

# Proposal of a full color automatic natural image region segmentation method with no limitation to the number of regions and the complexity of the area

Hideki Toda

<sup>1</sup>Faculty of engineering, University of Toyama, Japan  
Email: toda@eng.u-toyama.ac.jp

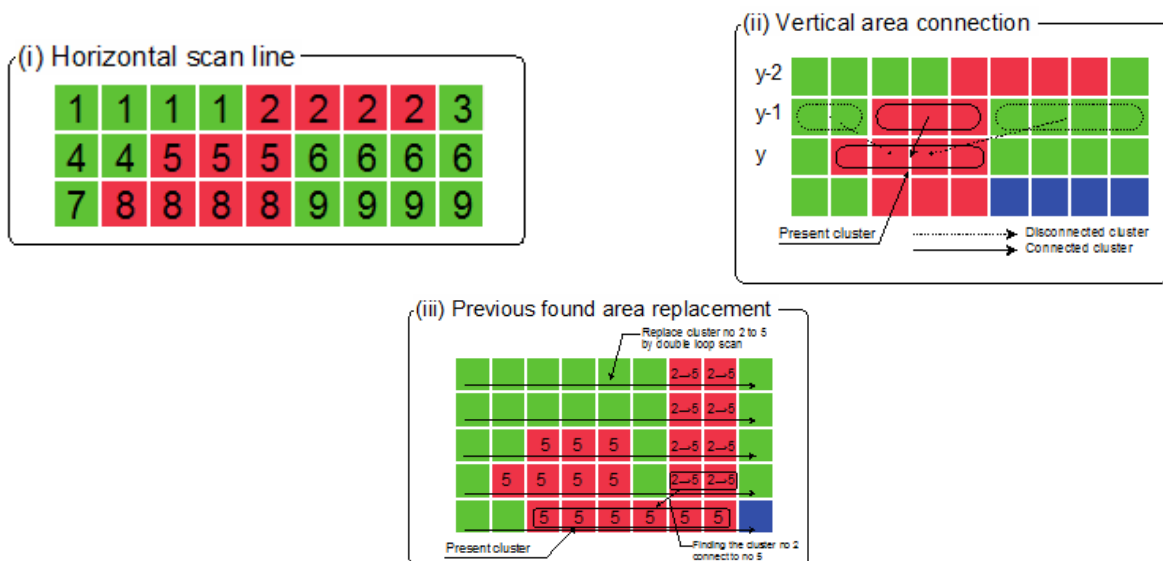
**Abstract**—In this paper, a full color natural image region segmentation method with no limitation to the number of regions and the complexity of the area was proposed, and the effectiveness was confirmed by some natural image pictures.

Automatic natural image region segmentation continues to be in high demand for a long time and this difficulty mainly depend on the large difference between the region division by the human perception and the result of the calculation theory approaches based on the color extraction. Also, the many region segmentation algorithms could work in the case of binary image. The proposed the mathematical procedure that (1) always area segmentation can be realized by only two times scan lines even an image took complex shapes, (2) it does not depend on the number of regions and (3) color and brightness evaluation functions are introduced. Experimental result shows that the proposed method can divide many complex shape areas which the number of regions is uncertain and our method can divide many objects with gradation patterns correctly in the natural full color image. Our method will reduce the complexity of the problem of recognition especially for the complexity growing by increasing the number of objects. It will play basic role for many image processing study fields.

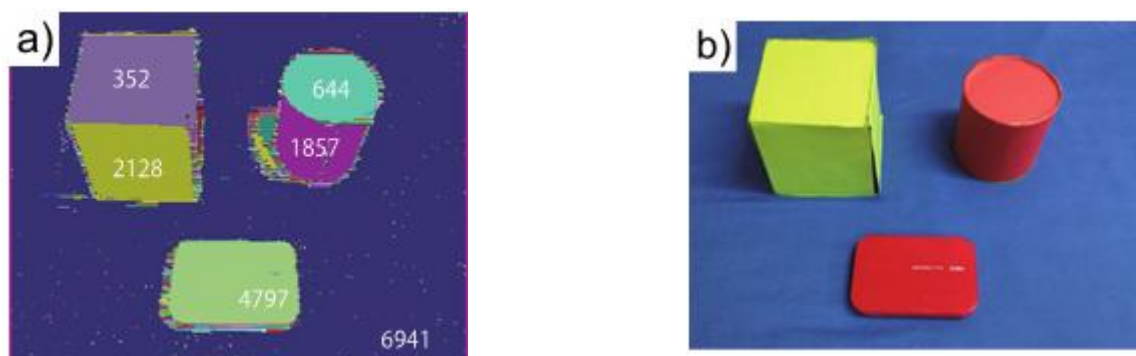
**Keywords**—Two times scan line algorithm, full color natural image region segmentation, clustering algorithm, nolimitation of segmentation areas.

## I. INTRODUCTION

In this paper, a full color natural image region segmentation method with no limitation to the number of regions and the complexity of the area was proposed, and some natural image pictures confirmed the effectiveness. Automatic natural image region segmentation has been continued to be in high demand for a long time [1-21] in the large field of image processing. The difficulty is mainly divided to two points. (1) The number of regions is uncertain. (2) The shape of the regions is unstable. A set of algorithm not to be affected by the above two difficulties was proposed in this paper. Fig.1 shows the proposed algorithm process flow. It can realize automatic natural image region segmentation by two-scan line process (horizontal and vertical) and continuously called one simple replacement subroutine [22]. A typical proposed algorithm result was shown in Fig.2 and the area was segmented even if there is a gradation area of the color.



**FIG.1 PROPOSED AUTOMATIC NATURAL IMAGE AREA SEGMENTATION METHOD PROCESS FLOW.**



**FIG.2A TYPICAL PROPOSED IMAGE PROCESSING RESULT. TWO RED OBJECTS AND THE GREEN OBJECT WERE EXTRACTED AS ONE REGION FROM THE TARGET IMAGE. NUMBER REPRESENTS THE CLUSTER NUMBER  $c$ .**

### 1.1 Previous proposed segmentation method

About the feature (1), a typical colored or monochrome area segmentation method is  $k$ -means method [23]. But, since it is necessary to determine the number of regions " $k$ " before the calculation, many incorrect result are occurred such that one region is divided into multiple areas and it does not always show the same area segmentation result. About the feature (2),

the  $k$ -means method also can not correctly work by the reason that one region is divided into multiple areas.

Area segmentation algorithm (labeling algorithm) is generally restricted to "binary image" [24-29]. Even though the target image is binary (0 or 1) image, the development of an efficient area connecting (labeling) algorithm is difficult [30-34].

Previously proposed fastest labeling algorithm to the binary image is "two times high-speed scan line algorithm" [30]. However, this type algorithm necessary highly complicated dynamic programming and difficult recursive tree-analysis in order to realize the labeling process, the load on the computer is high and the research has been conducted now. Imura's open CV library is the generally used above the two times high-speed scan line algorithm [35]. This library also customized for the binary image.

In addition, difficulty that is more complicated is color. Generally, natural image have many colors on the image and it is necessary to binary the full color image (many binary image will be generated correspond to the number of colors. This means the computational cost will enormously be increased). Cryst et al proposed the full color image extension of the two times high-speed scan line algorithm [33]. Their approach is that, firstly, the image was divided to small size of square areas (e.g.  $4 \times 4$  dots). Next, the dominant color in the color feature space of the small square area was extracted (e.g. red, black, yellow and so on) and the labeling process was executed after the extracted color area binarization. Total computational cost is (number of divided areas) $\times$ (number of the dominant colors) $\times$ (binary image labeling cost). One of large disadvantage of this method could not treat the large area and the difficult shape of the area by the reason that the divided small size square area's dominant color is not stable.

### 1.2 Outline

Section 2 explained the proposed full color natural image region segmentation algorithm. The proposed method is examined the mechanism of the area segmentation by the experiment 1 to 3 in section 3 and 4. As experiment 4, the computational cost was compared with the previously proposed Imura's binary image area segmentation method and other basic image filter (anti-alias, Sobel filter). At last, the proposed method was concluded.

## II. PROPOSED ALGORITHM

Fig.2 (a) shows a typical result of the proposed algorithm ((b) is the original image). Same color shows the same segmentation area. Two red objects and one green object are on the blue sheet and upper red object is divided two areas (the number shows the cluster number  $c$  described in section 2.1). By extracting the one colored area as one segmentation area (and the result is repeatedly stable), the object recognition and object tracing process will be easy to be realized.

### 2.1 Proposed algorithm structure

Our proposed algorithm flow is divided three processes,

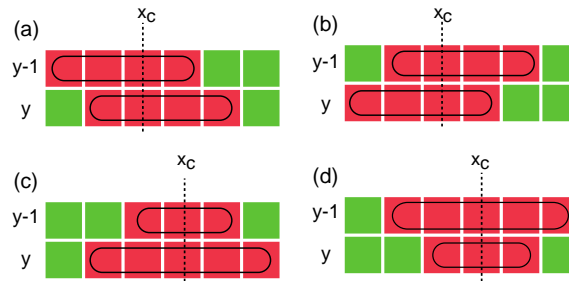
### 2.1.1 Horizontal (x-axis) scan line process:

As shown in Fig.1(i), if an evaluation function  $E$  takes 1 between two dots  $(x + 1, y)$  and  $(x, y)$  on the image, the cluster number record map  $map(x + 1, y)$  is set as  $c + 1$  and the number  $c$  is incremented ( $c$  is the cluster number, precise description of the evaluation function  $E$  is shown in section 2.2). If  $E$  takes 0, the  $map(x + 1, y)$  is set as  $c$  and the value of  $c$  is kept same. In addition, if the  $c$  is incremented when the scan line  $y$  is incremented.

### 2.1.2 Vertical (y-axis) area connection process:

Fig.1 (ii) shows the  $y$ -axis direction area connecting process. This process checks the small regions that are calculated by (i) process are connected to the vertical direction. In this connecting process, we find that there is 4 area connecting condition cases (Fig.3). In all cases, it is necessary that there is an overlap between the areas in  $y - 1$  and  $y$  in order to connect the two areas. In this process, the evaluation function  $E$  is used modified to  $y$ -axis such as  $\Delta V = |V(x_c, y - 1) - V(x_c, y)|$  where  $x_c$  is the center of the overlapping area between the two areas in  $y - 1$  and  $y$ .

If the area connection is found by using the process (ii), all of the cluster number  $c_1 = map(x_c, y - 1)$  are replaced to the cluster number  $c = map(x_c, y)$ . In order to realize the replacement, we defined the subroutine (iii) described below.



**FIG.3 FOUR AREA CONNECTION CONDITIONS IN VERTICAL (y-AXIS) AREA CONNECTION PROCESS.  $x_c$  MEANS THE CENTER OF X-AXIS OF THE OVERLAPPING AREA.**

### 2.1.3 Previously found area replacement process:

Fig.1 (iii) shows the previously found cluster area replacement algorithm. This algorithm takes a simple double loop program and it replace all the cluster number  $c$  in the  $map(x, y)$  to  $c + 1$ . It is shown in a programming code base,

```
for(int y=0;y<height;++y){
  for(int x=0;x<width;++x){
    if( map(x,y)==c ) map(x,y)=c1;
  }
}
```

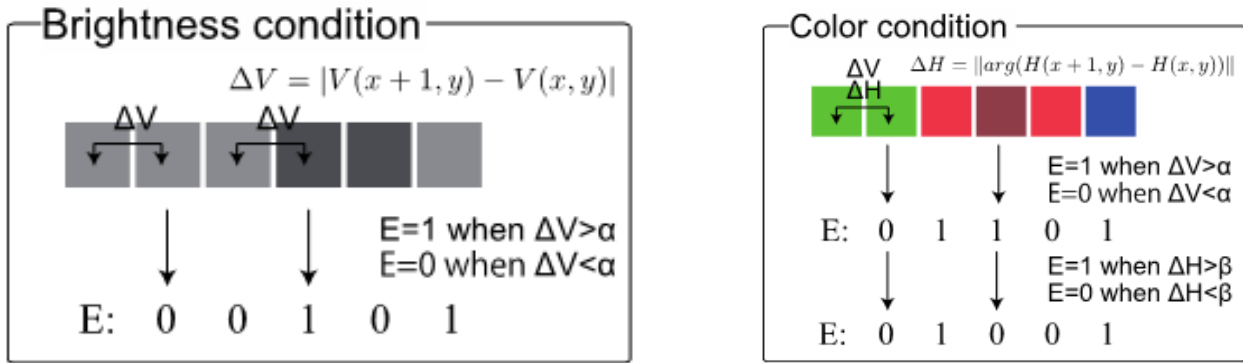
This calculation is simple replacing algorithm by referring to the memory continuously.

## 2.2 Definition of the brightness and the color evaluation function

In order to evaluate the difference of the brightness and the color between two dots  $(x, y)$  and  $(x + 1, y)$  on the image, we defined an evaluation function  $E$  in this subsection. Key point of the description of  $E$  is that it is not the core of the our proposed method in this paper (however, it is based on the human color and brightness perception mechanism), user defined other evaluation function  $E$  can be used. The evaluation function  $E$ , more precisely, should be defined by the experimental result of the human visual perception [36-39].

In section 2.1, we used the brightness and the color difference evaluation function as  $E$ . This evaluation function's outline is shown in Fig.4. First, RGB of the target image is converted to HSV space ( $0 < H < 360$ ,  $0 < S < 256$ ,  $0 < V < 256$ ).

This algorithm firstly finds the difference of the brightness change of  $V(x, y)$  even though the target dots have a color.



**FIG.4 PROPOSED THE BRIGHTNESS AND THE COLOR DIFFERENCE EVALUATION FUNCTION  $\bar{E}$  BETWEEN TWO DOTS  $(x,y)$  and  $(x+1,y)$ . IF THE  $\bar{E}$  EQUALS TO 1, THERE IS A BRIGHTNESS OR COLOR DIFFERENCE BETWEEN THE TWO DOTS**

$$\begin{aligned}
 \Delta V &= |V(x + 1, y) - V(x, y)| \\
 \Delta H &= |\arg(H(x + 1, y) - H(x, y))| \\
 g(V) &= 127 + \frac{64(255 - V)^2}{255^2}
 \end{aligned}
 \tag{1}$$

where *arg* means the angle difference of the two H values.

$$\Delta V > \alpha
 \tag{2}$$

where  $\alpha$  means the brightness difference threshold constant. If the condition Eq.2 is true (or false), the evaluation function will set E=1 (or E=0).

Next, we define the condition Eq.3 as shown below:

$$\Delta V \leq \alpha \wedge S > g(V) \wedge \Delta H > \beta
 \tag{3}$$

where  $\beta$  means the color difference threshold constant. Proposed method only have the two constant parameters  $\alpha, \beta$  inside the algorithm. The equation  $S > g(V)$  means that the dot has a color (not monochrome or gray scale). Eq.3 condition means that if the brightness condition (as same with Eq.2) is false and the color difference  $\Delta H$  is larger than  $\beta$  (under the condition of  $S > g(V)$ ), the two dots  $(x + 1, y)$  and  $(x, y)$  will consider to different regions. This algorithm represents that even if the brightness condition is false (normally, the areas are not connected condition in gray scale situation), if the color conditions would be true, the two area would be connected. If the condition Eq.3 is true (false), the evaluation function will set E=1 (E=0).

### III. EXPERIMENT

First, a gray-scale (not binary) image of desk light and office desk that was referenced in the study of image database [34] was used and the basic performance of the proposed method was confirmed (experiment 1). Next, the segmentation performance of complex shapes in the image such as Chinese character (experiment 2) was examined. Third, the natural color image segmentation result of an apple picture (experiment 3) was shown. As experiment 4, it was compared the proposed algorithm performance with the previously proposed method of labeling algorithm of Imura's open CV library.

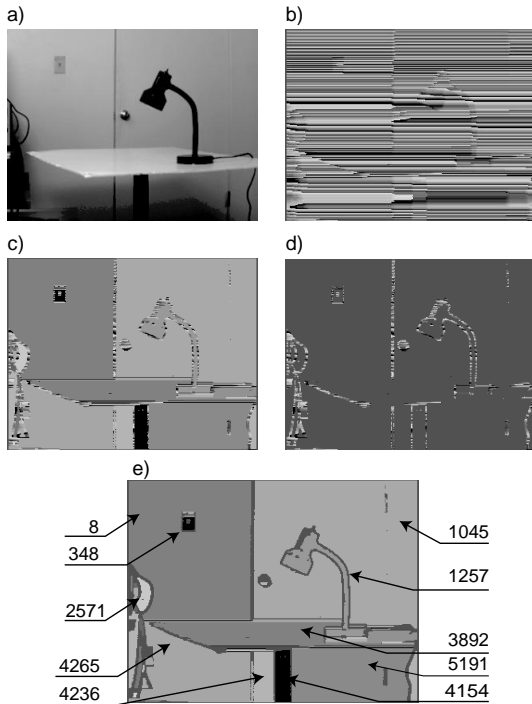
### IV. RESULT

#### 4.1 Result of experiment 1

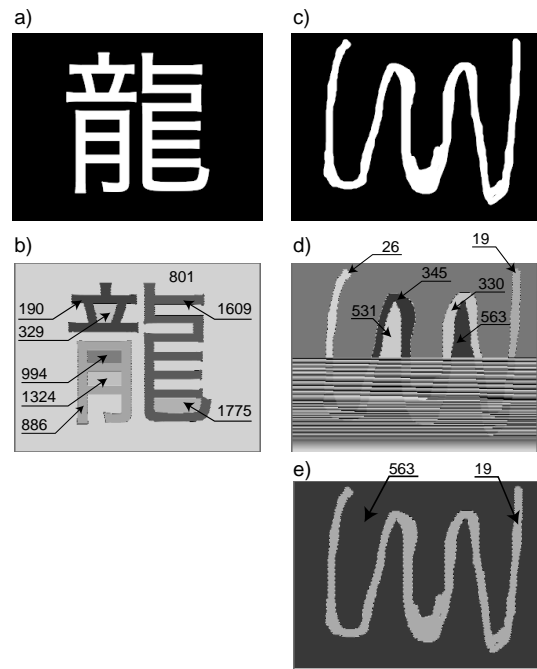
Fig.5 shows the result of experiment 1 (image size is 315x240 pixels). The threshold set  $\alpha=4, \beta=17$ . Since original image (a) is not binary image, basically it could not treat by some kind of simple binary image labeling algorithm. Since the plane areas such as wall or desk have not constant brightness, the area segmentation process is generally difficult or impossible for previously proposed algorithms. The result of matrix  $map(x, y)$  after the Horizontal ( $x$ -axis) scan line process is shown in Fig.5(b). From the result of Fig.5(c), the proposed method can extract many of parts by using the brightness changes such as

switch (cluster no 348), table (cluster no 3892), wall parts (cluster no 8, 1045, 4265), black light stand (cluster no 1257) and so on. Different cluster numbers are attached to different brightness in the figure. After the Horizontal scan line process, Fig.5 (b) represent that the  $map(x,y)$  is constructed from separated small horizontal line segments in each scan line. In this step, there is no relationship between  $y$ -axis scan lines. Fig.5(c) is the result after the process of the vertical area connection process. Each separated small horizontal line segments are connected each other in the axis of vertical direction.

Next feature of our proposed method is to extract an area segment of not contours or edges. In the Fig.5(d) shows that the area is smaller than 16 dots. Almost all the small areas are the contour regions of the image. Fig.5(e) shows the final result of the area that is larger than 16 dots.



**FIG.5 GRAY SCALE IMAGE SEGMENTATION EXAMPLE. (a) ORIGINAL GRAY-SCALE IMAGE. (b) IS HORIZONTAL SCAN RESULT. (c) IS VERTICAL AREA CONNECTION RESULT. (d) IS NOT CONNECTED AREA BY THE VERTICAL AREA CONNECTION RESULT. (e) LARGE AREAS (LARGER THAN 16 PIXELS) ARE PLOTTED FROM THE VERTICAL AREA CONNECTION RESULT**



**FIG.6 COMPLEX SHAPE AREA SEGMENTATION EXAMPLE. (a) CHINESE CHARACTER PATTERN AREA SEGMENTATION. (b) AT LEAST, 8 SURROUNDED AREAS ARE SEGMENTED BY THE PROPOSED METHOD. (c) IS HAND WRITTEN "w" SHAPE AREA SEGMENTATION. (d) IS THE MIDDLE OF ANALYSIS OF THE VERTICAL AREA CONNECTION (UNTIL  $y=120$ , THE IMAGE HEIGHT IS 240 DOT). THERE ARE 2 SEGMENTED AREAS ARE FOUND AFTER FINISHING THE VERTICAL AREA CONNECTION PROCESS AS (e).**

**4.2 Result of experiment 2**

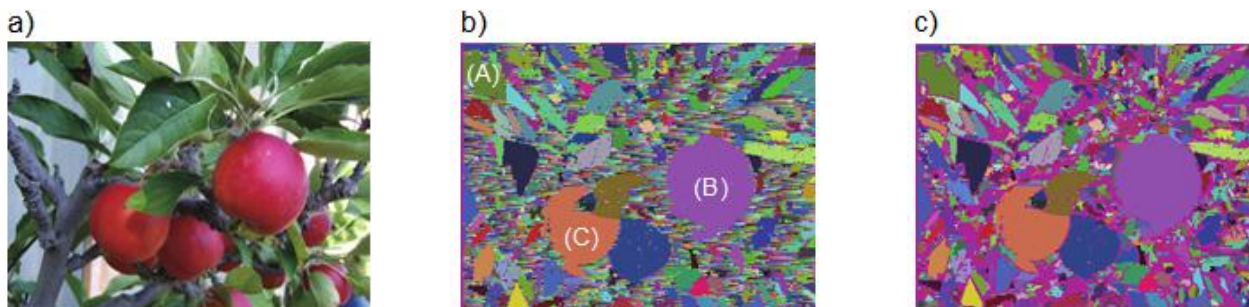
Fig.6 shows the result of experiment 2. Image size and the thresholds set  $\alpha, \beta$  are same with experiment 1. By the existence of subroutine (iii), the proposed method does not depend on shape of the convex-concave segment. Fig.6 (a) shows the original image of a sample of Chinese character and the (b) is the result. 8 separated regions are analyzed. Fig.6(c)-(e) shows the typical region extracting process of the proposed method. Fig.6 (d) stopped the analysis of the vertical area connection process (ii) when  $y=120$  (the image height is 240 dot).In the time, 7 regions are found and does not connect each other. Fig.6 (e) is the end of the analysis of the vertical area connection process and only two regions are found (no 19, 563). The process of the vertical area connection process (ii) and subroutine (iii) realizes those region connections automatically.

Fig.6 Complex shape area segmentation example. (a) Chinese character pattern area segmentation. At least, 8 surrounded areas are segmented by the proposed method. (c) is hand written "w" shape area segmentation. (d) is the middle of analysis of

the vertical area connection (until  $y=120$ , the image height is 240 dot). There are 2 segmented areas are found after finishing the vertical area connection process as (e).

### 4.3 Result of experiment 3

Fig.7 shows the result the gradation pattern contained full color image (apple, experiment 3). Fig.7(a), (b) are original image and the result in the case of  $\alpha, \beta$  are same with experiment 1 and 2. Fig.7(c) is the final result and the segmented area that is larger than 16 pixels are extracted from the vertical area connection process. The region (A) in the Fig.7(b) is the gradation area of wall and our method can extract it as one segmented area. The region (B) and (C) are the apple contained many of colors with gradation basically red and slight yellow gradation. Our method can treat these areas by the reason of existence of 2.2. Another region such as green leaves are also partly extracted and it is difficult to treat high frequency region (it is texture region) by our proposed method.

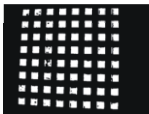


**FIG.7 TYPICAL FULL COLOR NATURAL IMAGE AREA SEGMENTATION EXPERIMENT OF OUR PROPOSED METHOD. EVEN THOUGH THE APPLE ARE CONSTRUCTED BY MANY OF COLORS AND GRADATION PATTERNS SUCH AS RED OR YELLOW (ESPECIALLY IN CASE (C)), THE PROPOSED METHOD CAN EXTRACT IT AS ALMOST ONE AREA.**

### 4.4 Result of experiment 4

Fig.8 shows the computational cost comparison of the proposed algorithm and the previous proposed labeling algorithm (Imura's open CV library [35]). The target image is mono-color Imura's image sample in the homepage (right side Fig.8). The calculation condition is Visual C++ of Windows7 (memory 1GB) on the Virtual PC VMWare Fusion at Mac OS X of MacbookAir 1.6GHz Core2 Duo 2GB. The calculation time of the Imura's library is 998.6 msec (standard deviation S.D. 28.8 msec,  $N=100$ ) and our proposed method is 389.7 (S.D. 18.5) msec. Our method is about  $990/389=2.5$  times faster than the Imura's algorithm, but the aim of this experiment is not the emphasis of the comparison of the speed for all kind of images. For comparison, the typical image processing calculation time is corrected to the table (anti-aliasing, Sobel filter) to the same target mono-color image.

Machine	Windows7 on VMWare Fusion on Mac OS X of MacBookAir 1.6GHz Core2 Duo 2GB	
Image Processing time	Mean calculation time (S.D.) [msec]	
5x5 pixels anti-aliasing process		120.1 (18.5)
Sobel filter (3x3 pixels)		46.0 (1.29)
Imura's opencv library for mono-color image		998.6 (28.8)
Our proposed Method for full color image		389.7 (18.5)



**FIG.8 THE COMPARISON OF THE PREVIOUS PROPOSED SEGMENTATION METHOD. RIGHT SIDE FIGURE IS THE TARGET IMAGE AND THE TABLE SHOWS THE COMPUTATIONAL TIME [MSEC] OF THE TARGET IMAGE**

Our proposed method's algorithm is mathematically not optimized as the Imura's method and the total computational cost is clearly large comparing with the previous method. Basically, the proposed calculation speed maintains by the simple double loop of subroutine (iii), and the tree-analysis / the dynamic complex program difficulties of the Imura's method reduce the speed.

More point that is important is the color. The target image of this experiment is mono-color image and our method can be applied to full color image (section 1.1). This property will be useful to natural image segmentation processing.

## V. CONCLUSION

In this paper, a natural image area segmentation method and confirmed the performance with gray-scale, complex shape, colored gradation images was proposed. The mathematical procedure have three features that (1) always area segmentation can be realized even an image took complex shapes, (2) it does not depend on the number of regions and (3) the color and brightness evaluation function E is introduced. Our method's important feature is that it can be applied to the natural full color image automatic area segmentation. It will reduce the complexity of the problem of recognition especially for the complexity growing by increasing the number of objects and it will play basic role for all field of image processing study including fields.

## ACKNOWLEDGEMENTS

This work was supported by JSPS KAKENHI Grant Number 15K12598.

## REFERENCES

- [1] H. Kou, H. Suzuki, J. Toriwaki, "One method of segmentation using edge information and region information", The Japanese Journal of the Institute of Electronics, Information and Communication Engineers, Vol. J74-D-II, 1991, pp. 1651-1660.
- [2] R. C. Gonzalez, P. Wintz, "Digital Image Processing", Addison-Wesley, 1977.
- [3] T. Kanade, "Survey region segmentation: Signal vs semantics", Computer Graphics and Image Processing, Vol. 13, 1980. pp. 279-297.
- [4] D. H. Ballard, C. M. Brown, "Computer Vision", Prentice-Hall, Inc., 1982.
- [5] R. Nevatia, "Image Segmentation", In Tzay Y. Young and King-Sun Fu editors, Handbook of Pattern Recognition and image Processing, chapter 9, Academic Press, 1986.
- [6] Y. Shirai, "Three-Dimensional Computer Vision", Springer-Verlag, 1987.
- [7] R. C. Gonzalez, R. E. Woods, "Digital Image Processing", Addison- Wesley, 1992.
- [8] N. R. Pal, S. K. Pal, "A review on image segmentation techniques", Pattern Recognition, Vol. 26, No. 9, 1993, pp. 1277-1294.
- [9] B. K. P. Horn, "Robot Vision", MIT Press, 1986.
- [10] W. Skarbek, A. Koschan, "Colour image segmentation -A survey -", Technical Report 94-32, Institute of Technical Informatics, Technical University of Berlin, 1994.
- [11] R. Jain, R. Kasturi, B. G. Schunck, "MACHINE VISION", McGraw-Hill, New York, 1995.
- [12] H. H. Bulthoff, "International Workshop on Biological Motivated Computer Vision", Springer-Verlag, 2002.
- [13] D. Marr, "Vision", Freeman, San Francisco, 1982.
- [14] I. E. Abdou, W. K. Pratt, "Quantitative design and evaluation of enhancement/thresholding edge detectors", Proc. IEEE, vol. 67, May 1979.
- [15] R. P. Johnson, "Contrast Based Edge Detection", Pattern Recognition, vol. 23, 1990, pp. 311-318.
- [16] D. C. Marr, E. Hildreth, "Theory of Edge Detection", Proceedings of the Royal Society of London, 1980, Vol. B-207.
- [17] J. Canny, "A Computational Approach to Edge Detection", IEEE Trans. Pattern Anal. Machine Intell., Vol. PAMI-8, No.6, pp.679-698, Nov 1986.
- [18] G. T. Shrivakshan, C. Chandrasekar, "A Comparison of various Edge Detection Techniques used in Image Processing", IJCSI International Journal of Computer Science Issues, Vol. 9, Issue 5, No 1, September 2012.
- [19] A. Otori, T. Watanabe, K. Suagawara, "Image Segmentation Using Statistical Testing", CVIM,09196072, Vol.26, 2002, pp.1-7.
- [20] I. Yasui, T.Nagao, "Recognition and Image Processing", Shokodo, 1992.
- [21] S. W. Zucker, "Region Growing: childhood and adolescence", Comput. Graphics and Image Processing, Vol. 5, 1976, pp.382-399.
- [22] H. Toda, "Divided into regions method, image processing and divided into regions program", Japan patent JP2013-234362, 2013.
- [23] S. Z. Selim, M. A. Ismail, "K-means-type algorithms", IEEE Trans. Pattern Anal. Mach. Intell, Vol.6, No.1, 1984, pp.81-87.
- [24] A. Rosenfield, J. L. Pfalts, "Sequential operations in digital picture processing", J.ACM, Vol.13, No.4, pp.471-494, 1966, Oct.
- [25] R. Lumia, L. Shapiro, O. Zungia, "A new connected components algorithm for virtual memory computers", Compt. Vis., Graph. Image Process., Vol. 22, No.2, pp.287-300, Feb 1983.
- [26] Y. Shirai, "Labeling connected regions, in Three Dimensional Computer Vision", pp.86-89, Springer-Verlag, New York, 1987.
- [27] T. Goto, Y.Ohta, M.Yoshida, Y.Shirai, "High speed labeling algorithm of connected area", Trans.Inst. Electron.Inform. Communi.Engnr. Jpn. (D-II), vol.72-D-II, no.2, 1989, pp.247-255.
- [28] Y. Okuyama, H. Kobayashi, K. Takenaga, K. Asada, "High speed method of raster scan type labeling method", Trans.Inst. Electron.Inform. Communi.Engnr. Jpn., (D-II), Vol.J73-DII, No.1, 1990, pp.36-45.
- [29] S. Naoi, "High speed labeling method by variable window size using the characteristic of the character information", Trans.Inst. Electron.Inform. Communi.Engnr. Jpn., (D-II), Vol. J80-D-II, No.7, 1997, pp.1793-1801.
- [30] L. He, Y. Chao, K. Suzuki, T. Nakamura, H. Itoh, "An Efficient Two-Scan Connected-Component Labeling Algorithm", Trans.Inst. Electron.Inform. Communi.Engnr. Jpn., (D-II), Vol. J91-D, No.4, 2008, pp.1016-1024.

- 
- [31] F. Chang, C. J. Chen, C. J. Lu, "A linear-time component-labeling algorithm using contour tracing technique", *Compt. Vis. Image Understand.*, Vol.93, No.2, 2004, pp206-220.
- [32] K. Suzuki, I. Horiba, N. Sugie, "Linear time connected component labeling based on sequential local operations", *Compt. Vis. Image Understand.*, Vol.89, No.1, 2003, pp.1-23.
- [33] Cryst, "Image analysis via high-speed multivalued labeling technology", [Online], Available from [<http://cryst.tv/experiment/ImageProcessing/DomainDivisionAndIntegration/OD0503.pdf>], accessed Jul 21, 2016.
- [34] S. Birchfield, C. Tomasi, "Depth Discontinuities by Pixel-to-Pixel Stereo", *International Journal of Computer Vision*, Vol.35(3), 1999, pp.269-293.
- [35] Imura, "high-speed labeling algorithm C++", [Online], Available from [<http://oshiro.bpe.es.osaka-u.ac.jp/people/staff/imura/products/labeling>], accessed Jul 21, 2016.
- [36] H. Yaguchi, I. Masuda, M. Kimoto, H. Haneishi, Y. Miyake, "Relation between Distribution of Color Matches and Color Discrimination Threshold", *Color Science Association of Japan*, Vol. 15(1), pp.77-78, 1991-05-01.
- [37] D. L. Mac Adam, "Visual Sensitivities to Color Differences in Daylight", *J. Opt. Soc. Am.*, Vol.32, 1982, pp.247-274.
- [38] M. R. Luo, G. Cui, B. Rigg, "The development of theCIE 2000 color-difference formula:CIEDE2000, *Color Research and Application*", Special Issue: Special Issue on Color Difference, Volume 26, Issue 5, pp. 340-350, October 2001.
- [39] Y. Tochihara, "Artificial environment design handbook", Maruzen Press (Japan), ISBN978-4-621-07921-8, 2007.