Applied Mathematics & Information Sciences
An International Journal

http://dx.doi.org/10.18576/amis/110624

Pixel Valued Adaptive Single Scale Center Surround Algorithm- An Innovative Approach for Illumination removal

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Received: 19 Aug. 2017, Revised: 22 Oct. 2017, Accepted: 27 Oct. 2017
Published online: 1 Nov. 2017

Abstract: This paper proposes an innovative approach for removing the non uniform illumination which is a major artifact in microscopic algal images. Center Surround Algorithm is used for correcting the non uniform illumination where the illumination and reflectance are separated but not completely removed. In this new algorithm the pixel values are replaced based on the geometric mean of the surrounding pixels and applying the Adaptive Single Scale Center Surround Algorithm to remove non uniform illumination. By determining inhomogenity and calculating zeros the illumination is completely removed. By iterating the convolution, the edges are also preserved. Many of the algal species look alike and are precisely identified only based on their features and not purely on their appearance. Non uniform illumination that affects the images is completely removed by the proposed method without affecting the features.

Keywords: Algae, Center Surround Algorithm, Image Denoising, Illumination, Single Scale Retinex

1 Introduction

The Algae are broad term, encircling organisms from the micro- to the macro-scale. Algae originate in a wide variety of water locations. Algae are primary manufacturer of oxygen, and so are important organisms for understanding and keep an eye on the environment [3]. The micro algal based biodiesel has potential to completely alternate diesel without competing with the food and other supplies of agricultural products[21]. Liquid biofuels are the alternative fuels with a potential to reduce dependence of the consumer society on the fossil-based fuels globally [6]-[10],[19]. Numerous studies were approved on the biodiversity of algae in India [4],[5],[15],[18].

Nowadays the physical methods of identifying algae are replaced by new algorithms which could be used in programs. Image processing plays a vital role in identifying algae by their images. In the early days, to identify algae, the specimens have to be collected from watery areas like seas, oceans, ponds rivers lakes etc. The specimens have to be preserved for processing. But this is replaced by image processing, which deals with the images of algae. To identify the species of algae the features have to be extracted.

As a first step, the image has to be preprocessed. Preprocessing is a process of recovering a good estimate of the original image from a corrupted image without modifying the useful structure in the image such as edges, discontinuities and fine details [12].

The algae images used in this paper are microscopic images. Most of the Microscopic images are affected by non uniform illumination. Underexposed or overexposed image regions caused by non uniform illumination may pose a significant challenge to computer vision algorithms, since any image characteristic, such as edges, colors or local features, become a lot harder to detect [24]. This can be corrected using Center Surround Algorithm (Retinex algorithm). The Center Surround Algorithm is an automatic image enhancement method that enhances a digital image in terms of dynamic range compression, color independence from the spectral distribution of the scene illuminant, and color/lightness rendition [14]. The Center Surround Algorithm achieves a

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good balance in dynamic range compression, edge enhancement and color constancy [25].

The microscopic images are affected by non uniform illumination. The textures of the algae images are found to be jelly. So when hard filters are used some of the features will get affected and the correct features could not be retrieved. So pixel valued adaptive Single Scale Center Surround Algorithm is proposed to remove non uniform illumination without affecting the edges. Single Scale Retinex Algorithm is one of the Center Surround Algorithm [16] that helps in sorting out the illumination and reflectance.

Introduction should argue the case for the study, outlining only essential background, and should not include the findings or the conclusions. It should not be a review of the subject area, but should finish with a clear statement of the question being addressed.

2 Materials and methods

The image datasets used for processing are

- NIES image dataset(Dataset from national institute of environmental studies Japan)
- Shigen.nig.ac.jp/algae
- ANSP Algae image database
- ADIAC image dataset

Image processing is the current trend to enhance the quality of image by removing the abnormality found in the image and extracts the needed information from the image. The imperfection found in the algae images are the non uniform illumination. It often leads to diminished structures or inhomogeneous intensities of the image due to different texture of the object surface and the shadows cast from different light source directions [1]. The center surround algorithm is used to correct the illumination found in microscopic images.

2.1 Discrete Cosine Transforms (DCT)

The illuminated image is normalized by using the low frequency components of discrete cosine transform. The illumination variation is compensated using DCTs odd and even components. The illumination variations which lie in the low frequency band are minimized by truncating some appropriate number of DCT coefficients.(DCT normalization). DCT of an image of size(m,n) can be written mathematically as

$$c(u,v) = \alpha(u)\alpha(v)\sum_{x=0}^{m-1}\sum_{y=0}^{n-1} i(x,y) * cos\left[\frac{\pi(2x+1)u}{2m}\right]$$

$$cos\left[\frac{\pi(2y+1)v}{2n}\right]$$

Where $\alpha(u)$ takes the value $\frac{1}{\sqrt{m}}$ when $u=0$ and $\sqrt{\frac{2}{m}}$. When u ranges from 1 to $m-1$.

$\alpha(v)$ takes the value $\frac{1}{\sqrt{n}}$ when $v=0$ and $\sqrt{\frac{2}{n}}$. When v ranges from 1 to $n-1$.

2.2 Homomorphic Filtering

Illumination reflectance model is implemented in the homomorphic normalization technique. According to this model the image is considered to have two primary components namely illumination and reflectance. The illumination component can be given as

$$X(a,b)$$

The reflectance component can be given as

$$Y(a,b)$$

Now combining the illumination and reflectance the image Z can be given as

$$Z(a,b) = X(a,b) * Y(a,b)$$

The low frequency components lie in the illumination, $X(a,b)$. Illumination intensity changes slower when compared to that of reflectance. So the frequency domain is executed for the filtering process. To perform the filtering the image has to be transformed from spatial domain to the frequency domain. This can be achieved using Fourier Transform. By using the high pass filter some low frequency components are eliminated. By implementing the inverse Fourier Transform the image is again transformed to the spatial domain [20]. The flow can be specified as

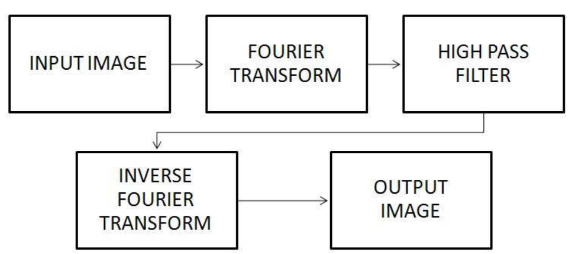


Fig. 1: Flow of homomorphic filter

2.3 Isotropic Smoothing

The luminance $l(x,y)$ can be estimated as a blurred version of original input image $i(x,y)$. A simple smoothing filter cannot be applied to produce the blurred output, but the luminance function can be constructed by minimizing the energy based cost function,

$$j((x,y)) = \int_x \int_y (l(x,y) - i(x,y))^2 dxdy$$

$$+\lambda \int_x \int_y l_x^2(x,y) + l_y^2(x,y)dxdy$$

Where the first term forces the luminance $l(x,y)$ to be close to the original image $i(x,y)$. The second term imposes the smoothing constrain on $i(x,y)$ and the parameter λ controls the relative importance of the smoothing constrain [23].

2.4 Anisotropic Smoothing

Anisotropic smoothing is similar to that of isotropic smoothing. The only difference is that it adds a weight function $\rho(x,y)$ to the cost function in addition. The fit between input images $i(x,y)$ and the luminance $l(x,y)$ is ensured by the weight function $\rho(x,y)$. Now the cost function can be rewritten as,

$$j(l(x,y)) = \int_x \int_y \rho(x,y)(l(x,y) - i(x,y))^2 dxdy$$

$$+\lambda \int_x \int_y l_x^2(x,y) + l_y^2(x,y)dxdy$$

2.5 Center/surround (or) The Retinex Algorithm

The Retinex theory was originally introduced to describe the human visual perception [2]. The Retinex theory was motivated by Land. Retinex is the combination of two words retina and cortex. This can be arranged as
Retina + Cortex = Retinex

Retina is an element of the eye which detects the scene whereas the cortex is a part of the brain which processes the information received from retina. In 1971 Land and McCann introduce the idea that image $I(x,y)$ is the product of two components, illumination $l(x,y)$ and reflectance $r(x,y)$ [11]. Image can be represented as

$$i(x,y) = r(x,y).l(x,y) \tag{1}$$

Where
$i(x,y)$ is image
$r(x,y)$ is reflectance
$l(x,y)$ is luminance
Luminance is achieved by illumination source. Reflectance is achieved by image objects. The (1) can also be written as

$$I = r.l \tag{2}$$

According to retinex algorithm the (2) can be written on logarithmic domain as

$$log\, i = log\, r + log\, l \tag{3}$$

From the (3),

$$log\, r = log\, i - log\, l \tag{4}$$

The equation can be further given as

$$r = exp(log\, i - log\, l)[14] \tag{5}$$

Single Scale Retinex

The Retinex is a member of the class of center surround functions where each output value of the function is determined by the corresponding input value (center) and its neighborhood (surround). For the Retinex the center is defined as each pixel value and the surround is a Gaussian function [11]. Single Scale Retinex is one suitable method for normalized the grey scale images [23]. The mathematical form of the single-scale Retinex is given by

$$r(x,y) = log(i(x,y)) - log(f(x,y) * i(x,y))$$

Where $r(x,y)$ is retinex output
$i(x,y)$ is the image intensity
* is convolution operatio
$f(x,y)$ is Gaussian function
$f(x,y) = k.e^{-(x^2+y^2)/\alpha^2)}, \iint f(x,y)dxdy = 1$
Where α is the standard deviation of the Gaussian function that determines the scale of single scale retinex [13].

2.6 The Proposed Method

The Single Scale Retinex method is adopted to correct the non uniform illumination in the gray scale images. By using the Single Scale Retinex [22] Algorithm the non uniform illumination cannot be removed fully. It can only divide illuminance and reflectance. The proposed method is an adaptive method of Single Scale Retinex Algorithm named as Pixel Valued Adaptive Single Scale Center Surround Algorithm. When removing the non uniform illumination the pixels in the edge will get affected. A novel adaption is made in the proposed method to preserve the edges of the features while correcting the non uniform illumination. Pixel value of each pixel is restored by calculating the geometric mean value of the surrounding pixels. By doing some revisions in the Single Scale Retinex Algorithm the non uniform illumination can be removed completely. The inhomogenity is completely figured out and by calculating the number of zeros the unevenness in the illumination is completely removed. The repeated convolution helps in restoring the edges of the images. Again normalization is done to give a better clarity to the image.

Algorithm for the proposed method is as follows:

1. Read the image
2. Pixel value of each pixel is replaced by calculating the geometric mean value of the surrounding pixels
3. Parameters for normalization is to be checked
4. Find the size of the image

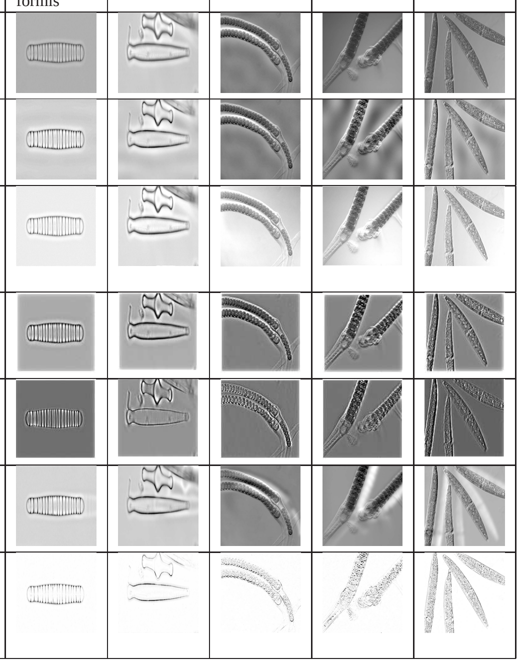
5.Calculate the spatial gradients
6.Figure out local inhomogenity
7.Determine weight functions
8.Initiate iterative convolution
9.Construct illumination invariant representation of input image
10.Normalize the image
11.Display the Output image

3 Results and Discussions

The microscopic images are affected by non uniform illumination. Table 1 shows the comparison results of Table 1 Result Comparison of images on various methods Homomorphic Filter, DCT, Isotrophic Filtering,

Table 1: Result Comparison of Images on Various Methods

Name	Diatoma monili formis	Peronia fibula	Aulosiralaxa	Calothrix Crustacea	Closterium acerosum
Original					
DCT					
Homo morphic					
Isotropic					
Anisotropic					
SSR					
Proposed method					



Anisotrophic Filtering, Single Scale Retinex and the Proposed Algorithm. The results of Single Scale Retinex show the splitting of illumination and reflectance. It is clearly observed that they are just corrected but not completely removed. In the proposed method non uniform illumination is removed completely without disturbing the features and edges. By repeating the convolution the edges are preserved which are clearly shown in the results of proposed method. The clarity of the image is also good which is attained by normalizing the image.
The quality metrics used for evaluation are

1.PSNR
2.MSE
3.MEAN
4.STD

Comparing the PSNR values of all the methods, the proposed method gives the best result which is shown in the Table 2. The Graphical representation of comparison

Table 2: Comparisons of PSNR Values

Name	Diatoma monili formis	Peronia fibula	Aulosiralaxa	Calothrix Crustacea	Closterium acerosum
DCT	33.2083	27.5447	33.0331	28.1580	29.8604
Homo morphic	38.7024	36.7441	39.8427	42.6673	49.2452
Isotropic	26.7698	23.9634	25.7611	24.8843	24.4046
Anisotropic	44.6681	43.2814	41.7343	40.9708	38.9489
SSR	47.9386	38.1216	44.1282	36.6988	39.9954
Proposed method	56.6136	48.3926	58.7113	54.2034	53.0644

of PSNR values is given in Figure 2.

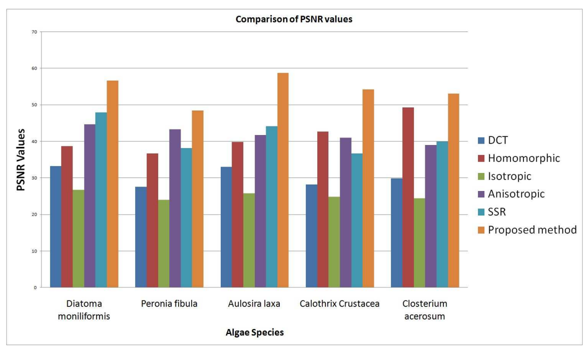


Fig. 2: Graphical representation of comparison of PSNR values

The Mean Square Error value is also comparatively low for the proposed method when compared with Homomorphic filter, DCT, Isotropic Filter, Anisotrophic Filter and Single Scale Center surround Algorithm is tabulated in Table 3. These results depict the proposed method is the best.

Table 3: Comparisons of MSE Values

Name	Diatoma monili formis	Peronia fibula	Aulosiralaxa	Calothrix Crustacea	Closterium acerosum
DCT	0.0063	0.0132	0.0087	0.0145	0.0119
Homo morphic	0.0044	0.0053	0.0039	0.0029	0.0072
Isotropic	0.0152	0.0204	0.0169	0.0204	0.0194
Anisotropic	0.0100	0.0111	0.0124	0.0131	0.0152
SSR	0.0078	0.0182	0.0138	0.0235	0.0182
Proposed method	0.0099	0.0179	0.0118	0.0152	0.0158

The Graphical representation of comparison of MSE values is given in Figure 3.

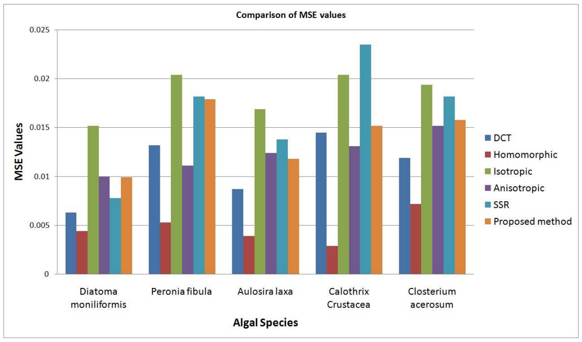


Fig. 3: Graphical representation of comparison of MSE values

The Mean value is also comparatively high for the proposed method when compared with Original image, Homomorphic filter, DCT, Isotropic Filter, Anisotrophic Filter and Single Scale Center surround Algorithm which is tabulated in Table 4.

Table 4: Comparisons of Mean Values

Name	Diatoma monili formis	Peronia fibula	Aulosiralaxa	Calothrix Crustacea	Closterium acerosum
Original	175.7577	201.1111	133.6064	119.7844	134.4530
DCT	210.1185	197.6057	139.1546	135.7178	172.1238
Homo morphic	149.3203	132.2438	105.3297	95.0567	128.3080
Isotropic	176.4772	175.5807	129.9624	175.5807	136.7614
Aniso tropic	114.9478	148.4309	119.5654	114.5848	98.9631
SSR	219.5443	209.2054	171.3455	188.8484	196.9403
Proposed method	247.8525	242.2066	243.9991	240.7002	238.0650

The Graphical representation of comparison of MEAN values is given in Figure 4.

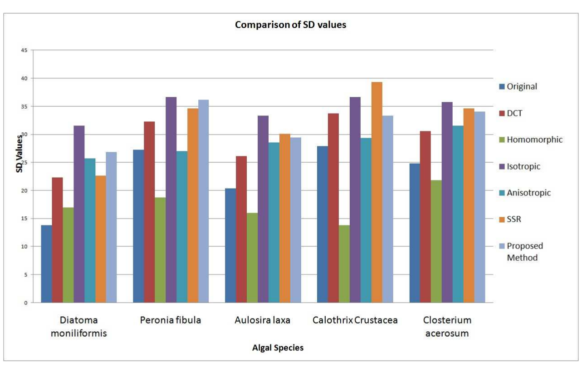


Fig. 4: Graphical representation of comparison of MEAN values

Table 5 shows the standard deviation values of the original image, Homomorphic filter, DCT, Isotropic filter, Anisotropic filter and single scale algorithm and the proposed method in which the proposed method shows the best results. The Graphical representation of comparison of SD values is given in Figure 5.

Table 5: Comparisons of SD Values

Name	Diatoma monili formis	Peronia fibula	Aulosiralaxa	Calothrix Crustacea	Closterium acerosum
Original	13.7732	27.2469	20.3781	27.8798	24.8416
DCT	22.3286	32.2570	26.1416	33.7229	30.5598
Homo morphic	16.9312	18.7776	15.9635	13.7909	21.8233
Isotropic	31.5812	36.6141	33.3060	36.6141	35.7590
Aniso tropic	25.6935	27.0340	28.5498	29.3675	31.5736
SSR	22.6233	34.5932	30.1011	39.3225	34.5932
Proposed method	26.8788	36.1626	29.4382	33.3209	34.0510

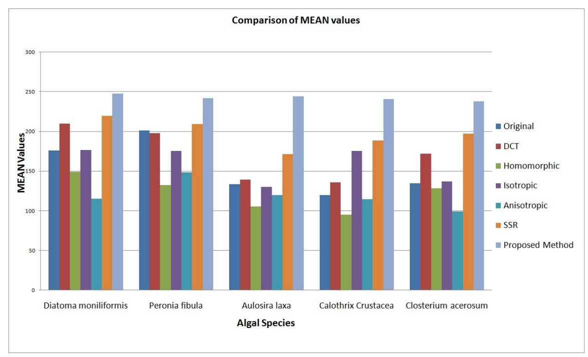


Fig. 5: Graphical representation of comparison of SD values

According to the subjective observation the proposed method has completely removed the non uniform illumination where as the Single Scale Retinex Algorithm just separates the illumination and the reflectance.

4 Conclusions

In the current years taxonomy of algae plays a major role. The microscopic images are taken for processing. By extracting the features of the image the classification can be done. To extract the features the images has to be preprocessed. The images are affected with non uniform illumination. Since the images are placed in the dark region the features has to be enhanced. This is done by substituting the pixel value according to the geometric mean of the adjoining pixels. The proposed method is Pixel Valued Adaptive Single Scale Center Surround Algorithm. The Single Scale Retinex Algorithm can separate the illumination and reflectance but cannot be completely eradicated. This is completely eradicated using the proposed system by saving the features.

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