# Removal of Shadows from a Single Image

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***Abstract*—Shadows are one of the important factors affecting computer vision. In images, shadows can provide useful information about size and shape of objects and at the same time complicate tasks such as segmentation and object detection. Different methods have been proposed for the detection and removal of shadows from images. However, the accurate detection and removal of shadows from a single image is a challenge. This paper proposes a simple method to detect and remove shadows in a single RGB image. The proposed approach of shadow detection is based on calculations in LAB colour space and the removal is based on evaluating a constant to recover the shadow free image.**

***Index Terms*—shadow detection, shadow removal, LAB colour space, illumination, reintegration**

## I. Introduction

Shadows are one of the major factors affecting the performance of computer vision applications. The relevance of shadows depends on the application. While shadows can give useful information about size and shape of objects, they can pose problems in feature detection and object detection. Thus, shadow detection and removal is a pre-processing task for computer vision applications such as scene analysis, object detection, and feature detection. Though it is easy for human eyes to detect shadows, it is hard to identify a method that could efficiently detect and remove shadows automatically. This is mainly due to the complexity of geometry, illumination and albedo in images.

Shadows can be mainly classified as hard and soft shadows. Soft shadows retain the texture of background object where as hard shadows have little texture. This makes detection of hard shadows complicated since they may be mistaken as dark objects rather than shadows. Since the illumination condition need not be uniform in a single image, there can be both types of shadows in a single image. Most of the works on shadow detection need calibrated cameras and multiple images for calibration. But the best technique should be able to extract shadows from a single image. This paper proposes a simple and fast method to detect and remove shadows from a single RGB image.

## II. Related Works

Shadow detection is a difficult task since it is hard to identify if a surface is dark by its nature or due to shadow. Various pixel-based methods and region-based methods were proposed to detect shadows in an image. Most of the works in shadow detection is based on the Illumination-invariant image proposed by G. D. Finlayson, S. D. Hordley, and M. S. Drew [1]. A method to identify and remove shadows from an RGB image is proposed in this work. Illumination-invariant image is used with original image to locate the shadow edges which are then set to 0. This edge representation is reintegrated followed by lightness recovery which yield a shadow-free image. A method for removal of shadows from images using Retinex algorithm was proposed in [2]. The problem with this approach is that the method requires calibrated camera and the results do not give photo-quality images. Since reintegration is a costly task, faster methods for reintegration using Hamiltonian paths in the image were proposed in [3] and [4]. But reintegration from Poisson equation [1] gives better results. Three different shadow-free image representations are given in [5]. At first, a 1D shadow-free illumination invariant image is formed. This is converted to an equivalent 2D chromaticity representation and then a 3D color shadow-free image is obtained by inpainting.

Fredembach and G.Finlayson [6] suggested that shadow regions differ from their shadow-free representation by a single factor. In this work, a method to obtain a constant at the shadow edge under simple constraints is proposed. At first the shadow edges are identified with the help of invariant image method followed by removal using reintegration. In the output image, luminance levels on both sides of the shadow are made almost identical and color balance is also kept. The method is simple, fast and efficient to remove shadows from images once the location of shadows has been found. The constant can be found in real time. This method gives good performance on outdoor images. But, for indoor images, or shadows created by other illuminants, this method does not provide good results.

Li Xu, Feihu Qi and Renjie Jiang [7] proposed a method to remove both vague and hard shadows from a single image. Classification is done on derivatives of input image to separate vague shadows and color invariant is used to get hard shadow edges. Reconstruction is done by solving Poisson equation. However, areas near shadow edges have artifacts. Arbel.E and Hel-Or [8] proposed a method to remove shadows from curved surfaces. This approach finds scale factors which are used to cancel the effect of shadows, including penumbra regions where illumination changes gradually. Using this scale factor estimation ensures that non shadow regions of the image remain untouched. The method gives high quality shadow-free images and can handle wide range of shadow images. Texture information in the penumbra is retained.

G. D. Finlayson, M. S. Drew, and C. Lu [9] proved that producing a 1D projection in the correct invariant direction will result in a 1D distribution of pixel values that have smaller entropy than projecting in the wrong direction. By minimising entropy, shadow removal is achieved. A method to detect shadows in single monochromatic image considering shadow-variant features is given in [10]. A drawback of this approach is that the probability that dark objects are considered as shadows is high. In a recent work by Ruiqi Guo, Qieyun Dai, and Derek Hoiem [11], a region-based approach to detect and remove shadows from an image was proposed. Segmented regions in the image are classified based on relative illumination, and using graph-cut, the labeling of shadow and non-shadow regions is done. Lighting of shadow-pixels is done to recover shadow-free image. The drawback is again that the darker areas of objects are mistaken as shadows and are removed.

In this paper, a simple and fast method to detect and remove shadows in a single image is proposed. The main stages of the approach are: shadow detection, shadow removal and post-processing to reduce error at shadow edges. Shadow detection is done considering the properties of shadow regions in the LAB color space equivalent of the RGB image. Shadow removal stage makes use of finding an effective constant which on multiplying with shadow regions can give shadow-free image. Finally post-processing is done to eliminate over-illumination of shadow pixels near shadow edges.

The paper is organised as follows: The shadow detection method is described in Section III, and the shadow removal is presented in Section IV. The Section V deals with the post-processing. The experimental results are presented in Section VI, and finally the approach is concluded in Section VII.

## III. SHADOW DETECTION

The shadow detection method in this work is based on the appearance of shadows in LAB colour space [12] equivalent of the RGB image. For detecting shadows, the RGB image is first converted to LAB colour space. Then based on the value of each pixel in L and B channels, it is classified as shadow or non-shadow pixel. The method is thus pixel-based.

### *A. The LAB colour space*

LAB colour space separates brightness information from colour information. LAB is made up of three channels - L is Lightness channel and two colour channels, A and B. A is the redness to greenness ratio, while B is the yellowness to blueness ratio. The A and B channels are based on the principal that a colour cannot be both red and green, or blue and yellow at the same time. Unlike RGB, where each channel has values in the range 0-255, with LAB the L channel has values from 0-100 (black to white) and the A and B channels contain values in the range –128 to +127. A positive value of A or B channel represents a colour on the magenta or yellow side and a negative number represents a colour on the green or blue side. 0 represents black, white or gray depending on the value in L channel. Fig. 1 gives a pictorial representation of the LAB color space.

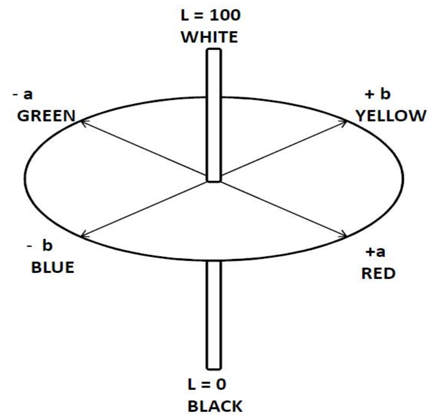
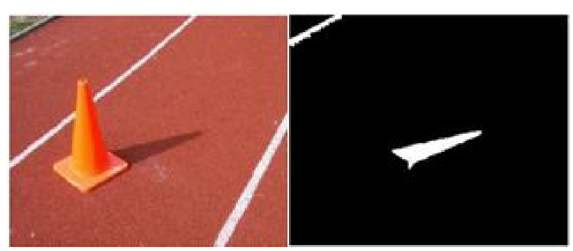



Fig.1 LAB color space

### *B. Shadow Detection*

Shadows arise in areas where light from source does not reach directly due to obstruction by some object. An object can also have self-shadow. Thus, shadow regions occur due to change in illumination condition in different areas of image. The illumination in shadow area is less compared to other regions in the image. Since L channel gives information on illumination, the values of L channel is much less in shadow region compared to non-shadow region. Also considering the properties of outdoor images (neither too yellowish or bluish), the B channel values are lesser in shadow regions compared to non-shadow regions. Combining the L and B channel values, pixels having both the values lesser than a threshold is set as shadow pixel and all others are classified as non-shadow pixels.

Morphological operations are done to remove isolated and misclassified pixels. This gives better results. Finally, to eliminate the misclassified shadow regions, a threshold is selected and applied which sets only the regions having number of pixels more than the threshold as shadow regions. Fig. 2 gives an example of result obtained by this technique.



(a) (b)

Fig. 2 (a) Original image (b) Detected shadow regions in shown as white.

## IV. Shadow Removal

For each shadow region identified in the detection stage, the average values of red(R), green(G) and blue(B) channels inside the shadow regions are calculated separately. Also the average values of red, green and blue channels just outside each shadow region is calculated. Constants for each channel is evaluated as ratio of average in non-shadow to that in shadow region. This is done for each shadow region separately. Thus for each shadow region, three constants are calculated, one per color channel. The R,G and B values of each pixel in a shadow region is then multiplied with the corresponding constants calculated for each channel in that region. This gives an image with almost same illumination in the shadow and non-shadow region.

## V. Postprocessing

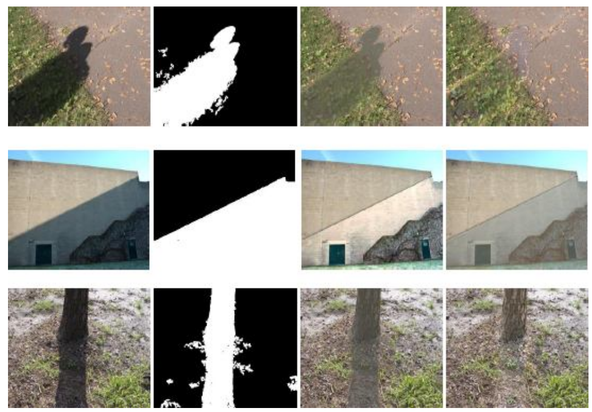
The pixels towards the edges of shadow regions are not as dark as those inside the shadow. This is due to the diffusion of light in the shadow edges. Thus towards the edges of each shadow region, there can be certain pixels which are over-illuminated after the shadow removal stage. These are eliminated using median filters. The resulting image has almost the same illumination in both shadow and non-shadow regions.

Thus the major steps involved are :
1. Convert the RGB image to LAB color space.
2. Classify pixels with lower values in both L and B planes as shadow pixels and others as non-shadow pixels (Based on a threshold).
3. Locate the shadow regions separately.
4. For each shadow region, do the following
    4.1. Compute the average values of R, G and B channels inside the shadow area.
    4.2. Compute the average values of R, G and B channels in the non-shadow area just outside the region.
    4.3. Calculate the ratio between average value outside and inside for each channel separately.
    4.4. Multiply each pixel in the shadow area with the constant calculated in 4.3.
    4.5. For the edge pixels in shadow area, use median filtering to eliminate high frequencies.

## VI. Experimental Results

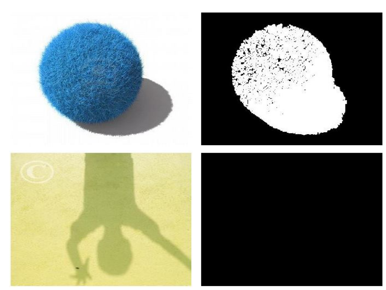
The system was implemented in MATLAB R2010a version.7.10. The entire shadow removal process was tested over real images obtained from dataset proposed in [11]. No assumption is made on the lighting conditions. Time taken for an image of size 256 X 256 is less than 5 seconds. The shadow region is made almost of same illumination of non-shadow areas. Results were compared with the shadow removal technique given in [6] which uses the addition of a constant to the shadow regions. Experimental results showing the outputs of the proposed approach and the approach of Fredembach and Finlayson [6] are given in Fig.3. The results demonstrate the superior performance of the proposed approach.

The proposed approach works well for images under the constraint that the ratio of yellowness to blueness in the image is maintained within a range such that misclassification does not occur in detection of shadow pixels. Fig.4 shows the case in which the approach fails to detect shadows due to the high yellow value in the shadow region which makes the B channel of the LAB equivalent of image to have high value inside the shadow region. Fig.4 also shows the case in which a blue object is detected as shadow since the B channel has low value inside the shadow region due to higher bluishness.



(a) (b) (c) (d)

Fig.3. Results of Shadow Algorithms: (a) Original images containing shadow; (b) Shadows detected are shown as white; (c) Output of shadow removal using constant addition [6]; (d) Output of the proposed method.



(a) (b)

Fig.4. Failure cases of proposed method: (a) Original image; (b) Shadow detected.

## Conclusion

A simple and fast method to detect and remove shadows from a single image is proposed. Shadow detection is done based on the lesser values of shadow regions in the L and B channels of LAB image. The removal of shadows is done by multiplying the shadow region by constants followed by post-processing. The shadow removal proposed in this paper gives fast and accurate results for real time images. A problem with this approach is that dark objects are misclassified as shadow areas. The work can be improved by making the shadow detection more perfect by imposing constraints on the color values. Also, region-based techniques as in [10] can be incorporated for recovering the exact texture in the shadow region.

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