Smoothing and Edge Enhancement for Creating Artistic Style Image

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Abstract

I present a method to combine smoothing and edge detection method to change an image into a different artistic style image by edge enhancement techniques. My approach is based on global color adjustment, local morphological processing guided by information in edge map, and local image merge guided by background color. Unlike existing methods which may suffer from bad performance in dark image and have a low computing speed, my method can achieve acceptable edge enhancement result with fast speed in different images including dark images.

1 Introduction

Transform an input image to a different artistic style in general involves image smoothing which helps reduce noises in the image, and edge enhancement, which helps convey edge information in the image more effectively. For example, a smoothed image will have a flatten intensity value in a sub-region, visually speaking it will remove some small texture details in the image, which make the image seems unreal or in a cartoon-style. For the detected and enhanced edges, in a word, can be treated as lines and curves, are effective tools to describe shapes. Basically, the task introduces in this project is competent for preserving technically useful information as well as generating visually beautiful images.

The major challenges to combine image smoothing and edge enhancement together to generate unrealistic image are the unwanted visual color changes and unobvious edges due to background color in the output image. Images after smoothing usually seem not as bright as the original image in human visual system. Therefore, apply direct image addition between image and dark edges results in a visually darker image compared to the input image. From histogram's view, there are lots of zero intensity value in the output image, causing the image to become darker. In addition, direct image addition has poor performance for images with great intensity value variation.

In this work, I propose HSI color transformation, adaptive edge enhancement and adaptive image merge method to deal with these challenges and combine them with existing image smooth and edge detection method to transform an input image to a different artistic style. Adaptive edge enhancement and image merging are local morphological processing, image addition or subtraction processed in a small region in the image spatial domain. First it divides image into sub-images and calculates needed information. Second, based on the result it processes the sub-image in different manners. Experiments show that my method can preserve color and achieve acceptable edge enhancement in different kinds of image.

1.1 Related Work

Image smoothing is important for this task since it can reduce noises in the image to get a clean edge map for further processing. Most commonly used smoothing algorithm for non-realistic image

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generation are bilateral filter or mean-shift filter [3]. However, Kang *et al.* [2] suggests that mean-shift filter usually produces rough region boundaries which is not suitable for direct edge detection. While bilateral filter have poor performance in preserving edges without choosing a suitable parameter for smoothing. In this work, I adopt L_0 gradient minimization [3] which can globally control the number of non-zero gradients therefore achieve good result in edge detection sub-task.

Edge detection is another important part in this task. Previous work [3, 2] usually uses difference-of-Gaussian filter originated from the Marr-Hildreth edge detector to extract lines. Although difference-of-Gaussian filter is effective in extract lines, Kang *et al.* [2] mentions that edge pixels extracted by it may not clearly reveal the sense of directedness due to the nature of the isotropic filter kernel. There are other edge detection methods as well, Canny edge detector [1], being proved for being a fast and effective edge detector, is applied.

2 The Proposed Algorithm

2.1 Pipeline Overview

The basic pipeline is shown in Figure 1. First step, L_0 gradient minimization [3] is implemented to do image smoothing. Second step, HSI transformation is applied to adjust the visual color of image for the first time. Third step uses Canny edge detector [1] to extract initial edge map from the smoothed image, then apply adaptive edge enhancement to the initial edge map to emphasize them. Fourth step merges the color adjusted image with enhanced edge map by adaptive image merge, then do the final color adjustment.

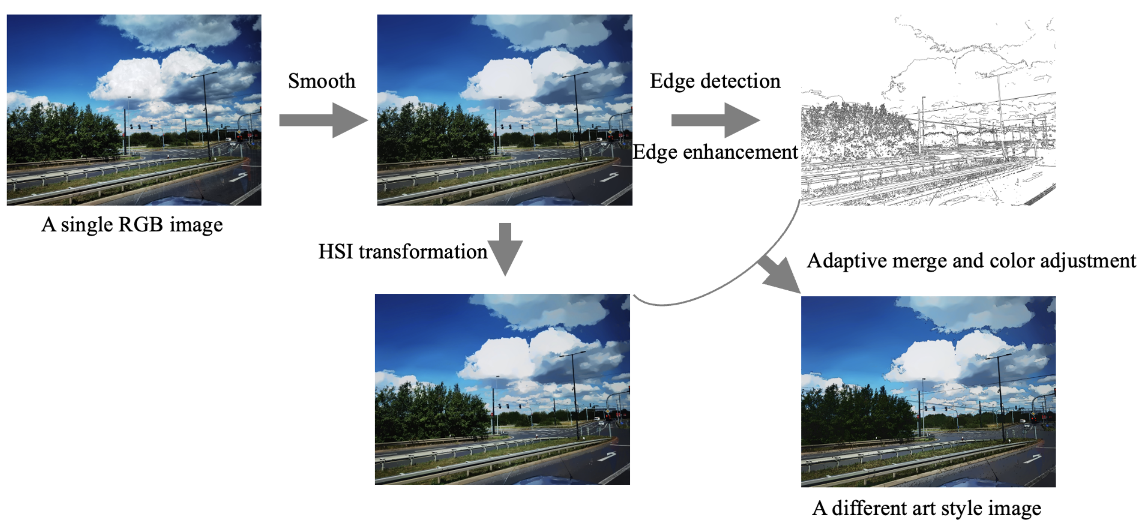


Figure 1: Pipeline overview.

2.2 Image Smoothing

In 2D image representation, L_0 gradient minimization [3] denotes by I the input image and by S the computed result. It counts number of pixels p whose magnitude of gradient is not zero. With the definition, S is estimated by the objective function:

$$\min_S \{\sum_p (S_p - I_p)^2 + \lambda \times C(S)\}. \tag{1}$$

The input image is firstly counted the number of pixels whose intensity value is smaller than a predefined threshold. If most of the pixels have intensity smaller than threshold, the input image is treated as dark image, and a small parameter for smoothing is applied. Otherwise, a big parameter for smoothing is applied. Given the parameter, L_0 gradient minimization is applied and smooths the image.

2.3 Color Adjustment

Color adjustment in this work consists of two different kinds of method. The first one is HSI transformation. It transforms the RGB input image and smoothed image to HSI color representation, the replace the saturation part of the smoothed image by saturation part of the input image. This process helps the image look more similar to the input image with respect to color. The transition equation is the following:

$$smoothed[h, s, i] = [H_1, S_1, I_1], \tag{2a}$$

$$input[h, s, i] = [H_2, S_2, I_2], \tag{2b}$$

$$smoothed'[h, s, i] = [H_1, S_2, I_1], \tag{2c}$$

where *smoothed'* is used for adaptive image merge.

The second method for color adjustment is Gamma correction, which adjust visual color in the last step. It is defined by the equation $V_{out} = V_{in}^{gamma}$, where V_{out} is the output luminance value and V_{in} is the input luminance value. When $gamma > 1$, the output image looks brighter, which helps moderate the visual effect of increasing number of low intensity value in the image.

2.4 Edge Detection

Canny edge detector [1] consists of 4 basic steps. First, a 5×5 Gaussian kernel is used to further smooth the image. Second, compute the magnitude and direction of gradient. Third, apply non-maximum suppression to the gradient magnitude. Fourth, apply double thresholding with different threshold based on input image and edge tracking by hysteresis. For a normal image, the high threshold *high* is $0.1 \times max$, where *max* is the max intensity value in the image. For a dark image, the high threshold is $0.04 \times max$. While the low threshold is always $0.5 \times high$.

2.5 Adaptive Edge Enhancement

Adaptive edge enhancement is based on edge density ρ, which is defined as:

$$C = \#\left\{p|p \neq 0, p \in S_{m \times n}\right\} \tag{3a}$$

$$\rho = C \div (m \times n), \tag{3b}$$

where p are pixels, $S_{m \times n}$ is a $m \times n$ region. By the definition, ρ represents how many edges exists in a certain region.

In practice, I first divide the edge map into k sub-image with size $\alpha \times \alpha$. However, due to the input image size in not always divisible, the true size of sub-images will differ in the boundary part of image. Then for each sub-image, ρ is calculated, and if $\rho < 0.1$, the sub-image's edges is low-density. Otherwise, the sub-image's edge is high-density. For the low-density sub-image, structural element se in shape of ellipse with size 3×3 is chosen. Otherwise, the size of structural element se is 2×2. At last, perform dilation $edge \oplus se = \{z|(\hat{se})_z \cap edge \neq \emptyset\}$ in each sub-image using the given structural element respectively, and combine all the sub-image to reform a new edge map with enhanced edges. In this way, regions where lots of detected edges existed are not over-emphasized while regions where exist few detected edges are well enhanced, thus achieves a clean enhancement in low-density edge region, and avoid overlapping in high-density edge region.

2.6 Adaptive Image Merge

In adaptive image merge, it first identify whether the input image is dark image. A dark image is defined as $i_{m \times n} : \#\{p|p < threshold, p \in i\} < 0.5 \times (m \times n)$. In practise, the threshold is set to 25. Then, both color adjusted image and enhanced edge map is divided into k sub-image with size $\beta \times \beta$. Similarly, due to the input image size in not always divisible, the true size of sub-images will differ in the boundary part of image. After image division, it calculates whether a sub-image is dark, and based on the result applies 2 different image merge.

For an image that is not dark, the output image *o* after image merging between color adjusted image *t* and enhanced edge map *e* is

$$e = e - 130 \tag{4a}$$

$$o = t - e. \tag{4b}$$

For the dark sub-image in a dark image, the image merge is

$$e = e - 230 \tag{5a}$$

$$o = t + e. \tag{5b}$$

Using this method, edges and images are merged together to achieve a edge enhanced image, as well as letting edges adapt to dark background color in order to been visually visible.

3 Experiments

3.1 Dataset

The evaluation dataset for edge enhancement objective performance evaluation is BIPEDv2. To simplify the evaluation process, I select only 13 images from the dataset and use origin RGB images as input. The edge maps in the dataset which are processed using the same edge enhancement method in this work and the original edge maps are the ground truth for evaluating the effective of edge enhancement.

3.2 Effective of Edge Enhancement

I conduct both objective and subjective performance evaluation for evaluating the effective of edge enhancement.

In the objective evaluation, intersection over union (IoU) and mean square error (MSE) are used to evaluate the edges technically. IoU is defined as:

$$IoU = \frac{A \cup B}{A \cap B} \tag{6}$$

while MSE is defined as if both enhanced edges *e* and ground truth *g* are in size $m \times n$:

$$MSE = \frac{1}{m \times n} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} \parallel e_{x,y} - g_{x,y} \parallel^2 . \tag{7}$$

The evaluation is between detected edges processed with and without adaptive edge enhancement. The objective assessment result is shown in Table 1. Though both IoU are quite low, which is mostly due to a large increase in the number of detected edges compared to ground truth (see Figure 2), however, adaptive edge enhancement can improve IoU performance, that is mostly about similarity, while only slightly increase some mean square errors.

Method	IoU	MSE
Without ours	0.12	0.08
With ours	0.23	0.12

Table 1: Comparison between edges with and without adaptive edge enhancement.

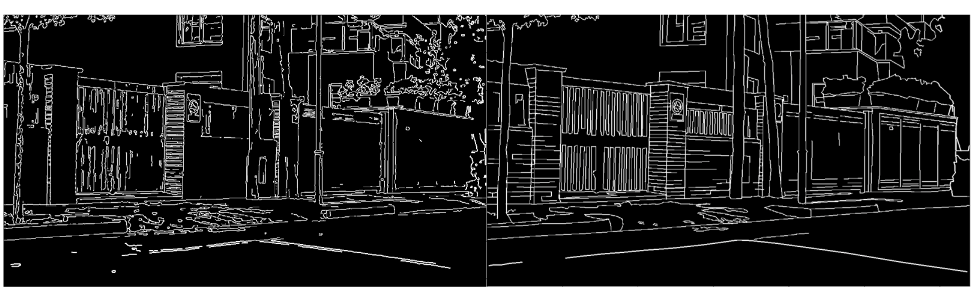


Figure 2: Comparison between edges using adaptive edge enhancement and ground truth.

The subjective evaluation in based on voting scale. According to Table 2, quality of edge enhancement is the factor used to determine the effective of edge enhancement. It will be given a number from 1 to 5, where 1 is the lowest and 5 is the highest evaluation. The result are shown in Table 3. Basically, adaptive edge enhancement can achieve acceptable quality of edge enhancement based on people's observation.

Quality of Image	Level of Edge Enhancement
Excellent	5
Very good	4
Acceptable	3
Poor quality	2
Non-acceptable	1

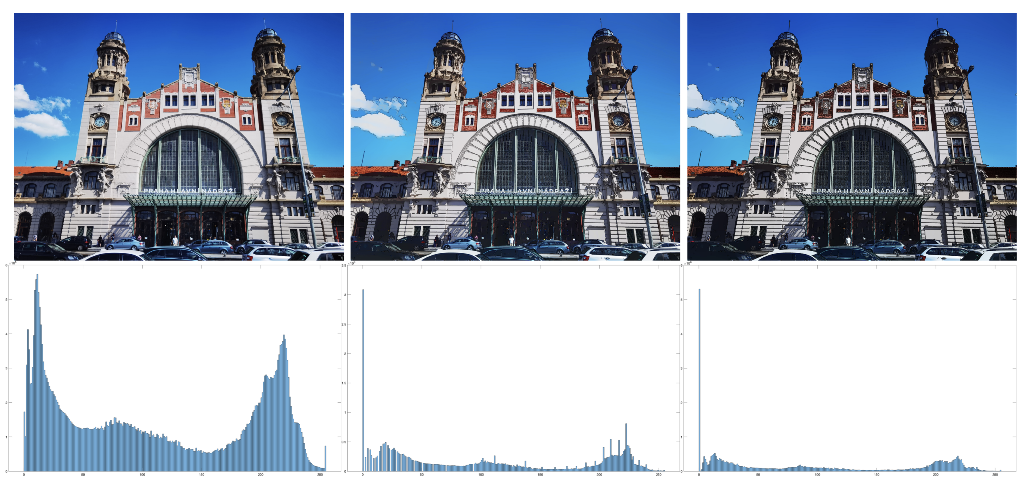
Table 2: Subjective evaluation.

Image type	Level of Edge Enhancement
Normal	between 3 and 4
Dark	between 3 and 4

Table 3: Subjective evaluation result.

3.3 With or Without Color Adjustment and Adaptive Image Merge

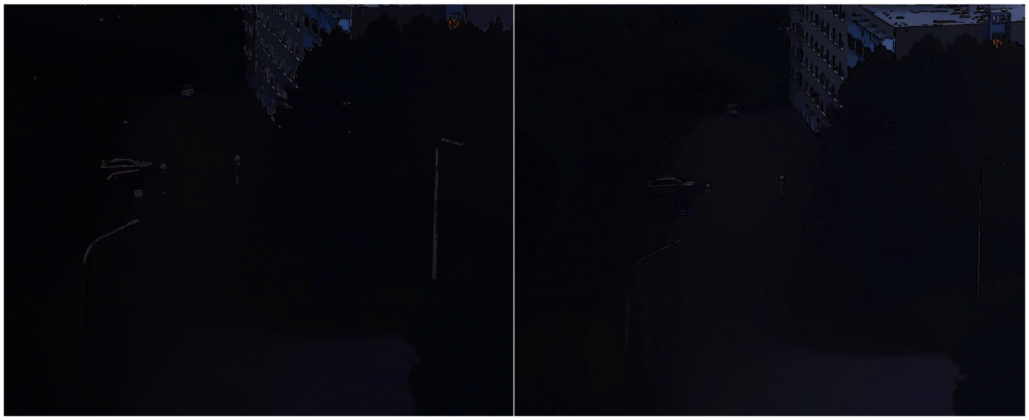
In this section, the comparison between using color adjustment and adaptive image merge and without using these two methods is conducted. As shown in Figure 3, the visual color and brightness in image using color adjustment and adaptive image merge is closer to the input image. However, if not using color adjustment and adaptive image merge, from human's observation, the image seems much darker than the input image. From histogram's view, though there still exists many zero intensity pixels, it reduces number of zero intensity value pixels by half compared to image without using color adjustment and adaptive image merge, as well as slightly increases number of pixels on the peak.



(a) Input (b) Ours (*gamma*=1.2) (c) Without ours

Figure 3: Result comparison with and without color adjustment and adaptive image merge. Histogram in (a) has Y-axis 6×10^5, histogram in (b) has Y-axis 3.5×10^6, histogram in (c) has Y-axis 6×10^6.

The performance of adaptive image merge in dark image in shown in Figure 4. Compared to the image processed without adaptive image merge, the image with it has more obvious and brighter edges in the dark background region.



(a) Ours (b) Without ours

Figure 4: Result comparison with and without adaptive image merge in dark image.

References

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