A New Approach for Lighting Effect Rendering

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Abstract. We propose a new approach to render different lighting effects on an image. Artists often use different stylizations for different lighting effects in the same image. However, existing work just try to extract shadows without distinction of their type. We introduce a lighting map to describe the different lighting effects and propose six non-photorealistic rendering based on artistic styles ranging from Chiaroscuro to comics. Giving an input image, we are able to automatically generate a lighting map which may be modified by the user to specify the types of shadow or light effects. Our model is flexible and specifically designed to help users and even amateur users, to semi-automatically stylize the different kinds of light effects in an image. It is designed to be integrated into an image editing tool.

1 Introduction

Artists have always used the lighting effects they perceive to create their illustrations. The depiction of the lighting conveys a special mood to the scene that creates psychological effects. For example, a front light prevents depth perception or, as is often the case, oblique light at 45°, produces an impression of depth and "ideal" volume. A low angle light creates unreal volumes and is often used for special effects [1](see Figure 1). These effects have been widely used in different styles ranging from Chiaroscuro to comics.

In computer graphics, actual researches only focus on general light or shadow detection despite many different types of lights or shadows exist. Some researches and tools only detect shadow in a scene or in images. Scherzer et al. [2] propose to calculate a physically exact map on a 3D scene. They sample the light source over different frames creating a shadow map for each one. A combination of temporal coherence and a spacial filtering is used to correct and speedup the final map creation. Other work propose to detect shadow in videos or image sequences [3], [4], [5]. Some work propose to detect shadow from a single image [6]. It is based on retinex theory (enhancement and illumination compensation of the lightness). They also propose to remove shadow from the input image. Note that few studies are based on one image and that such detections are often computationally heavy and do not permit to distinguish particular effects produced by lighting.

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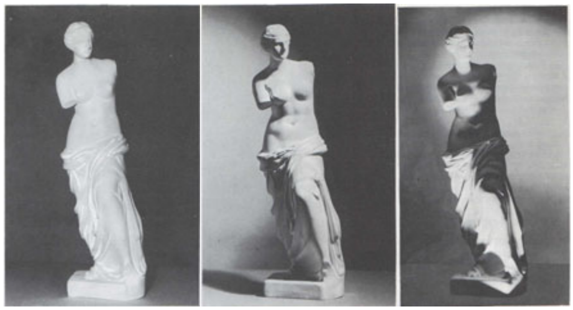

Fig. 1. Front light; oblique light and low angle light from [1]

After detecting shadow, one can stylize it. As mentioned by Stork [7], the knowledge of art historical problems is essential to create tools that can reproduce and extend traditional art. Most of existing tools or research for stylization are 3D-based or color-based. Existing 3D tools propose to vary the tone texture following the depth of the scene that supports level of abstraction, perspective or depth of field in toon shading [8]. Other work describes image-based methods to display soft shadows from 3D models [9]. They ensure that soft shadows are well-suited to image-based rendering techniques. Praun et al. [10] propose a system that creates hatching strokes in 3D scenes. This kind of drawing conveys lighting and properties of the material. There are parts in light like reflection which are important in images. A new approach for rendering and animating stylized highlights for 3D models has been proposed by Anjyo et al [11]. It is based on the halfway vectors. For now, this approach is not real time. Most of these papers only focus on one effect and do not propose multiple effects. Moreover, their visual interaction in the target image is never considered.

We propose an artistic based approach to stylize lighting in 2D images. Based on artistic movements and techniques, we introduce artistic shadow and lighting effects depicted by artists and six stylizations. We present our representation for the different lighting effects. Then, following the major artistic movements we detail our different stylization methods. Our results are given and commented.

2 Artistic Movements and Ligthing

Since graphical art tries to represent a scene according to relative object position, lighting has always been an issue. Photographs, stage directors, illustrators, painters use lighting to render the desired atmosphere on the scene. Furthermore, they enhance these effects giving them different stylizations such as the lighting effects represented in Chiaroscuro where light parts and dark parts are adjacent. This stylization increases the dramatic tension and creates the illusion of depth. We can cite Rembrandt, Georges de la Tour or le Greco as masters of this art. After this, impressionists played with reflection and transparency. They thought that color is light: “the principal character of a painting is light” (Edouard

Fig. 2. Natural light and artificial light from [1]

Manet). From these researches, one can deduce some specific aspects. There are different kinds of lighting effects. The appearance of the shadow depends on the light source. Two kinds of lights exist: natural lights, produced by the sun or the moon and artificial lights produced by punctual lights or fires. The direction and the appearance of the produced shadows depend on it. A light can be direct or diffuse. A directed light produces more violent contrasts (hard shadows) than a diffuse light which produces smoother transitions (soft shadows). That is called the "quality" of the light and the aspect of shadows also depend on it (see Figure 2). Certain surfaces allow the light reflection and, sometimes, dazzling effects can be created. For example, water and glasses often produce such effects. Different comics stylizations use these effects and propose also shadow stylizations with hatching, complementary colors and black flat areas.

It is easy to get the light source position in a 3D scene. The object characteristics are known and it is simple to apply different stylizations to the different parts of an object or to different kinds of shadows. The task becomes more difficult in 2D images because these information are no more available.

3 Lighting Map Description and Creation

We choose to represent the lighting effects with a map hereafter called `SL` map. The `SL` map is the same size as the input image and each lighting effect is represented by a color. These effects are hard and soft shadows that can be shades (unlit part of an object) or drop shadows and light that can be illuminated parts of the scene or dazzling effects.

We propose to create the lighting map, in two steps: detecting the shadow and refining the map to precise the different lighting effects. The first step is just a help for the user before refining the produced lighting map. As previously explained, we distinguish different sorts of shadows or lights. Automatically detecting shadow in any image is a very difficult task, particularly if we desire to obtain different variations.

Our main contribution in this paper is to stylize images getting the same information as the artists. Therefore, we consider that the representation of the `SL` map is the most important. For that reason, we propose to the user to refine the `SL` map to add the previous distinctions.

In the following, we present first a fast and easy method to produce a SL map. Then, we explain how we depict and refine the map to produce the defined sorts of shadows and lights.

3.1 Detecting Shadow

The first step of our method consists in a shadow detection of the input image. We choose to use the L1 norm which is well designed for shadow detection [12]. It is composed by three components: hue, saturation and lightness. A shadow is a decrease of the light intensity. The color (hue) and the saturation remain unchanged. Thus, we use lightness value to detect shadow. We propose to automatically detect a lightness threshold. We detect the maximum and the median values of lightness in the image. We calculate the difference between the maximum (max) and the median (med) values and divide it by $\mathcal{I}$ which is the number of intensity levels on 8 bits. We call $\mathcal{T}$ this threshold calculation. The global threshold $\mathcal{G}$ is computed as the product of the previous threshold $\mathcal{T}$ with the median value. For example, if max=247 and med=44, $\mathcal{T}$ is equal to $((247 - 44)/255) = 0.796$. $\mathcal{G} = \mathcal{T} \times 44 = 35.024$. With this method, only a part of the pixels, lower than the threshold of lightness, is considered. These pixels are considered as shadow without distinction. The other pixels are considered as illuminated parts.

To visually produce the distinction between hard and soft shadows, we propose two methods to depict the shadows. The first method consists in a binary SL map where black areas are shadows and white areas are the lit parts. The second method consists in preserving the value of the shadow lightness of the original image in the SL map, thus obtaining shadings in the SL map.

The different maps are shown with the first three images of Figure 3. The results obtained do not allow us to distinguish shades from a drop shadows, or dazzling effects from other illuminated parts. Thus, it is not sufficient for a detailed stylization. The next subsection describes what we must add in this map to obtain artist-like stylization.

3.2 Refining the Map

Our SL map is already black and white or grey-level colored. We propose to make a distinction between shades and drop shadows. We keep the desaturated colors for the shades. The user may colorize and change the color of the drop shadows in blue (see right picture of Figure 3).

Using our detection, we cannot distinguish black areas from shadows. All these areas are considered as shadows in the SL map. For example, if one of the character is black-haired, the detection process associates the black color with shadow. So the user can remove these black areas which are not shadows and replace them by white color. White parts of our resulting map represent the illuminated part of the scene in the picture. The user may precise in red the dazzling effects (see right image of Figure 3).

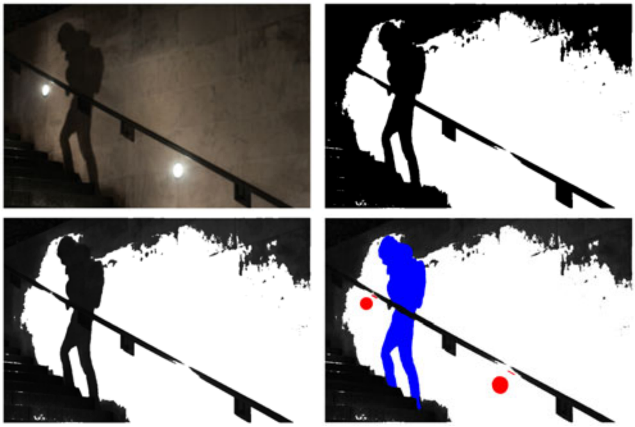

Fig. 3. Original photograph; black and white SL map; shadows with shadings SL map and representation of a drop shadow on the SL map in blue and dazzling effects in red

4 Applying Stylization

Following artistic studies presented in section 2, we present our different methods to stylize an image. Input images can be photographs, drawings or paintings. We propose six different stylizations: Chiaroscuro, Impressionism, complementary color, hatching, black flat areas and dazzling effects. For each stylization, the user chooses to apply the effect on a specific component ("color") of the SL map. We present each style and then explain our algorithm. Our results are presented section 5.

1. **Chiaroscuro:** Chiaroscuro technique was first introduced by Rembrandt to attract the viewer's eye on a specific part of the painting. It consists in creating a strong contrast between light and shadow using bright and dark adjacent regions (see Figure 4).
   To realize this effect on the image, we modify the light value of pixels which correspond to shadows in the SL map. We use the HSL model and for each pixel $P(P_h, P_l, P_s)$ with P_h, P_l and $P_s \in [0;1]$, the light value is computed as following: $P_l = P_l - \mathcal{T}/(P_l \times \mathcal{I})$ where $\mathcal{T}$ is the threshold (see section 3.1) and $\mathcal{I}$ the number of intensity levels. Since $\mathcal{T}$ is in $[0;1]$, the light value decreases according to the number of intensity levels chosen by the user. Moreover, as $\mathcal{T}$ depends on the difference between the maximal and the median light values, this computation preserves illumination relations in the image (a dark input image produces a darker target image).
2. **Impressionism:** Impressionism is a technique from the 19th century. The impressionists emphasize the accurate depiction of the previously defined "quality" of light [13]. They totally avoid very dark areas from their paintings. Illuminated objects are often represented with pastel colors and shades or shadows with saturated colors and smooth diminution of light (see Figure 5).

Fig. 4. The new-born by Georges de la Tour and The Nightwatch by Rembrandt

To represent this style, we have to create pastel colors and smooth variations of light value: $P_s = P_s + S \times \mathcal{T}/(P_s \times \mathcal{I})$ and $P_l = P_l - S \times \mathcal{T}/(P_l \times \mathcal{I})$ with $S = 1$ when P_s is in a shadow area of the SL map (resp. $S = -1$ when P_s is in a lit area). As previously mentioned, we do not change the global illumination of the scene and preserve it, applying the same proportion for lit parts and shadow parts.

Fig. 5. Irises by Monet; The ballet by Degas; Moret, view of Loing, may afternoon by Sisley and The Yole by Renoir

3. **Complementary color:** Some comics creators like to play with shadows and complementary colors to obtain harmonious images. If we represent colors on a hue wheel, a complementary color is the opposed color on the chromatic hue wheel [14]. For example, yellow and violet are complementary colors (see Figure 6, left picture).
   Thus, we propose to leave unchanged the saturation and lightness of shadows but to change the actual hue by its opposite.
4. **Hatching:** Hatching is often used to represent shadow in comics (see Figure 6, 2nd picture) or engraving style [15].
   To give a hatching aspect and particularly to the shadow part, we first propose to increase the contrast between pixels using Pratt filter. Then we propose to apply halftoning with short colored lines using Floyd-Steinberg algorithm [16]. The Pratt filter permits to obtain more contrasted lines and therefore to obtain more dark lines. As contrast has been increased in the image, some pixels are lighter and others darker. Then, we compute our shadow detection algorithm that produces hatched shadows. Thus, only some lines are detected as shadow.

Fig. 6. Einstein's life 1. Childhood by Daniel Goossens; Blueberry by Moebius; America's Best Comics (1947) and Officer Down by Joe Casey and Chris Burnham.

5. **Black flat areas:** Black flat areas are very common in american comics to represent shadow [17] (see Figure 6, 3rd picture).
   We simply propose to copy the black pixels of our SL map in the image.
6. **Dazzling effects:** Dazzling effects can be represented in various ways. It mainly depends on the object material and the light intensity. One can just represent it as a white area or add edges around it to enhance the contrast [15] (see Figure 6, 4th picture).
   We propose to compute an edge detection on the image using Meer et al. method [18]. Only edges corresponding to red areas in the SL map are added to the image to enhance the dazzling effects. If necessary, these edges can be stylized or blurred to preserve the global stylization of the image.

5 Results

This section presents the results produced using our SL map model. It allows the user to create different lighting effects on the same image following artist-like stylizations. This model is well adapted to general users and amateur users. All of these images have been produced in real-time on a Pentium 2.5GHz with 3Go of memory.

Figure 7 presents our result on a comics. Original highlights are not bounded by edges. Using the previously defined edge detection and our red areas for dazzling effects in the SL map, we add edges around the highlights. This is visible on the left of the armchair. A complementary color has been produced on the drop shadows represented by blue areas in the SL map. We can see that the color of the back of the armchair is no more red on drop shadows. We can notice that the user has not refined the black areas which do not correspond to shadows (original contours, hair and shirt). Even if the complementary color is computed on the black part of the SL map, that would not change the result in the black image areas since they are totally desaturated and without lightness. A Chiaroscuro effect has been added to the rest of the shadows, visible on the background wall.

Fig. 7. Original image by Lepixx; edge map; shadow map with reflections in red and drop shadows in blue; result with edges for reflections and complementary color on drop shadows and Chiaroscuro on shades

Fig. 8. Jeanne-Marguerite Lecadre in the garden by Monet; shadow map with drop shadows in blue; result with Impressionism stylization, complementary color on drop shadows and hatching shades

We also modify a well-known painting of Monet (Figure 8). Using our grey-level `SL` map with the blue specification for drop shadows, we first apply our Impressionism stylization. Then we produce a complementary color on the drop shadows. The Impressionism stylization permits to enhance colors in the shadow

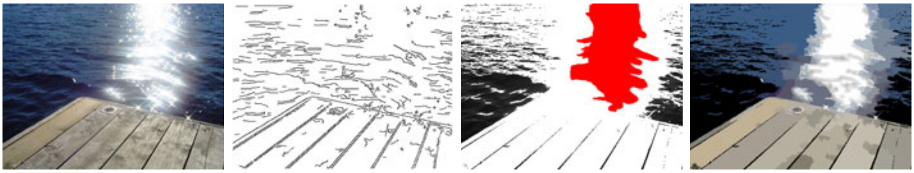

Fig. 9. Original; edge map; shadow map with reflection in red; result with segmentation, reflection and black flat shadows

areas and gives more saturated colors for the complementary stylization. Finally we achieve a hatching for all kinds of shadows.

Figure 9 is a photograph of water with a huge dazzling effect. This effect has been specified in red by the user in the SL map. The result image is a combination of black-flat areas for shadows and some blurred contours in the highlight part. The original photograph has been segmented to obtain a coherent colorization and to create a comics stylization.

6 Conclusion

We have proposed a new model for stylization of lighting effects on 2D images. The proposed stylizations are based on artistic studies ranging from Chiaroscuro to comics. While defining our model, we use different existing lighting effects to produce our lighting map. Some of these effects are specified by the user due to semantic and visual distinctions. Our model provides a helpful computer assisted tool for amateur users. This tool is flexible and allows different stylizations on different lighting effects.

In future work, we will improve our model by adding more stylizations and by adding colored light effects. We also plan to consider coupling our approach with a depth map in order to enhance the contrast between the different kinds of lighting.

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