Image Abstraction with Cartoonlike Shade Representation

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ABSTRACT

Luminance quantization, which maps the luminance values of an image to discrete levels, is widely used for image abstraction and the expression of a cartoonlike effect. Existing luminance quantization techniques use each pixel's luminance value separately, leading to a noisy image. Additionally, they do not take the shape of the imaged object into consideration. Thus, they suffer limitations in terms of cartoonlike shade representation.

We propose a new luminance quantization algorithm that takes into account the shape of the image. We extract the silhouette from the image, compute edge-distance values, and incorporate this information intothe process of luminance quantization. We integrate the luminance values of neighboring pixels using an anisotropic filter, using gradient information for this filtering. As a result, ourquantized image is superior to that given by existing techniques.

Keywords

Image Abstraction, Image cartoonize, cartoonlike shade generation, luminance quantization

1. INTRODUCTION

The purpose of image abstraction is to simplify color and shape. In particular, image cartooning makes images look like a cartoon. Abstracted imagesmake it easier to recognize a scene,because their color and shape information is very simple. For example cartoon is easier to recognize than real scene, so it is often used for children's contents. Because of this advantage, abstracted images are widely used in books and movies. Cartoon images have the following features:

1. Simple color and shade (not noisy)

2. Silhouette-like object shade

To express these features, we use luminance quantization, a simple and fast non-photorealistic rendering (NPR) technique. Conventional approaches change an image's luminance values to certain discretelevels to give simplified images. However, they use the luminance values of individual pixels,so they are limited in representing the shade that reflects the shape of the object, especially since real-world objects are influenced by complex lighting. So, conventional approaches can't represent neat shade like a cartoon.

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We propose an improved luminance quantization algorithm and image cartooning process. Our algorithm takes into account the shape of the depicted object. We extract the silhouette of the object and compute an edge-distance map, and then compute the gradient values of the pixels to create an anisotropic filter. Then we integrate neighboring luminance valuesusing this filter. Our algorithm thus results in an image that is less noisy and has cartoon-like shade.

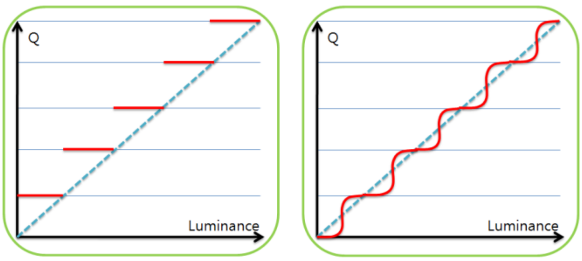
Our main contributions are the following:we represent cartoon-like shade by considering the shape information of the object, and we improve the quality of the luminance quantization image by integrating neighboring luminance values using anisotropic filtering.

2. RELATEDWORK

There are several NPR approaches to abstract the color in a 2D image. The most conventional approach is image segmentation and express with average color of region, which can simplifies image color but cannot preserve the original shape and detail.

More recently, filtering-based methods for image abstraction have gained popularity. The filtering approach is simple and very fast, so it is used widely. Filters include the blurring filter, the Kuwahara filter [Kuw76a], and [Pap07a] that is a generalization of various Kuwahara filters. Newer approaches include the bilateral filter [Tom98a] and the anisotropic Kuwahara filter. Thebilateral filter takes into account color and edge information, so it preserves the original shape. It is also very fast; Winnemoller et al. [Win06a] use this filter for video abstraction. The anisotropic Kuwahara filter expresses a painting effect by using an anisotropic filter within an existing Kuwahara filter. The above approaches express a cartoon-like effect through color simplification, but cannot express cartoon-like shad. For this, we use luminance quantization.

Quantization is a technique that is widely used with video, image, and audio. The original quantization [Cho89a, Zha95a] is a compression technique that is pursuing the save input information and reduce storage space. Apply this, Image quantization is used to reduce the cost on compressionand transmission costs by reducing the color information of the image.And quantization technique was used to representthe shading effect in NPR, which is luminance quantization. Conventional luminance quantization techniques individually change the luminance value of each pixel to a representative value. This leads to noise in the result image due to rapid stylization of luminance at the boundary (Fig.1-a). Therefore, in [Win06a] the tangent function is used to represent a smooth boundary and a natural transition between each step, solving the problem of sharp differences between the steps (Fig.1-b). This technique is simple and presentsthe shading effect well, so it has been widely used to express cartoon effects. However, the study in [Win06a] considers only the luminance information of individual pixels too , and thus does not reflect the morphological information of the image.



(a) **(b)**

Figure 1. (a) General luminance quantization (b) [Win06a]'s luminance quantization

Shape information is very important featurefor image abstraction. Many researchers have studied it: Kang et al. [Kan07a] proposed the edge tangent flow (ETF) technique that applies gradients to express a coherent line effect. Their method was extended to [Kan08a], which simplifies the shape and color of the image. Hertzmann [Her98a] and Hays et al. [Hay04a] determined the direction of the stroke by considering the form of the image to express the painting effect. Hochang et al. [Lee10a] utilized extra information on the image gradient from texture transfer and suggested a texture transfer technique with the direction. In their research on mosaics [Hau01a], Hausner used edge information to follow the direction ofthe edge to determine the direction of the tile. Although there have been many 2D-based studies that consider the shape of images, the form of the object has not been taken into account for the study of images' shade effects.

3. SHAPE-DEPENDENT LUMINANCEQUANTIZATION

Fig.2 shows our system flow. We use a 2D image as an input and apply Mean Curvature Flow(MCF) [Kan08a]. This gives an image with simplified color and shape. After that, we perform two steps. Firstly, we analyze the shape of the object. To do this, the silhouette is extracted and the distance of each pixel from the silhouette is calculated. In this step, flow information is extracted too.This step performed only once. After that, we integrate the luminance values of neighboring pixels using flow information, perform luminance quantization and modify luminance values using silhouette distance values. This step performed iteratively for all pixels of image. Finally, we apply MCF to shade shape clear up. Through these steps, we generate an image that expresses a cartoon-like shading effect.

3.1 Shape analysis

In order to express shade that reflectsshape of object, the shape information must be analyzed. Edge information is commonly used to reflect the shape of image. General edge detection techniques for image processing would extract too much information, so it is not suitable to extract result image which reflect shape like cartoons. Therefore in this study, we used the silhouette of the image and selected significant edge as shape information.

It is a simple matter to get the silhouette line of an object in a 3D environment since each object is saved in a separate space. Because of this, it is easy for extract boundary. In a 2D image, it is difficult to extract the silhouette of the foreground object since there is no depth information. (so, this is not perfect) We use mean-shift segmentation (result shown in Fig. 3-b) followed by user selection of the foreground

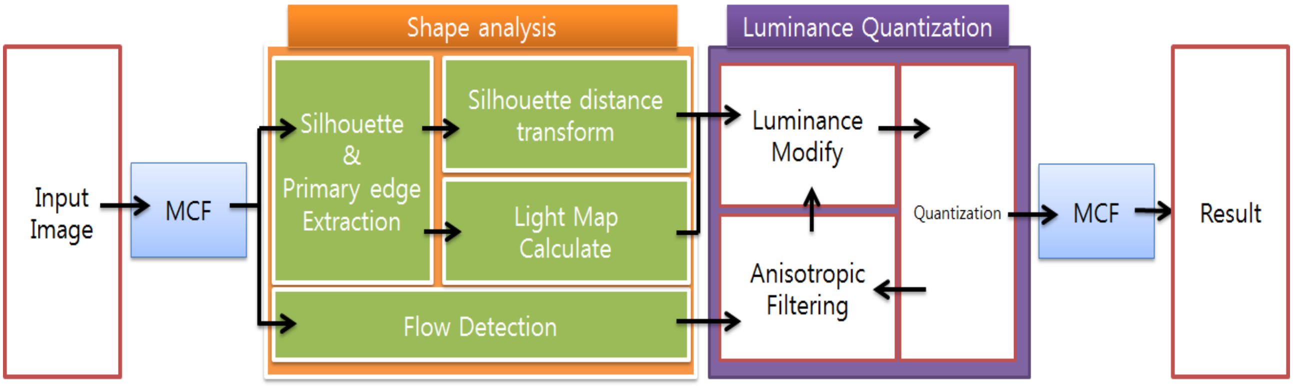
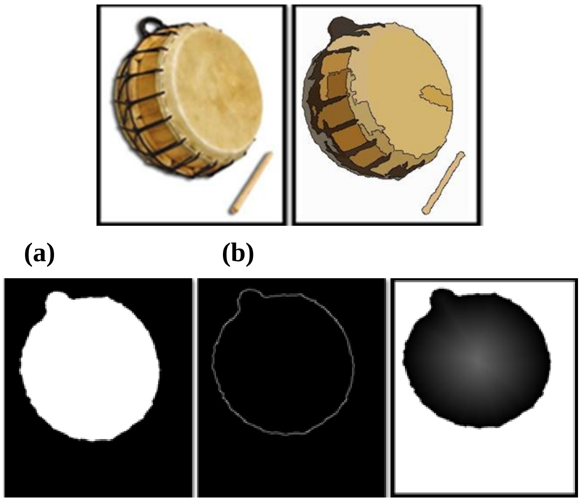


Figure 2. System Flow

object (Fig.3-c), which is then displayed as a white object on a black background

Performing an edge detection procedure gives the silhouette line (Fig.3-d). We then apply the edge-distance transform, an algorithm that extracts the distance between a pixel and the edge closest to it, on the pixels of the foreground object. This leads to an edge-distance map (Fig.3-e). The value of each pixel of the edge-distance map has been normalized to lie between 0 and 1.Thisedge-distance is used as an additional feature for luminance quantization, which will be covered later in this paper.

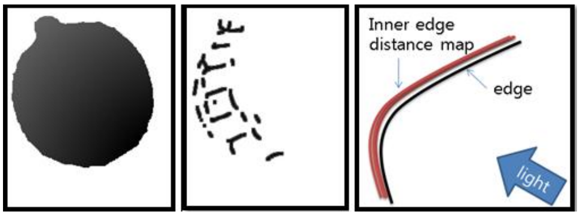


(a) (b) (c) (d) (e)

Figure 3. (a)original image (b) segmented image (c) extracted object (d) silhouette line (e) distance map

In the cartoon, there are not only silhouette-like shades but also other shades, for example creases of cloth and important curves. To express these shades, we calculate the direction of light and extract the significant inner edge. we suppose that strong edge is significant edge. Strong edges have strong gradient value, so it can be remained after apply smoothing. Use this, we apply Gaussian smoothing to image firstly. after that, we extract edge and use this as a significant edge. Using a method used to calculate light direction in photography and videography, we use the highlight points (as seen in Fig.4)to calculate the direction of the light. This allows us to generate a virtual light source. After that, we extract the inner edge. Because the edge image is very complex when we use normal edge detection, we use a smoothed image as input of edge detection algorithm. Then we rule some edges which near to silhouette out inner edge.

Figure 4. light direction in the photography and videography



(a) (b) (c)

Figure 5. (a) light map (b) inner edge distance map (c) concept of inner edge distance

We can get two important features from the light point and inner edge. One is the light-distance map and the other is the inner edge-distance map. The light-distance map (Figure 5-a) is a map of the normalized distance between each object pixel and the light point. We use the light map to prevent omni-directional shade generation, in other words, it enables us to generate shade on only one side of the object.

(a) (b) (c)

Figure 6. (a) edge image (b) normal edge distance map (c) example of edge movement

e calculatethe inner edge-distance map using a modified edge-distance transform. As we see in (Fig.6–a) and (Fig6-b), a normal distance transform gives distance values on both sides of an edge. Further, these values are spread over large area. This would lead to an unnatural shade. Hence, we modify the edge-distance transform to generate a narrow distance value, and we use a moved edge image made by moving the edge to the opposite side of the light (Fig.6–c). This gives the inner edge distance map. We see this in (Fig.5–b) and (Fig.5-c)

3.2 Luminance Modification and Quantization

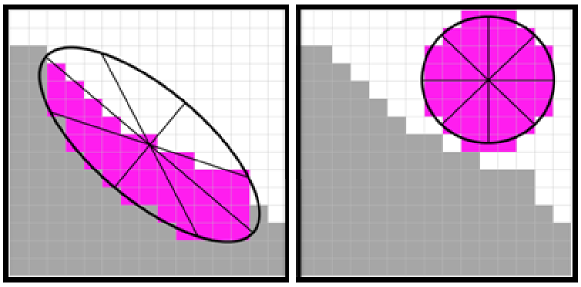
In this step, we apply two processes to all the pixels of image iteratively. The first is the use of an anisotropic filter to merge the luminance of neighboring pixels.This filtering applied anisotropic filter to pixel which have strong gradient. For find gradient, we use ETF field. On the contrast, if pixel do not have strong gradient, filter will be isotropic like (Fig.7) and (Fig.8)The second is the modification of luminance values using the silhouette distance map, the inner edge distance map and the light map. Finally, we apply quantization.

If we were to perform luminance quantization on the original input image, the result would be noisy because luminance values are not distributed evenly across an image. We need a coherent luminance distribution, for which we use a kernel that integrates the luminance values of neighboring pixels. We perform anisotropic filtering which takes into account image flow for the removal of image noise.

To facilitate image flow information, we use [Kan07a]'s method to utilize ETF (Fig.7-b). ETF, which interpolates gradient values, can extract more accurate and coherent pixel directions than other, more general methods that use Sobel or Laplacian filters. From the extracted ETF values, we calculate the structure tensor using x,y direction information. Using this matrix, we deform the circle filter to an anisotropic form. This filter reflects the flow of pixels. (Fig.7) is the ETF field obtained throughline integral convolution (LIC) [Cab93a], showing the orientation of each pixel in the image. In Fig.8 we can see how the anisotropic filter is applied. The luminance of the purple region is used as P in equation (1) below.

(a) (b)

Figure 7. (a) Original image (b)ETF field



(a) (b)

Figure 8. (a) Anisotropic filtering
(b) Isotropic filtering

We use quantization to express the shading effect on the smoothened input image. In order to express a shade thatfollows the borderline, we define fallowing rule.

- Darken the luminance as the silhouette gets closer, lighten it as the silhouette gets further.

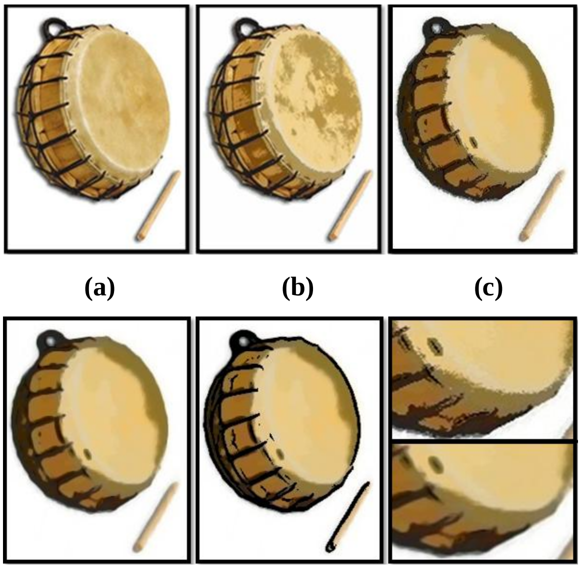
If the edge-distance value of the current pixel (P) is P_{dis} and its luminance value is P_{lum} we calculate $\tilde{P}_{lum}$ as follows:

$$\tilde{P}_{lum} = P_{lum} * (1 + W) \quad (1)$$

$$W = \log_{10}(k / W_{IL}) / 2 * LW \quad (2)$$

$$k = \frac{((P_{dis} * 100) + 1)}{((EF * 100) + 1)} \quad (3)$$

In order to calculate the luminance value that reflects the current luminance information and the information on the distance to the silhouette, we applied weighting based on the log function. Formula (1) shows the process of obtaining the weights W. We have used the effect control factor (EF) to adjust the value for log function. EF is the control variable that can adjust the distance value from the silhouette to where the shading effect is applied. The value of EF is between 0 and 1.As EF approaches 1, the value of K becomes somewhere between 0-1.Because P_{dis} is normalized into 0 - 1. Hence, the weighting value w is always negative and the final result is darker. Conversely, if the value of EF equals 0, the value of K is between 1 and100 and the weighting gets a positive value.0.25 is generally used as the value of EF. We divide this value k by W_{IL}, the inner edge-distance value. Through this we can generate shade on the inner edge region. As the value range of log(K) is -2 to 2, we use log(K) divided by 2. We multiple that value by light weightLW . We can get this value from the light map. The effect of this parameter can be seen in Fig.13.



(a) (b) (c)

(d) (e) (f)

Figure 9. Our results

(a)Originalimage (b)Conventional QT

(c)Our method (not MCF) (d)*(c)* + MCF

(e) *(d)*+Line (f) detail from *(c)* and *(d)*

Finally, the obtained $\tilde{P}_{lum}$ value is used as the input to the quantization process. We use the method used by Winnemoller et al. (Fig.1-(b)). Through this process, we get shade which is influenced by the shape. Finally, we apply MCF again for the arrangement of the shade.

4. RESULTS

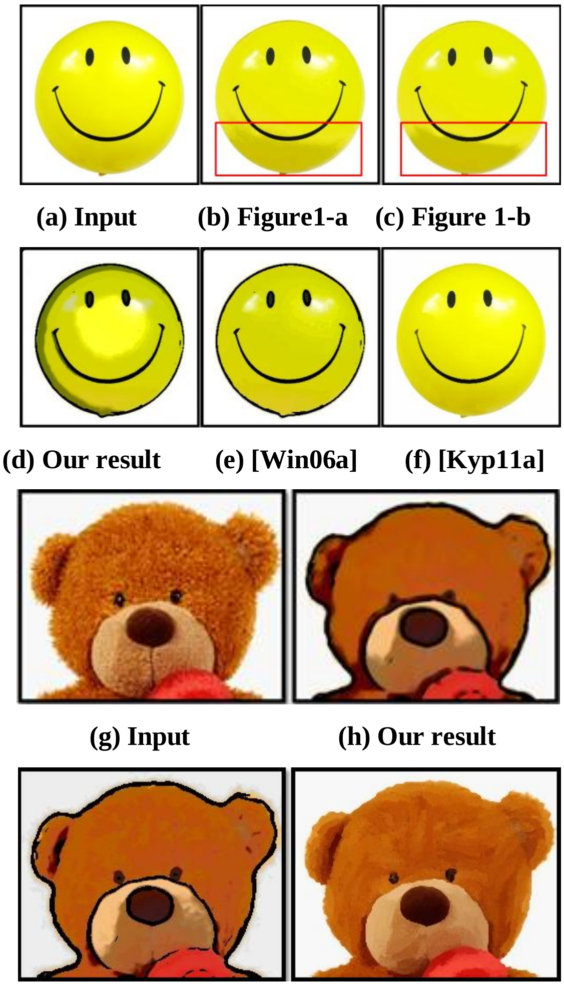
(Fig.9-a) is the input image, (Fig.9-b) is the result of conventional luminance quantization. (Fig.9-c) is the result of our anisotropic filtering and quantization. (Fig.9-c) maintains coherence among neighboring pixels and we can see the shade, it is scattered. (Fig.9-d) is the result of applying the MCF to (Fig.9-c). in this image we can see much better shade, although it is blurred. In (Fig.9-e), we enhance the edges. In the (Fig.9-f) we clearly see the shade on the object and we can check that shade arrangement by MCF.

(Fig.10) shows the result for different values of EF. A larger EF value results in an image with a larger shaded area.

(a) 0.05 (b) 0.25 (c) 0.75

Figure 10. Results by EF value

We compare our results with conventional methods in (Fig.11).(Fig.11-a) is input image, (Fig.11-b) uses conventional luminance quantization. (Fig.11-c), which is the result of applying the quantization described by (Fig.1-b), shows superior definition in the shaded area compared to (Fig.11-b). (Fig.11-d), which is our result, better represents object shape than conventional approaches. (Fig.11-e) is the result of the procedure described in [Win06a]. (Fig.11-f) is the result of using the anisotropic Kuwahara filter. Compared with these, our result exhibits shade which reflects the object's shape. From (Fig.11-g) to (Fig.11-j) are other comparisons.



(a) Input (b) Figure1-a (c) Figure 1-b

(d) Our result (e) [Win06a] (f) [Kyp11a]

(g) Input (h) Our result

(i) [Win06a] (j) [Kyp11a]

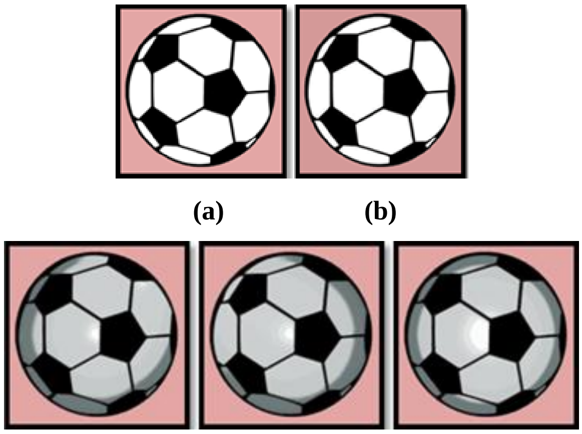
Figure 11. compare results with conventional researches

In (Fig.12), where the luminance is uniform, the shading is not expressed under conventional quantization. However, our method can generate shade.

(a) Input (b) Conventional (c) Our result

Figure 12. result of same-luminance image

(Fig.13) shows the results of varying the value of LW. (Fig.13-a) is input image. (Fig.13-b) is result of conventional luminance quantization. In (Fig.13-c), the light is at the top right; in (Fig.13-d), it is at the top left. In (Fig.13-e), the light is focused at the center of the object. Thus, we can control the shade effect through this parameter. We use this by making distance map. If user select light spot, system calculate light-distance map. This distance value is LW value. And if we don't use LW, we will get result



(a) (b)

(c) (d) (e)

Figure 13. Results by LW value

image like (Fig.13-e). That has omni-directional shade. And (Fig.15) is our additional results.

5. Conclusion and Future Work

In this paper, we proposed an image abstraction technique that is based onluminance quantization and takes into account the shape information of an image. We extracted the silhouette of the input image and utilized each pixel'sedge-distance from the silhouette as an additional feature. We were able to remove the noise while preserving the shape through anisotropic filtering. Through our algorithm, we could expressthe shading effects reflecting the shape of the image better than previous approaches.

The proposed algorithm has two advantages in terms ofthe shading effect compared to conventional luminance quantization. Firstly, the output we have producedmaintainsbetterconsistency among neighborhood pixels. This is because of anisotropic filtering, which considers the flow of the image in contrast to simple isotropic filtering. Thus, the noise was reduced compared to previous studies. The algorithm should be applicable to video content as well. Secondly, the shadow that tags along the shape of the image can be generated. Therefore, the shadow effect is more cartoonlike than in previous studies. In addition, through a simple parameter, the degree of shading can be adjusted and this can easily express variety of effects.

However, our algorithm has several limitations. Firstly, it is sensitive to the background of the image.

If the background is complicated, the result of the segmentation step is poor and object extraction becomes difficult.In (Fig14-a), we can see this limitation. To overcome this, we could use superior segmentation techniques (e.g. matting-based techniques). Secondly, our algorithm has problem when applied to very bright or dark image. Although we use light-map, we can't generate shade. (Fig14-b) Because dark image is very insensitive to luminance change.on the contrary, bright image is very sensitive to luminance change. So, it generates omni-directional shade. Thirdly, the execution time of our algorithm is very sensitive to the size of the anisotropic kernel. However, our algorithm is computationally parallelizable because it works on individual pixels;thus we can overcome this limitation by using a graphics processing unit (GPU). Finally, our algorithm needs some user interactions. If there are automatic object extract techniques, it can be improved

Figure 14. limitation

(a) left-original image, right-segmented image

(b) upper-light map, lower-result image

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Figure 15. Additional results(arrow : light)

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