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title: Photography and Other Imaging Techniques for the Visualization of a Sculpture

subtitle:

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abstract: This chapter aims to provide specialists and nonspecialists with insight into a range of photography and 3D modeling techniques for the study of bronze sculpture. Nonspecialists—those who find themselves in situations where professional photographers cannot be present—will find general guidance regarding production of high-quality images and what results can be expected. Advantages and drawbacks of available methods are discussed, including relative capability, costs, and time considerations when possible and relevant.

short\_title: Imaging Techniques

This chapter aims to provide specialists and nonspecialists with insight into a range of photography and 3D modeling techniques for the study of %%bronze%% sculpture. Nonspecialists—those who find themselves in situations where professional photographers cannot be present—will find general guidance regarding production of high-quality images and what results can be expected. Advantages and drawbacks of available methods are discussed, including relative capability, costs, and time considerations when possible and relevant. For a synthesis, see **table 13**.

This chapter provides, by necessity, only abbreviated and general guidelines. For detailed guidance on best practice for photographic documentation of cultural heritage, including image and metadata management, see {Warda 2011}, {Pozeilov 2015}, and other references cited below.

## 1 Visible-light photography: most common techniques

### 1.1 Lighting a bronze sculpture

Many bronze sculptures have reflective or glossy surfaces (**fig. 293**), and particularly in these cases, a uniform and diffuse light will help minimize specular reflection. Diffuse lighting means that light is directed at the subject from large-area sources, usually accomplished by use of reflection umbrellas or diffuser screens in front of the light sources or by using flat-panel LED arrays. Normal flash photography, which involves a single small light source near the camera, is usually undesirable. Normally, at least two light sources are recommended. For documentary photography, shadows should not be too “hard” and there should be even more light than for catalogue or commercial images, where dramatic lighting is often preferred.[[1]](#endnote-1)

Use lights that are designed for photography and have a high color rendering index (CRI). For documentary photography, use only one type of illumination source at a time; if light sources of different color temperatures are used (such as window light in combination with photo lamps), the color rendition may be significantly different on different parts of the subject. Always include a standard color scale bar and a tripod with the camera set on “aperture priority.” Selection of a high f-stop will significantly improve sharpness and depth of field, but will require longer exposures, which in turn necessitates a tripod.

Particularly with dark sculpture, the dynamic range (the difference in luminance between the darkest and lightest areas) cannot be captured in one exposure. In such cases multiple, “bracketed” images of different exposures should be captured. High dynamic range (HDR) algorithms can composite different exposures into a single image, but always retain the original files.

### 1.2 Raking-light photography

For the documentation of fine surface topography such as tool marks and evidence of wear, raking-light photography may be useful. Here, instead of diffuse lighting, a single, strongly directional light source is positioned at a very low angle to the surface, typically around 10 degrees. This arrangement causes minor irregularities in surface topography to cast shadows, making them easier to perceive. Altering the direction of the light source can reveal different features on any given surface. Raking light can be useful for standard photography, macro photography, and even photomicrography (see [II.2§2.1](#II.2§2.1) below).

### 1.3 Macro photography

In most circumstances, close-up or macro photography will be necessary to resolve details of technical interest. Specialized macro lenses, which are designed to minimize distortion, are preferred for this purpose. The closer-up the image is, the smaller the depth of field will be, and thus the greater importance of using a high f-stop. In situations where it is desirable to hold the camera by hand, dedicated macro flash units, such as lens-mounted ring flash units, can provide sufficient diffuse or directional light for high speed *and* high f-stop macro imaging. In situations where a high f-stop is insufficient to capture the desired depth of field, it is possible to take a series of photographs on a tripod, at successive points of focus, and use so-called focus stacking software to reconstruct a single fully focused image (this function is available in Photoshop under Edit: Auto Blend Layers).

### 1.4 Image quality and resolution

The quality of images produced will depend on both the resolution of the camera’s sensor (**fig. 369**) and the quality of the lenses used. For this reason, a professional quality digital SLR (D-SLR) camera is recommended. As of the year 2020, a typical D-SLR may be equipped with a 5200 × 3500 pixel (18 megapixel) sensor, which will capture a one-meter-high statue with a vertical resolution of 52 pixels/cm, corresponding to a pixel size of 0.2 mm on the statue. Professional medium-format cameras with 100+ megapixel sensors can be of great benefit, but are cost prohibitive for many labs.

### 1.5 Time required to properly photograph a bronze

The time required to photograph a bronze sculpture in a professional studio can vary dramatically depending on the nature of the object and the number of details required. The simple documentation of six low-gloss statuettes via four or five general views of each might take two and a half days: half a day for the setup, one day for the photographs, and one day for post-processing. On the other hand, the full documentation of a single large, dark, and glossy bronze with numerous details may take more than six days: half a day for the setup, two days for capturing images (which will require several lenses), and four days for post-processing.[[2]](#endnote-2)

## 2 Visible light photography: less common techniques

### 2.1 Photomicrography

The imaging of surface features smaller than one millimeter (polishing marks, details of tool marks, small inclusions, porosities, excrescences) may require higher magnification than macro photography, namely photomicrography. Traditional stereomicroscopes installed on articulated arms are very useful for this purpose, and these can be fitted with cameras for image capture.

High-quality, so-called digital microscopes (without eyepieces) offer additional capabilities and are increasingly widely used for technical examination of bronze sculpture. Most importantly, these microscopes usually incorporate automated focus stacking procedures that overcome the shallow depth of field inherent to photomicrography. Because the focus adjustments are precisely controlled by stepper motors, the microscope’s software can reconstruct a scaled 3D %%model%% of the field of view. Such topographic reconstructions can be useful for documenting, characterizing, and comparing fine features such as tool marks (**figs. 273, 285, 286,** [Case Study 4](#CaseStudy4)). With this type of 3D model, the sources of errors for precise calculations are numerous and measurements should therefore be considered with caution. Digital microscopes often have polarizers incorporated that can greatly reduce specular reflection, and some can be adapted for use with ultraviolet illumination.

If extremely fine, high-precision topographic measurements are required, a method called microtopography may be useful. Various techniques are available, with resolutions as small as 0.1 µm. This technique is expensive, slow, and can be generally be used only on samples smaller than 20 cm across.[[3]](#endnote-3)

There are also a wide range of low-cost handheld digital microscopes available with a variety of magnification ranges that can be tethered directly to a laptop computer. Some models are equipped with ultraviolet and/or polarized light sources. While the image quality is generally not as good as more expensive laboratory- and research-grade equipment, they may be adequate for routine examination.

### 2.2 Endoscopy

Endoscopes (alternately called borescopes) are common tools for those studying the techniques of bronze sculpture. They are rigid or flexible tubes with a lens at one end and some optical or digital means to transmit an image through the lens to an eyepiece, camera, or digital sensor. In most cases, a light source is incorporated into the endoscope’s tip. They can be used to examine the interior of a hollow sculpture by inserting the boroscope into the base (or any aperture) (**figs. 38, 370**). Image quality tends to be low, and images generated by a boroscope tend to be difficult to interpret because there is no external frame of reference, so careful attention to image annotation and captioning is critical. Recording video with audio narrative can also be an effective method of documentation.

The cost of endoscopes can vary tremendously. Models produced for industry or the medical field that have articulated heads (whose direction can be controlled from the exterior) and software that enables making measurements may be priced in the tens of thousands of US dollars, while simple USB models are available for less than one hundred US dollars.

### 2.3 Reflectance transformation imaging

An extension of raking-light photography is reflectance transformation imaging (RTI), which can be of great utility in documenting and visualizing fine surface topography as well as color and gloss. In this method, both the object and the camera are fixed; only the point light source (typically a flash unit) moves. A large number of photographs are taken of the object (usually between twenty-four and one hundred) as the light source is systematically moved all around the object (**fig. 371**). A reflective sphere is placed into the frame of each image and the position of the specular reflection of the light source on the surface of the sphere is used to calculate the direction of the light source.The software for compositing and viewing RTI images is open-source and free, making the technique readily accessible (**fig. 241**). Several mathematical image enhancement features are available that allow interactive relighting and enhancement of color and surface shape attributes.[[4]](#endnote-4)

## 3 Imaging with nonvisible light

### 3.1 Ultraviolet fluorescence photography

Organic materials such as varnish, pigments, glue, resins, and a variety of restoration material may fluoresce visible light when exposed to (invisible) ultraviolet light (UV). Photography of UV-induced visible fluorescence (often misleadingly called UV photography for short) may thus prove useful to visualize such materials on the surface of a sculpture (**fig. 191**). The method may be used in conjunction with macro photography and photomicrography.

Several types of UV light source are available, including LEDs, fluorescent tubes, and arc lamps. Generally, lamps emitting at 365 nm with minimal visible light emission are preferred. Standard digital cameras can be used for UV fluorescence photography, but require special filters in front of the lens to block UV and infrared (IR) transmission to the camera’s sensor. For details see {Pozeilov 2015}.

*Risks of misidentification/misinterpretation*

Although some materials emit important and specific color under UV, a variety of heterogeneous materials may emit similar fluorescence. Moreover, fluorescence is also affected by long-term light exposure and thermal aging. As a consequence, fluorescence does not generally allow for precise material characterization. Once fluorescent materials are localized by UV examination and photography, complementary analysis may be required to identify the materials present (see [II.5](#II.5)).

Additionally, organic %%coatings%% may be present even if little or no fluorescence is detected. Over time, copper ions may migrate into organic coatings, and this can cause dramatic quenching of fluorescence. In addition, some organic materials possibly present on bronze sculpture, including many synthetic resins, do not fluoresce.

### 3.2 Thermography and infrared (IR) photography

Repair %%patches%%, %%inlays%%, and other discontinuous areas of a bronze are often thermally isolated from their surrounding regions. When the surface is heated, for example by the sun or a tungsten lamp, the heat will be kept longer there, dissipating more slowly than on the surrounding large surfaces. IR thermography (IRT) typically uses a camera sensitive to long-wave IR light (about 9,000–14,000 nm) to image heat transfer and buildup on an object’s surface. The thermograms thus obtained have been used on bronze sculpture to investigate and map %%defects%%, mechanical and %%cast-on repairs%%, as well as inlays.[[5]](#endnote-5) Thermography in the mid-IR (about 3000–5000 nm) has also been applied to cultural heritage.[[6]](#endnote-6) Imaging in the near-IR (about 700–10.1 µm) or short-wave IR (1100–2500 nm), commonly used on many other types of artwork, is generally of limited utility in the examination of bronze sculpture.

## 4 Color measurement

Color measurement has been used on occasion for research related to bronze sculpture, either to evaluate conservation treatment methods,[[7]](#endnote-7) to characterize the color of different alloys,[[8]](#endnote-8) or to characterize the color of %%patinas%%.[[9]](#endnote-9) Most of these applications have been made in the context of experimental simulation (see [II.9§1.2](#II.9§1.2)) where sample size, uniformity, and geometry can be controlled.[[10]](#endnote-10)

A colorimeter or spectrophotometer may be used to measure color. These instruments illuminate a sample area under controlled conditions and measure the light reflected by the object. Colorimeters use filters to measure the amount of red, green, and blue light reflected from the sample, while spectrophotometers generate a detailed spectrum of the reflected light. In both cases, the resulting color measurements are normally made using the CIELab color space, defined by three variables, L\*, a\*, and b\*, as defined by the Commission Internationale de l’Éclairage (CIE) (**fig. 372**).[[11]](#endnote-11) Color measurement instruments commonly used for museum objects are usually handheld and cost anywhere from several hundred to several thousand US dollars.

Color measurement of bronze patinas can also be accomplished using visual matching to standard color swatches such as Munsell soil color charts as described in {Devogelaere 2017}.[[12]](#endnote-12)

*Risks of misidentification/misinterpretation*

The science behind color generation, color perception, and color measurement is complex. This is particularly true in the context of bronze sculpture because the color of bare metal is generated through a completely different physical mechanism than the color of patinas and oxidation layers.[[13]](#endnote-13) Bronze sculpture is thus much impacted by goniochromism—that is, the change of color with the angle of the observer.[[14]](#endnote-14) Where patinas (either organic, inorganic, or mixed) are not entirely opaque, meaningful and reproducible color measurement by any method may be difficult to achieve.

Color measurement is theoretically possible with digital photography following a color calibration protocol. However, in practice, color measurement of bronze sculpture with photography is extremely challenging. In addition to the difficulties mentioned above, accurate color measurement requires that the light falling on the measured area be the same color and intensity as the light falling on the calibration reference card. This poses a practical problem with three-dimensional sculpture, since any change in the angle of the surface, as well as local inconsistencies in intensity or color temperature of the lighting, can affect the measured color.

## 5 Photogrammetry and 3D scanning

Photogrammetry and 3D scanning can produce three-dimensional renderings of objects useful for documentation and dissemination of information on the appearance of a sculpture. There are currently three main techniques available: photogrammetry, structured light scanning, and laser scanning. These can be combined in various ways to produce mixed models. All of these technologies are developing rapidly, and costs for both hardware and software are falling. In addition to recording appearance, these methods can also be useful for physical measurement; this latter aspect of their use is addressed in [II.4§2.2.2](#II.4§2.2.2) and [II.4§2.3.4](#II.4§2.3.4). All of these methods require specialized knowledge and training, though photogrammetry is probably the easiest to learn and has the additional advantage of not requiring specialized hardware.

### 5.1 Photogrammetry

In photogrammetry, many photographs are taken of the subject from different angles and a 3D model is derived from a computational analysis of the individual images using dedicated software (**fig. 373**). Most photogrammetric work done in cultural heritage has been carried out with professional-grade D-SLR cameras, though it is also possible to build very high resolution models using medium-format cameras that record images of 100 megapixels and higher. Applications for smartphones are also now also available at very low resolution.

Depending on the quality and resolution of the source images, photogrammetry can provide a quite high-fidelity model of a bronze sculpture with good color accuracy, particularly if the photography is done in a studio with controlled lighting. These images can be useful for both public and scholarly audiences, providing the opportunity for high-quality web-based interactive viewing. Photogrammetry can also be carried out using UV and IR photography.[[15]](#endnote-15) Photogrammetry is being used more and more for bronze sculpture, notably to design models (**fig. 374**) and mounts (**fig. 375**), or to test reassembly of fragmentary statues. Large-scale bronzes can be captured using scanners mounted to drones.[[16]](#endnote-16)

### 5.2 Structured light scanners

Structured light scanners shine a regular pattern of light (usually a series of parallel lines) onto an object and then record an image of the pattern with a camera that is offset from the projection source. Software then analyzes the apparent distortion of the light patterns by the three-dimensional surface and generates a computer model of the form. Most structured light scanners also record standard photographic images of the subject using onboard flash lighting, which alternates at high speed with structured light pulses.

The lenses and sensors used in structured light scanners are generally of lower quality than a professional D-SLR, and lighting and color management are often a challenge. As a result, structured light scans often yield a final model that is less realistic and detailed in appearance than a photogrammetric model (**figs. 376, 377**), though the dimensional accuracy may be as good or superior. It may thus be used for precise measurements (**fig. 378,** see [II.4§2.2.2](#II.4§2.2.2)).

### 5.3 Laser scanners

Most laser scanners used in cultural heritage employ a rapidly rotating mirror to deflect a visible or invisible laser beam in a pattern that sweeps across the subject. The scanner integrates a range finder that accurately measures the distance to each of the millions of points that the beam traces, building up a high-resolution 3D model of the form. Often multiple scans from different vantage points are combined to produce the final model (**fig. 379**). Most laser scanners integrate cameras to provide “texture,” or photographic detail, that can be overlaid onto the 3D model (**figs. 380, 381**). However, as with structured light scanning, the relatively low quality of the cameras used can result in models that are less realistic and detailed in appearance than a good photogrammetric scan.

## Notes

1. Yosi A. Pozeilov recommends that the main light point toward the object at an angle of 50–60 degrees. The second lamp should be at 35–45 degrees. For this and other pointers, see {Pozeilov 2015}, 88. [↑](#endnote-ref-1)
2. These data were kindly provided by two photographers at the C2RMF, Anne Maigret and Alexis Komenda. [↑](#endnote-ref-2)
3. {Mélard et al. 2016}; {Page et al. 2016}. [↑](#endnote-ref-3)
4. {Dellepiane et al. 2006}. Free software and viewers can be downloaded from the Cultural Heritage Imaging website: <http://culturalheritageimaging.org/><http://culturalheritageimaging.org/Technologies/RTI/>. [↑](#endnote-ref-4)
5. {Mercuri et al. 2018, 2017}; {Orazi et al. 2016}. Different profiles, and consequently techniques of mechanical repairs, are detectable on the *Capitoline Wolf* ({Mercuri et al. 2017}). [↑](#endnote-ref-5)
6. See {Gavrilov, Maev, and Almond 2014}. [↑](#endnote-ref-6)
7. {Heginbotham, Beltran et al. 2014}; {Letardi et al. 2016}. [↑](#endnote-ref-7)
8. {Devogelaere 2017}; {Mödlinger et al. 2017}; {Radivojević et al. 2018}. [↑](#endnote-ref-8)
9. {Benzonelli, Freestone, and Martinón-Torres 2017}; {Formigli 2013a}. [↑](#endnote-ref-9)
10. {Letardi et al. 2016} carried out direct measurements on statues. {Devogelaere 2017} focused on ancient bronzes but working on experimental coupons. See also {Formigli 2013a}. [↑](#endnote-ref-10)
11. For an accessible synthesis of color science in the context of cultural heritage see {Berns 2016}. For more in-depth scientific insights see {Hunt and Pointer 2011} and {Johnston-Feller 2001}. And for a deep dive into color models and their application see {Fairchild 2013}. [↑](#endnote-ref-11)
12. {Devogelaere 2017}; {Munsell Color 2000}. [↑](#endnote-ref-12)
13. {Nassau 1987}. [↑](#endnote-ref-13)
14. The term was first proposed in {McCamy 1996}. [↑](#endnote-ref-14)
15. {Lanteri, Agresti, and Pelosi 2019}. [↑](#endnote-ref-15)
16. For more, see

    <http://culturalheritageimaging.org/Technologies/Photogrammetry/>. [↑](#endnote-ref-16)