Multi Scale Toggle Contrast Operator Based Image Analysis

Xiangzhi Bai, Fugen Zhou, Zhaoying Liu, Bindang Xue, and Ting Jin

Image Processing Center
Beijing University of Aeronautics and Astronautics, Beijing 100191, China
jackybxz163@163.com

Abstract. Toggle contrast operator could extract image features and has been used in different applications. In this paper, the toggle contrast operator is used for image decomposition and reconstruction. By using multi scale structuring elements, toggle contrast operator decomposes the original image as different images which contain image features of different scale. Also, the original image could be reconstructed from the decomposed images without any loss. Therefore, this image decomposition and reconstruction method could be used for different applications. An example of image enhancement application has been also demonstrated.

Keywords: Image decomposition and reconstruction; Toggle contrast operator; Mathematical morphology; Image enhancement.

1 Introduction

Decomposing image as different images which contain different image features and then processing the decomposed images to obtain an efficient result following different application purposes is important transform for image processing. Some transforms have been proposed to achieve this purpose, such as wavelet transform [1], curvelet transform [2], morphological pyramid transform [3] and so on. Two very important steps in these transforms are image decomposition and reconstruction. The purpose of the image decomposition is transforming the original image as different images which contain different image features corresponding to different image scales. Then, the decomposed images could be used for different image application purpose. The purpose of image reconstruction is transforming the processed decomposed images into the final image which achieves the application purposes. Many transforms need image sampling when they are used for image decomposition and reconstruction, which may loss some useful image information. So, un-sampling transform may be an efficient alternating way.

In this paper, a new image decomposition and reconstruction method based on multi scale toggle contrast operator is proposed, which is an un-sampling transform. Toggle contrast operator [4] could efficiently extract image features. Multi scale toggle contrast operator is used to decompose the original images as different images which represent different image features of different image scales. Also, the final

R. Chen (Ed.): ICICIS 2011, Part I, CCIS 134, pp. 278–283, 2011.

image could be reconstructed from the processed decomposed images. Moreover, the whole procedure of decomposition and reconstruction do not need image sampling and will not loss any image information. Therefore, the proposed method would be very useful for image processing. An application of image enhancement is demonstrated to show the efficient performance of the method. Moreover, the proposed method could be widely used for different applications.

2 Toggle Contrast Operator

Mathematical morphology is an important theory for image processing and is based on geometry and set theory [4]. Let f and B represent gray scale image and structuring element, respectively. Morphological dilation ($\oplus$) and erosion (Θ) operations of $f(x, y)$ using $B(i, j)$ are defined as follows.

$$f \oplus B(x, y) = \max_{u,v} (f(x-u, y-v) + B(u,v)),$$

$$f \Theta B(x, y) = \min_{u,v} (f(x+u, y+v) - B(u,v)).$$

By using morphological dilation and erosion, one type of toggle contrast operator is defined as follows.

$$TCO(x, y) = \begin{cases} f \oplus B(x,y), & if \ \ f \oplus B(x,y) - f(x,y) < f(x,y) - f \Theta B(x,y) \\ f \Theta B(x,y), & if \ \ f \oplus B(x,y) - f(x,y) > f(x,y) - f \Theta B(x,y) \\ f(x,y), & else \end{cases}.$$

This definition indicates that the gray value of each pixel in *TCO* is selectively replaced by the gray value of the same pixel in the result of dilation, erosion or the original image. The replaced pixels are with gray values close to the gray values of the same pixels in the original image.

3 Image Decomposition and Reconstruction

3.1 Multi Scale Toggle Contrast Operator

Structuring element in toggle contrast operator is a very important parameter. The extracted image features correspond to the used structuring element. However, there is only one structuring element used in toggle contrast operator. To extract all the features, multi scale structuring elements should be used. Suppose there are n scales of structuring elements $B_1, B_2, \ldots, B_n$. $B_i = \underbrace{B_1 \oplus B_1 \ldots \oplus B_1}_{dilation \quad i \quad times}$, $1 \le i \le n$. Then, the multi scale dilation and erosion of $f(x, y)$ using $B_i(u, v)$ are defined as follows.

$$f \oplus B_i(x, y) = \max_{u,v} (f(x-u, y-v) + \breve{B}_i(u,v)),$$

$$f \ominus B_i(x, y) = \min_{u,v}(f(x+u, y+v) - B_i(u, v)).$$

Based on multi scale dilation and erosion, multi scale toggle contrast operator could be calculated as follows.

$$TCO_i(x, y) = \begin{cases} f \oplus B_i(x, y), & if \ \ f \oplus B_i(x, y) - f(x, y) < f(x, y) - f \ominus B_i(x, y) \\ f \ominus B_i(x, y), & if \ \ f \oplus B_i(x, y) - f(x, y) > f(x, y) - f \ominus B_i(x, y) \\ f(x, y), & else \end{cases}.$$

3.2 Image Feature Extraction

The results of dilation and erosion have the following relationships relate to the original image. $f \oplus B(x, y) \geq f(x, y)$, $f \ominus B(x, y) \leq f(x, y)$. So, the gray values of the pixels in the result of toggle contrast could be divided into three classes: (1) pixels with gray values larger than the gray values of the same pixels in the original image, which represent the image features produced by dilation operation and is denoted by D; (2) pixels with gray values smaller than the gray values of the same pixels in the original image, which represent the image features produced by erosion operation and is denoted by E; (3) pixels with gray values equal to the gray values of the same pixels in the original image. Therefore, toggle contrast could be used to extract image features. The images features D and E are calculated as follows.

$$D(f)(x, y) = \max(TCO(f)(x, y) - f(x, y), 0),$$

$$E(f)(x, y) = \max(f(x, y) - TCO(f)(x, y), 0).$$

Then, the original image could be obtained by using D and E as follows.

$$f = TCO(f) - D(f) + E(f). \tag{1}$$

3.3 Image Decomposition

Based on multi scale toggle contrast operator using multi scale structuring element, multi scale image features D_i and E_i could be calculated as follows.

$$D_i(f)(x, y) = \max(TCO_i(f)(x, y) - TCO_{i-1}(f)(x, y), 0),$$

$$E_i(f)(x, y) = \max(TCO_{i-1}(f)(x, y) - TCO_i(f)(x, y), 0).$$

$$TCO_0(f)(x, y) = f.$$

At each scale, the original image is decomposed into there images: $TCO_i(f)$, $D_i(f)$ and $E_i(f)$. $D_i(f)$ contains image details produced by dilation operation. $E_i(f)$ contains image details produced by erosion operation. $TCO_i(f)$ represents smoothed images which is the base image at scale i.

After this decomposition, the decomposed images could be processed following different application purposes.

3.4 Image Reconstruction

Based on expression (1), the original image could be reconstructed as follows.

$$\begin{aligned} f = TCO_0(f) &= TCO_1(f) - D_1(f) + E_1(f) \\ &= TCO_2(f) - D_2(f) + E_2(f) - D_1(f) + E_1(f) \\ &= TCO_n(f) - D_n(f) + E_n(f) - \ldots - D_1(f) + E_1(f) \\ &= TCO_n(f) - (D_n(f) + \ldots + D_1(f)) + (E_n(f) + \ldots + E_1(f)). \\ &= TCO_n(f) - \sum_{i=1}^{n} D_i(f) + \sum_{i=1}^{n} E_i(f). \\ &= TCO_n(f) - F(D_i(f)) + G(E_i(f)). \end{aligned} \tag{2}$$

This expression indicates that, the original image could be easily reconstructed by using the decomposed three types images $TCO_i(f)$, $D_i(f)$ and $E_i(f)$.

3.5 Property

The procedure of image decomposition indicates that, this method does not need image sampling. So, the image could be decomposed without any information loss. And, the original image could be completely reconstructed from the decomposed image and does not need image sampling. So, the image could be reconstructed without any information loss. This will completely maintain the effect of image processing for different applications.

More importantly, different definition of the functions F and G in expression (2) may result in more efficient result.

4 Application of Image Enhancement

To show the efficiency the proposed method for image decomposition and reconstruction, an application of image enhancement is demonstrated.

4.1 Image Enhancement

A simple strategy of image enhancement is enhancing the image details of the original image. And, an efficient way is to obtain the largest gray values of pixels in image details at all scales. So, a simple image enhancement algorithm based on the multi scale toggle contrast operator is demonstrated below.

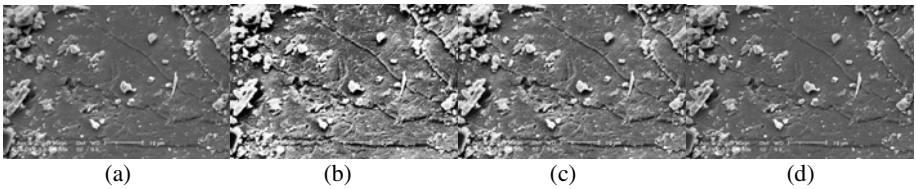
Step 1: Decompose the original image by using multi scale toggle contrast operator;

Step 2: Define F=G = $\max_i$;

Step 3: *Reconstruct* the result image using expression (2).

4.2 Experimental Results

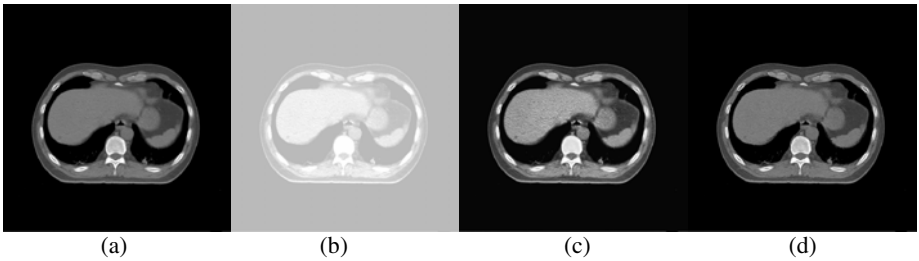
To show the efficiency of the image enhancement algorithm, the histogram equalization algorithm (HE) [5, 6] and contrast limited adaptive histogram equalization algorithm (CLAHE) [5] is used in this paper to compare with the proposed algorithm based on the proposed image decomposition and reconstruction method.



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

Fig. 1. Enhancement of mineral image. (a) Original image; (b) Enhanced result of HE; (c) Enhanced result of CLAHE; (d) Enhanced result of the proposed algorithm.

Figure 1 is an example of mineral image enhancement. Some details of the original image are not clear. Although HE makes some image details clear, many bright regions of the original image are over enhanced, which heavily affects the further application of the enhanced image. CLAHE obtains a better result than HE, but many regions are also over enhanced. The proposed algorithm based on image decomposition and reconstruction by using multi scale toggle contrast operator not only makes the original image clear, but also keeps the gray distribution of the original image, which achieves a better result than CLAHE and HE.



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

Fig. 2. Enhancement of medical image. (a) Original image; (b) Enhanced result of HE; (c) Enhanced result of CLAHE; (d) Enhanced result of the proposed algorithm.

Figure 2 is an example of medical image enhancement. HE could not enhance the original image because of large number of black pixels in the original image. CLAHE enhances the contrast of the original image, but some noises are also produced,

especially in the bright regions. The proposed algorithm based on image decomposition and reconstruction by using multi scale toggle contrast operator enhances the original image and makes the edge regions clear, which performs better than CLAHE and HE.

The experimental results show that because the image decomposition and reconstruction by using multi scale toggle contrast operator could extract image details. The decomposed images could be used easily used for image enhancement. Moreover, the proposed image decomposition and reconstruction could be also used for other image applications.

5 Conclusions

A new image decomposition and reconstruction method based on multi scale toggle contrast operator is proposed in this paper. Toggle contrast operator using multi scale structuring elements could decompose the original image into different images which contain image features corresponding to different image scales. Also, the original image could be reconstructed from the decomposed images without any loss. Moreover, this image decomposition and reconstruction method does not need image sampling. An example of image enhancement application shows that the proposed image decomposition and reconstruction method is useful and efficient. More importantly, this method could be also used for other image application areas, such as image segmentation, image coding and so on.

Acknowledgments. This work is partly supported by the National Natural Science Foundation of China (60902056) and the Aeronautical Science Foundation of China (20090151007).

References

1. Yang, G.Z., Hansell, D.M.: CT Image Enhancement with Wavelet Analysis for the Detection of Small Airways Disease. IEEE Transactions on Medical Imaging 16, 953–961 (1997)
2. Candes, E.J., Donoho, D.L.: Curvelets – a Surprisingly Effective Nonadaptive Representation for Objects with Edges. In: Rabut, C., Cohen, A., Schumaker, L.L. (eds.) Curves and Surfaces, pp. 105–120
3. Morales, A., Acharya, T., Ko, S.: Morphological Pyramids with Alternating Sequential Filters. IEEE Transactions on Image Processing 4, 965–977 (1995)
4. Soille, P.: Morphological Image Analysis-Principle and Applications. Springer, Germany (2003)
5. Huang, K.Q., Wang, Q., Wu, Z.Y.: Natural Color Image Enhancement and Evaluation Algorithm Based on Human Visual System. Computer Vision and Image Understanding 103, 52–63 (2006)
6. Wan, Y., Shi, D.: Joint Exact Histogram Specification and Image Enhancement through the Wavelet Transform. IEEE Transactions on Image Processing 16, 2245–2250 (2007)