# Chapter 56
# Color Acquisition, Management, Rendering, and Assessment in 3D Reality-Based Models Construction

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## ABSTRACT

*This chapter presents a framework and some solutions for color acquisition, management, rendering and assessment in Architectural Heritage (AH) 3D models construction from reality-based data. The aim is to illustrate easy, low-cost and rapid procedures that produce high visual accuracy of the image/model while being accessible to non-specialized users and unskilled operators, typically Heritage architects. The presented processing is developed in order to render reflectance properties with perceptual fidelity on many type of display and presents two main features: is based on an accurate color management system from acquisition to visualization and more accurate reflectance modeling; the color pipeline could be used inside well established 3D acquisition pipeline from laser scanner and/or photogrammetry. Besides it could be completely integrated in a Structure From Motion pipeline allowing simultaneous processing of color/shape data.*

## INTRODUCTION

In the field of Architectural Heritage (AH) analysis, conservation and management, color definition and reproduction is a key step, as demonstrated by the outstanding Henri Labrouste and Louis Duc drawings representing roman monuments, made in the years 1825-1830 (Gaiani, 2012) and as shown by today many attempts to faithfully reproduce the color in urban planning documentation (Falzone, 2008).

To have a faithful color characterization and reproduction, in the restoration field, many techniques have been developed and today it is possible to refer to three approaches (Santopuoli & Seccia, 2008):

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- Sample transcription: this technique requires a suitable support on which reproduce the color. The results are highly dependent on the expertise and the visual observation ability of the examiner. The method is useful for cataloguing but, being completely subjective, it cannot be used for reproduction;
- Visual comparison with color atlas (i.e. the 'Munsell book of color'): also this technique is highly dependent on the expertise and the visual observation ability of the surveyor;
- Diffuse reflectance measurement with instruments such as colorimeters (given the chromaticity CIE L*a*b* coordinates of the color), spectrophotometers (which, in addition, provide the curve of the diffuse reflectance as a wavelength function) or telephotometers (which output the same data of spectrophotometers, but with the ability to operate at relevant distances from the sample). These are the most accurate, simple and flexible tools available today. They provide excellent control of reflectance and color, but, covering a small area, in case of non-uniform color (almost always), they still require countless readings.

These techniques, beyond the ability of the operator, are unable to ensure a right color checking on a wide surface, and with a non-uniform color, that is the typical condition of AH (Apollonio et al., 2011).

Furthermore, they aren't able neither to exploit extensively digital media and digital techniques, nor to ensure the correct perception of a AH artifact color on a RGB display (i.e. LCD displays or DLP video projectors), nor to ensure its faithful reproduction on a printed support.

Conversely, the color characterization and reproduction using digital images is a powerful solution.

The problem of an accurate color description and reproduction using images could today be depicted as the problem to faithfully determine the color and tone level and can be solved by the chromatic and tonal definition (Reinhard et al., 2008).

The fidelity of color reproduction depends on a number of variables such as the lighting level during the acquisition step, the technical characteristics of the acquisition system, and the mathematical representation of color information throughout the acquisition and reproduction pipeline.

In particular, the values of a color in an image are the result of the interaction of the incident illumination, the object geometry, the object reflectance and the camera transfer function.

In general, the solution of this problem requires understanding and controlling environmental and artificial light sources over the measurement set. When illumination is reliably known, parameters for a surface reflectance function can be estimated using the image values (Lensch et al., 2003).

AH artifacts implies outdoor environments, where natural light characteristics are extremely complex and changeable; scenes are characterized by many elements belonging to different planes, curved surfaces reacting to light in several ways; we match with a wide range of materials characterized by different values of light reflection, porosity, transparency, etc. Therefore we cannot design a basis set of lighting conditions. For this reason the color capture and reproduction of masonry faces, historical architectural handmade and monumental-historical buildings, is a very complex issue.

These difficulties increase when the problem of chromatic and tonal definition and reproduction is addressed in the context of 3D reality-based models construction and visualization (Allen et al., 2004).

3D models from captured data are today an established technique for Architectural Heritage (AH) research, documentation, dissemination (Scopigno et al., 2011) and a faithful color capture and visualization is becoming more and more important with the growth of Structure from Motion (SFM) 3D capture techniques (Tomasi & Kanade, 1992), that integrate shape and color capture in an unique solution. In this case, illumination is not corrected at all, and the apparent color value is mapped onto the