STRUCTURE PRESERVING IMAGE ABSTRACTION AND ARTISTIC STYLIZATION FROM COMPLEX BACKGROUND AND LOW ILLUMINATED IMAGES

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Abstract

The paper deals with NPR filtering and image processing techniques to produce the structure preserving image abstraction and artistic stylization effect from complex background and low illuminated images. Structure preserving image abstraction and stylization is most useful in the animation process, film industry, and artistic illustration and education sectors for innovative teaching. Abstraction concept reduces the image complexity and Stylization produces good visual effect to human's sense. The work involves combining different NPR filtering techniques to create an effective NPR artistic illustration. The proposed technique consists of adoptive structure tensor flow, difference of Gaussian filter, 2D modified coherence shock filter, order dithering and Mean Curvature Flow (MCF). The work involves applying all these techniques in a series and the proposed scheme is found to give a good rendering effect on images with complex background and low luminance images. Moreover the proposed method does not require any kind of post processing techniques for abstraction and artistic stylization. The applied method produces the best abstraction effect and avoids halo effect. Implementation of proposed work is carried out in the Matlab environment. Efficiency of proposal work has been corroborated by conducting different experiments on various types of images and the results are compared with contemporary works. This approach is found to be computationally efficient in rendering effective structure preserving abstraction and stylization to the Human Visual System (HVS) and this approach opens up new research paths towards image and video stylization.

Keywords:

Non-Photorealistic Rendering, Adoptive Structure Tensor Flow, Mean Curvature Flow, Order Dithering, Difference of Gaussian Filter, Shock Filtering

1. INTRODUCTION

Non-photorealistic rendering (NPR) is an emerging processing technology which was deduced in the 19th century and emerged as a branch of image processing and computer graphics. Today, it is possible to adopt NPR techniques in the area of computer vision and visualization of computer interaction domain. Non-photorealistic rendering techniques which involve image abstraction, artistic stylization, line drawing, pen-and-ink illustration, HDR/Aerial image analysis, engraving, image analogy, color enhancement, pencil drawing, dithering, stippling, halftoning, hatching and mosaicking are being used to produce abstracted and stylized images [1].

By using computer graphics and NPR approaches reproduction of images from real world situations are abstracted to provide images sets to address particular needs. Abstraction techniques are also a part of Non photorealistic rendering and computer graphics methodology. The term abstraction is defined as extraction of useful information either from image foreground or from image background. Many simple and basic abstraction techniques are sobel edge detection, prewitt, Gaussian smoothing, some basic image enhancement techniques like dilation, erosion, image noise removal filter like , geodesic filtering , median filter, Difference of Gaussian (DoG) filtering, bilateral filter and so on. But due to their inherent limitations they fail to meet the expectations of the present day demand and therefore NPR technology has taken over the centre stage in the present research era. Principal objective of the work is to create a best artistic and rendering effect to images without compromising the output quality by concurrently applying the NPR filters and algorithms to produce the good abstracted and stylization images.

Non-photo realistic rendering (NPR) techniques mainly focus on preserving the dominant feature, suppression of unwanted features and to reduce the severe noise in an image by so as to enhance the object outline as well as object inner features in the given image scene and eventually reduce the image size. Abstraction techniques mainly concentrate on suppressing the shadow lighting effect, providing support to animation oriented activities, symbolic interpretation of scene and character. (e.g. apple ipod logo representation).

This paper describes image structure preserving abstraction and stylization for conveying effective visual quality by using complex image background, low illuminated image and images having severe noise. The main deliverable of the proposed abstraction and stylization system is to enable a user to easily generate effective and attractive illustrations. In this work an attempt has been made to effectively integrate the filters and algorithms by combining different NPR filtering techniques to create an effective NPR artistic illustration. The proposed technique consists of applying Adoptive structure tensor flow (STF), Difference of Gaussian filter (DoG), 2D modified coherence shock filter (CSK), Order dithering and Mean curvature flow (MCF) in series and if any extra noise is present in the filtered image then Bilateral Smoothing is applied for smoothing and noise removal purpose. The proposed scheme has been experimented on complex background and low-luminance images and the results are encouraging. Moreover the proposed method does not require any kind of post processing techniques for structure preserving abstraction and stylization. The proposed method produces the best abstraction effect and avoids halo effect. Implementation of proposed work is carried out in the Matlab environment. Efficiency of proposal work has been corroborated by conducting different experiments on various types of images and the results are compared with contemporary works. This approach is found to be computationally efficient in rendering effective structure preserving abstraction and stylization to human visual system (HVS) and this kind research can opens new research paths towards image and video stylization. The work involves exploiting the features of these filters through integration mechanisms to carry out the abstraction and stylization applications. The proposed image abstraction and artistic stylization rendering technique has the capability to convey regions, shapes, and inner boundary, out boundary as well as a particular region in an effective manner, suppress the random real time noise, preserve image structure, texture and be capable of providing 3D effect to 2D images. The complimentary advantage of this process is that it reduces the size of the image data [2].

NPR methodology not only deals with abstraction and rendering techniques but also gives same kind of priority to line drawing technique [3], video abstraction, mesh drawing, HDR image analysis for convey the shapes, pencil sketching, mosaic drawing, image synthesis, image based photo editing and stretching. It is also useful to solve the optimization problem in engineering and scientific applications.

Following are some of the significant contributions of this research work:

1. Studied the feasibility of fusing the NPR techniques such as adoptive structure tensor flow (STF), Difference of Gaussian filtering (DoG), coherence shock filtering (CSK), order dithering and mean curvature flow (MCF) to trim down the noise, complexity and intensify the enhanced sharp boundaries as well as image prominent structure..
2. Explored a novel framework by integrating various NPR image filters and algorithms to produce more effective and efficient structure preserved image abstraction and artistic stylization output.

Rest of the paper is organized as follows. Section 2 presents some of the interesting works related to the proposed framework. Section 3 presents the proposed methodology covering the technical details of the proposed framework. Details of the experiments conducted and the analysis of the results are presented in section 4 followed by conclusion and future work in section 5.

2. RELATED WORK

Although there are many techniques proposed by various artists, and even more theories have been proposed by various researchers and critics on how to achieve good visual design, yet a best technique is elusive until today. Because of this, a successful practical approach must necessarily draw on elements from many areas of practice and theory. If a practical system is designed to be as general as possible, its creation can improve understanding of what visual clarity means, and how it relates to communication. It can also provide a framework in which to unify concepts and techniques from many fields. Though many attempts have been made since decades to come out with efficient and effective techniques for image abstraction, the techniques could not be generalized and hence there is a scope to explore many other novel techniques for image abstraction [2] [3].

Salesin was the person who first introduced the advanced NPR filtering techniques and gave a major contribution to the field of image abstraction and rendering. He proposed the abstraction concept by using simple image processing techniques like outer boundary detection and simplification, inner feature preservation, edge detection techniques, smoothing algorithms, sharpening of an image, removal of noise from an image and so on.

Haeberli et al. [4] proposed paint by numbers for abstract image representation. First Stroke color and orientation were sampled from the source image and the Stroke order and scale are user-selected. Finally RGB noises were added to the previous output to obtain the abstracted and stylized image.

Haggerty et al. [5] proposed almost automatic computer painting. This paper is an extension of the Haeberli et al proposed work. In this work computer automatically chooses the Stroke order and scale based on image color and image orientation. But in paint by numbers: abstract image representation, users manually choose the stroke order and scale.

Anjyo and Hiramitsu [6] proposed stylized highlights for cartoon rendering and animation. In traditional cell animation, lights and shadows play a very important role for demonstration of cartoon and stylization images. The work principally deals with shapes and animations effect. Shapes represent the important event or object in an image and it also preserves the edge oriented information. Animation effects smooth the image regions and provide the dynamic lighting effect to images. This paper proposed a new highlight shader for 3D objects in cell animation. This work produces cartoon-like images by adopting Blinn's specular model rather than texture mapping techniques and involves translation, rotation, splitting, squaring and light shading. Based on these technical skills and operations, the system produces cartoon-like animated images.

Jan Eric et al. [7] proposed image and video abstraction by structure adaptive filtering method/system for producing the stylization and artistic illustration. The proposed techniques mainly consist of local orientation estimation, bilateral filter, DoG filter, and color quantization. Local orientation estimation is calculated using Eigenvector of tensor flow. For Vector Analysis the work overlaps the ETF with local tensor flow. ETF techniques are iteratively applied to obtain smooth tangent flow. During the next step a modified version of bilateral filter was applied in a direction perpendicular to the gradient of an image. This work adopted the best modified bilateral filter to address severe noise conditions and it gives an optimal solution to color quantization. During the third phase DoG filter was applied for boundary detection and dominant edge extraction purposes. As compared to Winnemollor et al. [8] approach, Kang et al. [23] proposed method could give a very good output because, bilateral filters in Winnemollor et al. [8] system suffered from horizontal and vertical artifacts. Although Kang et al paradigm overcomes drawbacks of Winnemollor approach and produces more effective 2D and 3D rendering but also faces more computational complexity because of the fact that Kang adopted DOG filter which applied on gradient direction. Kang et al. [23] paradigm produces the best abstracted and stylized images even though it consumes more computational time.

Eric et el. [9] proposed image and video abstraction by multiple scale anisotropic Kuwahara filtering. Initially image pyramids were created by using Schumacher methodology. Image pyramids mainly consisted of Gaussian filters for the removal of high luminance noise. Previously Filtered image was fed to the next stage to calculate the local structure estimation and anisotropic estimation on the basis of gradient calculation and major Eigenvectors. Local structure estimation and anisotropic estimation were done for preserving the Edge oriented information. The edge oriented information is then passed on to structure tensor flow to preserve the inner features and smoothen the image and the filtered output was subjected to anisotropic Kuwahara filter iteratively to preserve the very important features. That is the reason why core level filters are called as multiple scale anisotropic Kuwahara filtering. The edge preserving filters are normally used for image and video abstraction. However, sometimes they fail to filter low contrast regions and high contrast edges and to overcome this short fall multiple scale anisotropic Kuwahara filtering can be used. This filter properly removes the details in high contrast edges and also protects the shape boundaries in low contrast regions. Thus it maintains fairly a uniform level of abstraction across the image while providing an overall painting style look. The multiple scale anisotropic Kuwahara filtering simplifies and removes clustering artifacts by adopting the shape scale and orientation of the filters to the local structure of the input. Due to adoption of this filter to local structure, bidirectional image features are better preserved and emphasized. But the multiple scale anisotropic Kuwahara filtering fails to address HDR images and is unstable in the presence of high noise in the HDR images and it suffers from block of artifacts. It requires more computation power than other contemporary approaches.

The work proposed by David Mould on Texture preserving abstraction, preserves the important texture in an image, by adopting a variant of geodesic image filtering which preserves the locally strongest edges, leading to preservation of both strong edges and weak edges depending on the surrounding context. Few other detailed literature on NPR and image abstraction, artistic stylization and application has been reported by Kyprianidis et al. [10], Yongjin [11] and Kumar et al. [12].

3. PROPOSED METHOD

The proposed method of abstraction and artistic stylization of images from complex backgrounds and poor illuminated images paradigm involves five major steps. First, adoptive structure tensor flow (STF) is applied to suppress the irregularities, regularizing the contours, preserving dominant structure and prominent edge boundaries in an image. However, some edge information may not be clear and need to be enhanced by using Laplacian structure tensor relaxation. In the second step, Difference of Gaussian (DoG) filter is applied to render clarity on uncleared edges and provides a more clear line and boundary extraction. In the third step, we apply a modified coherence shock filter iteratively to provide a sharpening effect to the image, recover the hidden edges and regularize the uncanny edges. The image obtained at this stage may contain surface irregularities due to sharpening and need to be suppressed. Hence in the fourth step, we apply order dithering to appropriate non-realistic color depth in an image with a suitable palette. Compared to general dithering techniques it produces best rendering and stylized abstracted images. Finally, we apply the MCF to remove the irregularities in the image surface which produces artistic effect without any unpleasant effect on the human eye. The following sections provide a brief description about the NPR filters used in the proposed methodology and proposed framework is presented in the Fig.1.

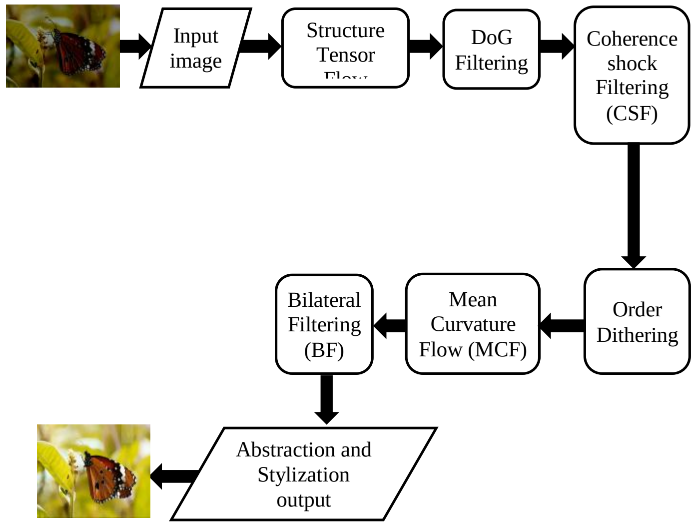

Fig.1. Proposed Structure preserving abstraction and artistic stylization framework

3.1 ADOPTIVE STRUCTURE TENSOR FLOW

Second moment matrix is a synonym for structure tensor flow technique that is purely a non-linear filtering technique. Nowadays most of the image processing applications depend upon structure tensor flow. Structure tensor flow works well if a given image has a low-illuminated, complex background and noise. Structure tensor flow replaces the general structure preserving techniques from many applications. Structure tensor flow has the following advantage over other traditional filtering techniques, STF is capable of calculating the local orientation estimation and integrates the local gradient information, avoids the blurring in an image, preserves the structure, texture and shapes without affecting their visual quality. Adaptive structure tensor flow is not only stuck to preserve the edge information, gradient information, it is also useful for image local structure estimation and enhancement of low-illumination and improves the overall contrast of an image. In this paper, first we applied the logarithm TMO [17]-[19] to enhance the low illumination image and the contrast in the image. Further, a Laplacian mask is applied to calculate the image gradient and the equation governing the mask can be written as:

$$g(x,y) = f(x,y) + c\left[\nabla' f(x,y)\right] \quad (1)$$

where

$$\nabla f = \begin{bmatrix} G_X \\ G_Y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix},$$

$f(x,y)$ is the input image,

$g(x,y)$ is the enhanced image, C is the coefficient values.

The Laplacian mask is written as:

$$G_x = \begin{bmatrix} \frac{\alpha}{1+\alpha} & \frac{1-\alpha}{1+\alpha} & \frac{\alpha}{1+\alpha} \\ \frac{1-\alpha}{1-\alpha} & \frac{-8}{1+\alpha} & \frac{1-\alpha}{1+\alpha} \\ \frac{\alpha}{1+\alpha} & \frac{1-\alpha}{1+\alpha} & \frac{\alpha}{1+\alpha} \end{bmatrix} \quad G_y = \begin{bmatrix} \frac{1-\alpha}{1+\alpha} & \frac{\alpha}{1+\alpha} & \frac{1-\alpha}{1+\alpha} \\ \frac{\alpha}{1+\alpha} & \frac{-8}{1+\alpha} & \frac{\alpha}{1+\alpha} \\ \frac{1-\alpha}{1+\alpha} & \frac{\alpha}{1+\alpha} & \frac{1-\alpha}{1+\alpha} \end{bmatrix} \tag{2}$$

where α = 0.195, *x*,*y* are image coordinates with respect to *x* and *y* axis. Laplacian image gradient is calculated by using the following formula.

$$\nabla f = |G_x| + |G_y| \tag{3}$$

$$f_x = G_x{*}I \quad f_y = G_y{*}I \tag{4}$$

This work perform the convolution operation where * is a convolution operator. Most cases low-dimensional structure and features analysis is calculated by using structure tensor flow. It also used to preserve the corner edge. Finally structure tensor is calculated and denoted as:

$$ST_n = \begin{pmatrix} \frac{f_x^2}{f_x \cdot f_y} \end{pmatrix} \begin{pmatrix} \frac{f_x \cdot f_y}{f_y} \end{pmatrix} := \begin{pmatrix} \frac{\alpha}{\beta} \cdot \frac{\beta}{\zeta} \end{pmatrix} \tag{5}$$

Subsequently, based on the structure tensor values we calculate the major and minor eigenvalues and eigenvectors. In structure tensors eigenvalues help to calculate the flat areas. It can be written as $\mu_1=\mu_2$. Straight edge is represented as $\mu_1>>\mu_2>0$ Corner edge is represented as $\mu_1>\mu_2>>0$. Major and minor Eigen values are calculated by using the following formula.

$$\mu_{1,2} = \frac{\alpha + \zeta \pm \sqrt{(\alpha-\zeta)^2 + 4\beta^2}}{2} \tag{6}$$

Eigenvector is calculated by using equation:

$$\eta = \left(\frac{\beta}{\mu_1 - \alpha} \right), \xi = \left(\frac{\mu_1 - \alpha}{-\beta} \right) \tag{7}$$

Low contrast region is preserved and error rate is calculated by using tensor relaxation, for that purpose we use Laplacian relaxation that is helpful to preserve the structural information and texture information in the image. Structure tensor magnitude should be greater than threshold values for creating, smoothening and preserving the structure information and it is mathematically represented as follows.

$$f_{smooth}(x,y) = \sqrt{\alpha(x)^2 + \xi(x)^2 + 2\beta(x)^2} > threshold \tag{8}$$

where threshold value is set to 0.03 and detailed implementation information is presented in [7] [13] [14].

3.2 DIFFERENCE OF GAUSSIAN FILTER (DOG)

Difference of Gaussian Filtering (DoG) is basically a line extraction and enhancement filtering technique. The filter is also used to show significant high discontinuities. Two Gaussian filters with different blurring radius are formed and the respective images after Gaussian filter are obtained. The resulting images are subjected to subtraction operation to obtain the result. Image edge and line extraction smoothing can be performed by convolution using appropriate spatial mask. Applying the spatial mask to an input image suppresses the high frequency spatial information. A general DoG is used for line extraction. The most important parameters for DoG filters are the smoothing radii (σ) for the two Gaussian blurs [15] [16]. It is observed that a small increase in the radius tends to give thicker appearing edges and a small decrease tends to increase the threshold for recognizing the edge. In most cases, a best result is obtained when the value for (*radius*-2) is smaller than the (*radius*-1). The DoG equation can be mathematically represented as follows.

$$f(I,\mu,\sigma_1\sigma_2) = \frac{1}{\sigma_1\sqrt{2\tilde{O}}}\exp\left(-\frac{(I-\mu)^2}{2\sigma_1^2}\right) - \frac{1}{\sigma_2\sqrt{2\tilde{O}}}\exp\left(-\frac{(I-\mu)^2}{2\sigma_2^2}\right) \tag{9}$$

More detail about DoG filtering is found in our previous research paper [2].

3.3 MODIFIED 2D COHERENCE SHOCK FILTER

The 2D Coherence Shock Filter [20]-[22] is an edge preserving filter and it also preserves the discontinued edges, which gives more importance to direction of the edges in an image. It involves either a dilation or erosion process depending on whether the pixel is present in the maximum or minimum influence zone [23].

$$It = -sign(\Delta u)\,|\nabla u| \tag{10}$$

The filter creates shocks between maximum and minimum influence zones so that the operation is within the range of the original image. The modified version of the coherence shock filter makes the edges more sharp and helps more accurate segmentation of region of interest. A slight modification to coherence shock filter is accomplished as follows.

$$I_t = -sign(\Delta u * I)\,|\nabla u| * I_{smooth} \tag{11}$$

where, *I* is the gradient image and I_{smooth} is an anisotropic filtered image [2]. The modified coherence shock filter combines the gradient image, anisotropic filtered image and –sign(Δu). The modified coherence shock filter gives a shining effect to the image by preserving hidden edges. Compressive information about coherence shock filtering is presented in [2] [23].

3.4 ORDER DITHERING

Human visual systems are capable of perceiving diverse colors and the machine is not capable of displaying and printing these diverse colors. For example a low resolution mobile display with lowest resolution cannot display a large number of colors and similarly all computer printers cannot print a large number of colors because of their limited capability. In such cases half toning and dithering helps to overcome these limitations. Dithering techniques arrange the dots of color points and arrange them into well-defined patterns. It is a technique used to create the inappropriate/non-realistic color depth in images with a limited color palette. The aim of dithering is to decrease the number of colors and to provide artistic effect to an image without any unpleasant effect to the human eye. It helps in converting original images into cartoon, halftone like images. The idea of dithering is mainly based on quantization and color approximation technique [24]. In this work, we are not using the dithering function supported by Matlab. Instead of that we adopted order dithering for providing the rendering effect to an image which provides parallel dithering capability. Order dither is part of the half toning paradigm. Although in some cases, half toning does not completely remove the quantization error. Order dithering is also mainly based on quantization but does not have any fixed threshold value during the dithering process. Order dithering allows image pixels to adopt different threshold values compared to other dithering techniques which operate with fixed threshold values and thereby making it a very efficient and fast dithering process. Order dithering paradigm reduces the quantization error in an image and reduces the color space from M bit to N bit. By generalized dithering one can easily spread the white noise to the entire image thereby reducing the color space from M Bit to N Bit. Order dithering is not only suitable for color images but also works equally well for gray scale images. Main quantization aim is to reduce the color space in an image without affecting the human visual perceptual system; Order dithering successfully fulfills the aim of quantization techniques. Generalized Dithering method is mainly categorized into 2 types:

- Error diffusion dithering
- Order dithering

In case of error diffusion dithering, it adds the white noise to the entire image in a uniform manner. One best example for Error diffusion dithering is Floyd-Steinberg dithering. Order dithering adds pseudo noise to the image and produces the regular pattern. Floyd Steinberg dithering techniques adopted the fixed threshold value and quantization errors are spread over to right and bottom edges and it does not deal with quantization error in a local manner whereas in order dithering quantization errors are locally handled. Order dithering filter mask is written as follows.

$$F_{orderdither} = \frac{1}{16}\begin{bmatrix} 0 & 8 & 2 & 10 \\ 12 & 4 & 14 & 6 \\ 3 & 11 & 1 & 9 \\ 15 & 7 & 5 & 13 \end{bmatrix} \quad (12)$$

$$D_{pixel} = F_{orderdither}(y \bmod n, x \bmod n) \quad (13)$$

where x and y are the position of the pixel in an image and n is a dithering matrix. Order dithering uses 4×4 matrix masks. The above filter mask is applied over to an entire image by subtracting the image pixel value using mask and quantizing with constant threshold. By using this Eq.(13), we calculate the each pixel threshold information. One more attractive feature of dithering techniques is its ability to repetitively apply a designed special matrix to create artistic and rendering images.

3.5 MEAN CURVATURE FLOW

It is implemented on the basis of linear diffusion equation and curvature concept can be mathematically defined as follows. Here $U(x,y)$ represent the image, x and y are coordinates.

$$\kappa = \partial_{smooth}U + \partial_{isotropic}U \quad (14)$$

where the derivatives of vectors $\partial_{smooth}U$ and $\partial_{isophotes}U$ are applied parallel to ∇u. ∂_{smooth} describe the smoothing the flow lines and $\partial_{isophotes}$ smoothing the isophotes curvature. In this paper we main adopted $\partial_{isophotes}U$ to regularize the isophotes curvature, where K denotes the isophotes curvature.

$$\kappa = \frac{U_x^2 U_{yy} - 2U_x U_y U_{xy} + U_y^2 U_{xx}}{\left(U_x^2 + U_y^2\right)} \quad (15)$$

MCF is used to remove the irregularities from complex background images. It effectively protects and conveys directional characteristics of shapes, features and textures. MCF is capable of identifying luminance contour on the image for suppressing unwanted irregular curves, removing noise and irregular peaks. It suppresses and elaborates the irregular curves in an input image and it provides a smoothing surface on input images. MCF can be mathematically expressed as [2] [23].

$$I_{MCF} = \kappa\left|\nabla U\right| \quad (16)$$

Further information related to MCF is found in [2] [22] [23].

3.6 BILATERAL FILTERING (BF)

Tomasi and Mundachi invented the bilateral filtering in the year1998 and BF is a non-linear filtering approach and hence it is used for image smoothing and noise removal purposes. It is used in multiple applications like smoothening, artistic stylization and denoising. It has two important parameters such as Gaussian spatial weight and Gaussian range weight is expressed as [25].

$$Bilateral\ Filter[I] = \frac{1}{W_p}\sum_{q \in s} G_{\sigma_s}\left(\|p-q\|\right) G_{\sigma_r}\left(\|p-q\|\right) * q \quad (17)$$

Sufficient information towards BF is presented in [25]. In this work, bilateral filtering is applied on the output produced by mean curvature flow (MCF) to synthesize the better structure preserving image abstraction and artistic stylization. In general, bilateral filter is more useful for image analogy and photographic style transfer, cartoon rendition in addition to smoothing and preserving the edges and very importantly photographic computation and manipulation.

The proposed method of integrated filter-based approach to image abstraction can be algorithmically expressed as follows:

Algorithm: Structure preserving abstraction and artistic stylization from complex background and low-illuminated lightning images.

Input: Complex background and low-illuminated images.

Output: Abstract and artistic stylized images.

Step 1: Apply Structure tensor flow for preserving the local orientation structural information and smoothing the images.

Step 2: Apply Difference of Gaussian filter for extracting dominant edges and lines.

Step 3: Apply a shock filter for recovering hidden edges and preserving the dominant edge information.

Step 4: Apply Order Dithering technique for reducing the color space and removal of quantization error.

Step 5: Apply Mean Curvature flow to regularize the irregular isotope curves in an image and it provides optimal flow effect to an image.

Step 6: Applying Bilateral Filtering noise suppression and rendering of abstraction and artistic stylization.

4. EXPERIMENTAL RESULTS AND COMPARATIVE ANALYSIS

The proposed work comprising the NPR framework is implemented using Matlab-2018a, 4GB RAM.

4.1 DATASET

Experimental images are taken randomly using Canon 1200 DSLR cameras and few from previously published journals and are presented in Fig.2. These test images have diversified subject matters such as complex background, low-contrast, low-illumination images and portrait images.

The sample images which contain large complex information, complex structure and natural scene images are chosen for the task. In Fig.2, we have presented 9 samples out of 250 samples considered.

4.2 EXPERIMENTAL RESULTS

In order to study the efficacy of the proposed technique for structure preserving abstraction and stylization of images from complex background and low-illuminated images, we conducted experiments on various types of natural and complex background images. This section presents few of the results obtained from the proposed method. In our experimentation, the structure tensor threshold value is set to 0.03, the Laplacian mask values to 0.195 by trial and error method. For difference of Gaussian filter, the σ_1 and σ_2 values are set to 5.0 to 4.5 and the deviation value μ is set to 0.6.

For the shock filter, the deviation value is set to 3.0 and the number of iterations is set to 25. In this work 128 bit and 255 bit dithering was adopted depending upon our image complexity and MCF is applied for smoothing the surface and regularizing the irregular surface. The MCF is designed using local isophote curvature; it provides smooth optimal flow to images. Finally, to ensure artistic stylization and removal of superficial noise, Bilateral filtering standard deviations and range parameters was set at σ_d =3.5 and σ_r =40 respectively to enhance intensity. The Fig 3 - Fig.5 shows the results of various stages of the proposed method of structure preserving image abstraction and artistic stylization from complex background and low-illuminated images.

Fig.2. Test samples

4.2.1 *Experiment 1:*

The experimental images presented in Fig.3 which mainly consist of natural low-illuminated and complex background input image and results obtained from our proposed framework after applying all NPR filtering methods over input testing sample. Experiment 1 vividly demonstrates the various stages involved in getting the desired output.

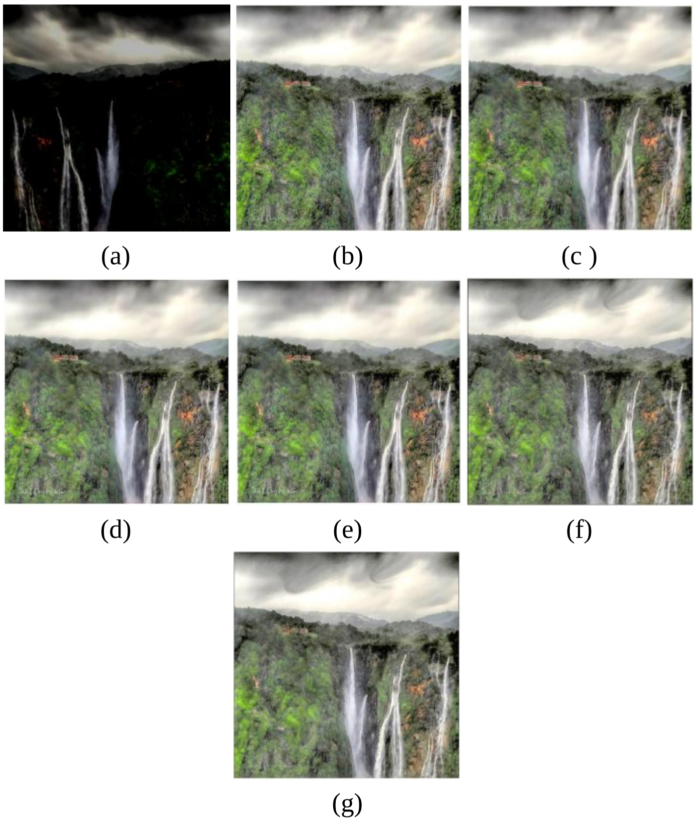

Fig.3(a). Input image (b) Output of Structure Tensor Flow(STF) (c) Output of Difference of Gaussian (DoG) Filtering (d) 2D Coherence Shock Filter (CSF) (25 Iterations) (e)128 bit order dithering (f) Mean Curvature Flow (MCF) (g) Output of Bilateral Filtering

4.2.2 *Experiment 2:*

The experimental images presented in Fig.4 which is obtained from the proposed framework and all NPR filtering methods are applied on the input testing image sample. Experiment 2 vividly demonstrates the various stages involved in getting the desired output.

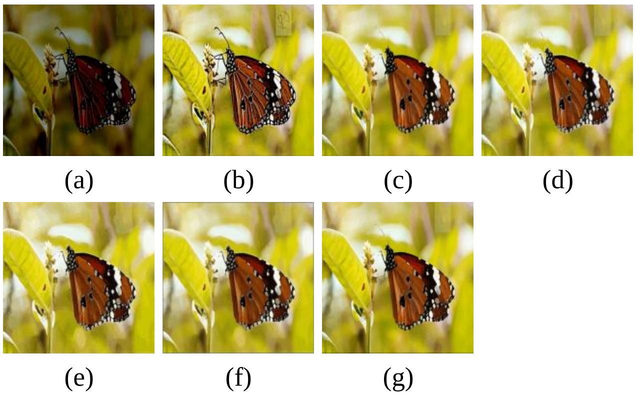

Fig.4(a). Input image (b) Output of Structure Tensor Flow (STF) (c) Output of Difference of Gaussian (DoG) Filtering (d) 2D Coherence Shock Filter(CSF) (25 Iterations) (e)128 bit order dithering (f) Mean Curvature Flow (MCF) (g) Output of Bilateral Filtering

4.2.3 Experiment 3:

We have also conducted an experiment on natural image with complex image background and the proposed method has produced the encouraging result.

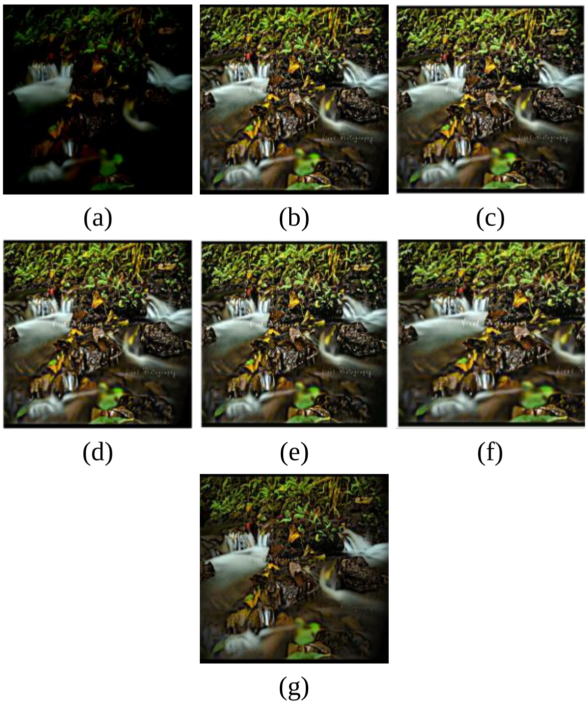

Fig.5(a). Input image (b) Output of Structure Tensor Flow(STF) (c) Output of Difference of Gaussian (DoG) Filtering (d) 2D Coherence Shock Filter(CSF) (25 Iterations) (e)128 bit order dithering (f) Mean Curvature Flow (MCF) (g) Output of Bilateral Filtering

The Fig.5(a) is an input image and Fig.5(b) to Fig.5(g) show the result of various stages of the proposed method of Abstraction and artistic stylization from complex background and low-illuminated lightening images.

4.3 COMPARATIVE ANALYSIS

Comparative analysis is also conducted by considering the previously published papers results [23] [26] and obtained results ensured the better abstracted and artistic stylization results with very low computational computing environment. Comparative analysis is present in the Fig.6.

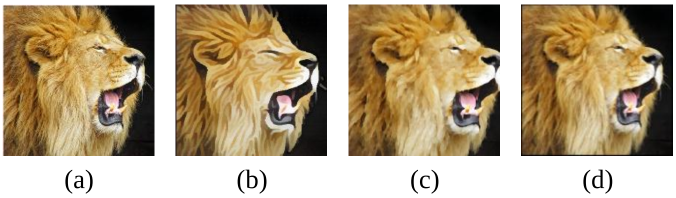

Fig 6. (a) Input image (b) Shape simplifying image abstraction [23] (c) Artistic edge and corner enhancing smoothing [26] (d) Proposed image abstraction and artistic stylization output

This work evaluates the proposed framework efficacy by calculating the image properties such as color [27], contrast [28], complexity [29], noise [30], sharpness [31], edge strength [32] standard deviation and mean at every stage which helps to enhance the desired features at appropriate stages and the assessment guidelines for carrying out the property refinement is as in [33]. This work gauges the quality of abstraction and stylization output by using tone mapped image quality index (TMQI) [34] output which assesses the image quality factor and neutrality of the artistic stylization output.

Finally, this work also adopts the Full-Reference Quality Metrics such as PSNR [35], SSIM [36] and MSE [12] [35] and No-Reference Quality Metrics such as PIQE [37] and NIQE [38] which are useful for image quality assessment (IQA). IQA consists of nonnegative scalar values which range from [0, 100]. In order to assess the MSE, PIQE and NIQE, the obtained values should be very low and to measure SSIM, TMQI and PSNR obtained values should be high. The output of experiment 1, experiment 2 and experiment 3 image property and image quality assessment values is present in Table.1 and Table.2. Detailed description about SSIM, PSNR, PIQE, NIQE and MSE could be found in [12] [33] - [38].

Table.2. Individual stage image property assessment by using proposed image abstraction and artistic stylization framework

Image Property Assessment	Input	STF	DoG	CSF	Dither	MCF	BF
Picture 1							
Color	8.97	25.12	24.62	25.3	25.56	23.04	22.78
Complexity	0.85	0.92	0.9	0.91	0.89	0.85	0.83
Contrast	7.98	6.13	5.7	5.74	5.73	5.61	5.31
Sharpness	2.75	10.08	6.3	8.42	8.52	9.39	6.71
Edge strength	16.72	36.23	24.45	41.27	40.31	35.33	25.62
Noise	1.89	3.69	0.15	1.41	7.099	2.17	0.28
Mean	29.36	135.2	136.8	139.7	141.14	136.93	137.7

Deviation	48.73	61.57	61.89	61.68	62.54	58.83	57.03
Picture 2							
Color	54.46	95.04	93.51	93.24	92.5	98.13	94.41
Complexity	0.96	0.84	0.81	0.82	0.8	0.79	0.78
Contrast	5.6	5.91	4.26	4.31	4.26	4.52	4.3
Sharpness	4.52	10.35	4.93	6.66	6.47	8.34	4.92
Edge strength	29.23	48.47	26.36	36.12	32.06	35.66	33.09
Noise	2.25	0.72	0.11	0.23	0.5	0.9	0.06
Mean	54.32	128.3	133.71	138.8	138.68	135.37	133.7
Deviation	47	79.83	77.19	77.63	77.75	79.33	77.98
Picture 3							
Color	23.19	53.75	51.77	55.73	55.08	51.89	47.64
Complexity	0.89	0.85	0.86	0.87	0.83	0.84	0.77
Contrast	7.36	11.21	10.32	11.08	11.16	10.66	8.87
Sharpness	3.09	17.51	15.17	18.09	17.74	15.06	10.5
Edge strength	23.04	68.48	63.72	66.02	63.05	57.53	48.66
Noise	1.22	11.19	2.5	11.93	38.41	2.62	1.06
Mean	11.74	58.85	61.48	66.84	69.58	76.61	47.66
Deviation	27.38	62.76	64.69	72.88	74.52	80.25	48.82

Table.3. Individual stage Image Quality Assessment (IQA) by using proposed image abstraction and artistic stylization framework

Image Property Assessment	Input	STF	DoG	CSF	Dither	MCF	BF
Picture 1							
SSIM	-	0.129	0.81	0.87	0.78	0.7	0.85
PSNR	-	6.59	20.71	24.41	19.81	16.27	23.93
TMQI-Naturality	-	0.22	0.68	0.65	0.59	0.55	0.65
TMQI-Quality	-	0.49	0.55	0.6	0.6	0.52	0.54
MSE	-	14254	551	235.24	679.3	1398	223.03
NIQE	4.54	3.3	3.7	3.9	6.59	2.63	3.7
PIQE	72.34	32.42	72.73	61.3	29.88	31.51	51.27
Picture 2							
SSIM	-	0.53	0.88	0.95	0.955	0.93	0.9
PSNR	-	9.7	19.36	24.52	26.4	20.09	21.77
TMQI-Naturality	-	0.12	0.41	0.37	0.25	0.27	0.25
TMQI-Quality	-	0.4	0.55	0.56	0.54	0.51	0.5
MSE	-	6963.4	752.9	229.47	148.9	636	368
NIQE	2.86	2.69	2.9	2.5	2.48	3.7	2.14
PIQE	55.41	45.64	63.85	24.52	55.59	76.8	51.29
Picture 3							
SSIM	-	0.15	0.67	0.7	0.61	0.47	0.43
PSNR	-	11.9	15.65	15.53	15.06	11.8	10.54
TMQI-Naturality	-	0.13	0.4	0.41	0.31	0.3	0.3
TMQI-Quality	-	0.4	0.43	0.51	0.5	0.35	0.35
MSE	-	4132.5	1767	1816.5	2027	6248	1876
NIQE	11.96	5.89	3.8	3.6	7.8	4.3	2.4
PIQE	70.61	35.16	64.02	58	41.05	56.6	40.68

5. CONCLUSION AND FUTURE WORK

In this paper, we have presented an integrated filter-based approach to produce structure preserving abstraction and stylization of images from complex background and low-illuminated images with low computational environment. The proposed method incorporates the features of various filters to produce the better result. The method does not require any kind of individual brush strokes and GPU's to produce abstraction and stylized effect. The proposed method is found to be effective for all types of blurred images, high contrast images, specifically rigid and complex background images. The experimental results obtained for various types of images are highly encouraging and are comparable with the other abstraction techniques. The approach is found to be computationally efficient in producing effective abstracted and artistic stylization like images apart from being simple in terms of its implementation. Proposed image abstraction and stylization create the new horizon in the domain of educational research [12] and animated film industry. The refined abstraction framework can also be used as pre-processing framework to explore desire focusing on prominent structure, archeological monument classification, extraction of text from heterogeneous complex background and graphical embossing images.

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