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Study on Processing Method of Image Shadow

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Abstract: In order to effectively remove disturbance of shadow and enhance robustness of information processing of computer visual image, this paper makes study on inspection and removal of image shadow. It makes study the continual removal algorithm of shadow based on integration, the illumination surface and texture, it respectively introduces their work principles and realization method, it can effectively carrying processing for shadow by test.

Keywords: Image shadow, Processing, Algorithm, Shadow removal.

1. Introduction

Image will be inevitably affected by many factors in the imaging process, especially in the city environment with the high density, the building shadows blocks information on the image, which leads to quality reduction of images. Shadow formation is caused due to lack of light radiation, which means loss of image information, it will have an impact on image matching, pattern recognition, feature extraction and digital photogrammetry, so it is necessary to make study on processing of image shadow and it has drawn attentions of more and more scholars. The shadow in the image will interfere with image information in computer visual image and degrade image quality, it will also lead unstable even failure in object segmentation, object recognition and tracking results etc, it will seriously affect the performance of image processing algorithm in computer visual image [1].

In order to effectively remove interference of shadow and enhance the robustness of information processing in computer visual image, this paper makes study on the inspection and removal method of image removal.

2. Principle and Method of Shadow Removal

Because shadow is related to light, so it has particular spectral characteristics, at the same time the shadow is appeared in the natural scene, therefore, it also has physical properties in specific scene, such as brightness, color, texture, edge gradient, etc. Brightness value of shadow in image is mainly depends on the reflectivity of surrounding indirect light source, because umbra receives more surrounding light source, its brightness value is generally larger than that of projection. When the light source turns into surface light source, here the projection can be subdivided into umbra and penumbra, the former refers to the background area fully sheltered and the latter refers to the background area partially sheltered [2]. This paper uses Fig. 1 to express their detailed meanings.

http://www.sensorsportal.com/HTML/DIGEST/P_2236.htm

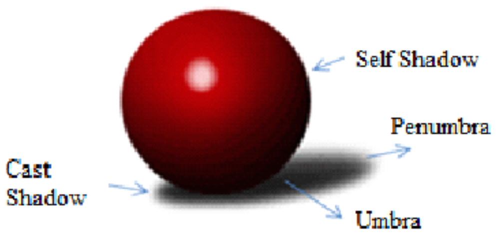


Fig. 1. Shadow classification.

Under natural conditions, the light emitted by the light source illuminates onto the object surface, will be reflected, scattered, refracted and transmitted. As in the outdoor, the object will not only be subjected to direct light of the sun but also to the reflected light of objects such as sky etc, there is also the internal reflection from internal, that is to say the object is illuminated by multiple light. Considering the complexity, this section only considers the object is subjected to direct light and reflected light (environment light). S. A. Shafer expands the model of double-color reflection, the spectral energy equals to spectral energy of incident light plus spectral energy of reflected light, the illumination model is as follows:

$$E(\lambda, x) = m_b(x)c_b(\lambda, x) + m_i(x)c_i(\lambda, x) + E_\alpha(\lambda) \quad (1)$$

In the formula, E(λ, x) is the spectral energy with wavelength λ onto x of dielectric surface, the sum of the first item and the second item in the right of the above formula is the received spectral energy of incident light on the object surface.

$$m_b(x) = (1-\rho_f(x))^2, c_b(\lambda, x) = e(\lambda, x)R_\infty(\lambda, x), m_i(x) = \rho_f(x), c_i(\lambda, x) = e(\lambda, x) \quad (2)$$

where $\rho_f(x)$ is the reflection coefficient of Fresnel, and $e(\lambda, x)$ is the spectrum distribution of x, $R_\infty(\lambda, x)$ is the surface reflection rate, $E_\alpha(\lambda)$ indicates the spectral energy of environment light on the surface of object, it will not change with changes in object surface and incident light. However, the spectral energy of incident light will change with the changes in object surface and incident light [3].

Shadow except has spectral characteristic, it also has some physical characteristics, such as brightness, chrominance, texture, gradient, edge etc.

2.1. Brightness

The brightness of one point in the space across RGB imaging equipment is as follows:

$$\rho_k(x) = \int E(\lambda, x)\sigma_k(\lambda)d\lambda \quad K = R,G,B, \quad (3)$$

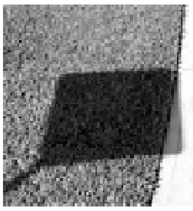
Of which, $\rho_k(x)$ k indicates the brightness value of one point x corresponds to 2Dimage, $E(\lambda, x)$ indicates the spectral energy in point x of space; $\sigma_k(\lambda)$ indicates the sensitivity of camera of wavelength λ in passage k. When the shadow area is umbra, a=0, and when the shadow area is penumbra then 0<a<1; when the area is not shadow, then a=1, it gets the following: the brightness in umbra area is less than that in penumbra area, similarly, it is less than that in non-shadow area. The brightness distribution of shadow image is indicated by Fig. 2(a).

2.2. Chrominance

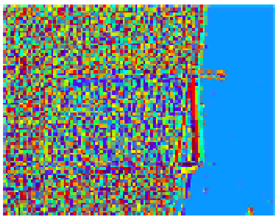
In the RGB color space, brightness and chrominance are existed together in the color components. In the outdoor scene, the environment light received by shadow is mainly composed of reflected light in blue sky, so the chrominance of blue components in shadow area is higher than that in other color components, the chrominance percentage relation of each color is as follows: blue component is larger than green component, similarly, it is larger than that of red component. In the HSV color space, the tone H, saturation S and brightness V of shadow is respectively separated, this is beneficial to analyze each color component of shadow. If certain area is covered by the shadow, the tone H in this area will change in the confirmed range, which indicates change information of angle in this area. The saturation S component in this area will also change in one confirmed range, which indicates the absolute difference in this area, the brightness V in this area indicates change information of brightness. Supposing that function meets the above conditions is F, this function indicates that grey value of one image point in the non-shadow area is Fnonshadow, the grey value of one image point in the shadow area is Fshadow, then Fnonshadow equals to Fshadow [4].

2.3. Texture

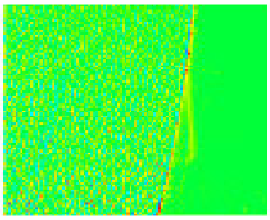
Under normal conditions, the texture of shadow, non-shadow and black object are all different, so gradient, information entropy, edge of shadow has slight difference compared with it. For example, in the shadow image, we make Log transformation for it, and then the gradient value of image has little change in the boundary stretches across the shadow area, the Fig. 2(c) uses Gauss derivative to obtain the image gradient of shadow. In the natural environment, the texture distribution of most black objects is relatively sparse, while the texture of general shadow area has uniform distribution in texture. Therefore, the information entropy in shadow area is different from that of black object, which is indicated in Fig. 2(d).



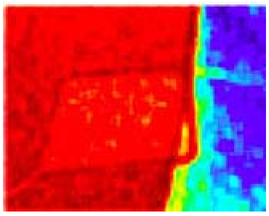
(a) brightness distribution



(b) texture distribution



(c) gradient distribution



(d) information entropy distribution

Fig. 2. Effect drawing of physical characteristics in shadow area.

The shadow test based on model is divided into the shadow test based on physical characteristics in the scene and the shadow test based on geometric characteristics of objects. The former uses light or geometric distribution to establish proper model to test shadow, because it has to make estimation for the light in the scene or the geometric distribution, so it can only be used in the special scene. The latter uses information such as object shape, size, height and relations between object and shadow etc to test shadow, the main difference of this method with shadow test based on physical characteristics in the scene lies in that it is no need to establish model and make estimation for the light source or scene in the image [5], but it has higher restrictions for the object [6].

3. Algorithm Study on Shadow Removal of Image

3.1. Algorithm of Shadow Removal Based on Integration

Shadow removal belongs to image reconstruction to certain extent, the basic idea of algorithm of shadow removal based on integration is: firstly, it makes logarithmic transformation for the original image and then calculates the gradient of logarithmic image after transformation, then it make special processing for the gradient value corresponds to the shadow boundary in this gradient image (for example it is set as 0) so as to eliminate shadow boundary [7]. Finally, through the integration transformation for gradient image (it is equals to inverse processing of gradient operation) and index operation to reconstruct image without shadow.

The algorithm of shadow removal based on 2-D integration mainly removes shadow boundary from original image and uses pseudo-inversefiiter, improved retinx theory or poissonsolution [8] etc. to obtain the original image without shadow. Here we only take poissonsolution equation as an example to introduce algorithm of shadow removal based on 2-D integration, the detailed algorithm is as follows:

Step 1, setting original image as I (x, y), transform it into the space of natural logarithm:

$$i(x,y) = In(I(x,y)), \qquad (4)$$

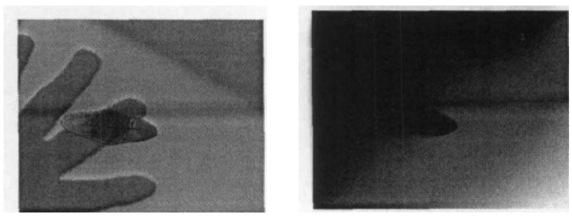
Step 2. obtain the gradient of i(x, y) so as to obtain boundary of logarithmic image:

$$\Delta i(x,y) = \left(\frac{\partial i(x,y)}{\partial x}, \frac{\partial i(x,y)}{\partial y}\right), \qquad (5)$$

Step 3. use function double $T\Delta i(x,y)$ to make threshold processing for $\Delta i(x,y)$:

Step 4., establish poisson equation of logarithmic image i(x, y), through solution of poisson equation to reconstruct logarithmic image without shadow, after obtaining logarithm then gets the reconstruction image without shadow.

Fig. 3 is the test result of algorithm of shadow removal based on 2-D integration, of which the first list is original image; the second list is the image without shadow after shadow removal. From Fig. 3 we can see that this algorithm can remove the shadow in the image and it can better recover the texture information of coverage area of shadow, in addition, the image after shadow removal has better visual effect. But this algorithm needs to solve poisson equation as well as positive and negative Fourier transform to recover the image without shadow, so it wastes time and the image without shadow has obvious manual processing.



(a) Original image (b) Image without shadow after recovery

Fig. 3. Effect of shadow removal based on 2-D integration.

3.2. Algorithm of Superficial Shadow Removal Based on Light Change

The formation of shadow can be regarded as brightness change of image due to light reduction, so we can indicate one shadow image to multiply one factor of light change surface in certain area of image without shadow.

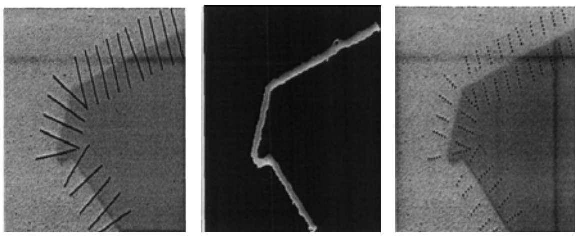
$$\bar{I}_k(x,y) = I_k(x,y) \bullet C_K(x,y), \quad (6)$$

In the formula: $C_K(x,y)$ indicates the factor of light change surface. The key point of this algorithm is to calculate complete shadow and penumbra region $C_K(x,y)$. In the following we will introduce the calculation methods of these two areas $C_K(x,y)$.

1) Calculation of factor K of light change in complete shadow area

This calculation mainly includes the following steps:

Step 1. Firstly, create one spline for each pixel point s of shadow boundary, the spline direction of normal direction of shadow boundary, the length of spline is depends on the width of penumbra; it is generally sets three times of penumbra width. In the following, neglect the data point of penumbra area in the shadow boundary. Fig. 4 is the process of establishing spline, each pixel point in Fig. 4 all creates one spline verticals to shadow boundary (the black is the setting spline), Fig. 4 is template of penumbra, Fig. 4(c) is the spline after neglecting data in penumbra area.



(a) (b) (c)

Fig. 4. Application of spline to search surface factor of light change: (a) Place spline along shadow boundary; (b) Penumbra template; (c) Final sampling point of spline.

Step 2 It defines the following formula according to energy formula, (t) is penumbra area, w(t)=0; s(t) is complete shadow area, c(t)=0.

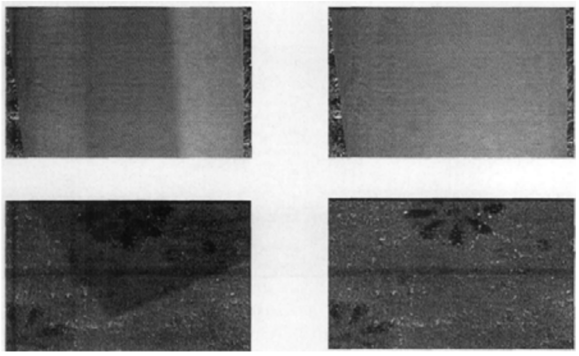
$$E(s) = \int w(t)\,|\,s(t) - [g(t) + c(t)]^2\,dt + \int (\frac{\partial^2 s}{\partial t^2})^2\,dt \quad , \quad (7)$$

Step 3. Calculate the total energy of spline integration S

Step 4. Use gradient descent and confirm total energy E to obtain the minimal C (t) that is the surface factor of light change.

2) fk (x.y) calculation in penumbra area

If the spline curve is thin plane, we can adopt difference of plane function F (x, y) on the thin plane and pixel value $\bar{I}_k(x,y)$ of penumbra area in original image to calculate fk (x.y). As for the texture surface, the obtained manpower (x is not smooth and it will change with texture, so before using fk (x.y). we need to make smoothing for fk (x.y).



(a) Original color image (b) Recovered image without shadow

Fig. 5. Effect of shadow removal based on calculation of light change surface.

Fig. 5 is the effect drawing of using light change surface q(x trying to remove shadow. Of which Fig. 5(a) is the shadow image of the first act curve and Fig. 5(a) is the shadow image of the second act with rich texture, Fig. 5(b) is the recovered image without shadow. From Fig. 5(b) we can see that algorithm of shadow removal based on light change surface can better remove the shadow in the texture, at the same time, because it has fully considered the brightness effect of umbra on penumbra, which enables image without shadow more close to the actual image and it has better visual effect. But this algorithm of shadow removal process has not considered effect of shadow on texture characteristics in shadow area, so it can not keep texture in original shadow are and non-shadow area continuity.

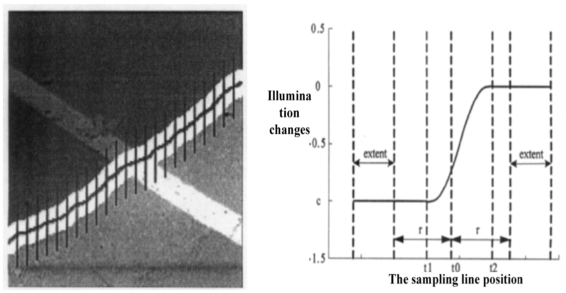
3.3. Algorithm of Shadow Removal Based on Texture Continuity

The key point of test algorithm on shadow based on texture continuity lies in establishing one gradient image area. Two steps of gradient image construction are as follows: 1) estimate the change surface of light and remove its effect on gradient in penumbra area, so that it can get gradient area cloud without light effect. 2) estimate the effect of umbra on texture characteristics of the whole shadow area, and transform texture characteristics in shadow area, enable the texture characteristics in non-shadow area keep continuity, so that it can get one new image gradient area Gs.

1) Calculate light change surface and remove its effect on penumbra area.

a. Use one drawing tool such as brush to roughly mark shadow boundary;

b. Draw one horizontal or vertical sampling line gets through shadow boundary for each pixel across shadow boundary, and use it to simulate light change surface c(x, y). Fig. 6(a) is one vertical sampling line across boundary, Fig. 6(b) is the change curve of light surface with position of sampling line, of which t0 and r is respectively the center and diameter of brush. [t1, t2] is penumbra area; extent is used to calculate the area of calculating gradient characteristics.



(a) (b)

Fig. 6. Vertical sampling line (a); Model of light change (b).

c. The estimated light change and position of penumbra area along with sampling line;

d. The gradient image cloud after removing shadow;

2) Estimate effect of shadow on texture characteristics in the whole shadow area and transform texture characteristics in shadow area, make its brightness keep uniform with texture characteristics in bright area

a. Establish the expression formula of gradient transformation in shadow area; we can use mean value of sampling and variance of gradient area to simulate texture characteristics. If the given target mean value is u and variance is σ.

$$G^s == u^t + \frac{(\overline{G^s} - u^s)\sigma^t}{\sigma^s}, \tag{8}$$

b. Estimate effect parameter of shadow.

Supposing that gradient distribution in shadow boundary is even and shadow effect is independent on image without shadow, then we can use the following formula to calculate the effect parameter of shadow, u_{se} and $\sigma^2{}_{se}$ are respectively the mean value and variance of gradient image along with shadow boundary in one side of complete shadow area.

$$\begin{cases} u_{se} = u_b^s - u_b^t \\ \sigma^2{}_{se} = \sigma_b^{s^2} - \sigma_b^{t^2} \end{cases}, \tag{9}$$

c. Calculate target parameter;

Calculate the object parameter through effect parameter of shadow according to the following formula

$$\begin{cases} \overline{u}^t = \overline{u^s} - u_{se} \\ \overline{\sigma}^t = \sqrt{\sigma^{s^2} - \sigma_{se}{}^2} \end{cases}, \tag{10}$$

d. Calculate the gradient value after transformation in shadow area;

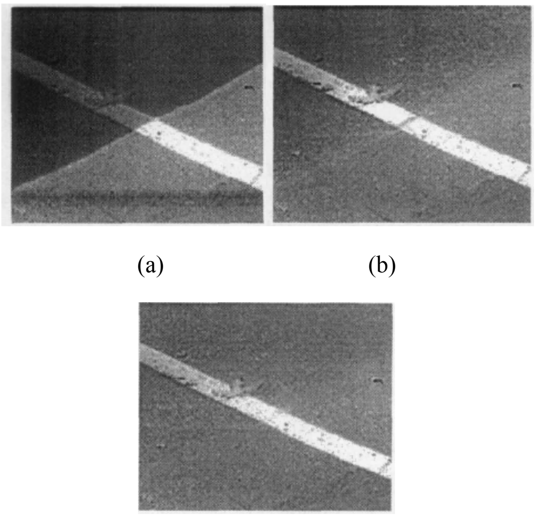
Fig. 7 is the effect drawing of using algorithm of shadow removal based on texture community. From Fig. 7 we can see that this algorithm can not only effectively remove shadow, but also it can make the image after shadow removal have continual texture characteristics in the whole image. The advantage of this algorithm is that the image without shadow has better visual effect, its main disadvantage is: the user needs to roughly designate shadow boundary that is penumbra area in the realization process of algorithm, it is inconvenient, in addition, this algorithm needs to solve poisson equation and operation is very large.

(a) Original color image (b) Recovered image without shadow

Fig. 7. Effect drawing of shadow removal based on texture continuity.

4. Test Analysis

Fig. 8(b) is the image without shadow using algorithm of shadow removal based on light change surface, this algorithm has fully considered change of light change surface in penumbra area and constant characteristics of light change surface in umbra area, it also considers geometric structure, which enables the image without shadow after reconstruction better retain texture information of image. But this algorithm has not considered effect of shadow area on texture characteristics in shadow area, so it makes texture in shadow area and non-shadow area discontinue. Fig. 8(c) is the image without shadow using algorithm of shadow removal based on texture continuity, this algorithm is implemented in gradient area. In the process of shadow removal, it simultaneously considers effect of light change on gradient in penumbra area and shadow effect on texture characteristics in the whole shadow area. Therefore, the image texture without shadow after reconstruction has better continuity, but this algorithm can not keep texture continual between shadow area and brightness area there is one loomed boundary between them, because it can not precisely determine range of penumbra area and the improper model reconstruction, in addition, the shortcomings of this algorithm is: it needs to solve poisson equation, calculation complication is very higher, it needs to artificially designate shadow boundary and it is inconvenient.



(a) (b)

(c)

Fig. 8. Test result. (a) Original color image; (b) Calculate effect of shadow removal on light change surface; (c) Removal effect of shadow with continual texture.

5. Conclusions

Results and Discussion: This paper makes profound study on three common algorithms such as algorithm of shadow removal based on integration, algorithm of shadow removal based on surface factor of light change and algorithm of shadow removal based on texture continuity. It introduces the principles of algorithms in details and summarizes the detailed realization process, it also analyzes the advantages and disadvantages of each algorithm by comparison and test. We should emphasize at the analysis and study on psychical mechanism of shadow formation and solve problem of weak universality of algorithm as well as effectively reduce the complication of algorithm.

Acknowledgements

Image will be inevitably affected by many factors in the imaging process, especially in the city environment with the high density, the building shadows blocks information on the image, which leads to quality reduction of images.

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