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An Image Abstraction Algorithm based on Local Extremum Filtering

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Abstract: For the traditional image abstraction methods are not well preserved edge information, this study propose an image abstraction method based on the local extremum filter. First, calculate the maximum and minimum values of each pixel on its neighborhood. Second, replace the current pixel value with the weighted value. At last, use the DoG edge detecting operator to enhance the smoothed image to obtain the final abstract image. The experiment shown, this method has a better smooth effect than others, especially on area smoothing and edge preserving.

Key words: Extremum filter, image abstraction, stylization rendering, edge enhancement

INTRODUCTION

In the scene painted, artists often only focus on the object of interest while ignoring other information in the scene, meanwhile for the objects of interest into the composition of some imagine, this is the abstraction process. The abstraction refers to reduce or generalize the information content of a scene. The main idea is to keep the information related to a specific purpose and filter out irrelevant details (Wang *et al*., 2013). Abstraction reflects the human imagination to a certain extent but also can improve the image understanding, promote visual communication, so it has wide application prospect. In recent years, research on image abstraction has attracted more and more people domestic and international researchers concern also emerged many excellent image abstraction related algorithms.

DeCarlo and Santella (2002) designed a photo abstraction system based on visual perception. Use an eye tracker to track testers' attention, the eye region of interest is emphasized and ignores the details of other areas. The abstract image similar cartoon style is composed of simple lines and color blocks area. This method relies on the special equipment support, lack of practical. Winnemoller *et al*. (2006) provides an automatic real-time video abstraction algorithm. The method uses a nonlinear diffusion filter (Bilateral Filter, Barash and Comaniciu, 2004) to smooth areas of low contrast details, while the Gauss differential operator edge extraction line enhancement features high contrast regions, simulate the abstraction with cartoon effect. However, the algorithm for image edge to maintain the shape and coherence has some limitations. Kyprianidis *et al*. (2009) improved Winnemoller's method, realized the real-time image abstraction using anisotropic Kuwahara filter (Kyprianidis *et al*., 2010), filter kernel shape is determined by the gradient direction of the image and the tangential direction. Compared with the Winnemoller algorithm, the method to maintain the image edge information and shape consistency than the former. However, filter kernel to calculate each of the partitions within the window the average and variance, efficient algorithm greatly affected. Cong *et al*. (2011) uses the user interactive mode will be an image into a combination of abstract and realistic, effective algorithm but requires more user interaction.

This study designed a novel extremum value filter and proposed an image abstraction algorithm based on it, can obtain better effect of image abstraction. The main idea of the algorithm can be generalized as the following. First, searching the local region of pixels maximum and minimal value and fitting out two extremal. Second, according to the neighborhood pixel variance distribution, use different strategies to determine the new pixel value. Finally, enhance the edges of the filtered image using Kirsch operator to obtain the final image abstraction results. In searching for the extremum of local area, in order to reduce the influence of image noise, no algorithm selects the local maximum and minimum values but the right pixel value as the region of extremum value determined according to size of area of the window.

METHOD

The main objective of image abstraction is to remove the unwanted image details, retaining the structural characteristics of the image information. Our main contribution is to design a novel extremum value filter, the

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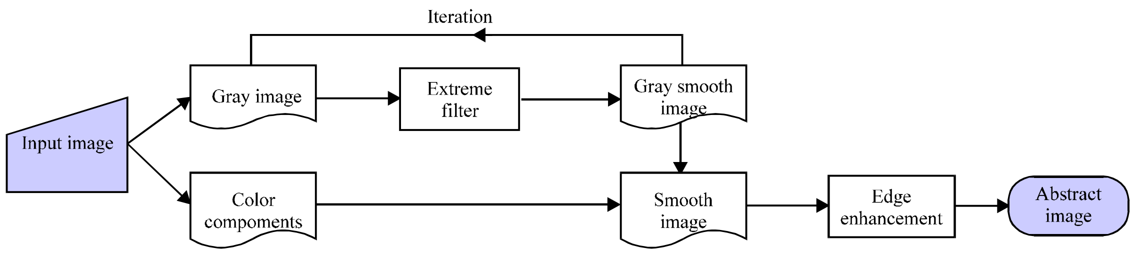

Fig. 1: Framework overview

whole process of implementation of the algorithm shown in Fig. 1. It includes the following five steps: (1) Convert the input image to YIQ color space to separate the grayscale and color components; (2) Filter the gray-scale image by the extremum filter to get the gray smoothing image (may be needed for certain iterations); (3) Convert the results for iterative solution to RGB color space, then enhance the edge to get the final abstract renderings.

Color space conversion: YIQ color space derived from the North American NTSC television system color television signal transmission standard. Here, the Y component represents the brightness (gray level) information, I, Q components of the two carrying color information. I component represents from orange to blue color change and Q represents the amount from purple to yellow-green color change. By converting the color image from RGB to YIQ color space, the luminance of the color image information and chrominance information separately processed separately. The conversion formula from RGB to YIQ color space can be defined as (Reinhard *et al*., 2001):

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.229 & 0.587 & 0.114 \\ 0.596 & -0.274 & -0.322 \\ 0.212 & -0.523 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{1}$$

Extreme filter designing: Many filters are used for smoothing the image in image processing, such as the Median filter (Fu and Shou, 2002), the bilateral filter (Winnemoller *et al*., 2006) and other common filters. However, these filters have their own advantages and disadvantages in different applications. Median filter for the low level salt and pepper noise or speckle noise removal has a good effect but bad for the high level noise. Because the median filter only considering the spatial relationship of the pixels, the filtered image is often blurred seriously and the edges cannot be better preserved. The BF not only considering the positional relationship between pixels but also of the color differences, so the result is better than MF. However, it cannot preserve the sharp edges, especially after several iterations. Figure 2 shown the results smoothed by different filter. We can easily find that MF is better than BF in preserving edge but inferior in region smoothing. Neither of the two filters can satisfied the two commands that are both preserving the sharp edges and the better smoothing effect, so we need design a novel filter for image abstraction.

In view of this, we propose a novel extremum filter. Firstly, identify local areas maxima and minima values; secondly, detect whether current pixel is an edge point; At last, choose different process flow according to the determination. In the following section, we'll describe the designing of the novel filter in detail.

Detect the edge point: Pixels on edge usually have a common property that is they are in large different compare to its adjacent pixels color. The larger the color difference, the larger the variance in the local area is, so we use the local variance as the criteria. Set P as the current pixel, S is the local area including N pixels around P (P is in the center of S); E(S) is the mean value and pi is a pixel of S, so the local variance D can be defined as:

$$D = \frac{1}{N}\sum_{p_i \in S}(p_i - E(S))^2 \tag{2}$$

Here, we set T as a variance threshold. When D is greater than T, we consider the current point as an edge point and process it separately; otherwise, consider it as a regional internal pixel and using the extremum filter for smoothing. By experience, for the normalized image, we suggest that the value of T should between 0 and 0.1.

Calculate the local extremum value: It is well known that there is an abnormal output value (very low or very high) in local area when the image is polluted by noise. To prevent noise interference, the local max or min value cannot be used for calculating (because it might be noise). Our processing schedule is as following: First, sort the pixel values within the region by descending order. Then,

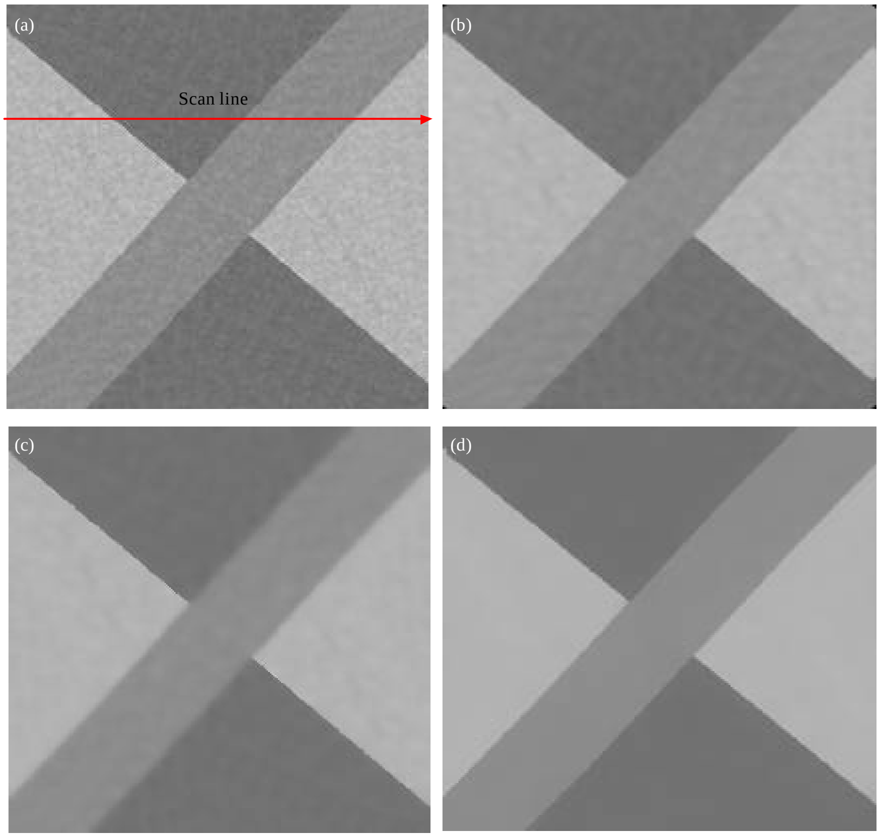

Fig. 2(a-d): Smoothing effect by different filter, (a) Input image, (b) Median filter, (c) Bilateral Filter and (d) Our method

choose the k-th element of the sored pixel value as the maxima value of the region p_{max} and the penultimate k element as the minima value p_{min}. Here k is the filter's window size.

Determine the filtered value: When the two step process is completed, the current pixel value Pout can be determined refer to the following equation:

$$p_{out} = \begin{cases} (p_{max} + p_{min})/2, & d < T \\ p_{max}, & D \geq T \text{ and } |p_{max} - p| \leq |p_{min} - p| \\ p_{min}, & D \geq T \text{ and } |p_{max} - p| \geq |p_{min} - p| \end{cases} \quad (3)$$

Firstly, determine whether the current pixel P is an edge pixel according to the value of variance d. If P is not an edge pixel (d is smaller than T), we make the average value of p_{max} and p_{min} as the output value. Otherwise, we consider that P is an edge pixel and the local extremum value is defined as the output value directly. How to select the max or min value is determined by the pixel distance between pixel P and the max or min extremum value. In summary, the processing flow can be described as the following pseudo code:

```
For Each Pixel
{
    Step1: Find the local extremum value Pmax and Pmin.
     Sort(S);
     Pmax =S(k);
     Pmin =S(k^2-k+1);
    Step 2: Calculate the local region variance value d;
    Step 3: Determine the Filtered Value;
            if(d<T):

    pout = (pmax+pmin)/2

       else:

    pout = (|pmax-p|≤|pmin-p)> pmax: pmin;
}
```

Figure 2 shows the result by our novel filter and the other common filters (MF and BF). All the filter size is 7. By contrast, we found that our method not only to achieve a better smoothing effect, while preserving sharp edge information.

In order to compare the different filtering effect more clearly, Fig. 3 shown the scan line plots for the local pixel values. In the figure, the blue line represents the input image; the green line represents the image filtered by MF, the red line is by BF and the black line is by our method (the extremum filter). Obviously, there exist three edges in the input image (the yellow zones in Fig. 3). The sharpest edge appears in zone A, the other two are weaker. For the sharp edge, e.g. in zone one, when the image is filtered by the three filters separately, the edge information is preserved well. While when the edge information is weaker, e.g. in zone B or C, the BF filter result present a smooth edges but our extremum filter result still preserve the sharp edges. Meanwhile, for the smoothing effect (the light green zones), using the extremum filter, the output value is almost in a horizontal line, while other filters still have the fluctuations. It further indicates that compare to the MF and BF, the novel extremum filter can remove almost all the unnecessary details and still preserve the sharp edges.

Edge enhancement: To get a better stylized effect, artists usually add some lines to enhance the main object. To simulate this process, computer can be achieved by the edge enhancement. This study, we use the DoG algorithm (Zhang, 2005) to enhance the filtered image and the final abstract image is obtained.

EXPERIMENT AND ANALYSIS

Present approach is implemented on a Win7 OS computer, which has an Intel® Core™3.2GHz CPU and 4GB Memory. The programming code is completed by means of Matlab R2012a development environment. Figure 4 shown part of the experiment results. The first line shown the input image, the second line shown the smooth image filtered by extremum filter, the third line shown the abstract effect by our method (filter size is 5, twice iterations, d = 0.02), the last line shown the result by Winnemoller's method (Bilateral Filter) (filter size is 5, twice iterations, d = 0.2). The results show that the proposed filter is applied to the abstraction image processing, can effectively remove unwanted image details, such as flower or grass texture, also can preserve the sharp edges, such as the petal edges and the shadows. So the edge enhancement effect is more prominent. Furthermore, our method does not require color quantization, saving computation time, reducing unnecessary color distortion.

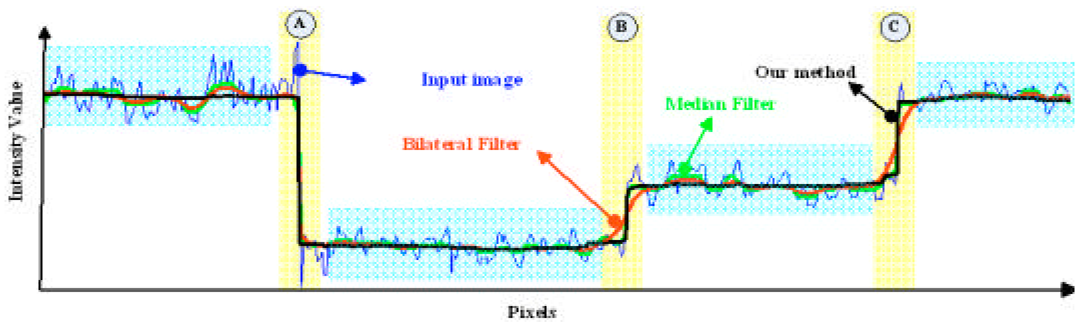

Fig. 3: Variation of the scan line pixels

Fig. 4(a-d): Continue

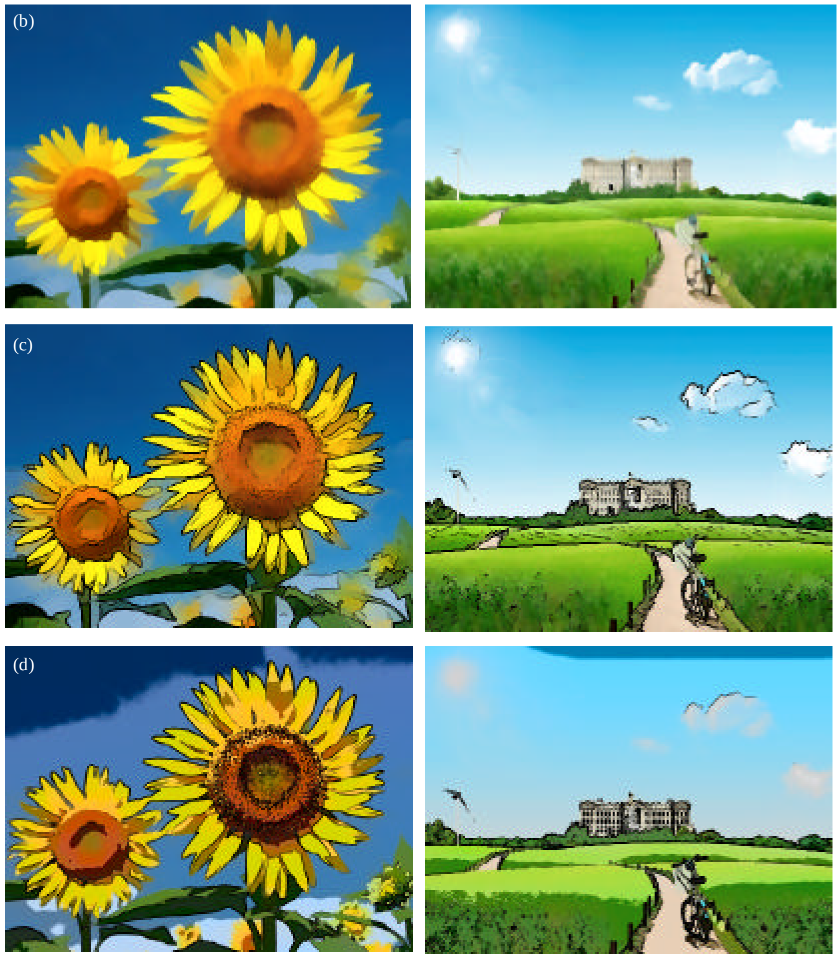

Fig. 4(a-d): Some experiment results , (a) Input image, (b) Median filter, (c) Bilateral Filter and (d) Our method

CONCLUSION

This study presents a novel extremum filter and the filter is applied to the image abstraction. The experiments show that our approach can get the better smooth effect than the common filter, such as the Median Filter and the Bilateral Filter, even in the dramatic color change region (grass, stamen or hair area etc.). Also, it can maintain the edge sharpness of the salient edges to get the edge enhancement effect. One work should be in further study that how to determine the variance threshold d automatically, so that we can more easily detect the edge point.

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