Using Maya® to Create a Virtual Museum

Brittany D. Cox and Roy S. Berns; Studio for Scientific Imaging and Archiving of Cultural Heritage; Program of Color Science, Rochester Institute of Technology, New York/USA

Abstract

Access to museum artifacts has greatly expanded through virtual museums. There are several approaches to creating this experience. One is to collect many images from many viewpoints of both the artwork and environment. The second is to use computer graphics (CG) to create a virtual space, in which are placed artwork, defined by their shape, color, macrostructure, and microstructure. The second approach was tested using the CG software, Maya® with the mental ray plug-in. Physical measurements of the artwork's shape, diffuse color, and macrostructure via surface normal were measured using equipment common to an imaging studio: a digital camera and strobes. Microstructure was defined within the CG software. This approach was tested on a painting in the style of Vincent van Gogh. The painting was rendered in a variety of ways: photo-realistically, with a picture varnish applied, and as a colored metal. Lighting was either a typical studio set up or raking light. Details are given to produce such renderings using studio equipment and Maya® for virtual gallery applications.

Introduction

From a college art history class to a connoisseur, groups and individuals view digital images of fine art when it is infeasible to visit a museum or gallery. Artwork can be viewed as static images, static images with interactive pan and zoom, or within a virtual museum where either many static images are combined, or through the use of computer graphics (CG) software. For static images or combined static images, there is a single camera-lighting geometry. Any texture and gloss information depends on the skill of the photographer and the specific imaging system. If such information is inadequate in the static images, reshooting is required. When CG is used to create a virtual museum experience, the camera-lighting geometry is defined during rendering. This can result in static images where the visibility of an artwork's color, texture, and gloss is at an optimal balance. CG can also be used to create a virtual museum where the viewer is changing their position relative to the lit artwork as a way to experience artwork remotely.

Rendering realistic images of two-dimensional fine art requires information about diffuse color, macrostructure defined by a surface normal or height map, and microstructure defined by a bidirectional reflection distribution function (BRDF). All three of these characteristics can be calculated or measured in different ways. Color can be captured using the Dual-RGB technique [1, 2] to estimate spectral reflectance or by using a variety of other spectral or standard imaging techniques [2]. Macrostructure, when defined by a surface normal map, a map of a surface's relative topography, can be calculated using photometric stereo [3] or reflectance transformation imaging (RTI) [4]. Both are image based and as such, are much less expensive than instrumentation used to directly measure height. Although a height map is more accurate, visual experiments have shown that a surface normal map is an adequate substitution [5]. Microstructure, or BRDF, is measured and modeled using a variety of techniques, with a preference for image-based techniques [6]. Although it is beneficial to know the BRDF of an object, it is not necessary when using CG. The software is generally capable of approximating the way light will react when it comes in contact with the surface without knowing its specific BRDF. (The limitation is when the artwork has appreciable spatially varying microstructure.)

One of the most popular commercial products for producing CG renderings is the software Maya® with the mental ray plug-in, here after referred to as Maya. This publication describes how a museum-imaging studio setup coupled with Maya can produce renderings of fine art with texture and gloss information under multiple simulated lighting configurations.

Experimental

Artwork intended for use in a virtual rendering was imaged using a simplified four-light method, 4LI-S [7, 8]. In this method, four images are taken with four different lighting directions combined with a threshold-based averaging technique and photometric stereo to acquire diffuse color information (sometimes called the diffuse albedo) and a surface normal map. The lighting setup is shown in Figure 1 with each of the four different lights circled. There is a light positioned to the top, left, right, and bottom at approximately 45° from the center of the imaging area of interest and approximately equidistant from each other around an annulus.

Figure 1. Lighting setup using four different strobes for illuminating objects from four different directions. The lights are positioned to the top, bottom, left and right of target area. This image was taken at the Museum of Modern Art, Queens, as part of an imaging demonstration.

This setup was used to take images at each lighting direction of a diffuse white background, a color calibration target, the artwork of interest, and a glossy black cue ball, resulting in 16 total images. These images were used to flat field, color correct, define lighting direction, and perform the photometric stereo technique [8] proposed by Woodham in 1980 to calculate surface normal [3]. Woodham's photometric technique is based on the observation that a reflectance map is capable of incorporating reflectance from a surface, the geometry in which an object is imaged, e.g. lighting direction, and the illumination of a scene into a function of surface orientation in terms of image intensity, or pixel intensity [3].

Previous research performed by Berns *et al.* utilized this lighting configuration and imaging sequence and also incorporated polarizers in front of each light and camera. The use of cross polarization satisfied the requirement of a Lambertian surface for the photometric stereo technique but, unfortunately, also resulted in blurry images [7, 9]. To improve image quality and simplify the imaging process, the polarizers were replaced with a mathematical thresholding technique to computationally remove highlights from each of the four images [7 – 9]. This thresholding technique compares individual pixel values to a scalar of the average of four pixel values excluding the maximum. In other words, if a pixel value is a given percentage higher than the average, excluding the maximum of all four pixels, then it is considered a highlight.

Pixel data that were not associated with a highlight were used to calculate a normal map. The diffuse color map was calculated as an average without the maximum of all four images of the painting following flat fielding and color correction. The resulting diffuse and normal map images for a painting in the style of Vincent van Gogh are shown in Figure 2. As a diffuse image, macrostructure is not readily seen. The normal map contains macrostructure information. The resulting diffuse color and surface-normal maps were combined in Maya and then rendered with a user supplied lighting and viewing combination, as well as surface material attribute settings. The workspace, where a painting is illuminated from above with a directional light and from below with a low intensity and wide angle fill light created from Maya's spotlight option, is shown in Figure 3.

Maya is an animation, modeling, simulation, and rendering software that includes a general-purpose renderer called mental ray. Mental ray uses rendering techniques such as a scanline rendering algorithm and binary space partitioning algorithms to render ray-tracing effects. Mental ray supports physically correct simulation of general global illumination and is capable of simulating combinations of diffuse, glossy, and specular reflection and transmission [10].

Maya uses multiple shaders, or shading groups, that specify how a surface reacts to light. A shading group is a collection of information about material, texture, and lighting that is used to accurately shade or render an object or scene [11]. Some of these shaders allow geometric features like bump and displacements maps to create an illusion of surface relief. These shaders provide parameters that can be manipulated to adjust material properties, ambient lighting, diffuse and specular color, and reflectivity [10]. Some of the material shaders include Blinn, Phong, Lambert, and Phong E. The Blinn surface shader has been selected for use in the rendering of the images presented here because although the Phong shader is recommended for glossy plastic looking materials and the Blinn shader is recommended for metallic looking surfaces, Blinn is recommended for use with bump and displacement maps because it will produce less noise or artifacts in the highlights than the Phong shader [12].

Figure 2. Diffuse color (left) and normal (right) images of a van Gogh style painting resulting from the simplified four-light method.
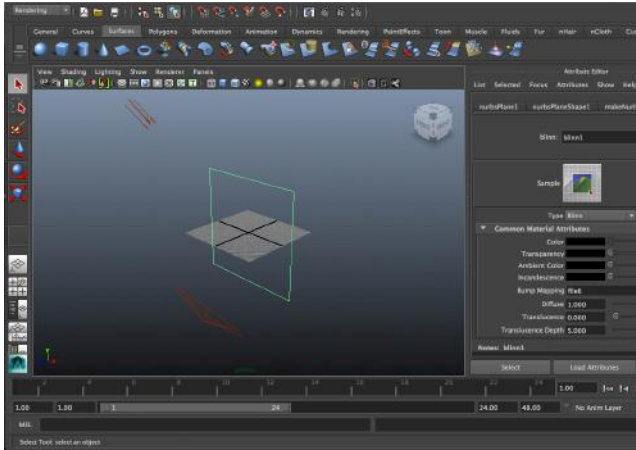
Figure 3. *Maya® workspace showing a painting illuminated with two different lights, a directional light from above and a diffuse fill light from below.*

This shader allows control of the size of highlights and how the surface reflects its surroundings. This is done by adjusting the values for Eccentricity and Specular Roll Off, respectively [12]. The Blinn shader also has parameters that are common to many of the other surface shaders. These parameters include Specular Color, Diffuse, and Reflectivity [13, 14].

The Specular Color parameter represents the color of highlights on the surface of an object. Reflectivity represents an object's ability to reflect its surroundings where a value of 0 represents no reflections and 1 represents clear reflections. For example a value of 1 would be used for chrome or mirror materials. Diffuse represents a value that determines the object's ability to reflect light. The higher the Diffuse value the closer to the (user defined) surface color the object will appear. A value of 0 will result in no light being reflected. These are only a few of the parameters that can be manipulated as part of the Blinn shader.

Results

The rendered image shown in Figure 4 (left) was rendered with user defined parameter settings starting with the default settings for the Blinn shader. These parameters were adjusted until the rendered images appropriately emphasized the glossy nature of the painting. The parameters that were changed were Diffuse, Eccentricity, Specular Roll Off, Specular Color, and Reflectivity. These parameters were changed to 1, 0, 0, White, and 0 respectively. Parameter settings are given in Table 1.

To display what varying the lighting would produce without changing any physical parameters of the painting, a series of close ups are shown in Figure 5 with the lighting direction changing from top left, to top center, to top far right. The shadows cast from each different lighting configuration change accordingly as evident in these images. Maya is capable of rendering images with an endless combination of lighting configurations from just a diffuse color map, normal map, and appropriate shader or shaders.
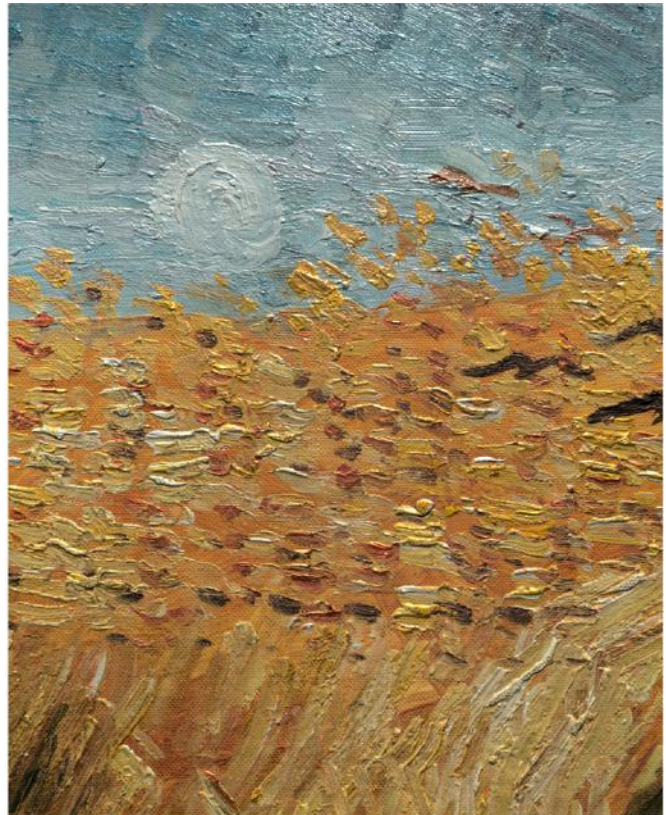

Figure 4. *Rendered images of the painting using Maya to simulate directional lighting from above and fill lighting from below with its matte, existing varnish (left) and simulated picture varnish (right).*
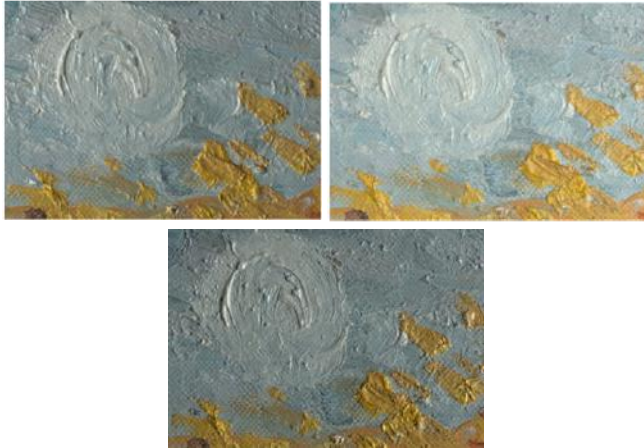
Figure 5. Rendered image of a close up section of a painting with directional lighting coming from top left (top left), top center (top right), and top right (bottom) generated using Maya® and mental ray.

Images were re-rendered to simulate the addition of a glossy picture varnish across the surface of the painting. The glossier rendering was obtained by adjusting the parameter values for Eccentricity from 0.000 to 0.152, Specular Roll Off from 0.000 to 0.545, and Reflectivity from 0.000 to 0.400. The varnish-simulated image is shown in Figure 4 (right). The "varnished" painting exhibits larger and more pronounced highlights compared to the original rendering, which are most noticeable in the top portion of the painting due to the proximity of the overhead lighting.

Not only is this CG rendering process capable of changing material properties to simulate a matte or glossy surface, it is also capable of rendering images with different lighting configurations to achieve effects similar to raking light imaging.

By changing the configuration of lighting shown in Figure 3 to include more grazing angle illumination with high intensity light coming from above the painting and two low intensity fill lights to provide ambient lighting, a rendering with a similar appearance to raking lighting is achieved. This rendering is shown in Figure 6 (left). More pronounced shadowing occurs with this type of lighting than in the previous renderings.

Specular enhancement renderings are also possible with this CG rendering process. By using similar lighting to that of raking lighting and by changing a few key parameters, a metal-like appearance is achieved. The benefit of these types of renderings is emphasizing the painting's surface shape [15]. The parameters that are changed are the same parameters that were changed to make the painting appear varnished.

The Diffuse value was changed to 0.4 to reduce the effect of the surface color on the rendering. Eccentricity was changed to 0.3, to increase the size of the highlights. Specular Roll Off was changed to 1, to increase how well the surface reflects the light in the scene; and Reflectivity was changed to 0.3 to increase the painting's overall reflectivity. A rendering of the specular-enhanced painting is shown in Figure 6 (right). A list of parameters and their settings for each rendering is shown in Table 1.
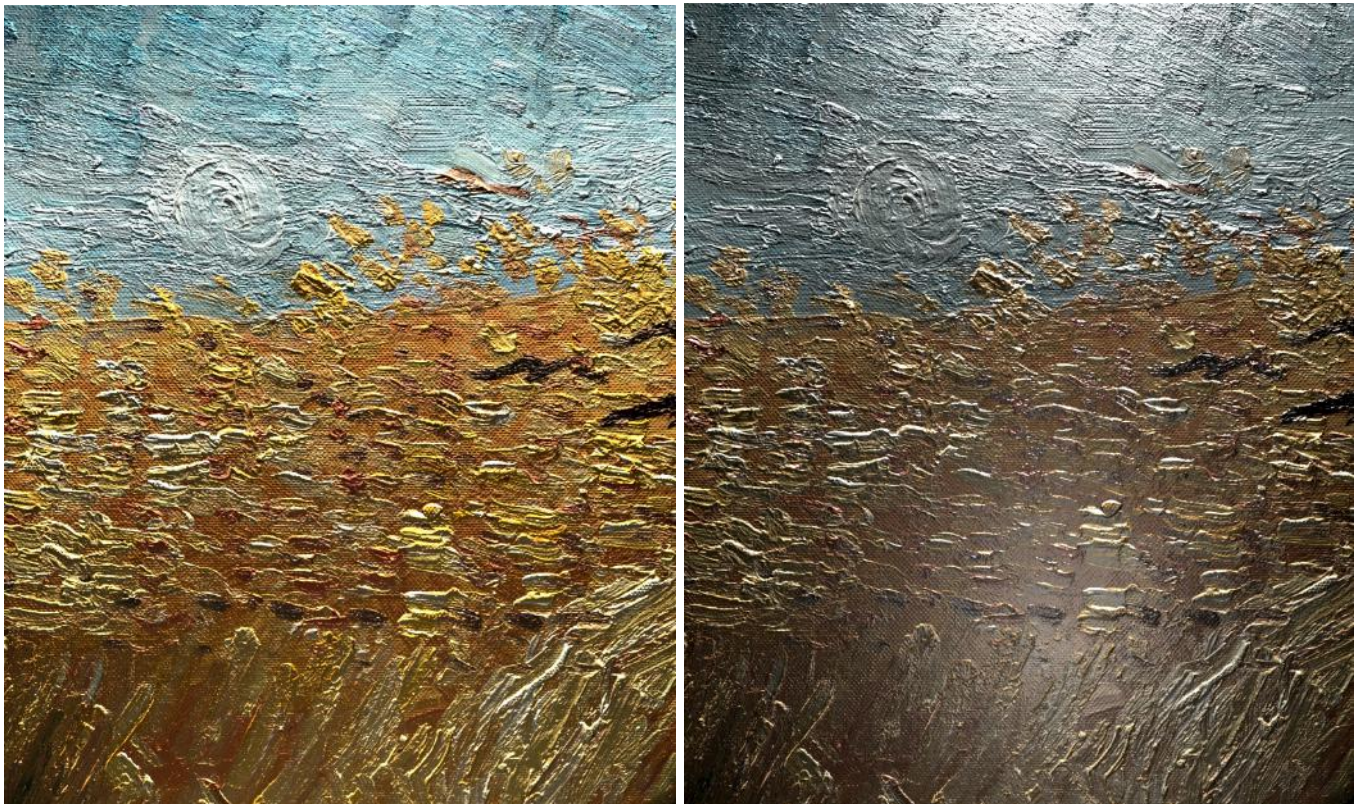

Figure 6. Rendered image of a painting with simulated raking light (left) and specular enhancement (right).

Table 1. Blinn Shader Parameter Settings for each rendering.

Parameter	Matte Painting	Glossy Painting	Specularly Enhanced
Diffuse	1	1	0.3
Eccentricity	0	0.152	0.3
Specular Roll Off	0	0.545	1
Specular Color	White	White	White
Reflectivity	0	0.4	0.3

Conclusion

Maya[®] and mental ray were used to generate images of a painting from a static lighting direction, with a lighting direction that moves across the surface of the painting, and with raking light. These rendered images accentuate the texture in the painting in addition to emphasizing the reflective properties by showing how the moving light changes the areas that are highlighted or in shadow without having to reshoot the primary images.

This CG rendering process and software combination was also used to simulate changes in surface properties from a matte surface to a glossier and even metallic-like surface. By selectively changing a few parameters surface material properties were changed without affecting the surface texture defined by the painting's normal map.

The rendered images and outlined procedure demonstrate how Maya[®] and mental ray can be used to display paintings of different, uniform gloss levels for a virtual gallery with a variable light source. The location, angle, and type of lighting can be altered to accentuate different surface properties of a painting in accordance with each museum or institution's lighting preferences considered. The images generated are capable of showing impasto, highlights, and shadows that correspond and react to the lighting chosen for each rendering. Multiple images with varying lighting directions can also be rendered and combined to produce a short video of how light interacts with the surface of the painting as an added feature to the virtual gallery.

References

[1] Y. Zhao, L. Taplin, and M. Nezamabadi, "Using the Matrix R method for spectral image archives," in *Tenth Congress of the International Colour Association*, 2005, pp. 469–472.

[2] R. S. Berns, L. A. Taplin, M. Nezamabadi, M. Mohammadi, and Y. Zhao, "Spectral imaging using a commercial colour-filter array digital camera," *14th Trienn. ICOM-CC Meet.*, vol. II, pp. 743–750, 2005.

[3] R. J. Woodham, "Photometric Method for detemining surface orientation from multiple images," *Opt. Eng.*, vol. 19, no. 1, pp. 139–144, 1980.

[4] T. Malzbender, D. Gelb, and H. Wolters, "Polynomial texture maps," in *SIGGRAPH 2001 Conference proceedings*, 2001, pp. 519–528.

[5] L. Chen, "Systems Evaluation for Computer Graphics Rendering of the Total Appearance of Paintings," M.S. Thesis, Rochester Institute of Technology, 2013.

[6] G. J. Ward, "Measuring and modeling anisotropic reflection," *ACM SIGGRAPH Comput. Graph.*, vol. 26, no. July, pp. 265–272, 1992.

[7] R. S. Berns, T. Chen, D. R. Wyble, and L. Chen, "Updated practical total appearance imaging of paintings," Technical Report Rochester Institute of Technology, art-si.org, 2012.

[8] B. D. Cox and R. S. Berns, "Imaging artwork in a studio environment for computer graphics rendering," *Proc. SPIE* 9398, *Meas. Model. Reprod. Mater. Appear.* 2015.

[9] R. S. Berns and T. Chen, "Practical total appearance imaging of paintings," in *IS&T Archiving Conference, Copenhagen, Denmark*, pp. 162–167.

[10] Autodesk Inc., "mental ray Manual," *Autodesk Help File for mental ray*, 2013. [Online]. Available: http://docs.autodesk.com/MENTALRAY/2014/ENU/mental-ray-help/. [Accessed: 06-Oct-2014].

[11] Autodesk Inc., "Maya User Guide: About shading networks," 2015. [Online]. Available: http://download.autodesk.com/global/docs/maya2014/en_us/index.html?url=files/Asts_About_shading_networks.htm,topicNumber=d30e615884. [Accessed: 19-Mar-2015].

[12] Autodesk Inc., "Blinn," *Maya User's Guide*, 2015. [Online]. Available: http://download.autodesk.com/global/docs/maya2014/en_us/index.html?url=files/Shading_Nodes_Blinn.htm,topicNumber=d30e636070. [Accessed: 11-Mar-2015].

[13] Autodesk Inc., "Common surface material attributes," *Maya User's Guide*, 2015. [Online]. Available: http://download.autodesk.com/global/docs/maya2014/en_us/index.html?url=files/Shading_Nodes_Blinn.htm,topicNumber=d30e636070.

[14] Autodesk Inc., "Common surface material Specular Shading attributes," *Maya User's Guide*, 2015. [Online]. Available: http://download.autodesk.com/global/docs/maya2014/en_us/index.html?url=files/Shading_Nodes_Blinn.htm,topicNumber=d30e636070. [Accessed: 11-Mar-2015].

[15] Cultural Heritage Imaging, "Reflectance Transformation Imaging: Guide to RTIViewer1," 2013. [Online]. Available: http://culturalheritageimaging.org/What_We_Offer/Downloads/rtiviewer/RTIViewer_Guide_v1_1.pdf.

Author Biography

Brittany D. Cox is a Ph. D. student at Rochester Institute of Technology where she is currently pursuing her degree in Color Science.

Roy S. Berns holds the Richard S. Hunter Professorship in Color Science, Appearance, and Technology at Rochester Institute of Technology (RIT). He has directed the Munsell Color Science Laboratory and graduate programs in Color Science at RIT. He is the director of the Andrew W. Mellon sponsored Studio for Scientific Imaging and Archiving of Cultural Heritage. Berns is an IS&T Fellow with lifetime achievement awards from the International Association of Colour, the U.S. Inter-Society Color Council, and the Colour Group of Great Britain.