IMAGE SEGMENTATION USING ACTIVE CONTOUR (SNAKE)

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ABSTRAK

Kata kunci: Segmentasi Gambar, Active Contour, Pengolahan Gambar Digital.

1. Introduction
With the advances of digital imaging technologies, the field of computer vision and digital image processing develop rapidly. Computer vision has contributed significantly to other fields such as robotics, computational intelligence, entertainment as well as medical imaging. Along with computer vision, digital image processing is often needed to acquire important information from digital images. One of many important tasks in image processing is image segmentation.

Image segmentation is a process to separate an object from its background or from other objects in an image. Object separation is useful when further processes need to be applied to an object, without modifying other parts of the object such as the background. Since the result of image segmentation will affect the next processes conducted, developing an accurate image segmentation is a crucial process. There are three types of image segmentation:

- **Classification-based**, segmentation based on similarity of pixels. The easiest way to perform this type of segmentation is by using a threshold.
- **Edge-based**, segmentation process to obtain a line in an image which is considered as an edge of an object. The edge will separate an object from its background or from other objects.
- **Region-based**, segmentation is performed based on collection of pixels that have many types of associations such as texture, color or gray level, and starts from a point within the image to other neighborhood points.

In this paper, an image segmentation system is designed to obtain a good result with a fast process. This segmentation method employs an active contour which will be described in Section 2. The whole system of the method is presented in Section 3, followed by the presentation of some experiment results in Section 4 and then concluded in Section 5.

2. Active Contour
Active contour, also called as snake, is a spline that uses the energy minimization procedure to impose a contour toward a particular feature. The method was first proposed by Kass et al.\[2\]. Active contour is a popular method in computer vision as well as digital image processing area.\[3,4,6\]. Snake is mathematically represented using the following equation:

\[ E_{\text{snake}} = \int_{s=0}^{s} E_{\text{int}}(\nu(s)) + E_{\text{img}}(\nu(s)) + E_{\text{con}}(\nu(s)) ds \]  

(1)

where:

- \( E_{\text{snake}} \) is the energy function of the active contour from which an object is detected.
- \( \nu(s) \) is the contour (curve).
- \( E_{\text{int}} \) is the internal energy of the active contour affecting the motion of the contour.
- \( E_{\text{img}} \) is energy from the input image including low level features such as edge points.
• $E_{con}$ is the external constraint imposed by either users or high level processes.

$E_{int}$ is given by:

$$E_{int} = \alpha(s) \left( \frac{d v(s)}{ds} \right)^2 + \beta(s) \left( \frac{d^2 v(s)}{ds^2} \right)^2$$

where:

- The derivative $d v(s) / ds$ calculates the energy affecting the elasticity of the contour.
- $\alpha(s)$ is the parameter for elasticity.
- The second derivative $d^2 v(s) / ds^2$ calculates the energy affecting the curvature of the contour.
- $\beta(s)$ is the parameter for curvature.

The active contour formula shown in Equation 1 is further expressed numerically using the following equation:

$$Ax = f_X(x, y)$$

where $f_X(x, y)$ is the edge magnitude of the image, and $A$ is a penta-diagonal matrix having the following pattern:

$$A = \begin{bmatrix}
    c_1 & d_1 & e_1 & 0 & \ldots & a_1 & b_1 \\
    b_2 & c_2 & d_2 & e_2 & 0 & \ldots & a_2 \\
    a_3 & b_3 & c_3 & d_3 & e_3 & 0 & \ldots \\
    0 & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\
    \ldots & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\
    e_{s-1} & 0 & \ldots & a_{s-1} & b_{s-1} & c_{s-1} & d_{s-1} \\
    d_s & e_s & 0 & \ldots & a_s & b_s & c_s
\end{bmatrix}$$

The values of $a$, $b$, $c$, $d$ and $e$ can be obtained by using the following equations:

$$a_s = \frac{\beta_{s-1}}{h^4}$$
$$b_s = -\frac{2(\beta_s + \beta_{s-1})}{h^4}$$
$$c_s = \frac{\alpha_s}{h^2}$$
$$d_s = -\frac{2(\beta_{s+1} + \beta_s)}{h^4}$$
$$e_s = \frac{\alpha_{s+1}}{h^2}$$

where $s$ represents the index of the contour points and $h$ is the space between points in the contour. An iterative solution can then be formulated as follows:

$$x^{(i+1)} = \left( A + \frac{1}{\Delta} I \right)^{-1} \left( \frac{1}{\Delta} x^{(i)} + f_X(x, y) \right)$$

where $I$ is an identity matrix, $x^{(i+1)}$ is the new $x$ position of the contour, and delta is a step size. The $y$ position of the contour points can be obtained in similar way using the following equation:

$$y^{(i+1)} = \left( A + \frac{1}{\Delta} I \right)^{-1} \left( \frac{1}{\Delta} y^{(i)} + f_Y(x, y) \right)$$

3. Segmentation Method

The proposed image segmentation method consists of four main steps: preprocessing, initialization, parameter calculation, and contour deformation. The flowchart of the system is presented in Figure 1.

3.1 Preprocessing

Preprocessing is an optional step and aims to produce a better segmentation. This step consists of four tasks: gray scaling, blurring, color inversion and threshold. Depending on the nature of the input image, each process can be chosen to enhance the result.

Gray scaling is a process to convert a colored image, e.g. RGB image, into a gray level image. There are many different approaches to perform this conversion. In this paper, the following formula is used to obtain the gray level of each pixel: $0.299R + 0.587G + 0.114B$.

Blurring in this preprocessing is performed to thicken the edge of an object. In this experiment, Gaussian blur is used. Gaussian is one of many powerful smoothing filters, in that the detail of the image is kept while the noise is reduced.
The color inversion process is a simple process that changes the low value pixel into high value and vice versa. The result of this process is known as negative images. Threshold is a process to convert a gray level image into a binary image with a threshold value as a limit that determines whether a gray level pixel will be converted into 0 (black) or 255 (white).

### 3.2 Initialization

The initialization step is an important step as it affects the success of the process of active contour. This includes the initialization of the active contour (initial contour) and also the initialization of the matrix that is needed to deform the contour (matrix $A$, see Equation 4). The closer the initial contour to the desired boundary, the more success is the segmentation. The number of points of the initial contour also affects the size of matrix $A$.

### 3.3 Parameter Calculation

As described in Section 2, active contour is influenced by three parameters: alpha, beta and delta. Alpha and beta are part of the internal force, and will be used to calculate matrix $A$, whereas delta is used to process matrix $I$ and also affects vector $x$ and $y$ which are the $x$ and $y$ position of the contour points.

### 3.4 Snake deformation

After all the elements of the active contour formula are calculated, the contour can be deformed by calculating the $x$ and $y$ position of each iteration, until it stops when it converges to the desired boundary. This is done by using the formula in Equations 5 and 6. The flowchart of this step is given in Figure 2.

### 4. Result and Discussion

The method has been implemented into segmentation software to validate the proposed method. The first result that will be presented here has been pre-processed using all the preprocessing option as described in Section 3, and setting alpha = 1.0, beta = 0.7 and delta = 12.0. The result of this experiment is shown in Figure 3.

Different values of alpha, beta and delta have been observed as well. Both alpha and beta have values in the range of 0 and 1 whereas delta can be any value greater than 0. The experiments were performed on the same image, with size $170 \times 194$ pixels and used the gray scaling and threshold preprocessing. The results of these experiments are presented in Figure 4, for various values of alpha, Figure 5, for various values of beta, and Figure 6, for various values of delta.
It can be seen in Figure 4 that the bigger the value of alpha, the closer the contour converges to the object. Figure 5 shows that the variation of beta values does not significantly effect the convergence process. However, it determines the shape of the contour. Figure 6 shows that if the value of delta is big, the converged contour is closer to the desired object.
Some experiments to analyze the effect of preprocessing have also been carried out. The experiment results are presented in Figure 7 for the preprocessing invert process and in Figure for the threshold process. Preprocessing invert is important when the gray value of the object is greater than the gray value of the background. Inversion, in this case, will change the edge value of the image, thus will help the contour to detect the edge.

Preprocessing threshold is essential to omit unnecessary edges so that it would not interfere the segmentation process. Figure 8 illustrates this problem.
Figure 7. The Segmentation Result of Inverted Images Using $\alpha = 1$, $\beta = 0.8$ And $\Delta = 8.0$

Figure 8. The Segmentation Result of Threshold Using $\alpha = 1$, $\beta = 0.8$ and $\Delta = 8.0$.

5. Conclusion
An image segmentation system using active contour have been designed and implemented. The experiment results show that active contour can be well used for image segmentation. Choices of parameter values might affect the result of the segmentation. The higher the value of alpha and beta, the closer the converged contour to the object, although the value of beta is not as significant as the value of alpha. The greater the value of delta, the faster the contour moves to the desired object. In addition, some preprocessing may improve the performance of the segmentation.

Bibliography