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Calibration of Camera for Light Quality Measurements of Low-Power Lamps

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Abstract

Environmental concerns and power efficiency point to increased use of power efficient lamps. Different manufacturers and price targets produce a wide range of light outputs, varying in intensity and spectral distribution. This type of apparatus also presents a non-linear load to the electric power supply, introducing some problems that should be taken in consideration and corrected as much as possible.

To be able to measure light quality, we propose a technique that uses a conventional digital photographic camera and a set of colour-reference reflective cards. By analysis of the obtained images, a colour quality index can be computed and used to compare different type of lamps. The calibration of the set-up is crucial for the approach and some problems need to be solved for the reliability of the method.

Keywords: Illumination, Low power lamps, Light quality evaluation.

1. Introduction

Different types of low power lamps are brought to the market in response to a consumer awareness of the benefits of lower power consumption, both in monetary and environmental costs. Lamp prices vary according to luminous output, light quality, type of fixture and manufacturer.

Nowadays we can find apparently similar lamps, from different manufacturers, promising comparable light outputs with big power savings compared to the traditional

We propose a simple method to measure light intensity and quality recurring to a simple standard digital photographic camera and a few colour reference cards.

The main problem of using a normal digital camera is the calibration procedure. The output images are obtained using a non-linear response, known as the Gamma-Law, and with some heavy data processing schemes that are proprietary of the camera manufacturers, being the details unavailable.

In this paper we present a preliminary calibration method that is being tested to measure the light quality and, with some refinements, to measure in the same system, the luminous output of the lamps.

In a parallel approach, we are also analysing the electrical load characteristics of the lamps, measuring not only the electrical power consumption but also the harmonic contents of the current.

2. The setup

The approach uses the digital images of a color reference card (Fig.1), taken with a common digital camera.

This reference chart was constructed in a digital image processing program, drawing the squares in uniform color and using as reference the values published for some photographic standard professional color reference charts. From this image we produced several prints, using a commercial photofinishing shop.

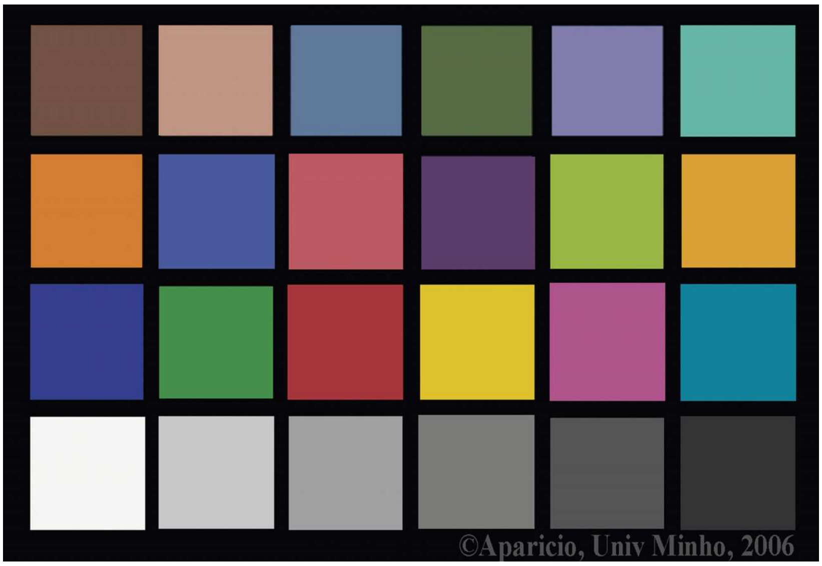

Fig.1 – Color Reference Chart.

The card, illuminated by the lamp under test at a controlled distance, is photographed with a standard camera, using the ‘daylight’ settings.

From the images, we used the standard digital image processing program to obtain an average values for the three components R-G-B for the six grey regions at the bottom of the colour chart.

TABLE I – MEASUREMENTS IN 2 IMAGES, DAYLIGHT.

	spot 1			spot 2			spot 3			spot 4			spot 5			spot 6		
#	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B
1	217	223	209	199	206	190	169	174	167	135	138	129	97	98	93	53	58	54
6	235	238	227	222	225	216	192	195	184	151	154	143	110	112	109	65	67	64

The numeric values in Table I are not linearly related to the light intensities. This relationship is translated by the Gamma-law, a power function (1) where *u* is the voltage value, converted to the numeric value for the digital image

$$u = k \cdot i^{\gamma} . \tag{1}$$

The exponent, usually referred as γ, is a constant with normal value of 0.45. This relationship was established in early CRT television applications, where the image intensity output was found to relate to the voltage control by a similar Gamma-law, with the inverse coefficient value of 2.2. Applying the 0.45 pre-correction to the voltage signal, a practically linear image reconstruction was achieved.

This relationship has been maintained since, with several adjustments for specific cases, producing a non-linear relationship, several times not accounted for and with direct consequences on the studied results [1].

A second problem arise when the adjustments of the limit value conditions (minimum and maximum values) are not precisely met, introducing variations in the transfer function, but that are usually accepted in image terms.

This problem was already found in the images of the chart, where the neutral grey squares do not present the same evolution for the three components (Table II).

TABLE II – GAMMA CORRECTED MEASUREMENTS

	spot 1			spot 2			spot 3			spot 4			spot 5			spot 6		
#	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B
1	0.85	0.88	0.82	0.78	0.81	0.75	0.66	0.68	0.66	0.53	0.54	0.51	0.38	0.38	0.37	0.21	0.23	0.21
6	0.92	0.93	0.89	0.87	0.88	0.85	0.75	0.77	0.72	0.59	0.60	0.56	0.43	0.44	0.43	0.26	0.26	0.25

We are still testing several alternatives to correct this situation.

The use of several images (only #1 and #6 are presented in the tables) with different exposures was intended to allow to study the gamma-law implemented on the particular camera sample we used.

5. Conclusions

This work is at the first stage (camera calibration methods), but we already found some results that were unexpected: we got a better approximation using different *gamma* values for the colour channels. Using 2.5, 2.2 and 2.45 for, respectively, *red*, *green* and *blue* we obtained a better linear fitting. This was discovered for one of the cameras and in daylight illumination. We are testing the consistency of this result for that particular camera and checking if the other cameras present similar behaviours.

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