Automatic Contour Extraction from a CT image of Blood Vessel Region around Renal Aorta

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Abstract: Constructing a three-dimensional blood vessel model for a numerical blood flow analysis requires the extraction of contour coordinate data for on the blood vessel region from a two-dimensional medical image obtained by such methods as MRI, CT and ultrasonic-echo cardiography by a manual image analysis that is labour-intensive and time-consuming. This constitutes a bottleneck to the practical use of a numerical analysis to predict blood flow for application to medical examination and treatment. A method for automatically extracting contour coordinate data by using pattern recognition by the genetic algorithm (GA) and Snake is proposed. This method provides the required contour data from a medical image so that a blood vessel model can be created for a numerical blood flow analysis.

1. Introduction

We have been studying the application of a numerical flow analysis to blood flow prediction for medical examination and treatment. A three-dimensional blood vessel model for the numerical analysis is constructed by stacking two-dimensional contour line planes, after extracting the required data for the contour line of the blood vessel region from a medical image obtained by such techniques as MRI and CT. The work required for extracting the contour data of the blood vessel region, which includes measuring the coordinates of some typical points representing the chracteristic contour line and recording the obtained data, requires extensive effort and time to process several hundred images, thus inhibiting the practical use of a numerical blood flow analysis for medical examination and treatment. These limitations can be resolved by applying a new method for automatic contour extractin of the blood vessel region from medical images by using pattern recognition and contour extraction with Snake. It is difficult for a computer to precisely recognize the blood vessel region in a medical image which reflect the bone, internal organs and other blood vessels.

Pattern matching by GA is introduced in this study to enable a computer to recognize the blood vessel region on a medical image. Snake, as proposed by Kass, was adopted for automatic extraction of the contour line data for the recognized blood vessel region in the medical image. Snake involves the application of the energy-minimum principle for total energy defined by summarizing the spline energy and image energy. Studies to apply Snake for the contour extraction of internal organs have been conducted. The results of these studies indicate the suitability of Snake for extracting the contour line of a region. The subject of this present study is the blood vessel region around the renal aorta on a CT image.

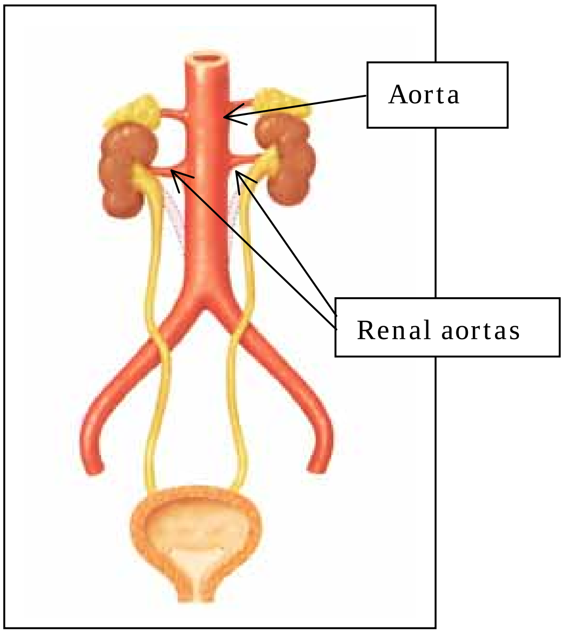


Fig.1 Renal aorta and abonominal aorta

2. Method

Fig.2 shows the flow chart of the proposed method that involves the automatic contour extraction of blood vessel region in this study. The blood vessel region on a CT image can be recognized in computer by using GA pattern-matching scheme. A chromosome generated in GA consists of 4 parameters which involve center point x coordinate, y coordinate, rotate angle α and magnification k (Fig.3). Each parameter has eight bits; therefore, one chromosome has a thirty-two bit sequence which can take “0” or “1” in each bit. The optimal solution is obtained by iterating the operation of crossover, reproduction and mutation in GA. The original image is first converted to a binary image, from which is made a template image of the blood vessel region. This template image is used to recognize the blood vessel region on the CT image as the required region with pattern matching of GA. The contour data of the recognized blood vessel region are determined by Snake from edge energy on the image.

The presence of bones and organs close to the recognized blood vessel region causes an error in contour recognition by Snake. The reflected region on the CT image, excepting the recognized blood vessel region, is eliminated. We detect the edge of the recognized blood vessel region by gradient filter. Some initial control points for Snake are automatically located around the blood vessel region, and the coordinates of these control points on the contour line are finally obtained when the solution converges in the energy minimum iterative calculation to search for the optimal solution.

3. Theory

3.1 Pattern matching by GA

Template matching was adopted as the method for pattern matching. Many chromosomes which have information containing the x,y coordinates of the center point, rotation angle α and magnification k are randomly generated, before the optimal solution is searched by the iterative operations of reproduction, crossover and mutation. The optimal solution represents the blood vessel region on the CT image. Each parameter has a 8-bit sequence which takes “0” or “1” in each bit, and one chromosome has 32bits of information. The GA scheme in this study employs two-point crossover, the elite strategy for reproduction and some point mutations.

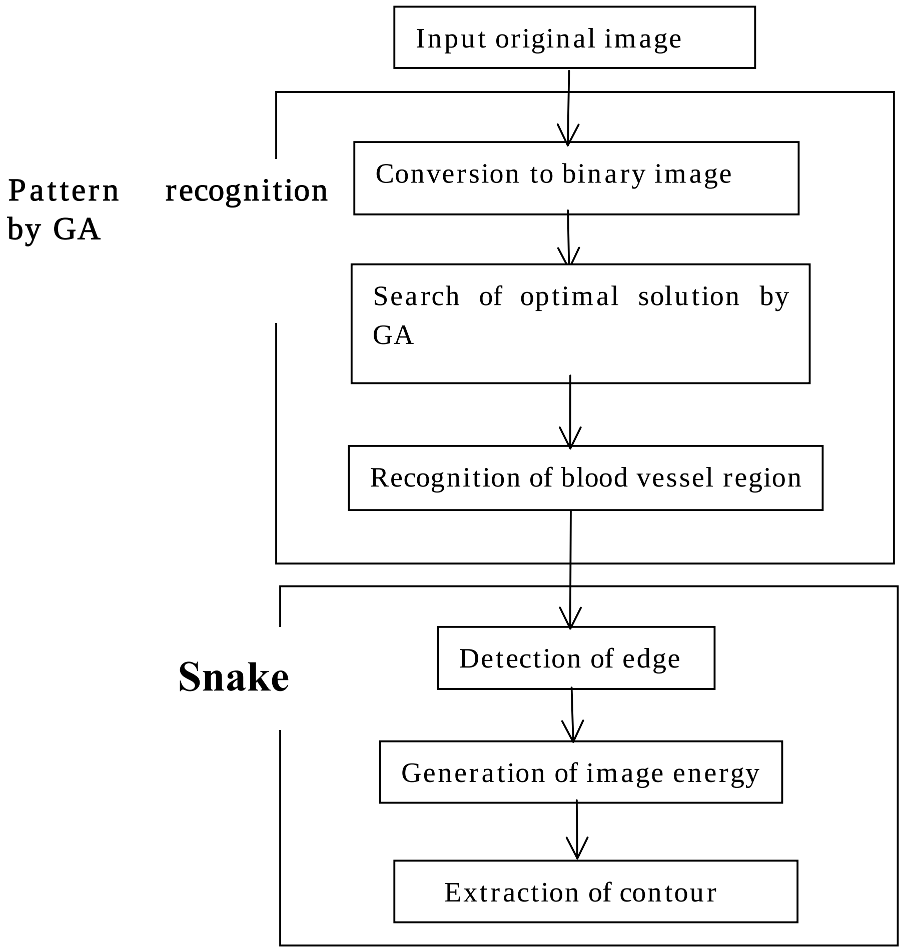


Fig.2 Procedure of automatic contour extraction of objective blood vessel region

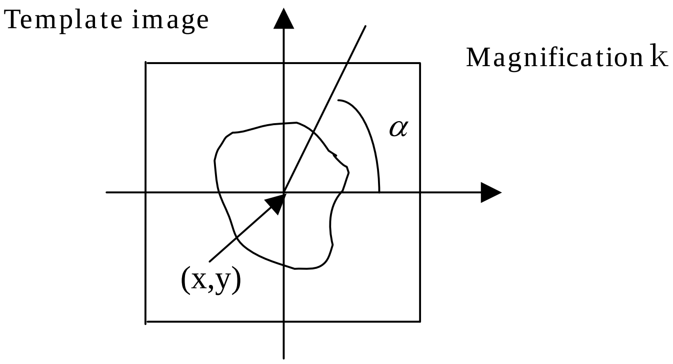
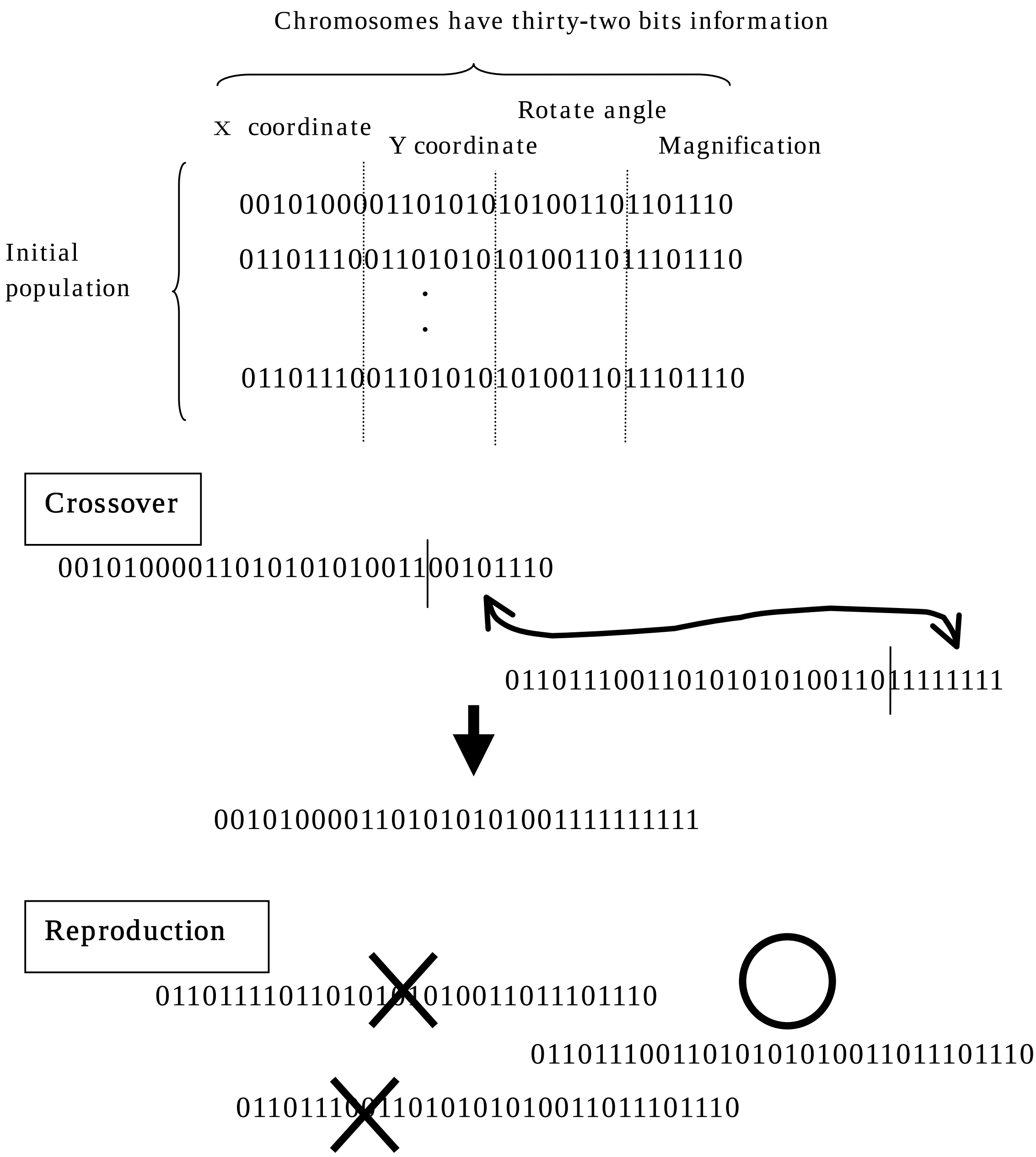


Fig.3 Parameters on a template image



Mutation

1101111011001101010000010101101

1101111011001101010001010101101

Fig.4 Operations in GA

3.2 Contour extraction by Snake

Snake determines the energy minimum contour curve by minimizing the approach for the total energy which is defined as summation of the internal energy and the image energy. Total energy E_{Snake} is expressed as follows:

$$E_{Snake} = \int_0^1 E_{\text{int}}(v(s)) + E_{image}(v(s))ds \tag{1}$$

The internal energy function is defined as follows:

$$E_{\text{int}} = \frac{1}{2}(\alpha |v_s(s)|^2 + \beta |v_{ss}(s)|^2) \tag{2}$$

where α, β are parameters adjusted by the user. Changing α enables Snake to control the ease of shrinking, while changing β enables Snake to control the ease of curving.

The image energy is defined as follows:

$$E_{image} = w_{line}E_{line} + w_{edge}E_{edge} \tag{3}$$

where line energy E_{line} is the intensity of brightness, being defined as

$$E_{line} = I(x, y) \tag{4}$$

and E_{edge} indicates the edge energy, being defined as

$$E_{edge} = d(x, y) \tag{5}$$

where $d(x, y)$ indicate the distance between control points and the closest edge defined by the suspected Euclid distance conversion.

The minimum value of the total energy is determined by derivative method as follows:

$$\frac{\partial \mathbf{E_{Snake}}}{\partial \mathbf{x}} = \mathbf{0} \tag{6}$$

$$\frac{\partial \mathbf{E}_{\mathbf{Snake}}}{\partial \mathbf{y}} = \mathbf{0} \tag{7}$$

The foregoing equations can be summarized as

$$\mathbf{Ax} + \mathbf{f}_{\mathbf{x}}(\mathbf{x}, \mathbf{y}) = \mathbf{0} \tag{8}$$

$$\mathbf{Ay} + \mathbf{f}_{\mathbf{y}}(\mathbf{x}, \mathbf{y}) = \mathbf{0} \tag{9}$$

The Euler scheme is applied to these equations as follows:

$$(\mathbf{A} + \boldsymbol{\gamma}\mathbf{I})\mathbf{x}_{\mathbf{t}} = \mathbf{x}_{\mathbf{t-1}} - \mathbf{f}_{\mathbf{x}}(\mathbf{x}_{\mathbf{t-1}}, \mathbf{y}_{\mathbf{t-1}}) \tag{10}$$

$$(\mathbf{A} + \boldsymbol{\gamma}\mathbf{I})\mathbf{y}_{\mathbf{t}} = \mathbf{y}_{\mathbf{t-1}} - \mathbf{f}_{\mathbf{y}}(\mathbf{x}_{\mathbf{t-1}}, \mathbf{y}_{\mathbf{t-1}}) \tag{11}$$

where γ is a parameter to control the convergence speed of calculation. Snake uses some initial control points that are located around the objective contour which are converged to the contour line by iterative calculation.

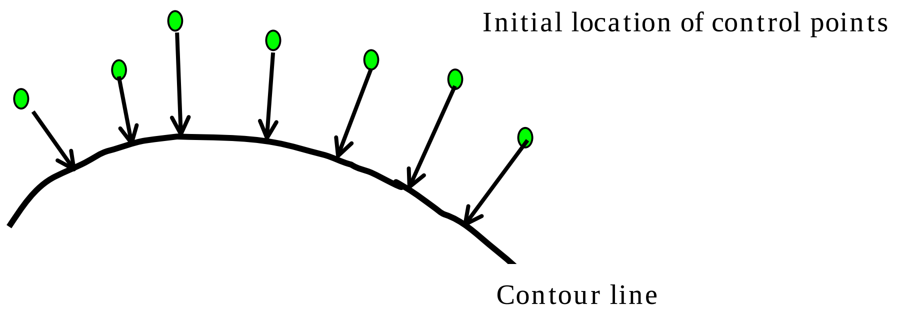


Fig.5 Concept of Snake

4. Results and examination

The results of applying this method are presented for the renal aorta and aorta on the CT image(512×512 pixels) shown in Fig. 6. This figure shows the circular shape of the blood vessel region incorporating the aorta, and Fig. 7 is the binary image to which Fig. 6 has been converted. A template image(50×50 pixels) was next produced for pattern recognition by GA. The rate of mutation was 0.8, the rate of crossover was 0.8, and the number of chromosome was 130. The calculation continues until the value of the fitness function is 0.96, this value being adopted for pattern matching in all images. Fig. 9(a) shows that the blood vessel region of the aorta has been recognized as the objective region by using the template image with pattern recognition of GA. The example shown in Fig. 9(b) for another image has good results with the rate of recognition attaining 100%.

The contour of the foregoing region is next extracted by using Snake to define the distance between the control point and edge of the object region as the image energy and extract the contour by minimizing the total energy that has been defined. It is important to note that the presence of edges for another region near the objective region can lead to an error by

Snake. This is illustrated in Fig. 6, in which the edges for another regions such as bone, internalorgans and other blood vessels have disturbed the precise contour extraction of the objective region by Snake. It is therefore necessary to eliminate any other regions that are near the region to be recognized. Fig. 10 shows the result for the recognized region after eliminating other neighboring regions. The edges of the recognized region are detected by gradient filter. To define the image energy function for optimal calculation by Snake, an image energy field is generated in which the image energy value at each pixel is defined by the suspected Euclid distance conversion(Plus incremental one takes incremental two in the horizontal or vertical direction, and Plus incremental $\sqrt{2}$ takes incremental three in the opposite direction). Fig. 11 shows the image energy distribution given by the suspected Euclid distance conversion, in which black indicates the lowest level of the image energy which takes the 0 value on the gray scale, and white color indicates the highest level of the image energy which takes the 255 value on the gray scale. The greater the distance between the control point and edge become, the lower the level of the image energy become.

In the next stage, several control points were located to provide an initial value around the center of the region recognized by GA; 20 such control points were used in this case, although any number can be selected. Table 1 shows the parameter values for Snake in this study. The iteration calculation continues until the control points meet the edge of the objective region. Fig. 12 shows the path of each control point moving from its initial location to the edge, and Fig. 13 shows the result for another image.

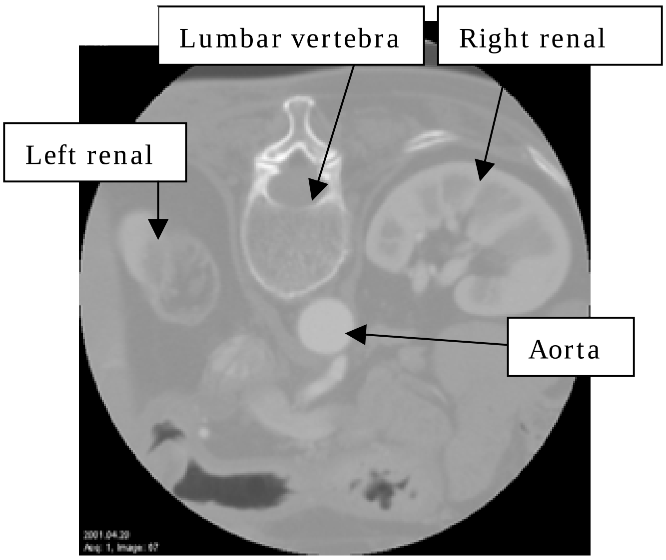


Fig.6 Aorta on CT image

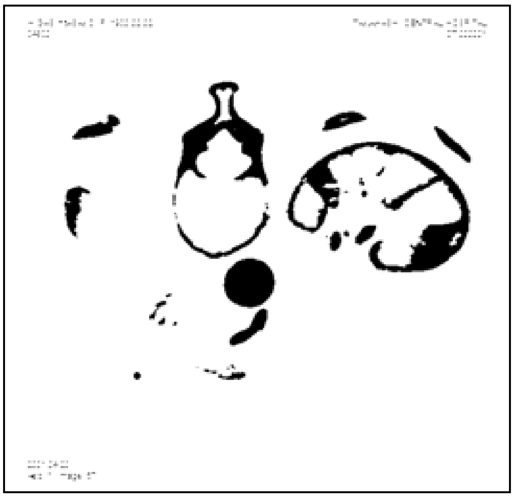


Fig.7 Conversion to binary image

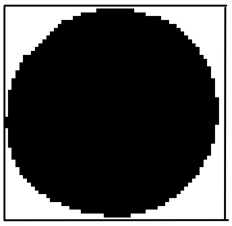
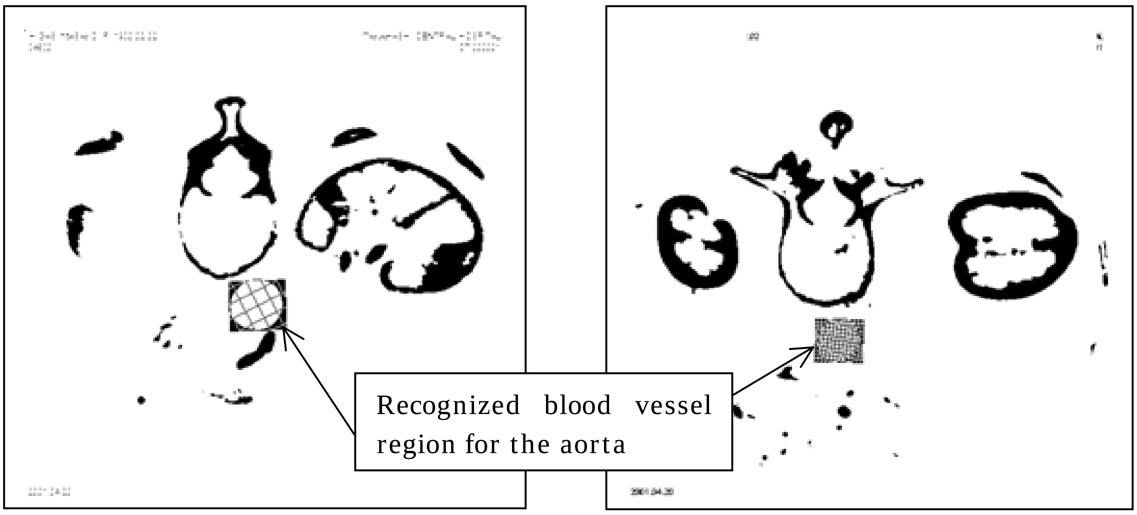


Fig.8 Template image

Table 1. The value of parameters in Snake

α	0.0008
β	0.0008
γ	1.001
w_{line}	0.0
w_{edge}	0.3



(a) (b)

Fig.9 Recognized blood vessel region by GA

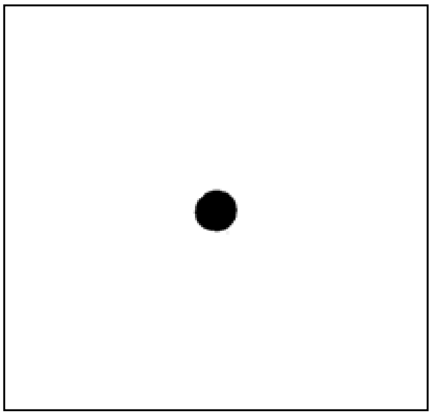


Fig.10　Only blood vessel region exists after eliminating other region

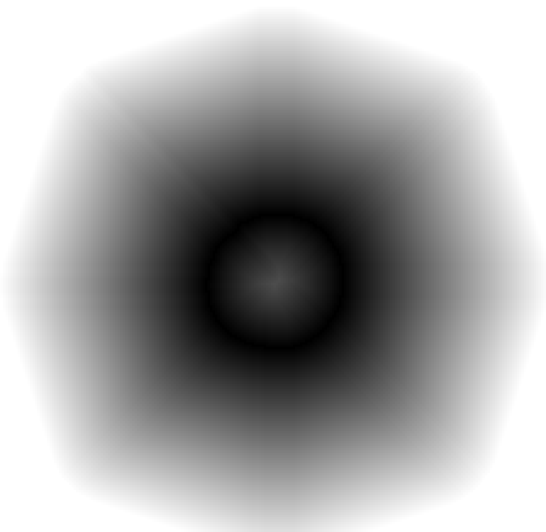


Fig.11 Image energy distribution given by the suspected Euclid distance conversion

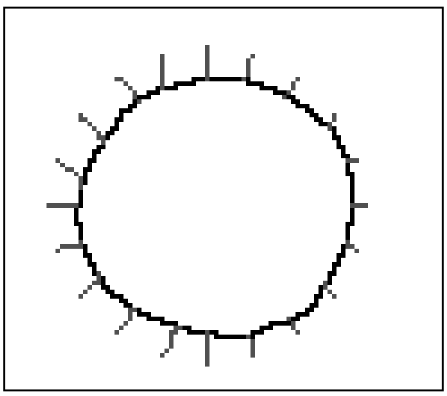
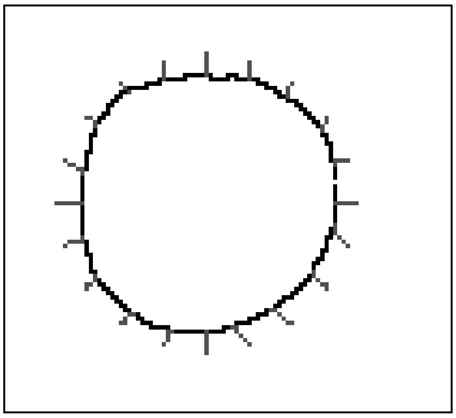


Fig.12 Path of each control point from its initial location to edge

(a)



(b)

Fig.13 Results for another image

5. Conclusion

We have proosed a new method for uatomatic contour extraction of an objective blood vessel region from a CT image. This new method is much more efficient than manual extraction, and an improved algorithm is being developed.

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