Shadow Detection and Removal from a Static Image

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Abstract— **For human eyes it is not difficult to distinguish shadows from objects. However, in most situations, identifying shadows by computer is a challenging research problem which is a type of segmentation problem in digital image processing. In real time systems, the automated path finding robots can easily detect obstacle and take alternate path but the problem is that they also consider shadow as a part of obstruction. In this project a hybrid algorithm is proposed to detect and extract cast shadow from a still image using mask thresholding and structuring element feature. The shadow is removed with appropriate energy functions. The proposed algorithm consists of two modules. The first module gives the detection of shadow whereas the second module gives the removal of shadow. Exploiting the geometric property of shadow, structuring elements and morphological operations, cast shadow region is extracted. Finally, it is remapped on original image to visualize the extracted region. The energy functions like additive model, basic and advanced model and YCbCr models are used. Some of the important applications can be in processing satellite images, object tracking in video and, image matching and enhancement.**

Index Terms— **Shadow detection, Shadow removal, Shadow Mask, Contra harmonic filters, image processing.**

I. INTRODUCTION

A shadow is an area where direct light from a light source cannot reach due to obstruction by an object. A shadow occurs when an object partially or totally occludes direct light from a source of illumination. The aim of this project is to detect and extract cast shadow region from a still image. As the aim is to identify a particular region in a digital image so, it is a problem of segmentation under digital image processing.

II. SHADOW

Fig. 1 illustrates the formation of shadow due to the presence of an object between a non-point light source and the region where the shadow is cast upon. In this scenario, the shadow is seen to be comprised of two regions, the inner umbra and the outer penumbra. Umbra is the dark area in shadow formed by the complete obstruction of light, whereas, penumbra is the lighter area in the shadow formed due to partial blocking of direct light from the source. Since the illumination in the umbra region is much less compared to that in the penumbra and the lit area, it is the darkest shadow region. The texture detail in this region of shadow is mostly corrupted. The penumbra region looks much more diffused, but retains the texture information.

The main difficulty in locating the penumbra region arises due to the diffused boundary between the penumbra and the lit area. An image may be considered to be a composition of two components that represent illumination and reflectance [1].

The illumination component depends upon the light source which illuminates the scene, whereas, the reflectance element is based on the property of the surface or object which is illuminated.

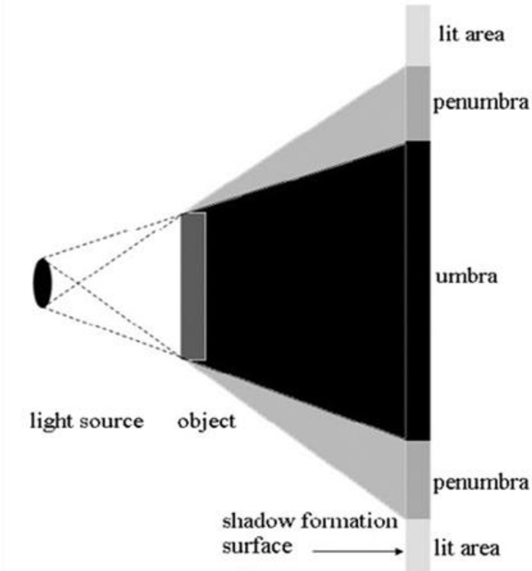

Fig. 1: Shadow formation model

Hence, an image $I(x,y)$ could be expressed as

$$I(x,y) = R(x,y) . L(x,y)$$

A. Types of Shadow

Generally, shadows are of two types: self-shadow and cast shadow (See Fig.2). A self-shadow is the part of the shadow where illumination is completely absent. Shadow cast by an object onto the background of a scene is called cast shadow. For a non-point source of light, a cast shadow is further sub-divided into umbra and penumbra regions.

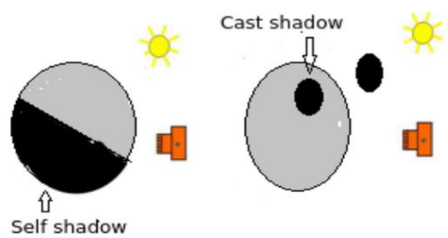

Fig. 2: Self-shadow and cast shadow formation

Another types of classification of shadow is based on the

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intensity. Depending on the intensity the shadow is divided into two parts one is hard shadow and another is soft shadow. Hard shadow occurs when light is applied on a particular object straightly. Soft shadow occurs when the light applied on a particular object is scattered.

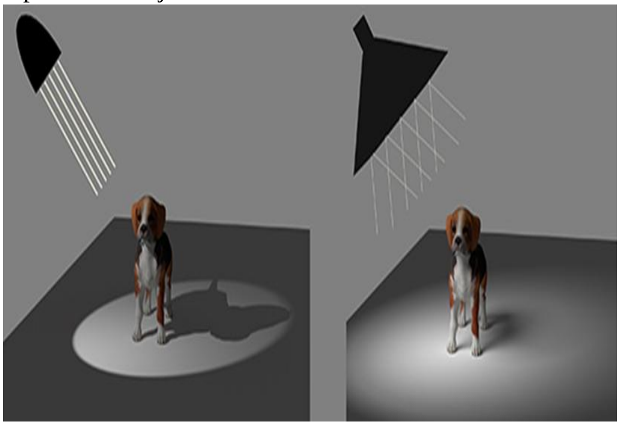

Fig. 3: Hard is shown on the left side soft shadow is on the right side

B. Properties of Shadow

There are two properties of shadow one is geometric property and another is spectral property. They are discussed below

1. Geometric Properties of Shadow:

Geometric property of shadow is very useful for shadow extraction. There is single light source (Fig. 2.). Light is obstructed by the object and shadow is formed. Left side is self-shadow region. Right side is cast shadow region. The intensity of self-shadow pixels is lower than intensity of cast shadow pixels. The intensity of directly illuminated part of object is greater than both of cast shadow and self-shadow pixels.

2. Spectral Properties of Shadow:

The radiance of light $L_r(\lambda,P)$ reflected at a given point P on a surface in the 3D space is formulated as follows

$$L_r(\lambda,P) = L_a(\lambda) + L_b(\lambda,P) + L_c(\lambda,P)$$

Where $L_a(\lambda)$, $L_b(\lambda,P)$, $L_c(\lambda,P)$ are the ambient reflection term, the body reflection term, and the surface reflection term respectively, and λ is the wave length. The ambient illumination term does not vary with geometry because it is accounted for all the light indirectly reflected among surfaces in the environment. In case of no direct light due to obstruction by an object, the radiance of reflected light

$$L_r Shadow\ (\lambda,P) = L_a(\lambda)$$

This represents the intensity of the reflected light at a point in a shadow region.

III. WHY SHADOW DETECTION AND REMOVAL

Many computer vision applications dealing with video require detecting and tracking moving objects. When the objects of interest have a well-defined shape, template matching or more sophisticated classifiers can be used to directly segment the objects from the image. These techniques work well for well-defined objects such as vehicles but are difficult to implement for non-rigid objects such as human bodies. We can consider the following image to clarify the matter.

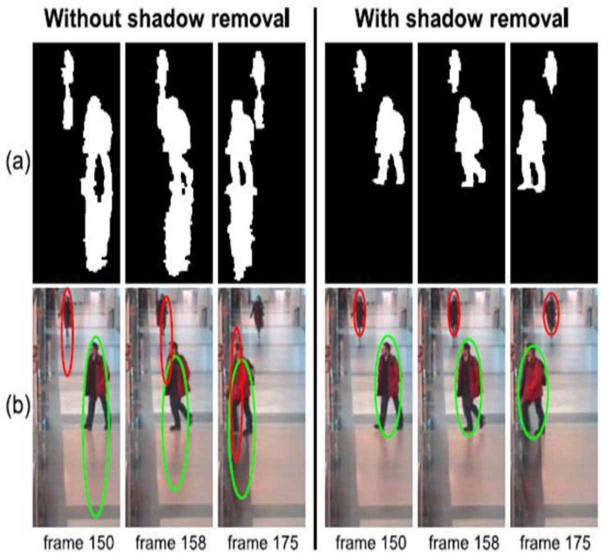

Fig. 4: A case where the correct tracking trajectory can only be obtained when shadow is removed

In the above figure we see a cc camera footage. when we want to track the peoples then it shows the shape including their shadows. This is explained in the portion (a). We get the actual shape when shadow is removed in the portion (b).

With shadow detection process we gain some advantages. Recently we can measure the height of a building or another large thing from the aerial images from the satellites. These are discussed in many studies. So, there are a lot of necessities for the shadow detection and removal process.

IV. DIFFERENT TYPES OF SHADOW DETECTION AND REMOVAL METHODS

In still images shadows can be detected into two major section one is model based and another is feature based. [2], [3], [4].

A. Shadow Detection Methods

1. Model based shadow detection
2. Feature based shadow detection
    a) Threshold based shadow detection
    b) Edge based shadow detection
    c) Other feature-based shadow detection
3. Compared shadow detection

B. Shadow Removal Methods

1. Interactive shadow removal methods
    a) Bayesian approach [5].
    b) Pyramid based shadow detection and removal [6]
    c) Shadow detection and removal approach by Miyazaki et al.[7]
    d) Shadow detection and removal approach by Eli Arbel and Hagit.[8]
    e) Shadow detection and removal approach by Gong et.al.[9]
2. Automatic shadow removal methods
    a) Shadow removal using multiple Retinex paths.[10]
    b) Shadow removal by Fredembach and

Finlayson.[11]

c) Shadow removal from curved area in [12]

V. OUR SHADOW DETECTION AND REMOVAL METHODS

Our shadow detection and removal methods are discussed here. The requirements and the related issues are also mentioned.

A. Requirements

1. MATLAB software.
2. Shadow included images as input.
3. OS Platform-Windows 7 and onwards.

B. The Basic Features of This Thesis

1. *De-Shadowing*: - Removing all the shadow elements completely from the input image.
2. *Input Image*: - Image is in RGB space, with color values between 0 and 1. The image contains one homogeneous texture, in part in the shadow and in part in the light.
3. *Mask:* - Pixels in the shadow are assigned with the value of 1, pixel in the light are marked with a 0, and a smooth transition is allowed.
4. *Type*: - This string declared in the MATLAB code helps us identify the approach to be adopted for detection and removal of shadows. The methods to choose from are: - Additive Model, Basic Light Model, Advanced Light Model, YCbCr Model

C. Some Method Related Issues

Some method related issues are discussed below

1. RGB Color Space

The RGB color model is an additive color method in which red, green and blue light are added together in various ways to reproduce a broad array of colors [13, 14]. The average color values of red, green¸ and blue (primary)components in image is obtained which is further considered as dark pixels of shadow regions. After this, shadows are detected by comparing average R, G, and B values with original R, G, and B values of image.

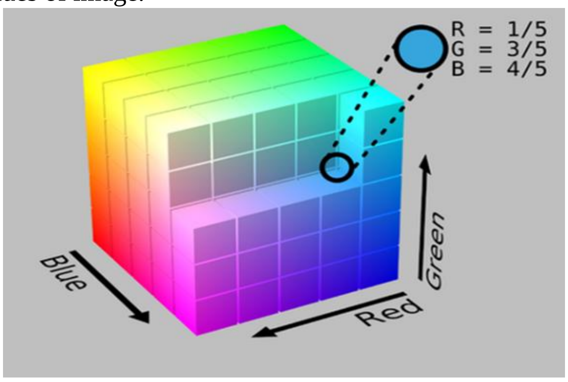

Fig. 5: RGB color space

2. Contra Harmonic Filters

There are different types of filter exists to remove the pepper and noise from an RGB image. The contra harmonic filter is the most popular nonlinear filter for removing impulse noise, because of its good denoising power and computational efficiency. It is a nonlinear digital filtering technique, often used to remove noise. The main idea of the contra harmonic filter is to run through the signal entry by entry, replacing each entry with the mean of neighboring entries. The pattern of neighbors is called the "window", which slides, entry by entry, over the entire signal. For 1D signal, the most obvious window is just the first few preceding and following entries, whereas for 2D (or higher-dimensional) signals such as images, more complex window patterns are possible (such as "box" or "cross" patterns). If the window has an odd number of entries, then it is simple to define: it is just the middle value after all the entries in the window are sorted numerically. The definition of contra-harmonic filter is: [15]

$$Contra - Harmonic\ Mean(A) = \frac{\sum_{(i,j)\epsilon M} A(x+i,y+j)^{P+1}}{\sum_{(i,j)\epsilon M} A(x+i,y+j)^{P}}$$

This function will filter the image by the nonlinear contra-harmonic mean method. This function works for only monochrome, 8 bit per pixel and 24 bit per pixel images. The contra-harmonic mean filter is member of a set of nonlinear mean filters which are better at removing Gaussian type noise and preserving edge features than the arithmetic mean filter. The contra-harmonic filter is very good at removing positive outliers for negative values of P and negative outliers for positive values of P. where the coordinate (x+i, y+j) is defined over the image A and the coordinate (i j) is defined over the N x N size square mask.

An example is shown below

Fig. 6: An example of contra harmonic filter application

3. Morphological Operations

Morphology is a broad set of image processing operations that process images based on shapes. Morphological operations apply a structuring element to an input image, creating an output image of the same size. In a morphological operation, the value of each pixel in the output image is based on a comparison of the corresponding pixel in the input image with its neighbors. [16]. The most basic morphological operations are dilation and erosion. We will also discuss opening and closing which are also morphological operations. Opening generally smoothed the contour of an object and eliminate thin protrusions which is combination of erosion followed by dilation. Closing also tends to smooth sections of contours but fusing narrow breaks and long, thin gulfs and eliminating small holes and filling gaps in the contour which is combination of dilation followed by erosion. Dilation adds pixels to the boundaries of objects in an image, while erosion removes pixels on object boundaries. The number of pixels added or removed from the objects in an image depends on the size and shape of the structuring element used to process the image. In the morphological dilation and erosion operations, the state of any given pixel in the output image is determined by applying a rule to the corresponding pixel and its neighbors in the input image. The rule used to process the pixels defines the operation as a dilation or an erosion. This table lists the rules for both dilation and erosion.

Table 1: Rules for Dilation and Erosion

operation	*rule*
Dilation	The value of the output pixel is the maximum value of all pixels in the neighborhood. In a binary image, a pixel is set to 1 if any of the neighboring pixels have the value 1. Morphological dilation makes objects more visible and fills in small holes in objects.
Erosion	The value of the output pixel is the minimum value of all pixels in the neighborhood. In a binary image, a pixel is set to 0 if any of the neighboring pixels have the value 0. Morphological erosion removes islands and small objects so that only substantive objects remain.

a) Morphological Dilation and Erosion Of A Gray Scale Image

The following figure illustrates this processing for a grayscale image. The figure shows the processing of a particular pixel in the input image. Note how the function applies the rule to the input pixel's neighborhood and uses the highest value of all the pixels in the neighborhood as the value of the corresponding pixel in the output image.

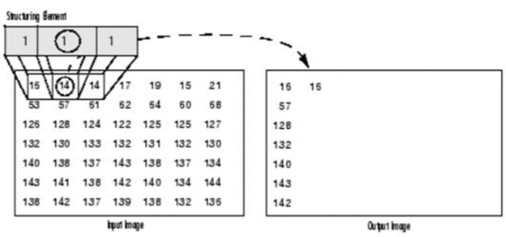

Fig. 7: Morphological dilation of a grayscale image

At the case of erosion, the reverse phenomenon happened.

4. Threshold Function

Threshold function is basically used for detecting the shadow area. Thresholding is done by the use of mask. The mask describes the pixel lightness of the image. To create mask the gray scale image is converted into binary image. The total image is divided into shaded and non-shaded area. Depending on the masking the threshold value is assigned. In this case it assigns binary values, such that the pixels in the shadow are assigned with the value of 1 and pixel in the light are marked with a 0(or vice versa), and a smooth transition is allowed. Our method is automatic so if the mask is not given a global thresholding will be used for shadow detection. We can see the following example, where the original image is shown on the left side and corresponding thresholded image is shown on the right side. It is basically a binary image. It is noticeable that the binary image is rough. Further it will be smoothened.

Fig. 8: thresholded image example

5. Energy Functions

After the shadows are detected, the next task is to define an energy function to remove shadows. Our proposed method uses four method to remove shadow. Additive Model, Basic Light Model, Advanced Light Model and Combined additive and light model-based shadow removal in YCBCR color space are used. The output of all the models are almost same. But in some cases, a slight difference may be noticeable. They are different to their methodology.

a) Additive Shadow Removal

This is rather a simple shadow removal technique in which an additive correction of the color intensities in shadow area is done. In this we first compute the average pixel intensities in the shadow and lit areas of the image. The shadow and lit area of the image are obtained as shadow core and lit core through a morphological operation called erosion. Erosion is performed on the mask using the structuring element. The average pixel intensities in the shadow area and light area are computed separately. Then the difference between them is added to the shadow area.

b) Basic, Light Model-Based Shadow Removal

The ratio of shadow area and light area luminance is computed. This ratio is multiplied with the shadow mask bit wise. The resultant multiplication is added to the light mask. Then the resultant addition is multiplied with the original image bitwise.

c) Advance, Light Model-Based Shadow Removal

The ratio of the luminance of the directed, and global lights is computed. For this 1 is subtracted from the shadow average. Then the ratio of light average area and the subtracted shadow average area is computed. 1 is added to the resultant ratio. The smooth mask is subtracted from 1.the subtracted smooth mask is multiplied with the added ratio. The resultant multiplication is again multiplied with the original image bitwise. Finally, the ratio of the added ratio and the resultant multiplication is computed

d) Combined Additive and Light Model-Based Shadow Removal InYCbCr Color Space

At first the RGB image is converted to the YCbCr form. The average channels in YCbCr color space is computed. Next, we use additive method for correction on Y channel and model-based method for correction on cb and cr channel.

VI. ALGORITHM

The algorithm is divided into two section one in shadow detection section and another is shadow removal section.

A. Algorithm for Shadow Detection

To detect the shadow, we have to perform the following steps

1. load RGB image.
2. Convert the RGB image into corresponding grayscale image. The size of the image is extracted.
3. Contra harmonic filters are used to remove the salt and pepper noise from the image.
4. Mask creation for the image segmentation. In this case it assigns binary values, such that the pixels in the shadow are assigned with the value of 1 and pixel in the light are marked with a 0(or vice versa), and a smooth transition is allowed.
5. Depending upon the mask the light mask and the shadow mask is selected.
6. Defining structuring element as follows,Structuring element = [0 1 1 1 0; 1 1 1 1 1; 1 1 1 1 1; 1 1 1 1 1; 0 1 1 1 0].
7. Determining the light core and shadow core. these are determined by performing a morphological operation called erosion function on the structuring element with the light mask and shadow mask respectively.
8. Finally, the mask is smoothened by the convolution function. The convolution function is performed over the shadow mask and the ratio of structuring element and the sum of structuring element. the convolution function Returns the central part of the convolution of the same size as shadow mask.
9. The smoothened mask is superimposed on the original image to detect the shadow.

B. Algorithm for Shadow Removal

To remove the shadow, we have to perform the following steps

1. After detecting the shadows from the above algorithm average pixel intensities for both the shadow area and the light area are calculated in each portion of red, green and blue. So, the colors in shadow regions have larger value than the average, while colors in non-shadow regions have smaller value than the average values. Images are represented by varying degrees of red, green, and blue (RGB). Red, green, and blue backgrounds are chosen because these are the colors whose intensities, relative and absolute, are represented by positive integers up to 255.
2. We have used four correlated shadow removal method such as Additive Model, Basic Light Model, Advanced Light Model and Combined additive and light model-based shadow removal in YCBCR color space are used.
3. After performing the shadow detection and removal all the outputs are shown.

VII. EXPERIMENT AND RESULT

The experiment and results are discussed below

A. Experiment

1. Original Image

Fig. 9: Original image

This is the original image which we have considered as an example from which we want to remove shadow using the shadow removal and detection method which we have developed. This image will be the input to our module, the final output of which will an image with the shadow removed. The method we have developed is applicable to a wide range of images having different formats like png, tif, jpg, jpeg, etc. The image we have considered here is of png format. This is the first step in our method, the subsequent steps will be shown as we proceed.

2. Mask Image

Fig. 10: Mask image

A mask is a black and white image of the same dimensions as the original image (or the region of interest you are working on). Each of the pixels in the mask can have therefore a value of 0(black) or 1(white). When executing operations on the image the mask is used to restrict the result to the pixels that are 1(selected, active, white) in the mask. In this way operations restrict to some parts of the image. The mask describing the pixel lines on the image. (segmentation of the shadow). pixels in the shadow are assigned with the value of 1, pixel in the light are marked with 0, and a smooth transition is allowed.

3. Shadow Core

Fig. 11: Shadow core

After we construct the mask of the image, a morphological operation called erosion is performed on the original image with shadow using this mask and a predefined structuring element. Erosion can be viewed as a morphological filtering operation in which image details smaller than the structuring element are filtered from the image. In equation it is represented as –

$$A \ominus B = \{z|(B)z \text{ subset } A\}$$

Where A and B are sets in Z, A⊖B denotes erosion of A by B and the equation means that the erosion of A by B is the set of all points z such that B, translated by z, is contained in A. Thus, after erosion we get an image which is referred to as shadow core (pixels not on the blurred edge of the shadow area).

4. Light Core

Fig. 12: Light core

For obtaining shadow core mask was eroded by a predefined structuring element. Likewise, for obtaining lit core compliment mask is eroded by the same structuring element. Here erosion process is the same as described for shadow core. Shadow core and lit core are used for averaging pixel intensities in the shadow and light area respectively.

5. Smooth Mask Image

Fig. 13: Smooth mask

Smooth mask is an image that is obtained by performing 2-D convolution of mask and structuring element. This is implemented through function conv2(A, B, shape). The first parameter is the mask and the second one is the structuring element. For the third parameter shape, 'same' is used which returns the central part of convolution that is of the same size as the mask. Convolution is the process of moving a filter mass over the image and computing the sum of products at each location except that the filter is first located by 180°. Convolution is used for spatial smoothing of an image. Smoothing filters are used for blurring a noise reduction. Blurring is used in preprocessing tasks, such as removal of small details from an image prior to (large) object extraction, and bridging of small gaps in lines or curve.

B. Result

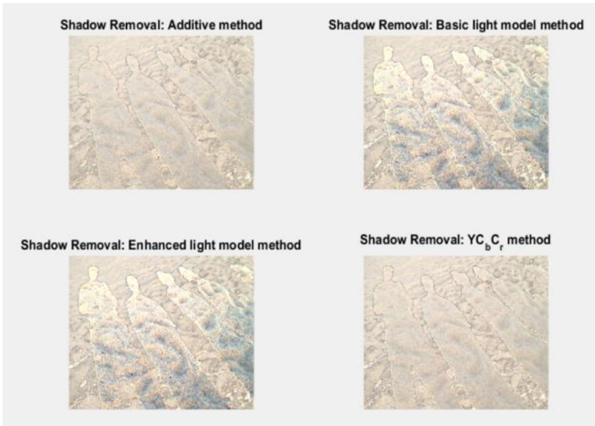

Fig. 14: Output image

Once we have the shadow core, lit core and smooth mask, shadow removal can be performed using the above through one of the four methods. The four methods are additive method, basic light model method, advanced light model method and Combined additive and light model-based shadow removal in YCBCR color space method. Each of these methods uses a unique technique and has a basic set of steps to proceed.

Though these methods vary in the methodology used, output of all is the same, original image with the shadow removed from it.

VIII. CONSTRAINS

There are some constrains with our proposed method.

A. Objects should be of uniform color.

B. Only one light source illuminates the scene, and shadow and object are within the image.

C. Light source must be strong enough.

D. Shadows are cast on a flat or nearly flat surface or non-textured surface.

We will be clear with an example. An image with an ununiformed background is taken.

Fig. 15: Input image with ununiformed background

The corresponding output is shown below

Fig. 16: Output of the ununiformed image

The output image cannot remove the shadow properly. This is why the input image should be uniformed.

IX. CONCLUSION AND FUTURE WORK

The proposed hybrid algorithm is working in case of controlled environment scenario. But for the implementation of shadow detection in real time system our first objective should be to reduce the number of constraints as mentioned previously so that it will produce results more accurately and precisely. Another challenging future work in this field can be the situations when we have two light sources and getting two shadows for single objects. Generally, these situations happen when we walk on the street in night and we get our two shadows because of continuous street lights standing from starting point to end point. Finally, we can implement this technique into an automated robot which will walk like a human being. It will find the path itself. If it encounters an obstacle, it will detect it and get alternate path. Similarly, if it detects shadow, it will not bother and cross over it without deviating.

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