An Efficient Quadtree Method Based on SDT for Noise Image

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Abstract: Since the existing quadtree image segmentation methods decide the presence of image information using the maximum and minimum pixel value within an image block, they are very sensitive to noise. Although many image segmentation methods have been researched up to date, they can not execute the optimum image segmentation if noise is included in an image because there is no accurate parameters which can distinguish noise. For that reason, all application using the existing quadtree segmentation has potential of decreasing in performance due to noise. This paper proposed a quadtree image segmentation based on SDT (Standard Deviation Threshold) that can effectively extract image information parameters from a noise image. This method has the advantage of distinguishing the presence of image information even if the image has noises caused by communication. Furthermore, this paper verified through test comparison that the proposed quadtree segmentation could estimate more accurate image information parameters than the existing ones even in noise-added environment.

1. INTRODUCTION

Most image processing researches have aimed at solving image edge detection, texture analysis, image segmentation, shape analysis, motion estimation, and image recognition that are basic problems in computer vision using a digital computer. Among others image segmentation, which is process of dividing a given image into similar regions, has very long history in research on the computer vision field. When human looks for some scene through his/her eyes, brain visual system subdivides complex scene into simple objects and then detects only objects of interest. This image segmentation is applied to many different useful parts such as detecting cancer cells from medical image or detecting a way from satellite pictures. Since image segmentation commands the decisive part of image system and decides the comment of final result analyzed, it is one of the most difficult missions in the image processing field. For this reason, it occupies a prominent position in image analysis and pattern recognition that are basic most in computer vision. Image segmentation is executed by using clustering, edge, and texture to input image. One of its typical methods by clustering is quadtree segmentation.

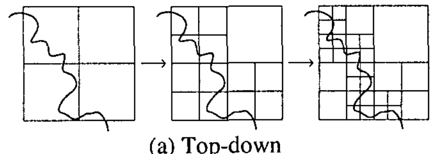
The existing quadtree segmentation decides segmentation by using the gray level deviation of maximum and minimum pixel value within an image. For this reason, if one impulse noise, which transforms pixel intensity value, is added to image with homogeneous information, gray level deviation will become bigger and finally image is divided. The existing methods are very sensitive to noise and cannot execute quadtree image segmentation accurately for noise image. Thus, such problems should be improved in all fields applying image segmentation.

To solve such a problem, this paper proposed an effective quadtree method for noise. This method used SDT instead of gray level deviation which is the existing standard of image segmentation in order to identify that how much similar information is included in an image.

2. QUADTREE SEGMENTATION

Quadtree decomposition is strong technology to divide two-dimension homogeneous image. Because gray level image usually has various information, quadtree decomposition allows to divide image with different size. Moreover, quadtree decomposition can express image data efficiently, so it is used for image data compression. Quadtree decomposition procedure can be executed by top-down or bottom-up.

Typically in a top-down quadtree decomposition, a full quadtree data structure is formed by splitting a single parent node into four descendant nodes. Then all descendants are recursively split until some minimum bound is reached. A bottom-up approach executes quadtree decomposition after dividing image into minimum block size. That is, it examines the uniformity of pixel intensity distribution about adjacent four blocks. If they are uniform, they are composed into a bigger block. Fig. 1 shows a top-down and bottom-up procedure.


(a) Top-down

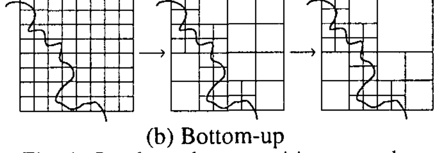

(b) Bottom-up

Fig. 1. Quadtree decomposition procedure.

Suppose that R represents the entire image region, R is divided into N subimages, $R_1, R_2, \cdots, P_N$. Then, divided images satisfy the following expression.

(a) $R = \bigcup_{i=1}^{n} R_i$,

(b) R_i is connected region, $i = 1,2,\cdots,N$

(c) $R_i \cap R_j = \Phi$, for all i and j, $i \neq j$

(d) $P(R_i) =$ TRUE, for $i = 1,2,\cdots,N$, and

(e) $P(R_i \cap R_j) =$ FALSE, for $i \neq j$

where $P(R_i)$ is a logical predicator for pixel value within R_i and Φ is empty set. In (a), divided images constitutes the entire image; in (b), pixel values within an image is next door each other; in (c), divided images are not folded; in (d), pixel values within divided images should be satisfied and (e) means from *P*'s view that image R_i and R_j are different

A main point of quadtree segmentation is the evaluation criterion of image segmentation. This criterion evaluates the presence of image information and decides the division into subquadrants. One of typical criterions uses pixel value deviation within an image block. If deviation is less than threshold and satisfies $P(R_i)=$ TRUE, then block R_i is not subdivided because it is considered one with similar information which has few change in pixel intensity. In contrast, deviation is more than threshold and satisfies $P(R_i)=$ FALSE, then block R_i is subdivided into four small sub-images.

If image size is $2n$x$2n$, resolution level(L) can be expressed as $n+1$. Suppose that quadtree segmentation threshold is Th, the evaluation criterion of deciding image segmentation is given by

$$|MaxPixVal_L - MinPixVal_L| \leq Th \qquad (1)$$

where $MaxPixVal_L$ and $MinPixVal_L$ are maximum and minimum pixel values of image block R_i in resolution level L.

3. QUADTREE SEGMENTATION BY SDT

Although most quadtree segmentation is executed by using excellent bottom-up, the proposed method will present an improved algorithm by analyzing problems of top-down.

Top-down quadtree subdivides multiform region, starting with the entire image until all regions become uniform vertically. The purpose of this image segmentation is to look for objects or the meaningful part of objects. However, noise in an image becomes the biggest problem in image segmentation. In other words, Equation (1) is quite effective in the general situation, but is not in the image with irregular noises. Therefore, a new evaluation criterion not sensitive to noise is needed for image segmentation that is strong to noise.

In resolution level L, average deviation D_L is given by

$$D_L(k,l) = PixVal(k,l) - m_L \qquad (2)$$

where $PixVal_L$ is pixel value of image R_i with size of $k \times l$ and m_L is pixel mean of R_i. Standard deviation σ_L using Equation (2) is given by

$$\sigma_L = \sqrt{\frac{1}{k \times l}\sum_{p=1}^{k}\sum_{q=1}^{l} D_L^2(k,l)} \qquad (3)$$

The following Equation (4) is proposed in order to optimize image segmentation to a noise image. It used the fact that even if an irregular impulse noise such as Gaussian white noise is added, it has no effect on the change in SDT.

$$|m_L - \sigma_L| \leq Th \qquad (4)$$

If Equation (4) is satisfied, image R_i information is considered similar region and is not divided into subquadrants. On the other hand, if Equation (4) is not satisfied, image R_i information is considered not similar region and is divided into subquadrants. When this principle is used, it is possible to limit subquardrants division even if similar image information has noise.

4. SIMULATION RESULTS OF TEST IMAGE

Before discussing simulation results, first evaluation of image quality will be defined to compare with other previous research results. Image evaluation uses Peak Signal to Noise Ratio (*PSNR*) of Equation (5) when its size is $2n$x$2n$, but gray level image is 256.

$$PSNR = 10\log_{10}\left\{\sum_{i=0}^{2^n-1}\sum_{j=0}^{2^n-1}\frac{255^2}{[x(i,j)-y(i,j)]^2}\right\} \qquad (5)$$

where $x(i,j)$ is the pixel value of coordinate i and j of original image and $y(i,j)$ is the pixel value of image to be evaluated.

To evaluate the performance of the proposed quadtree algorithm, it is tested by various 256 gray level images. The size of test images is 512x512 and they are shown in Fig. 2.

(a) Airplane (b) Lenna

(c) Boats (d) Elain

Fig. 2. Test images.

To evaluate performance in the same environment, both the existing quadtree provided in Matalb 6.1 (using qtdecomp.m) and the proposed quadtree were set in identical size of 32x32, 16x16, and 8x8 for image segmentation and in block size of 4x4. And threshold was set within error range of 2.4%, as shown Table 1, in order to be similar in block location and size in environment without noise.

Table 1 A number of image segmentation without noise, unit[dB]

Methods	Original qudtree	Proposed quadtree
Threshold	*Th* = 104	*Th* = 24.32
Airplane	3934	3838
Lenna	2632	2719
Boats	3469	3496
Elain	2179	2164

Fig. 3 is a graph that shows image distortion according to increase in noise by adding Gaussian white noise of mean zeros (using imnoise.m). It suggests that when identical noises were added to four test images, image distortion was also identical. Also, in image distortion environment, the performance of the existing and the proposed quadtree was compared and evaluated.

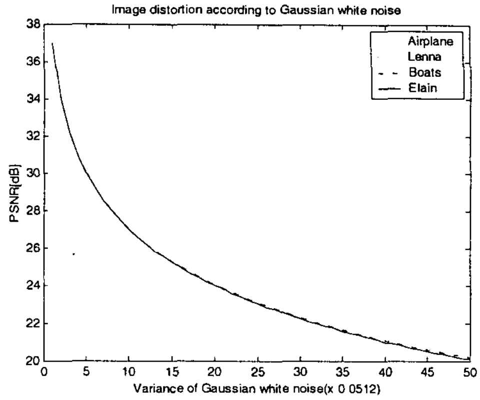
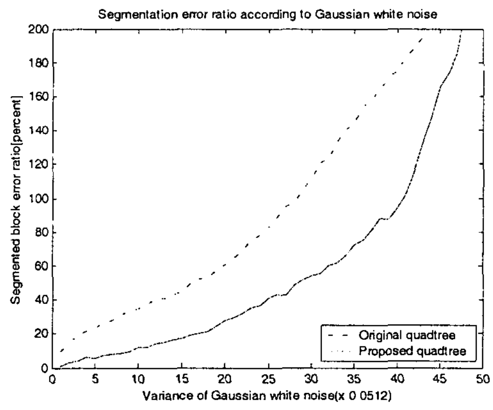


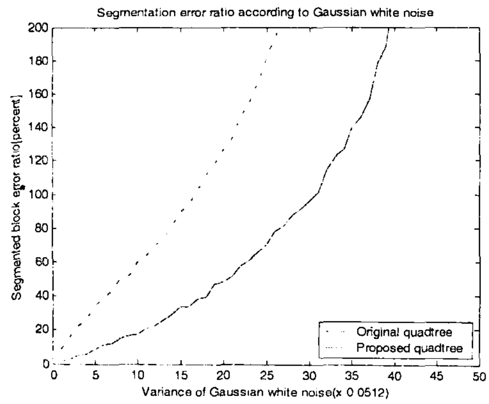
Fig. 3. Image distortion according to Gaussian white noise (mean value: zero).

Fig. 4 illustrates the changes in error rate of image segmentation according to increase in noise when Gaussian white noise was included. For all test images without noise, both the existing and the proposed methods executed image segmentation accurately within error range. In the existing method, as noise increased, the error rate of image segmentation also rapidly increased. In contrast, since the proposed method less misunderstood noise as image information, the change in error rate maintained a much lower slope. Such results mean that the top-down quadtree using evaluation criterion for improved image segmentation proposed in this paper is more effective for noise than the existing method.

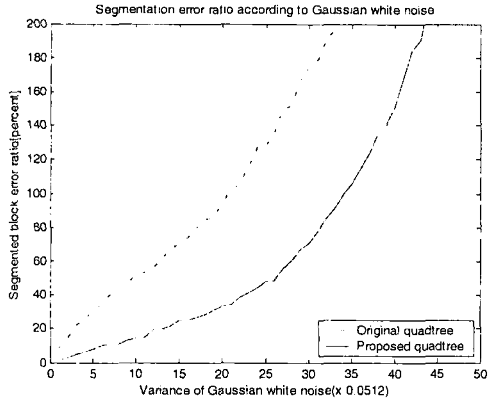
Fig. 5 shows the example of image segmentation between the existing and the proposed quadtree about Airplane test image without noise. Fig. 5(a) was obtained when threshold(*Th*) was 104 using Expression (1), while Fig. 5(b) was obtained when threshold(*Th*) was 24.32 and error range was 2.4% using Expression (4). It demonstrates that both methods have identical image segmentation, without noise.



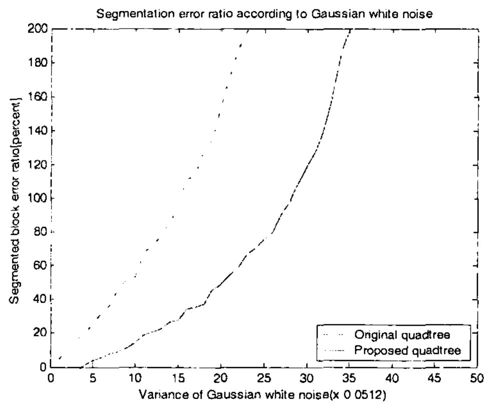
(a) Airplane



(b) Lenna

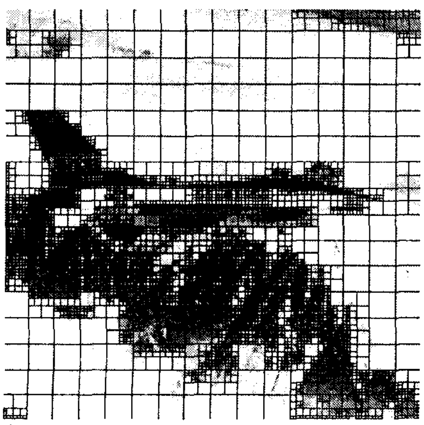


(c) Boats

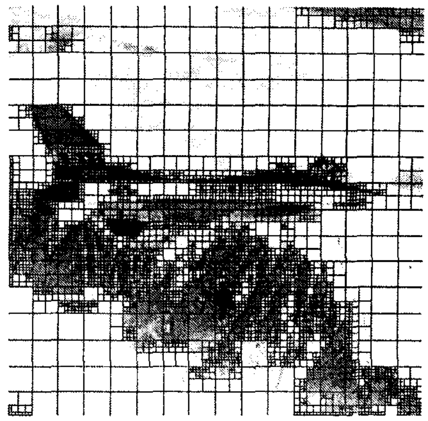


(d) Elain

Fig. 4. Graph for comparison with quadtree segmentation according to Gaussian white noise.



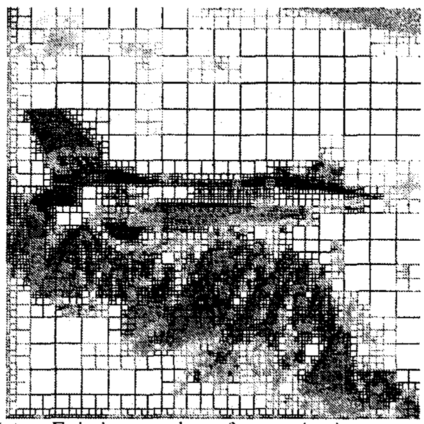
(a) Existing quadtree (Th=104, a number of block: 3934)



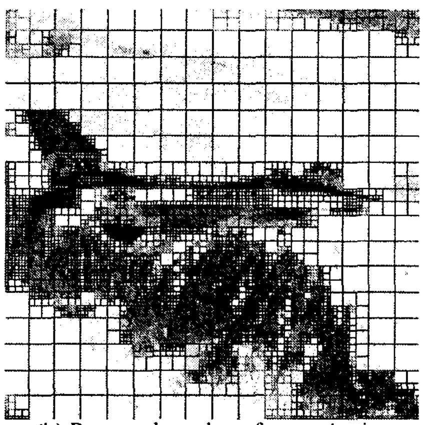
(b) Proposed quadtree (Th=104, a number of block: 3934)

Fig. 5 Example of quadtree segmentation without noise.

Fig. 6 is the example of comparing noise estimation when test image became distorted by PSNR 26.9759 dB under the influence of Gaussian white noise with mean 0 and variance of 0.512. Fig. 6(a) was divided by the existing quadtree. Because of noise included in image information, the number of image segmentation greatly increased and error rate was reached 35.84%. On the other hand, Fig. 6(b) shows that the proposed quadtree could limit error rate to 10.96% under the same condition. These results suggest that the proposed method can deal with noise effectively.



(a) Existing quadtree from noise image
(a number of block : 5344, block increment : 35.84%)



(b) Proposed quadtree from noise image
(a number of block : 4465, block increment :10.96%)

Fig. 6. Example of noise estimation of quadtree according to Gaussian white noise (mean : 0, variance : 0.512).

5. CONCLUSIONS

This paper proposed quadtree image segmentation for noise image which can estimate image information parameters effectively using SDT. This method was designed by using that pixel standard deviation within image block has less effect of noise. In order to compare noise estimation, test image quality was distorted under the Gaussian white noise. The results suggested that the proposed method in this paper more effectively limited the error rate of number of image segmentation due to noise than the existing method. Therefore, it was verified through test comparison that the proposed quadtree executed image segmentation more effectively than the existing method in environment both with and without noise.

In future, this method will be applied to image compression and image recognition on the basis of the proposed quadtree in environment with noise.

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