Dynamic Paintings: Real-Time Interactive Artworks in Web

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Abstract
In this work, we present an approach to creating dynamic paintings that can be re-rendered interactively in real-time on the web. Using this approach, any existing painting can be turned into an interactive web-based dynamic artwork. Our interactive system provides most global illumination effects such as reflection, refraction, shadow, and subsurface scattering by processing images. In our system, the scene is defined only by a set of images. These include (1) A shape image, (2) two diffuse images, (3) one background image, (4) one foreground image, and (5) one transparency image. A shape image is either a normal map or height. Two diffuse images are usually hand-painted. They are interpolated using illumination information. The transparency image is used to define the transparent and reflective regions that can reflect the foreground image and refract the background image, both of which are also hand-drawn. This framework that mainly uses hand-drawn images provides qualitatively convincing painterly global illumination effects such as reflection and refraction. We also include parameters to provide additional artistic controls. For instance, using our piece-wise linear Fresnel function it is possible to control the ratio of reflection and refraction. This system is a result of a long line of research contributions. On the other hand, the art-directed Fresnel function that provides physically plausible compositing of reflection and refraction with artistic control is completely new. The art-directed warping equations that provide qualitatively convincing refraction and reflection effects with linearized artistic control are also new. You can try our web-based system for real-time interactive dynamic paintings at http://mock3d.tamu.edu/.

Keywords
Dynamic Paintings, Interactive Paintings, Web-Based Artistic Interfaces

Introduction and Motivation
Non-photorealistic rendering (NPR) has emerged as a subfield of computer graphics during 1990s to produce computer generated images that invoke the appearance of being created "by hand" [26, 10] by emulating broad artistic styles such as outlines and silhouettes [13], technical illustrations [11], pen and ink drawings [7, 20], impressionist [16] and cubist paintings [21, 25, 22], Chinese painting [3, 17], charcoals [19, 8], and stippling [18]; as well as artistic tools and mediums such as brush strokes [28, 30, 12, 15], watercolor [5]. Convolutional Neural Networks has turned out to be effective for style transfer [9, 24].

In recent years, there has also been growing interest to turn specific paintings into dynamic computer-generated images with moving lights and cameras. These paintings can have non-realistic components. For instance, Murphy developed a non-photorealistic approach for matching shapes and colors of the artwork of Disney background painter Eyvind Earle who uses non-realistic shadows [23]. "Atelier des Lumières" group developed large-scale video projections of many of Vincent van Gogh’s well-known works [6]. Liu created a 3D version of a Jiangnan water country painting by the contemporary Chinese artist Yang Ming-Yi as the primary visual reference [17]. Justice created dynamic time-lapse animations based on some of the works of Edgar Payne, using Barycentric shading as the core of his procedure [14] (see Figure 1a). Subramanian obtained painterly reflection, refraction, and caustics with a classical wine and glass still life painting [27] (see Figure 1a). Clifford created time-lapse animations of two of Anne Garney’s paintings for different times of the day [4].

Problem Definition
The main problem with these methods is that they are still based on the standard computer graphics pipeline. There is still need for a modeling and animation software such as Maya or Blender even if proxy geometry is simple. Moreover, there is also need for a shader software such as Arnold or Renderman even for expressive depiction. In this work, we propose a completely different pipeline. All information from shapes to materials is provided by images. Shapes are defined either by normal maps or depth maps. Shading parameters are also provided by a set of control images. Using these images we can obtain physically plausible local and global illumination with complete style control. There already exist solutions to obtain diffuse reflection, shadows, reflection, and refraction with a set of images [31, 29, 1, 2]. An example that shows how to diffuse rendering is computed is shown in Figure 2. More examples of illustrations or paintings that are obtained interactively in real-time using our web-based system are shown in Figures 3, 4, 5, 11, and ??.

In this work, we describe physically plausible yet stylistically expressive transparency. A real transparent layer must
Figure 1: Examples of previous works of dynamic paintings with dynamically changing shadows, reflections, and refractions using moving light sources. These images are not created in real-time. Although the methods allowed to create of such non-photorealistic results with complete control, the process is still based on a standard computer graphics pipeline that requires modeling and animation software to run the shader to obtain animations. These animations, therefore, still took a significant amount of time to render. In this work, by using a completely different pipeline, we can obtain real-time rendering with dynamically changing shadows, reflections, and refractions using moving light sources.
Figure 2: An example demonstrating the pipeline for diffuse rendering. $I_0$ and $I_1$ are the control images, $\Omega_0$ and $\Omega_1$, are weight images that satisfy the partition of unity. Here, we compute $\Omega_0$ from a shape image just using image processing. $I = I_0\Omega_0 + I_1\Omega_1$ is the final rendering obtained by taking a weighted average of the two control images.

Figure 3: Interactively created illustrations based on “Self-Portrait in Spherical Mirror”, a lithograph by Dutch artist M. C. Escher.

refract the background image and reflect the foreground image. Moreover, reflection and refraction must be combined by using the Fresnel equation, which provides a weighted average of reflection and refraction based on the incident angle. The inclusion of such a physically plausible transparency operation in digital compositing is very useful for the post-processing stage. Instead of re-rendering the whole scene, artists can simply control the Fresnel function to obtain desired effects. Such control can significantly improve the efficiency of the image synthesis process by moving some of the effects in 3D rendering to post-processing through digital compositing. It can also provide 2D artists to design physically plausible painterly refraction and reflection effects during image manipulation.

Art-Directed Fresnel Function

One of the key parts of our approach is an art-directed Fresnel function that can allow the physically plausible combination of reflections and refractions. Figure 6 demonstrates that it is possible to control results using a single slider with two parameters. The first parameter controls the incident angle position where we want to obtain total refraction and the second parameter control the incident angle position where we want an equal mix. An additional control allows changing Fresnel from total refraction to total reflection as shown in Figure 7.

Our Fresnel function starts with a piecewise linear approximation of the real-Fresnel function. This particular sequence is provided for a single index of refraction. We allow users to change the incident angle positions (i.e. $\sin\theta$) of two control points of this piecewise linear function, which turned out to be sufficient to obtain visually convincing Fresnel effects. The top row in Figure 6 shows painterly compositing effects. The middle row directly shows Fresnel control using a black background and white environment map, in which full black means full refraction and full white means full reflection. In this case, the bottle is simply a normal map image. Gray is a weighted average of reflection and refraction. The last row shows actual Fresnel functions, in which grey areas are not reached to be used.

Linearized Reflections & Refractions

We replace standard reflection and refraction effects with linearized transformations for art-directed intuitive control. These linearized transformations provide warping effects that are visually similar to 3D realistic rendering since they indirectly correspond to underlying physical phenomena of reflection and refraction.

Mock-3D Objects

We also replace transparent 3D objects with transparent images that to provide partial 3D information, which we call “mock-3D objects”. These images can be inserted into any digital paint system without any significant structural change. We visually demonstrate that it is possible to obtain qualita-
tively convincing reflection and refraction effects with a minimal amount of 3D information, such as normal as a vector field and thickness [31]. This 3D information, moreover, does not have to be complete or consistent for obtaining convincingly composites. The images that provide 3D information can directly be obtained through 3D rendering by harvesting normal and thickness information. More important for 2D artists, they can be directly sketched or painted based on artists’ intentions.

Conclusion

Our approach provides the ability for 2D artists to efficiently include refraction and refraction into their artworks and allow intuitive artistic control over visual results (See Figure 10). Using this approach, artists can create artificial, but still believable, versions of the original images as well as original artwork that can be dynamically manipulated. Our system is available for any artist to create dynamic artwork. The link to our web-based software is mock3d.tamu.edu. The system is developed using java-script and WebGL. The interfaces of our system for normal maps and depth maps are shown in Figures 8, and 9.

References

Figure 6: Our Fresnel function allows to combine reflection and refraction with an art directed control.

Figure 7: Additional Fresnel control: from total refraction to total reflection.
Figure 8: The interface of our web-based system for normal maps. See mock3D.tamu.edu/normalmap/index.html.

Figure 9: The interface of our web-based system for height maps. This one can provide shadows. See mock3D.tamu.edu/shadow/index.html.
Figure 10: Another example of vector field compositing demonstrates the effect of thickness in addition to a normal map. (a) shows reflection and refraction composited with our Fresnel function. (b) shows glossy reflection and translucent refraction combined with our Fresnel function. (c) directly shows Fresnel control with an index of refraction using a black background and white environment map.


Figure 11: Interactively created paintings based on “Atavistic Ruins after the Rain”, an oil painting by Salvador Dali in 1934. In this case, we used a depth map to model the scene. We changed the position and color of key light. Note subtle movement of shadows.


Figure 12: Interactively created paintings based on “The Persistence of Memory”, an oil painting by Salvador Dali in 1931. In this case, we used a depth map to model the scene. We changed the position and color of key light. Note subtle movement of shadows.