR scenes.

Conclusions

In this article we have presented a renewed version of an image database to test colour constancy and other imaging algorithms related with colour and human vision. In this newer version we have added high dynamic luminance range images, RAW formats and accurate colorimetric data of the shots.

We are proposing this IDB also for testing different kind of algorithms based on other aspects of human vision, like e.g. perceived contrast and lightness [30], or image enhancement techniques.

Acknowledgement

The authors would like to thank Renato Figini and Roberto Pelanda from Konica Minolta Sensing Italian Branch for providing the devices used for this research.

References

1. Rizzi A, Gatta C and Marini D (2003), YACCD: Yet another color constancy database, *Proceedings of Color Imaging VIII, IS&T/SPIE's International Symposium on Electronic Imaging*, **5008**, 24-35.
2. YACCD database website (2012), [http://eidomatica.di.unimi.it/index.php/research/idb/yaccd – last accessed November 2012].
3. Rizzi A, Bonanomi C, Gadia D and Riopi G (2013), YACCD2: yet another color constancy database updated, *Proceedings of Color Imaging XVIII, IS&T/SPIE's International Symposium on Electronic Imaging*, **86520A**.
4. Rizzi A, Bonanomi C, Gadia D and Riopi G (2013), YACCD2: an image database to test color constancy and color appearance algorithms, *Proceedings of the 9th Colour Conference of GdC – Associazione Italiana Colore*, **IXB**, 40-47.
5. Funt B, Barnard K and Martin L (1998), Is machine colour constancy good enough?, *Proceedings of ECCV98*, 445.
6. Finlayson G, Hordley S and Hubel P (2001), Color by correlation: a simple, unifying framework for color constancy, *IEEE Trans. on Pattern Analysis Machine Intelligence*, **23** (11), 1209-1221.
7. McCann JJ (2004), Mechanism of color constancy, *Proceedings of the IS&T/SID's 12th Color Imaging Conference*, 29-36.
8. McCann JJ (2005), Do humans discount the illuminant?, *Proceedings of Human Vision and Electronic Imaging, IS&T/SPIE's International Symposium on Electronic Imaging,* **5666,** 9-16.
9. McCann JJ (2006), Measuring constancy of contrast targets in different luminances in complex scenes, *Proceedings of IS&T/SID's 14th Color Imaging Conference*, 297-303.

10. McCann JJ (2007), Aperture and object mode appearances in images, *Proceedings of Human Vision and Electronic Imaging, IS&T/SPIE's International Symposium on Electronic Imaging,* **6492**.
11. McCann JJ and Rizzi A (2011), *The Art and Science of HDR Imaging*, John Wiley & Sons.
12. Image database website (2012a), [http://www.cs.sfu.ca/~colour/data/ – last accessed November 2012].
13. Image database website (2012b), [http://web.media.mit.edu/~wad/color/exp1/new/ – last accessed November 2012].
14. Image database website (2012c), [http://color.psych.upenn.edu/hyperspectral/ – last accessed November 2012].
15. Image database website (2012d), [http://www.ee.oulu.fi/research/imag/color/pbfd.html – last accessed November 2012].
16. Marszalec E, Martinkauppi B, Soriano M and Pietikäinen M (2000), A physics-based face database for color research, *Journal of Electronic Imaging,* **9** (1), 32-38.
17. Image database website (2012e), [http://www.eecs.harvard.edu/~ayanc/oldcc/dbs.html – last accessed November 2012].
18. Chakrabarti A, Hirakawa K and Zickler T (2010), Computational color constancy with spatial correlations, *Technical Report TR-09-10, Harvard School of Engineering & Applied Science.*
19. Image database website (2012f), [http://people.kyb.tuebingen.mpg.de/pgehler/colour/index.html#publication – last accessed November 2012].
20. Gehler PV, Rother C, Blake A, Minka T and Sharp T (2008), Bayesian color constancy revisited, *Proceedings of 2008 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR)*, 1-8.
21. Image database website (2012g), [http://www.cvc.uab.es/color_calibration/database.html – last accessed November 2012].
22. Parraga CA, Baldrich R and Vanrell M (2010), Accurate Mapping of Natural Scenes Radiance to Cone Activation Space: A New Image Dataset, *Proceedings of IS&T CGIV 2010/MCS'10 - 5th European Conference on Colour in Graphics, Imaging, and Vision - 12th International Symposium on Multispectral Colour Science*, 50-57.
23. Image database website (2012h), [http://www.psy.ritsumei.ac.jp/~akitaoka/colorconstancy2e.html – last accessed November 2012].
24. Image database website (2014a), [http://research.edm.uhasselt.be/~oancuti/Underwater_CVPR_2012/ – last accessed January 2014].
25. Ancuti C, Ancuti CO, Haber T and Bekaert P (2012), Enhancing underwater images and video by fusion, *Proceedings of 2012 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR),* 81-88.
26. Image database website (2014b), [http://faculties.sbu.ac.ir/~moghaddam/index.php/main/page/11 – last accessed January 2014].
27. Image database website (2014c), [http://www5.cs.fau.de/research/data/multi-illuminant-dataset/ – last accessed January 2014].
28. Bleier M, Riess C, Beigpour S, Eibenberger E, Angelopoulou E, Tröger T and Kaup A (2011), Color constancy and non-uniform iIllumination: can existing algorithms work?, *IEEE Color and Photometry in Computer Vision Workshop*.
29. Image database website (2012i), [http://www.uef.fi/spectral/spectral-image-database – last accessed November 2012].
30. McCann JJ and Rizzi A (2003), The spatial properties of contrast, *Proceedings of the IS&T/SID's 11th Color Imaging Conference*, 51-58.

Appendix

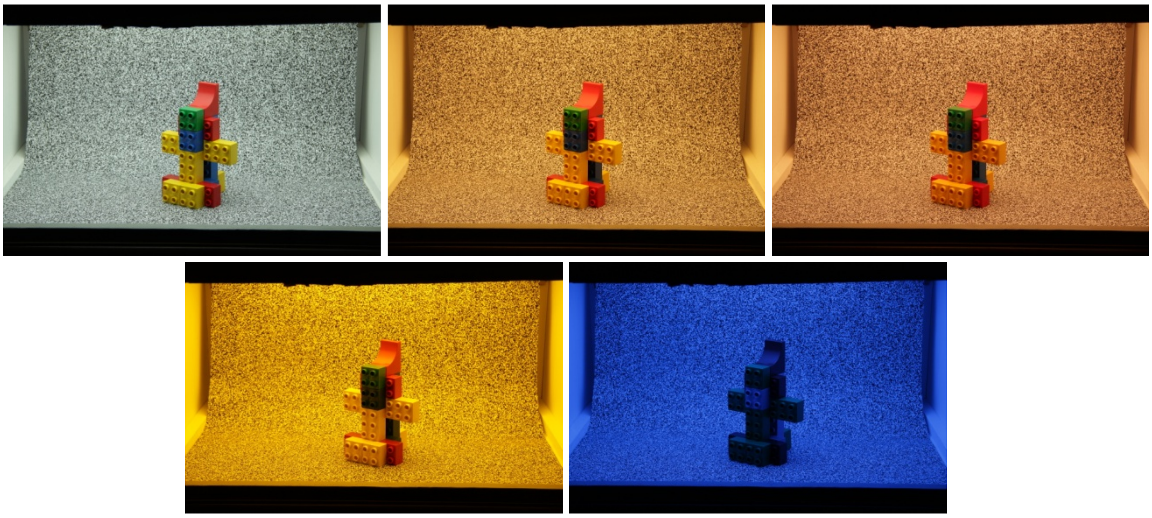


Figure A1: Toy Shuttle under the selected illuminants. High frequency background, diffuse lighting.

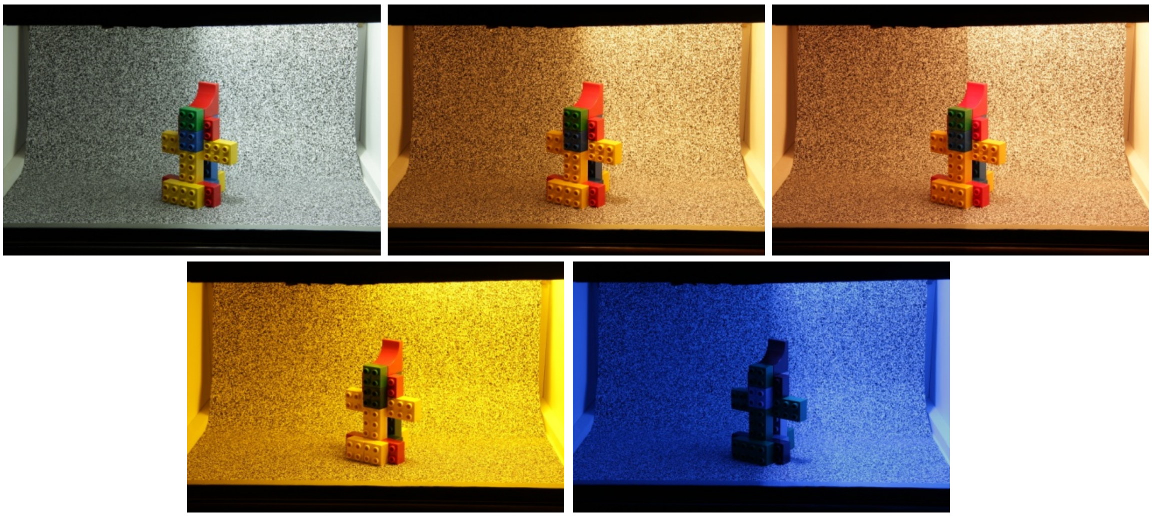


Figure A2: Toy Shuttle under the selected illuminants. High frequency background, with shadows.

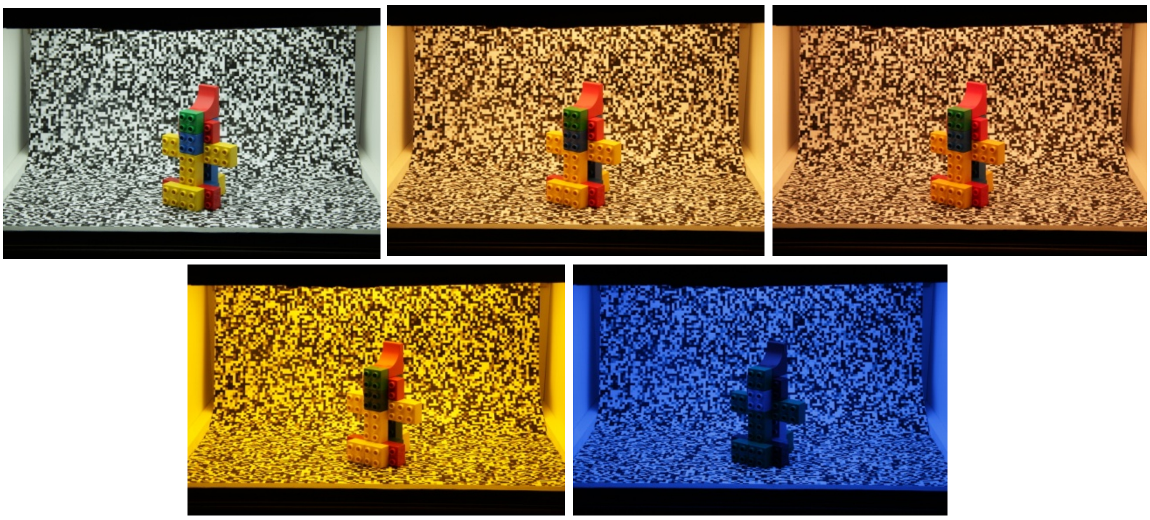


Figure A3: Toy Shuttle under the selected illuminants. Low frequency background, diffuse lighting.

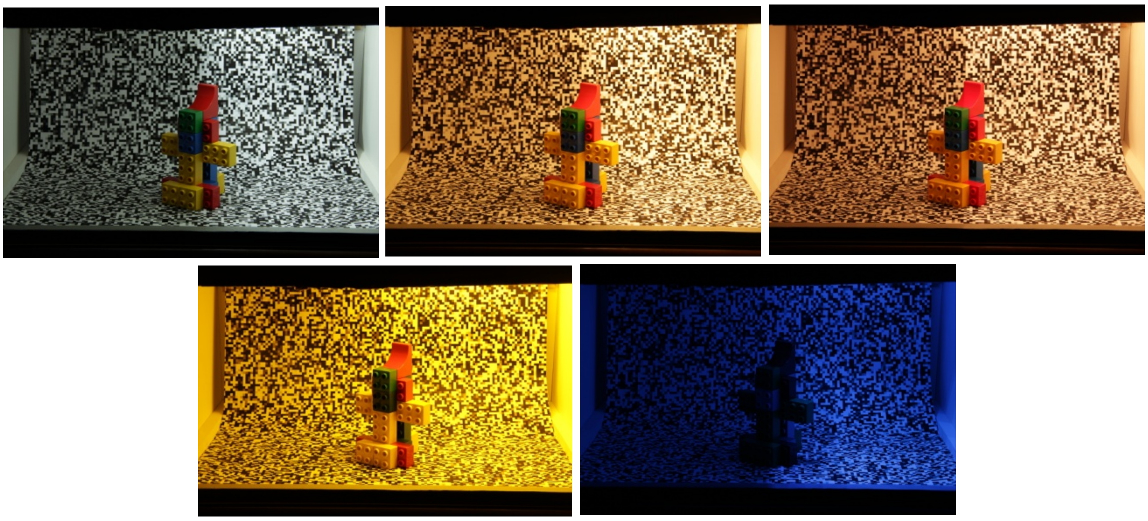


Figure A4: Toy Shuttle under the selected illuminants. Low frequency background, with shadows.