Color rendering and museum lighting
Field study based on the refurbishing the lighting of the Sistine Chapel

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Museum lighting got into a new phase of development with the use of LED-luminaires. LEDs provide “safe” light for the museum objects, as it contains no UV-radiation, and no IR-radiation. The description of color rendering is – however – still highly debated, thus lighting designers have trouble to find best LED sources for illuminating the artifacts, especially if it comes to the illumination of paintings [1,2,3].

We got the task within an EU project to specify LED spectra to illuminate the frescos within the Sistine Chapel in the Vatican, where Michelangelo’s Last Judgment can be seen[4].

Different color rendering and color preference calculations provide different results for a given light source spectral distribution (see e.g. [5]). For demanding color applications lighting designers often used a very high number of different colored LEDs and left it to the museum curators to decide on the most pleasing spectral distribution. Thus e.g. for the new illumination of the Mona Lisa in the Louvre a selection of 34 LEDs was used [6].

For paintings of historic importance not the most pleasing illumination should be selected, but an illumination as the painter had seen his piece of art under the illumination he/she had used to create the picture. For the Renaissance frescos this was certainly “Mediterranean” daylight. (There are anecdotes that Michelangelo painted parts of frescos under candle light, but certainly he selected his paints under daylight of high illuminance; no color discrimination – even for a master as Michelangelo – is possible under candle light.)

The use artificial light of the same color quality and illuminance as daylight is not possible, neither from the art protection nor the saving of energy point of view. The museum curators requested a 3000 K to 3500 K correlated color temperature illumination, as this was the standard all over the Vatican Museum.

As a possible solution we started from the most up-to-date color fidelity metric, the CRI2012[7]. This metric uses the CIE 10° color matching functions (CMFs), as they come nearer to reality as the 2° CMFs, CIECAM02 color appearance model [8], with its UCS extension for color difference calculations [9], a very special set of test samples [10] and an updated non-linear formula to transform color difference to fidelity indices.

Although this new formula seemed to describe LED light and tri-band fluorescent light color rendering better as the traditional methods [11], we had concerns it two points.
The test sample spectra were certainly very different from the fresco paint spectra, therefore first reflectance spectra were measured within the Sistine Chapel: A projector illuminated in the dark Chapel a small part of a fresco, and a luminance measuring spectroradiometer measured the reflected spectrum from a small part of the fresco, as sown in Figure 1.

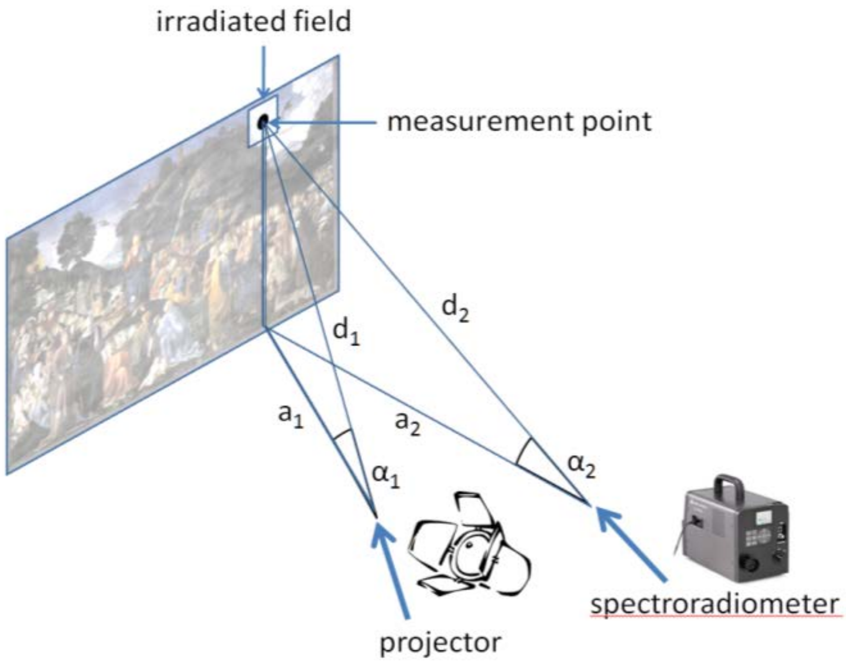

Figure 1. Measuring fresco reflectance with „non-touching” method.

More than 200 samples from frescos of different painters, representing typical complexion colors, leaf green, colored clothing, sky blue, etc. were measured and a data-base of reflectance spectra was built up.

Our second concern was how to bridge the 6500 K daylight and say 3500 K requested artificial lighting chromatic adaptation difference. Finally we concluded that one should use the built in chromatic adaptation correction of the CIECAM02 model, and look for the corresponding colors under 3500 K and lower illumination of the original colors seen on the frescos under daylight illumination.

A new "color fidelity for corresponding colors" computer program was built up, where – as further fine tuning – the cone fundamental based CMFs of CIE TC 1-36 are used that are still under consideration. The program optimizes the spectrum of a given number of LEDs to provide for the fresco colors the corresponding stimuli of the same pigments seen under daylight.

As in the Sistine Chapel a very high number of LEDs has to built in, we restricted the number of different LED types to four: a Warm White LED, a red, a green and a blue LED, and optimized the peak wavelength of the colored LEDs, and their relative intensity to get the corresponding colors correctly for a 30 cd/m^2 luminance (in the CIECAM02 program).

The installation of the LED lighting takes place in these days, and by the ISCC Conference we will be able to report on the outcome of the project.

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