Line Drawing for Conveying Shapes in HDR Images

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Abstract- In this paper, we present NPR techniques to convey important shapes in HDR images. Line drawing is important to convey shapes in an image to produce good illustrations for scientific purpose. The proposed method make use of the global tone mapping operator, 2D anisotropic filter, 2D modified coherence shock filter, weight parsing technique and bilateral filtering. Global tone mapping operator is used to suppress the high luminance image region and helpful to convert HDR images to LDR images. 2D Anisotrophic filter preserves the local structure orientation features and suppresses the severe noises. Weight parsing technique is used to highlight the outline boundary. Coherence shock filter is applied iteratively to enhance the edge information in an image. Bilateral filter with a fixed deviation value is also applied to preserve the boundary in the line drawing image. The proposed method has been experimented on HDR images, images with complex or cluttered background and does not require any kind of post processing techniques for line drawing. Implementation of the proposed work is carried out in MATLAB environment. Efficiency of the proposed work has been corroborated by conducting different experiments on various types of images and the results are compared with other contemporary work. The approach is found to be computationally efficient in producing effective line drawing for human visual system (HVS)..

Keywords – High Dynamic Range (HDR), Human visual system (HVS), Non Photorealistic Rendering (NPR), global tone mapping, weight parsing, anisotropic filter, coherence shock filter, bilateral filter.

I. INTRODUCTION

Line drawing and pencil drawing techniques come under NPR technique. Line drawing is an effective tool to convey shapes in 3D structure for its understanding. Most of the line drawing techniques depend on one or more traditional approaches like Canny edge detector, Sobel edge detector etc. These traditional approaches may produce desired result for simple type of images but may fail to produce effective line drawing when the depth of domain increases. Advancement in NPR methodologies and modern digital systems look towards efficient and effective methods for line drawing [1].

Line drawing techniques are most useful for numerous applications such as smoothing isophote curves, stipple drawing, mosaics engraving, simplifying visual cues [2, 3], cubist rendering, mesh rendering cartoon rendering of 3D object, noise suppression, conveying shapes, pen and pencil sketch illustration etc.[4,5], to name a few. It is also useful to solve the optimization problem in engineering and scientific applications. In line drawing, lines are the important features to convey shapes [6, 7]. Generating the best line drawings, pencil drawings, mosaics drawings need creativity in addition to the best technical methodology.

This paper describes line drawing for conveying shapes in HDR images. Line drawing techniques provide the best visibility to HDR images. The main goal of the any line drawing system is to enable users to easily generate effective and attractive illustrations [8]. In this work, we made an attempt to effectively integrate global tone mapping operator, 2D anisotropic filter, 2D modified coherence shock filter, line weight parsing techniques followed by bilateral filter to produce more effective line drawing. We have exploited the features of these filters through integration to effectively convey shapes in HDR images through line drawing, which is useful for many applications. The proposed line drawing technique is capable of conveying regions, shapes, inner boundary and outer boundary as well as a particular event in an effective manner. Any line drawing technique essentially reduces the size of image data and suppress the random and real time noise, preserving image structure, shapes and capable to provide 3D effect to 2D images.

In this work, we mainly consider HDR images. HDR images/photographs are commonly obtained by multiple exposure technique [8]. Capturing multiple standard photographs of same scene or object with different exposure time and merge all of them will produce an HDR image. HDR images are represented in 32 bit floating point number [9, 10, and 11] and the luminance value is very high compared to real one. So HDR images are not suitable for displaying in LDR devices such as computer monitor, projector etc., In such situations, we need conversion techniques for converting 32 bit HDR floating values to 8 bit LDR integer values. The conversion techniques must produce best visual impression/effect and preserve the details of original picture. These techniques are called as tone mapping. Here, we have implemented global tone map operator to protect the regions and luminance information in high contrast image regions [12, 13, and 14]. During implementation of the global tone map operator with adoptive histogram equalization, a mask is used for covering the white patches [15 16, 17]. In connection with global tone mapping, we have implemented anisotropic filter to preserve the low contrast region in an image, modified 2D shock filter for extracting the inner lines and recovering the hidden edges from previous filters results. We adopt weight parsing technique to highlight and protect the outline boundary. Finally, a simple bilateral filter is applied for preserving regions and to smooth the image to obtain a best line drawing.

The rest of the paper is organized as follows. Proposed Methodology are explained in section 3. Experimental results are presented in section 4. Concluding remarks are given in section 5.

II. RELATED WORKS:

Several researchers have made an attempt to propose effective techniques for line drawing. The following paragraphs give an overview of the literature related to line drawing and HDR images.

Tumblin and Rushmeier [18] proposed the global tone mapping operator method to preserve the global oriented features and suppress the high intensity color luminance values in HDR images. Tone mapping operator method mainly focused on preserving the spectator overall feeling of brightness. The method uses the global tone mapping operator used in [19]. The method has less computational costs but may not produce the best visual effects to complex scenes and low contrast region in an image.

Tumblin et al., [20] developed a mathematical model of human vision system to analyze HDR images. The model provides the light dependent visual effect for converting HDR to LDR images. Their global tone map reproduction operator converts the real-world luminance’s to the human perceiving display values. Display values are chosen to match closely the brightness of the real-world image and the display image. If the display luminance falls outside the range of the frame-buffer then the frame-buffer value is clamped to fit this range.

Drago et al., [21] proposed the logarithmic mapping algorithm with the simplified assumption that the human vision system has a logarithmic response to light intensities. The algorithm uses a logarithmic base between 2 to 10 for each pixel to preserve contrast and detail. The algorithm includes two user controllable parameters: one for maximum display luminance and another for contrast.

Tumblin and Turk et al., [22] proposed the anisotropic diffusion method to display high contrast regions from HDR images and preserves the sensitive edges in LDR images. Larson et al., [23] proposed histogram adjustment techniques for conversion of HDR to LDR images. But this technique is not suitable for all type of images and formats.

Raman and Chaudhuri [24] proposed Bilateral Filter Based computing for Variable Exposure Photography. They address the problem of automatic compositing of a scene from images obtained through variable exposure photography. They consider the High Dynamic Range Imaging (HDRI) problem and review some of the existing approaches for directly generating a Low Dynamic Range (LDR) image from multi-exposure images. Their main technique is used to convert HDR image to LDR image. In this approach, bilateral filter and mapping function is used to preserve the region and suppress the noise. The strong edges in an image are preserved while weak edges or textures are completely smoothed out. The desired qualities for the mapping function for solving HDR problem in non-irradiance domain is that the final image must have proper contrast, well-exposedness and should not have saturation in the upper and lower intensity values. For a particular pixel location, the matting function must assign higher weights for intensity values from those image locations, which have higher contrast, well-exposed and have minimal saturation.

Li et al., [25] proposed bilateral filter approach to display LDR images from HDR images. In their approach, images are divided into 2 layers. They use global tone mapping function to suppress the base layer illumination and to preserve the image feature in enhanced layer. Finally they combine both the layers to obtain the LDR image.

Bishwas et al., [26] proposed a simple tone mapping operator for HDR images. In their methodology, they implemented global tone map operator along with S-function type operator. The S-function type operator takes the average of the global luminance and local luminance by using median filter. The method improves the visibility and avoids the gradient defects and halo artifacts problem.

Duan et al., [17] proposed a histogram based tone mapping for HDR image. The method uses global tone map operator, local tone map operator and linear equal mapping of both global and local tone map operators. Global tone map operator preserves the high contrast regions but fail to produce the better results in low contrast regions. On the other hand, local tone map operator preserves the low contrast regions but fail to produce the better results in high contrast regions. So they merge both the global and local tone map operators using linear equal mapping to produce better results in both high contrast as well as in low contrast regions in an image. But the method fails to produce the best output for complex background images.

Salisbury et al., [27] proposed a system for interactive pen-and-ink illustration, where they use an edge detector to construct the outline strokes and also to clip the interior strokes. The method may not produce accurate outline for complex images and also is not suitable for all types of images.

Doug et al., [28] proposed stylization and abstraction of photographs based on mean shift color image segmentation. The technique transforms images into a line-drawing style using bold edges and large regions of constant color. But the method may not produce satisfactory results for images with complex structures.

Wen et al., [29, 30] proposed a method, which also uses mean-shift segmentation technique for producing a rough sketch of the scene. Gooch et al., [31] presented a facial illustration system based on a difference-of-Gaussians filter. The filter is used in conjunction with binary thresholding to produce a black-and-white illustration.

Costa et al., [33] proposed a line drawing model. In their work, they first highlight the interior and outline the portion of an image using 3D mesh edge extraction method. Later they adopt segmentation and smoothing for line drawing and noise removal purpose. Connectivity between lines is achieved using chains of line techniques. A weight map parsing is used to brighten/ thickening the extracted lines in the output image. Effectiveness of the output is not same for all kinds of images and sometimes continuity between lines may not be obtained due to poor quality of images.

Dang et al., [18] proposed a method based on suggestive highlights and principal highlights along with suggestive contour and geometric contour to highlight lines for conveying shapes in images. But the method may not produce satisfactory results for all types of images specifically color images with complex structures.

Henry et al., [34] proposed a coherence line drawing system based on edge tangent flow and flow based difference of Gaussian filter (FDoG). Edge tangent flow preserves and estimates the local orientation from image. FDoG filter is iteratively applied to extract the lines effectively from images to produce best line drawing. This method may not produce effective line drawing when the image consist of low contrast region and low contrast edges.

From the literature survey it is found that the methods proposed for line drawing for conveying shapes in images possess certain limitations in terms of quality output or in handling type of input image. Most of the works related to line drawing have used only gray scale and natural images. However, to the best of our knowledge, no woks related to line drawing using HDR images have been reported in the literature. Also the methods have been implemented using GPU devices and OpenGL languages along with shading library, which demands high computation and sophisticated environment for implementation. Since the implementation of the proposed work is carried out in MatLab environment using local library functions, it is simple and does not require any sophisticated high computing environment.

III. Proposed Methodology

The proposed method of line drawing for conveying shapes in HDR images involves five major steps. In the first step, an adoptive histogram based global tone mapping operator is applied to convert HDR image into LDR image. In the second step, anisotropic filter is applied to suppress the irregularities and to preserve the prominent local edge boundaries in an image. However, some edge information may not be clear and need to be enhanced. Thus, in the third step, we apply coherence shock filter iteratively to provide sharpening effect to an image. The image obtained at this stage may have irregularities in edges and boundaries. In the fourth step, we apply line weight computation and parsing to remove the irregularities and preserve the outer boundary of an image. Finally, we apply bilateral filter to remove the unwanted noises and preserve the local edges and outer regions. These steps produce the important shapes in HDR images in effective manner to convey information without upsetting human visual effect. The following sections provide a brief description about the filters and the proposed algorithm.

3.1 Adoptive Histogram Based Global Tone Mapping Operator

The adoptive histogram based global tone mapping operator is implemented using logarithm function. The logarithm function can increase or decrease the brightness and luminance of an image. The histogram based global tone map operator can compress the higher luminance values in a given image and reduce the halo artifacts [12, 15, 17]. It can also differentiate the various regions in HDR images like dark, bright, light, and dim. The global contrast is calculated using the equation.

$$GC = C\ Ya \quad \ldots(1)$$

Where Ya is the average luminance values of whole image and C is a multiplicative factor. Average luminance is calculated by using the equation.

$$Ya_{average} = \exp[\frac{1}{n}\sigma \log(\varepsilon + I(x,y)] \quad \ldots\ldots..(2)$$

where n is the total number of pixels in an image, $I(x, y)$ luminance value, ε is a smallest value used to define the singularity that occurs with 0 values, but in our implementation, we set ε value to 0.5 for image enhancement and error reduction purpose. In the next step, we need to find out the key value (*C*), which is nothing but the multiplying factor to bring the high luminance values closer to 1 and the low luminance values closer to zero. The key value (*C*) acts as an intermediate point for low and high luminance values. In most of the works, the key value (*C*) is chosen directly to obtain LDR images from HDR images. But in our approach, we try to calculate the key value (*C*) as suggested in [17] based on the standard values from 0.05 to 0.8 as follows.

$$C = 0.30 * 2\text{^} (\log ya - \log l_{min} - v\log l_{max} / \log l_{max} - \log l_{min}) \quad \ldots\ldots... .. .(3)$$

Larger *C* value tends to produce the bright image and smaller *C* value tends to produce dark image. The computed key value (*C*) is used equation (1) to obtain global contrast (GC). The result obtained from the equation (1) may not be satisfactory for all kinds of images, so it is necessary to adopt some histogram adoptive methodology [17] by calculating min and max values of luminance in an image using linear equal mapping technique.

$$Le,n = l.n + \beta(e,n-1\cdot n) \quad \ldots\ldots(4)$$

Where β value should be in between 0 to 1. If the β value become 0 then quantization is linear. If β value is 1 then quantization is histogram equalized. The halo artifacts due to linear equal mapping can be avoided with the help of anisotropic filter.

3.2 2D Anisotropic Filter

Anisotropic filter is used to smooth and enhance edges and texture in an image. This filter effectively suppresses the unwanted noises from input images and produces best rendering and noise free images. Implementation of anisotropic filter involves various steps as follows:

The first step is to calculate the local gradient information of a color image I where I = (x, y) denotes pixel information.

I(f):R2 grad → R3grad

Subsequently, the local adoptive smoothing based on the local gradient information of an image is performed. Further, the smoothing kernel is locally calculated choosing Gaussian forms given in [35, 36, 37, 38]

$$G(dir) = \exp\left\{\frac{1}{2}\left(\frac{dir.a^{+}}{sigma_1^2}\right) + \left(\frac{dir.a^{-}}{sigma_2^2}\right)\right\} \quad \ldots(5)$$

Here, dir is the location vector, a+ and a- are the vectors perpendicular to the local gradient. Values sigma1 and sigma2 are appropriately choosed. The Color image orientation and region direction derivative information is calculated using the formula.

$$\frac{\partial f}{\partial x} = \left(\frac{\partial R}{\partial x}.\frac{\partial G}{\partial x}.\frac{\partial B}{\partial x}\right) \quad \frac{\partial f}{\partial y} = \left(\frac{\partial R}{\partial y}.\frac{\partial G}{\partial y}.\frac{\partial B}{\partial y}\right) \ldots \quad \ldots\ldots(6)$$

The local gradient is calculated to highlights important portions in an image by means of Eigen vector and Eigen values. It can be mathematically expressed as follows.

$$(dI)^2 = \begin{pmatrix} \frac{dx}{dy} \end{pmatrix}^T = \begin{pmatrix} \left(\frac{\partial f}{\partial x}\right)^2 \frac{\partial f}{\partial x}\frac{\partial f}{\partial y} \\ \frac{\partial f}{\partial x}\frac{\partial f}{\partial y} . \left(\frac{\partial f}{\partial x}\right)^2 \end{pmatrix} = \begin{pmatrix} \frac{dx}{dy} \end{pmatrix} \quad \text{…(7)}$$

With the help of sequential gradient magnitude, the largest Eigen value in a given matrix is calculated as follows

$$\alpha = \left(\frac{\lambda 1 - \lambda 2}{\lambda 1 + \lambda 2} \right) \quad \text{……(8)}$$

The gradient magnitude is computed using finite difference approximation for partial differential equation as follows.

$$\| \nabla f \| = \left\{ \left(\frac{\partial f}{\partial x} \right)^2 + \left(\frac{\partial f}{\partial y} \right)^2 \right\}^{\frac{1}{2}} \quad \text{…..(9)}$$

Anisotropic filter not only smooth the image but it also gives more importance to preserve the edges gradient strength. In this work, we estimate the corner and edge strength for the purpose of preserving corners and also to smooth edges by using the equation.

$$Corner = (1 - \alpha) \| \nabla I \|^2 \quad \text{…………………………..(10)}$$

During smoothing and local orientation protection process, corners must be preserved. A corner is identified as an isotropic with large local gradient strength. The corner strength is estimated as

$$C = (1 - \alpha) \| I^2 \| \quad \text{………………………..…(11)}$$

To preserve corners, we divide the standard deviations by another 1+C. The final variances in (5) are then given by:

$$\sigma_1 = \frac{(1-\alpha).sigma}{(1+c)} \quad \sigma_2 = \frac{\sigma}{(1+c)} \quad \text{…………………………......(12)}$$

Where σ is an image noise factor. The variance of the image noise σ can be estimated globally by calculating the images local variances. Based on local orientation estimation, we can measure the noise factor. Anisotropic filter preserves large homogeneous and heterogeneous noise free regions.

3.3 Modified 2D Coherence Shock Filter

2D Coherence Shock Filter [39, 40, 41] is an edge preserving and smoothing filter, 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.

$$It = -sign(\Delta u) | \nabla u | \quad \text{…………………………..….(13)}$$

The filter creates shocks between maximum and minimum influence zone and it represents that the shock filter is within the range of 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:

$$I_t = -sign(\Delta u * I) | \nabla u | * I_{\text{smooth}}, \quad \text{…………………..……..(14)}$$

Here, I is a gradient of an image and Ismooth is an anisotropic filtered image. The modified coherence shock filter combines the gradient image, anisotropic filtered image and –sign (Δu). The modified coherence shock filter gives connectivity to dominant image edges and shining effect to an image by preserving hidden edges. Shining effect is useful for highlighting the discontinuity edges and also useful for dominant edges connectivity.

3.4 Line weight computation and parsing

Line weight computation and parsing technique is mainly based on tangent vector flow field. Tangent vector flow field can be used to highlight the direction of each outline dominant edges in an image. Line weight computation and parsing technique is most useful for tracing the outline edges in gray scale images. But this technique may not be suitable for preserving the interior local oriented structure information and may not be suitable for color images for highlighting the outline boundary. To overcome this drawback, we adopted the anisotropic and shock filter, which effectively handles the color images [17,33,42,43,44,45].
The importance of this technique is to trace the outline of an image with minimum weight stroke. For that purpose, line weight computation and parsing consider the direction vector V(I) =V(x,y)= {u(x,y) , v(x,y)}, and the starting point choosed by user. With the choosed initial point, line weight and parsing techniques is applied to entire image.
The line weight parse cost/ vector field cost C(i, j) , where i, j are neighboring pixel, can be written as

$$C(I,J) = \frac{1-|V(I).|(I-J)|}{|V(I)||J-I|} \quad \text{……………………………….….(15)}$$

Where V(I) denotes vector field value at the pixel I, and (J-I) is the displacement vector from I to J. $1-|V(I).(I-J)_{/}\ |V(I)||J-I|$ computes the cosine of angle between v(I) and |J- I |. That is, the cost of a vector field (Eq. 15) is proportional to the angle formed by vector field and desired direction. This technique renders the outline. Line weight computation parsing produces best realistic line effect and pencil shading painting.

3.5 Bilateral filter

Bilateral filtering is a non–linear filtering technique. Here we adopted the bilateral filtering techniques for dominant edge and line extraction purpose. Bilateral filter also capable of smoothing the images and suppress the noises. Bilateral filter is a combination of Gaussian spatial weight and Gaussian range weight. The bilateral filter can be expressed as:

$$\text{Bilateral filter[I]} = \frac{1}{W_p}\sum_{q\in s} G_{\sigma_s}(\|p-q\|)G_{\sigma_r}(\|p-q\|)*q \quad \text{………………………(16)}$$

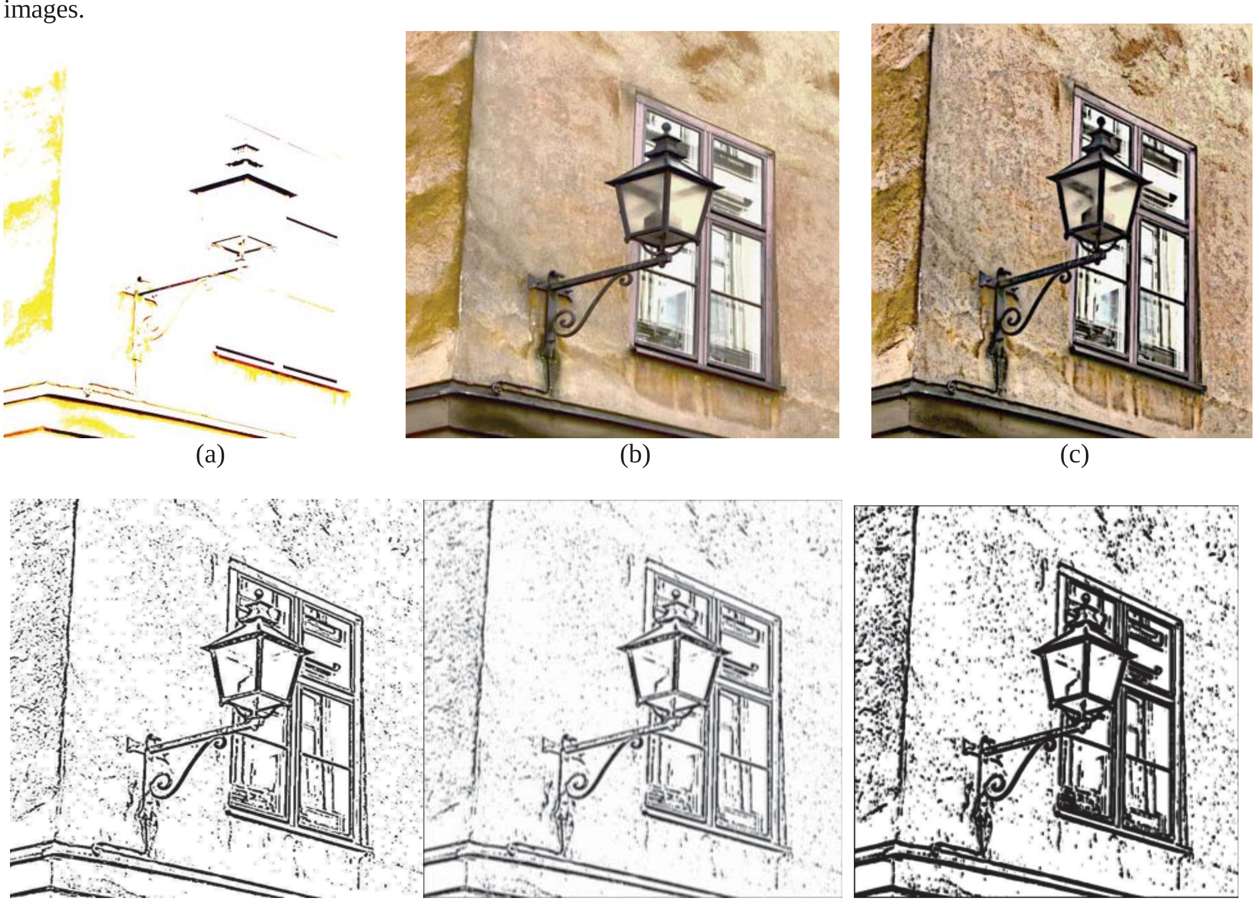
Where p is seed point in a given image, $\frac{1}{W_p}$ is a normalization factor, $G_{\sigma_s}(\|p-q\|)$ is a spatial weight, and $G_{\sigma_r}(\|p-q\|)$ is a range weight. σ_s denotes the extent of the spatial kernel and σ_r denotes the minimum amplitude/radiance, at the last, we multiply the last pixel intensity to spatial weight and range weight. Spatial weight in bilateral filter is for thickening the seed pixels, which are having same intensity and range weight provides the connectivity between pixel to pixel, which have same intensity levels.
In the proposed work, the bilateral filter is applied to the output produced by line weight computation and parsing technique to remove irregularities and to smooth outlines, edge normalization, and to convey shapes in HDR images. In general, Bilateral filter is more useful for photographic computation and manipulation, photographic style transfer, cartoon rendition in addition to smoothing and preserving the edges.

The proposed method of integrated filter-based approach for line drawing for conveying shapes in HDR images can be algorithmically expressed as follows:

Algorithm: Line drawing for conveying shapes in HDR images
Input: Raw image
Output: Line drawing image
Method:
Step1: Apply Histogram based global tone mapping operator for converting the HDR image into LDR image.
Step2: Apply anisotropic filter to preserve local orientation features and dominant edges.
Step3: Apply shockfilter for recovering hidden edges..
Step4: Apply Line weight computation and parsing to regularize and protect the outline tracing in an image.
Step5: Apply bilateral filter for smoothing and line extraction purpose.
Algorithm ends.

IV. EXPERIMENTATION

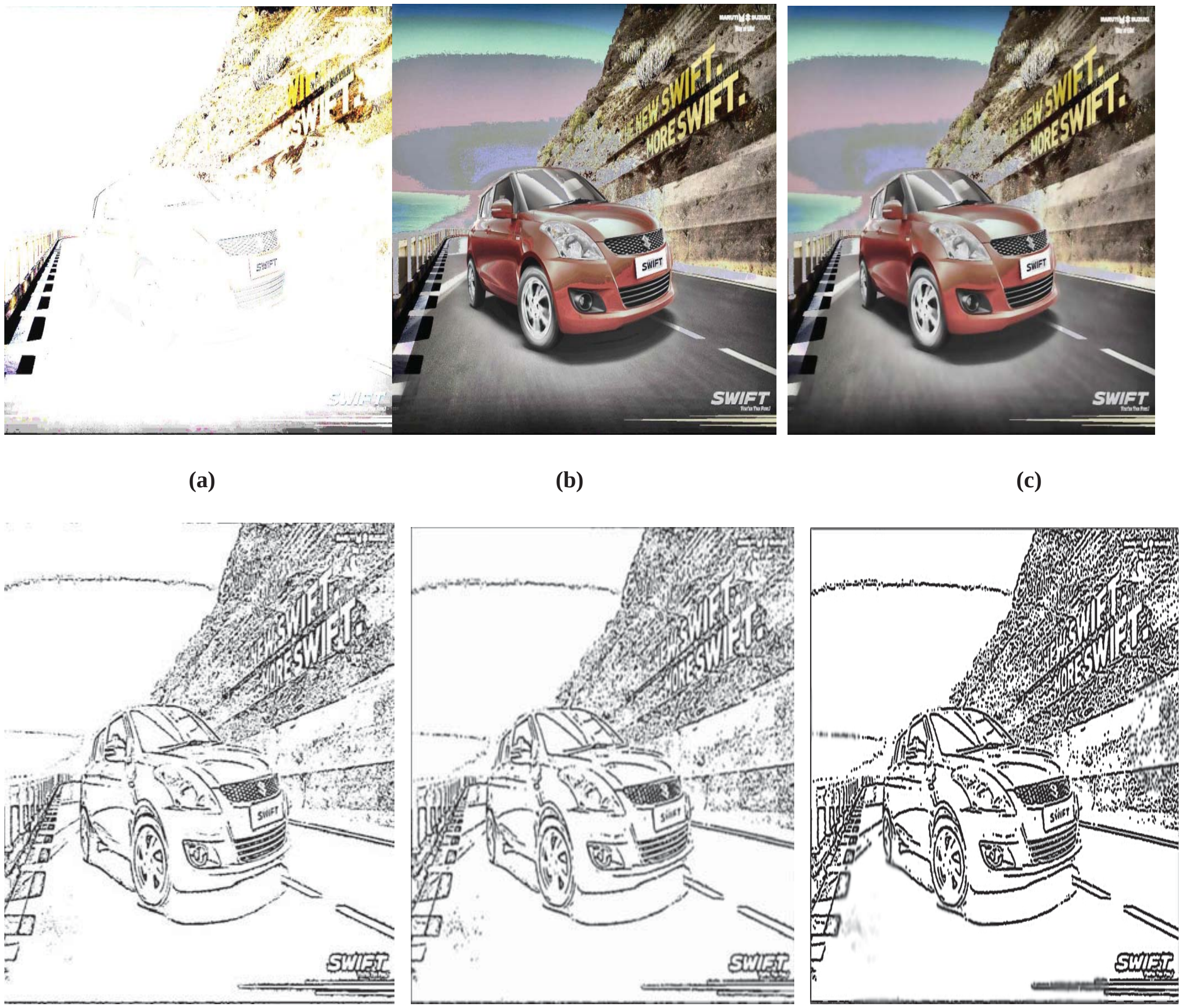
In order to study the efficacy of the proposed technique, we conducted experiments on various types of HDR images and natural images. In this section, we are presenting few of the results obtained from the proposed method. In our experimentation, we set global tone map operator (ϵ) value to 0.5, the kernel value σ for anisotropic filter to 3.2 and anisotropic filtering half-width to 5.5. For shock filter, the deviation value is set to 3.0 and the number of iterations is set to 20. In Line weight computation and parsing, error tolerance value is set to 0.7. The Bilateral filter is designed to protect and extract dominant lines and edges. For bilateral filter, σ value is set to 1 and radiance is set to 0.5, Figure 1 shows the results of varies stages of the proposed method of Line drawing for conveying shapes in HDR images.



(a) (b) (c)

(d) (e) (f)

Figure 1**: (**a) Input image (b)Global tone mapping operator output (c) Anisotropic filter output (d) Shock filter (40 Iterations) (e) Line weight parsing (f) Bilateral filter



(a) **(b)** **(c)**

(d) **(e)** **(f)**

Figure 2: (a) Input image (b)Global tone mapping operator output (c) Anisotropic filter output (d) Shock filter (40 Iterations) (e) Line weight parsing (f) Bilateral filter.

Figure 1 and 2 clearly demonstrate that the proposed Line drawing technique for conveying shapes in HDR images produce good results. First, the Global tone mapping operator is applied to LDR image. In the subsequent steps, we serially applied the anisotrophic filter, shock filter, line weight computation and parsing and bilateral filter. Anisotrophic filter preserves the local orientation structure information and it produces the rendering effect that is shown in the Figure 1 and 2. Shock filter provides the good connectivity between dominant edges and recovers the hidden edges. Line weight computation and parsing technique regularize and protect the boundary outline tracing in an image. The bilateral filter extracts line and edges.

We have also conducted an experiment on natural HDR image and the proposed method has produced the encouraging result. Figure 3(a) to 3(b) shows the result of various stages of the proposed method of Line Drawing for conveying the shapes from natural images.

(a)

(b)

Figure 3: (a) Natural HDR as Input image (b) Output Image

V. CONCLUSION

In this paper, we have presented an integrated filters based approach to produce effective line drawing from HDR images. The proposed method incorporates the features of various filters to produce the better result. The method does not require any individual brush strokes to produce line drawing effect. The proposed method is found to be effective for all types of HDR, and complex background images. The experimental results obtained for various types of images are highly encouraging and are comparable with the other Line drawing techniques. The approach is found to be computationally efficient in producing effective line drawing from HDR images.

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