Dual-Layer Light Source with Textured Lighting Gel

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Abstract

We propose a new light source representation to intuitively model complicated lighting effects with simple user interactions. Our representation uses two layers; an emissive layer which is a traditional diffuse area light source with a constant emission, and a lighting gel layer which introduces variations to the emission. The lighting gel layer is mapped with a texture for colored shadows without modeling a 3D scene. The two layers are transformed inde- pendently to cast the texture with different effects. To cast lighting on a planar canvas in 2D design, the proposed light source can be created and edited in the 2D canvas directly, without switching to 3D world space.

Introduction

Vector graphics provide a powerful and flexible model for de- sign and are often characterised by clean lines and flat appearance. Recently, we see increased adoption of 3D effects by artists and de- signers who strive to add realistic 3D lighting into their 2D designs. Producing such effects manually requires significant effort and ex- pertise (e.g. here). Lighting design has always been an important problem in visual effects [Dorsey et al. 1991]. For this reason there has been lots of research into modelling the light field around the light sources such as [Ashdown 1995; Zhu et al. 2021].

We propose a dual-layer light source model (DLLS) which uses 2D images to cast patterns, enabling artists to create colored shad- ows. This DLLS model simplifies the interaction model for artists working in 2D graphic design applications avoiding the need for free viewpoint 3D scene navigation to position and add lighting.

Overview

Our work is inspired by light gels which are transparent colored films placed in front of mono-chrome lights to cast color patterns. DLLS has two layers, a light emitting layer and a gel layer. We let the emissive layer be a constant color diffuse emitter. The emission along a ray is determined by intersection with gel texture which is mapped with a specular-transmittance-only bidirectional transmittance distribution function (BTDF) [Walter et al. 2007].

$$L_{DLLS}(\mathbf{x}_e, \mathbf{x}_g) = L_e f_t(\mathbf{x}_g), \mathbf{x}_e \in \Omega_e \wedge \mathbf{x}_g \in \Omega_g,$$

where $\mathbf{x}_e$ and $\mathbf{x}_g$ are the positions on the domain of emissive layer Ω_e and gel layer Ω_g respectively, L_e is the constant out-going radiance from emissive layer, $f_t(\mathbf{x}_g)$ is the BTDF evaluated at the position $\mathbf{x}_g$ on the lighting gel layer. In our implementation we chose the emissive layer to be elliptically shaped enabling anisotropic lighting effects.

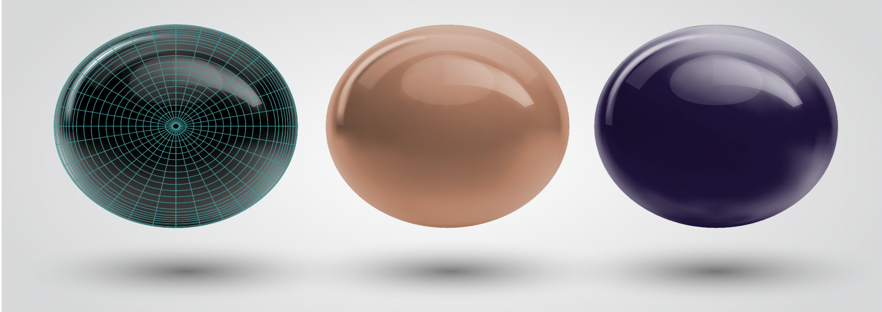


Figure 1 : Creating lighting effects using existing tools can be a slow and arduous process

The Scale of Emission

When the lighting effects such as shadow are changed, the irradiance on the canvas is supposed to be approximately unchanged. Therefore, we need to scale L_e appropriately. We approximate the irradiance at the center of texture on canvas excluding the factor of light gel layer

$$I\left([x_t, y_t, 0]^\top\right) \approx \hat{I}_c = L_e \frac{A_e {\alpha_s}^2}{(z_e/\alpha_s)^2} = \frac{\pi\,(1-\alpha_e)^2\,{\alpha_s}^4 k_a k_b}{{z_g}^2} L_e$$

where A_e is the area of emissive layer, $I\left([x_t, y_t, 0]^\top\right)$ is the irradiance on canvas at $[x_t, y_t, 0]^\top$, $\hat{I}_c$ is its approximation which we would like to keep constantly unchanged. Consequently, L_e has to be updated when any of α_s, α_e, k_a and k_b are changed,

$$L_e = \frac{\hat{I}_c {z_g}^2}{\pi\,(1-\alpha_e)^2\,{\alpha_s}^4 k_a k_b}.$$

Method

A 3D model (left-top) illuminated by a 2D gel texture (left-bottom) using Dual Layer Light Source representation.

Placement of Lighting Gel Texture

The texture used for creating DLLS is placed at position $[x_t, y_t, 0]$, and scaled to dimension $w_t \times h_t$. Both emissive layer and lighting gel layer are parallel to the canvas, and their normals are the same as the negative **z** axis, which is [0, 0, –1]. The emissive layer is degenerated to a point at $[x_t, y_t, +\infty]$. We place the lighting gel at a distance of $|z_g|$ from the canvas which is above the height of any 3D objects on the canvas.

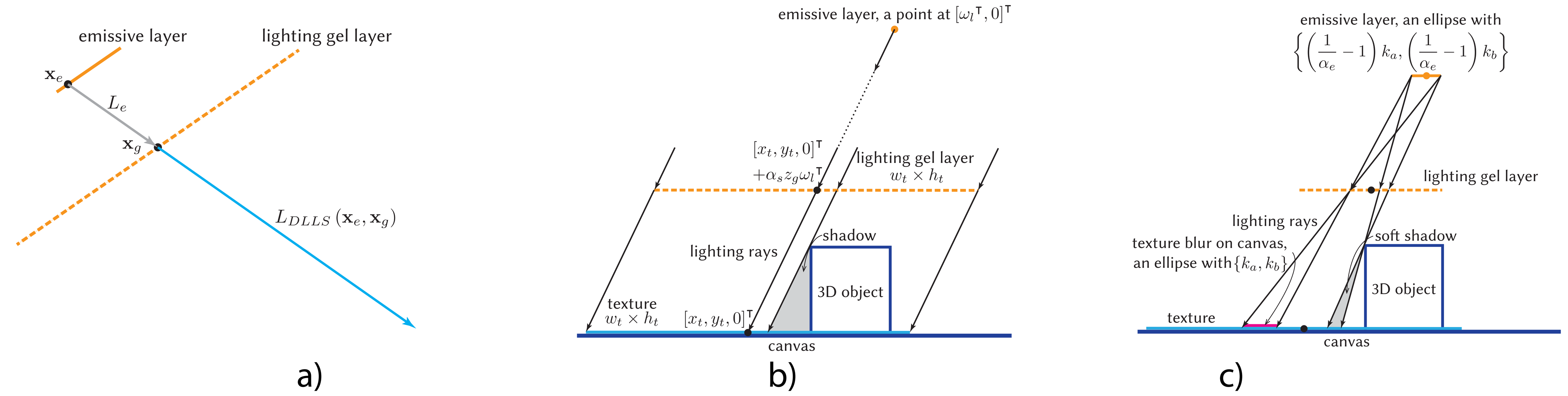


Figure 2: Scene configuration with DLSS (a) The emission of layer L_e is modulated by the lighting gel layer, providing the emission of the DLLS. (b) Shadow casting by changing the direction of lighting. (c) Anisotropic blur of lighting effects.

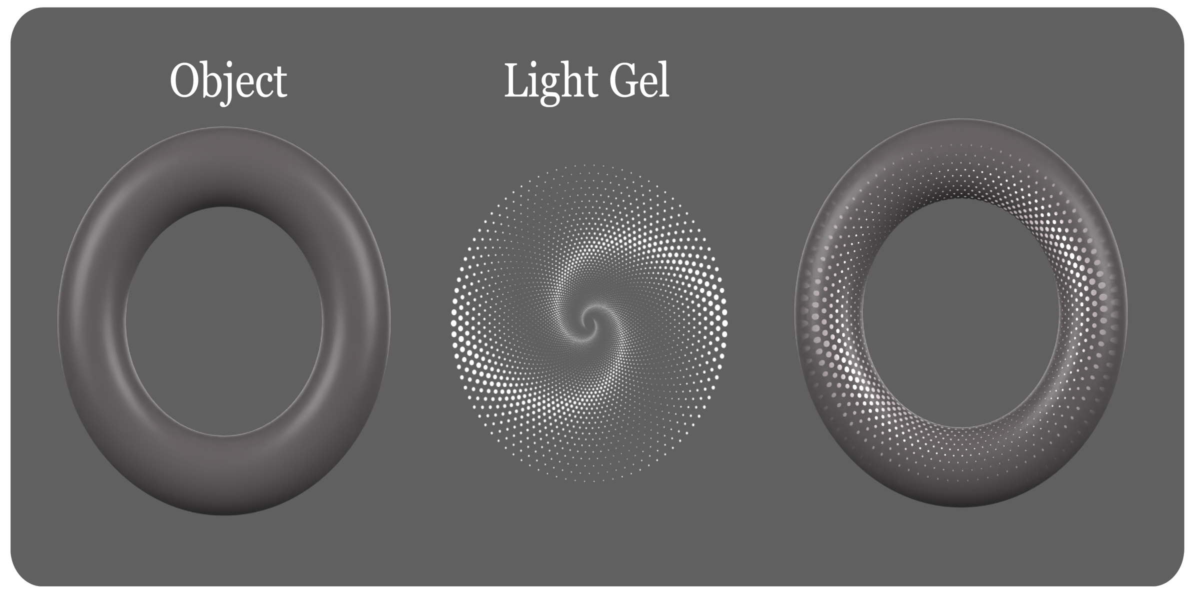
Shadow Direction and Length

The shadow is rendered by changing the direction from the lighting gel layer to the emissive layer.
The direction to cast shadow is , $[x_s, y_s]^\top, {x_s}^2 + {y_s}^2 = 1,$ and the parameter of shadow length is $\alpha_s \in (0, 1]$,which is the dot product of lighting direction and the normal of the canvas. Hence, the direction of lighting is $\omega_l = \left[-x_s\sqrt{1-{\alpha_s}^2}, -y_s\sqrt{1-{\alpha_s}^2}, \alpha_s\right]^\top$
The lighting gel layer is translated to $[x_t, y_t, 0]^\top + (z_g/\alpha_s)\,\omega_l{}^\top$,in which the z coordinate is kept same as z_g. The emissive layer is translated to $[\omega_l{}^\top, 0]^\top$, where we use a 4D homogeneous coordinates to represent an infinite position.

Anisotropic Blur

If the emissive layer is a point as defined previously, the pattern of incoming lighting on the canvas is determined by the lighting gel texture only. Nevertheless, the pattern can be blurred when the emissive layer is an ellipse with finite area. Users can use the blurriness to generate soft shadows without creating a pre-filtered lighting gel texture.
When the lighting direction is not perpendicular to the canvas, the amount of blur becomes anisotropic, which is generated with the major axis and minor axis of the emissive layer.
Given an anisotropic elliptical blur kernel on the canvas with semi-major axis of k_a and semi-minor axis of k_b , the emissive layer is with semi-major axis of $(1/\alpha_e - 1)\,k_a$ and semi-minor axis of $(1/\alpha_e - 1)\,k_b$

Results



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