



## Shadow detection and removal from a single image

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### 1. Introduction

The presence of shadows has been responsible for reducing the reliability of many computer vision algorithms, including segmentation, object detection, scene analysis, stereo, tracking, etc. Therefore, shadow detection and removal is an important pre-processing for improving performance of such vision tasks.

Decomposition of a single image into a shadow image and a shadow-free image is a difficult problem, due to complex interactions of geometry, albedo, and illumination. Many techniques have been proposed over the years, but shadow detection still remains an extremely challenging problem, particularly from a single image.

Our goal is to create a system that can automatically detect shadow regions and then remove from simple images. While detecting all shadows is expected to remain hard, we make some constraints related to the images.

### 2. State of the art

Shadow detection has been an active field of research for several decades. Most research is focused on modeling the differences in color, intensity, and texture of neighboring pixels or regions.

For example, M. Baba et al [1] detect shadow by a K-means clustering method on color distribution. A darker cluster is classified as shadow region. In [2], they detect the shadow region based on the shadow

density, which is defined as a measure of brightness. Then the shadow is removed by modifying the brightness and color. In the end a smooth filter is used to correct boundaries between sunshine and shadow regions. This algorithm provides good results, but it imposes many constraints of the surfaces in the image.

Some of the most popular approaches in shadow removal are represented by the work of Finlayson and colleagues whose work differ from other methods that are based on color constancy conditions as the lightness algorithms, in using a so-called illuminant invariant approach [3,4,5]. Instead of attempting to estimate the color of the scene illuminant, illuminant invariant methods attempt simply to remove its effect from an image.

More recently, state of the art algorithms learn to detect shadows in images from a training database of images and their corresponding labeled image. The innovative work of Guo et al. [6] is based on graph-cut to solve the labeling of shadow and non-shadow regions. Shadow removal is then performed by an image matting approach and then the shadow free image is recovered by relighting each pixel in the shadow.

### **3. Our methods**

We present an algorithm to automatically detect shadows and remove them from simple consumer images. We start from the idea that for home-use photograph an important application would be to be able to remove the shadows cast by objects into the ground. Our algorithms are developed in Matlab and C++.

#### **3.1. Shadow detection**

For shadow detection we present an approach based on statistics of intensity:

- ➔ We represent the picture in the YCbCr color space. We focus on the Y channel, and compute its histogram. Histogram dissension gives us a more contrast image at the Y channel.
- ➔ We compute the full average of the image at Y channel
- ➔ Then we perform sliding window iteration through the image. The sliding window size is reduced iteratively
- ➔ In order to decide which pixels belong to the shadow, we engage two approaches:

a) We consider being part of the shadow those pixels that have the intensity lower than 60% of the full average

b) Compute the non-shadow point's average for the sliding window. We consider being part of the shadow, the pixels that have the intensity lower than the 70% of the window's average

➔ After this, we compute the median filter to reduce the noise

As a further improvement, we can introduce a segmentation algorithm and we can use our method for each of the segments.

The algorithm finds the lower intensities areas in the picture, and this can be darker object or darker textures not related to shadows (false detection). For such situations, we can further decide if we have a shadow by taking into consideration that its border is smooth (the border is usually rough for objects).

The result of the shadow detection is a binary shadow mask, which will be the input to the shadow removal algorithm.

### 3.2. Shadow removal

#### Model based shadow removal

We use a simple shadow model, where there are two types of light sources: direct and ambient light. Direct light comes directly from the source, while environment light is from reflections of surrounding surfaces. For shadow areas part or all of the direct light is occluded.

The shadow model can be represented by following formula:

$$I_i = (t_i \cos \theta_i L_d + L_e)R_i$$

-  $I_i$  represents the value for the  $i$ -th pixel in RGB space

-  $L_d$  and  $L_e$  represent the intensity of the direct light and environment light, also measured in RGB space

-  $R_i$  is the surface reflectance of that pixel

-  $\theta_i$  is the angle between the direct lighting direction and the surface norm

-  $t_i$  is the attenuation factor of the direct light; if  $t_i = 1$  means the object point is in a sunshine region, if  $t_i = 0$  then the object point is in a shadow region

We denote by  $k_i = t_i \cos \theta_i$  the shadow coefficient for the  $i$ -th pixel and by  $r = \frac{L_d}{L_e}$  the ratio between direct light and environment light.

Based on this model, our goal is to relight each pixel using this coefficient in order to obtain a shadow free image.

The new pixel value is computed based on the model proposed in [6]:

$$I_i^{shadow\_free} = \frac{r + 1}{k_i r + 1} I_i$$

### Additive shadow removal

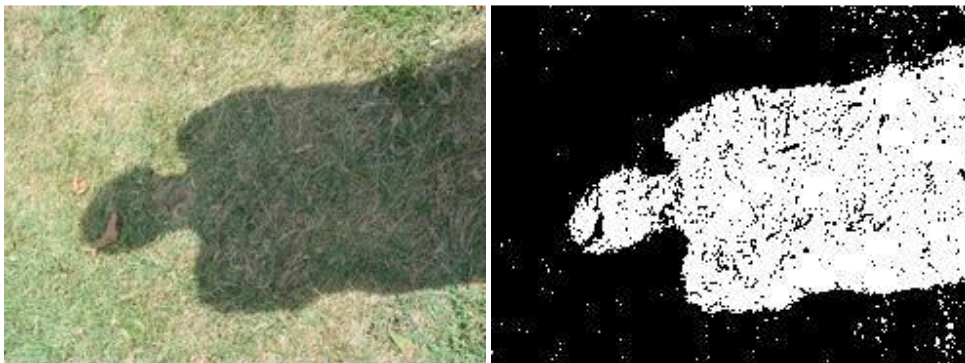
Another – rather simple – shadow removal technique was an additive correction of the color intensities in the shadow area. We computed the average pixel intensities in the shadow and lit areas of the image (let's call them  $E_{shadow}$  and  $E_{lit}$ ) and added this difference to the pixels in the shadow areas.

### Combined shadow removal

The third shadow removal method was the combination of the previous two ones. We converted the images to the YCbCr color-space. After, we used the additive method for the correction on the Y channel, and the model-based method for the correction of the Cb and Cr channels.

## 4. Results

Here are some results of our shadow detection and removal methods. On the first row there is the original image and the mask resulted from the shadow detection algorithm (In these images the mask still contains noise).





The shadow detection has good results at homogeneous regions, but for more textured regions it could result in false detections.

Regarding shadow removal algorithms, we saw that the light based model has the benefit of preserving the texture in the images, while shadow is removed. Some issue still exists at the boundaries of the shadow, mainly due to the sharp edges of the shadow masks.

More results can be seen at:

<http://www.inf.u-szeged.hu/projectdirs/ssip2011/teamF/>

## 5. Conclusion and future work

Shadow removal is a difficult task. Many methods have been proposed to solve this problem in the past decades. Our approach is based on analyzing statistic of intensities related to illumination. Our system can remove shadows from homogeneous textures. In future we plan, to extend and improve our algorithms to work on complex images.

## Bibliography

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