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Image segmentation based on GGVF Snake model and Canny operator

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Abstract

For the complexity and particularity of an image, in the case of high noise, it is difficult to extract the target edge contour by applying the generalized gradient vector flow active contour model (GGVF Snake),which affects the accuracy of convergence. A method based on the combination of GGVF Snake model and Canny operator is proposed to extract the target edge contour of the image.The edge detection result of the refined Canny operator is used as the edge mapping to draw the initial contour,and the GGVF is used as the external force field for iterative evolution to extract the image contour and complete the segmentation purpose.

Keywords

GGVF Snake model; refined Canny operator; iterative evolution.

1. Introduction

The extraction of image contour boundaries is the underlying task in the fields of image processing, computer vision, pattern recognition, etc. It is a key issue in the understanding and cognition of the entire image feature information, and provides advantages for later image recognition, enhancement, restoration, and segmentation. The foundation is also the most important part. It is even more difficult to accurately and quickly extract target contours from complex background images. With the progress of the times and the development of computer technology and chips, computer graphics have become larger and more complex, and the speed and accuracy of image contour extraction have become higher and higher. A precise image contour information can be used in visual matching[1], motion tracking[2],3D target reconstruction[3], image recognition[4]and other aspects have a wide range of applications.

The active contour model is also called the snake model. It is a model for image contour extraction proposed by kass[5]and others. The gradient vector flow snake model[6](GVF Snake model) is compared with the traditional snake model. Wide capture range and excellent convergence ability, but when the two edge contours of the depression are very close, the GVF Snake model is difficult to converge to the target. In response to this problem, many scholars have conducted in-depth research on this issue. Xu and Prince proposed a generalized gradient vector flow model[7] (Generalized Gradient Vector Flow, GGVF) as an external force field and proposed a GGVF model, which introduced A pair of weight coefficients that change with the image gradient controls the external force field. This function is a decreasing function of the image gradient. Zhang et al.[8]proposed an anisotropic diffusion adaptive gradient appropriate flow model to improve the segmentation performance of the GVF Snake model.

For complex images, a single parameter active contour model cannot extract a specific target contour model. If the image contains high noise, it will affect the accuracy of convergence. Using the result of the refined edge detection operator as the edge mapping can effectively extract the target edge contour.

2. Mathematical representation of Snake and GVF Snake model

Also known as the active contour model snake model[5](Snake model), which is a movement in the plane I(x,y) scalable parametric curve $X(s)=(x(s),y(s))$, $s\in[0,1]$ The process of deformation and evolution under the combined action of internal and external forces is essentially to find the minimum value of the energy function. The minimum energy function can be expressed as:

$$\mathrm{E}=\int_0^1 [E_{int}(X(s))+E_{ext}(X(s))]ds$$

Internal energy term E_{int} :

$$E_{\mathrm{int}}(X(s))=\frac{1}{2}\left(\alpha(s)\left|X'(s)\right|^2+\beta(s)\left|X''(s)\right|^2\right)$$

External energy E_{ext} :

$$E_{\mathrm{ext}}^1(x,y)=-\left|\nabla I(x,y)\right|^2$$

$$E_{\mathrm{ext}}^2(x,y)=-\left|\nabla G_\sigma(x,y)*I(x,y)\right|^2$$

$\alpha(s)$ and $\beta(s)$ in the formula are weight parameters, which control the elasticity and rigidity of the parameter curve respectively to ensure the continuity and smoothness of the contour curve. Researchers have found problems with the traditional Snake model: First, the initial contour position is sensitive, and the initial contour needs to be close to the target edge, otherwise it cannot converge to the true boundary; second, the contour curve cannot be converged to without proper external force as a guide The depression of the image. For traditional Snake, the gradient vector flow[6](GVF) vector field is introduced to minimize the energy functional: ε :

$$\varepsilon=\iint \mu\left(u_x^2+u_y^2+v_x^2+v_y^2\right)+\left|\nabla f\right|^2\left|V-\nabla f\right|^2 dxdy$$

In the above formula u_x 、 u_y 、 v_x 、 v_y are the first derivatives of u and v in the directions of x and y , and parameter μ is the regularization parameter that controls the integrand that weighs the first term and the second term. The first term of the above functional is a uniform term, which can produce a slowly changing vector field $V\left(x,y\right)$; the second term is a data term, which can calculate the edge gradient value ∇f . When the gradient value ∇f is relatively small, it means that it is in the flat area of the image at this time, and the partial derivative of the vector field is the dominant one, which will produce a slowly changing field; when the value of ∇f is large, it means that it is in the edge area of the image. The second data item $\left|\nabla f\right|^2\left|V-\nabla f\right|^2$ is taken as the dominant, and the minimum value of the functional is ε and only $V=\nabla f$ is set.

3. Generalized Mathematical Model GVF represents

The GVF Snake model is difficult to converge for two slender and close recesses. Two weighting coefficients that change with image information are introduced into the GVF field. The external force field of GGVF[7] can be expressed as the following partial differential Solution of the equation:

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$$V(x,y,t)=\mathrm{g}(|\nabla f|)\nabla^2 V(x,y,t)-h(|\nabla f|)[V(x,y,t)-\nabla f]$$

Where

$$\mathrm{g}(|\nabla f|)=\exp(-|\nabla f|/k)$$

$$\mathrm{h}(|\nabla f|)=1-\exp(-|\nabla f|/k)$$

The first term in the above formula is a smoothing term, and the second term is a data term, which is mainly used to protect the boundary of the image. $\mathrm{g}(|\nabla f|)$ and $\mathrm{h}(|\nabla f|)$ are weight functions, which depend on the gradient of the edge mapping of spatial changes, so the weight itself is spatially variable . When the gradient value gradually increases, the value of the diffusion term weight coefficient $\mathrm{g}(|\nabla f|)$ gradually decreases, so when the boundary contour is reached, the gradient value is the maximum, and the diffusion coefficient is basically zero, and $\mathrm{h}(|\nabla f|)$ has a larger value, which protects the image boundary Function, stop the diffusion; in the mean area, the diffusion term weight coefficient $\mathrm{g}(|\nabla f|)$ has a larger value, while the data term coefficient $\mathrm{h}(|\nabla f|)$ is a smaller value, the diffusion term is dominant.

4. Edge detection operator

The edge detected by the Canny[9,10]operator is used as the edge map of the GGVF Sanke model, and on this basis, iterative solution is performed to improve the anti-noise performance of the GGVF model. The basic principle of Canny operator edge detection: use the first-order directional derivative of the two-dimensional Gaussian function in any direction as the noise filter, filter by convolution with the image, and then find the local maximum value of the image gradient for the filtered image To determine the edge of the image.

The Canny operator filtering function performs filtering processing on the image, which greatly improves the smoothness of the image and reduces noise. Take the two-dimensional Gaussian function:

$$G(x,y,\sigma)=\frac{1}{2\pi\sigma^2}e^{\frac{x+y}{2\sigma^2}}$$

The Gaussian function is used to control the smoothing process of the image, and the image $f(x,y)$ is smoothed, and the result is:

$$g(x,y)=G(x,y,\sigma)*f(x,y)$$

Calculated:

$$A(x,y)=\sqrt{G_x(x,y)^2+G_y(x,y)^2}$$

$$\alpha(x,y)=\arctan\left(\frac{G_x(x,y)}{G_y(x,y)}\right)$$

In the above formula, $A(x,y)$ reflects the edge intensity at (x,y) points on the image, and $\alpha(x,y)$ is the direction of the vertical edge.

Use the dual threshold method to distinguish the edge, set a high threshold and a low threshold, when the edge pixel is higher than the set high threshold, then the point is an edge point; when the edge pixel is lower than the set low threshold , Then the point is not a pixel; when the pixel is at the set high threshold and low threshold, then you need to see whether the adjacent pixel

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of the pixel has a pixel higher than the set high threshold, if there is, it is An edge point, if not, it is not an edge point.

Prewitt operator[11] is a kind of first-order differential operator edge detection. It uses the gray difference between the upper and lower, left and right adjacent points of the pixel to reach the extreme value at the edge to detect the edge, remove some false edges, and smooth the noise.The principle is to use two directional templates to perform neighborhood convolution with the image in the image space. One of the two directional templates detects horizontal edges and the other detects vertical edges.

Roberts operator[12]is a 2*2 template that finds edges through a local difference operator, and the difference between two adjacent pixels in the diagonal direction approximates the gradient amplitude to detect the edge. The edge of the processed image is not smooth, and it is sensitive to noise, and the positioning accuracy is not high.

Sobel operator[13]is a first-order differential operator, discrete difference operator, the local average is in the difference, the center pixel and the pixel weight in other directions are calculated, and the image gradient is calculated using different templates in the horizontal and vertical directions. value. Use a damaged steam pipe compensator as shown in Figure 1 to extract the edge contour, use different edge detection operators to perform edge detection on the steam pipe compensator, and compare the results in Figure 2.

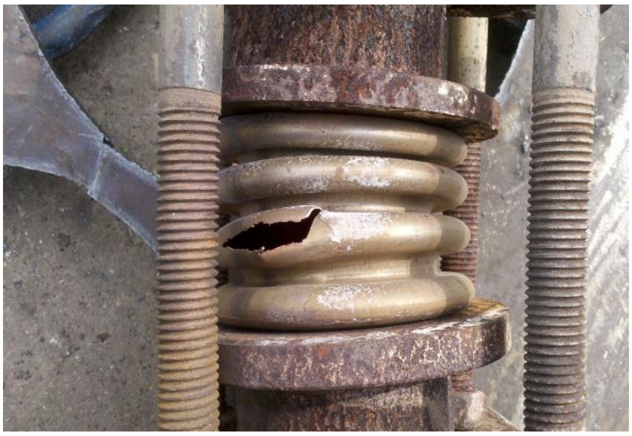
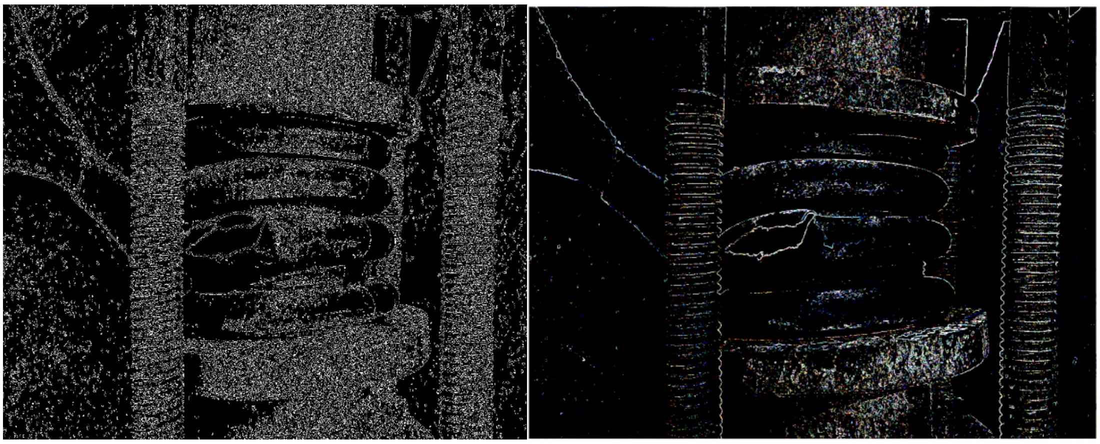


Figure 1 Initial diagram of steam pipeline compensator



(a) Canny operator detection (b) Prewitt operator detection

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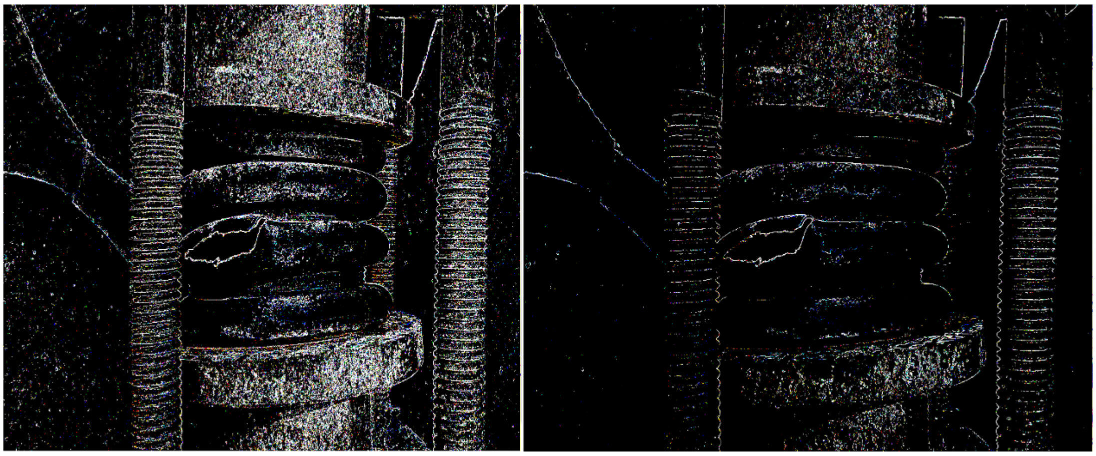

(c) Roberts operator detection (d) Sobel operator detection

Figure 2 Operator detection results(a)(b)(c)(d)

It can be seen from the above figure that the Canny operator itself has relatively strong anti-noise performance and high detection performance for weak edges. Robert operator positioning is more accurate, but because it does not include smoothing, it is more sensitive to noise. Both the Prewitt operator and the Sobel operator are first-order differential operators, while the former is an average filter, and the latter is a weighted average filter and the detected image edge may be greater than 2 pixels. Both of these have better detection effects on images with gradual gray scale and low noise, but the processing effects are not ideal for images with mixed complex noise.

5. Mathematical morphology refines the edge contour

Using the edge operator to detect the edge of the image directly, there will be multiple or thicker gradient curves. This phenomenon will affect the iterative evolution of the contour and cannot converge to the correct edge contour. The edge result obtained by the edge operator is refined Processing so that it can get a clear edge gradient curve. The mathematical morphology method is to delete the pixels that satisfy the transformation in order and cyclically after a series of structural elements with a certain shape are given. The thinning of the image needs to ensure that the image cannot be destroyed, and the image is reduced regularly. This process is also called the thinning process.

The parallel thinning algorithm[14]is used to refine the eight-connected domain of the elements, and the diagonal elements are retained. The element p can be deleted only when the conditions are met: $X_H(p)=1$; $2 \le \min\{n_1(p), n_2(p)\} \le 3$; $(x_2 \vee x_3 \vee \overline{x_8}) \wedge x_1 = 0$ and rotate 180^0 after iteration. Wherein $X_H(p)$ refers to the number of times that a point changes from white to black (from 1 to 0) when it moves counterclockwise or clockwise in the neighborhood of $N(p)$ and $N(p)$ represents the eight neighborhood of pixels. $n_1(p)=\sum_{i=1}^{4} x_{2k-1} \vee x_{2k}$ and $n_2(p)=\sum_{i=1}^{4} x_{2k} \vee x_{2k+1}$ indicate the number of four neighborhoods containing one or two black pixels in $N(p)$.

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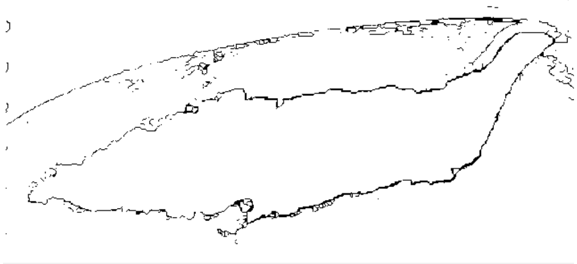
(a)Unrefined Canny operator

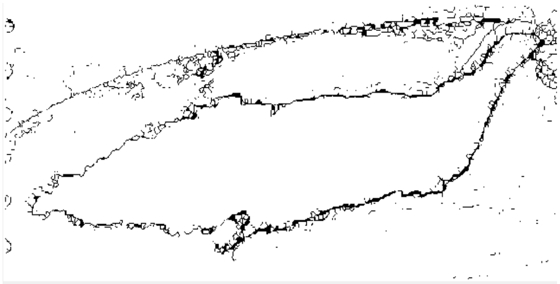
(b)Refined Canny operator

(c)Unrefined Prewitt operator

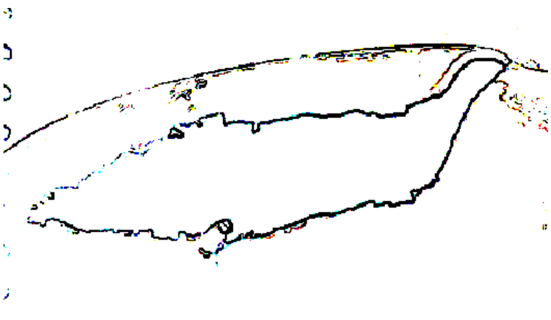


(d)Refined Prewitt operator

(e)Unrefined Roberts operator



(f)Refined Roberts operator



(g)Unrefined Sobel operator

(h)Refined Sobel operator

Figure 3 Comparison of unrefined and refined contours

Keep the original information of the edge, and ensure that the original information cannot change the edge, that is, the connection and trend of the edge, because this information is an important basis for image understanding and target recognition; apply mathematical morphology to it Refinement processing, processing the damaged part of the image, as shown in Figure 3. Obviously from the above picture, the thinning process can make the outline of the image more obvious and clearer.

6. Simulation experiment

The simulation experiments in this article are all done on the same computer, running in Matlab (2016b) environment, and the computer PC is adapted: Intel(R) (TM) Core i7-4790 CPU @ 3.60GHz 8.00GBRAM. The initial contour model of the GGVF Snake model is drawn manually. The red dashed line is the initial curve, the blue is the iteration process, and the red is the

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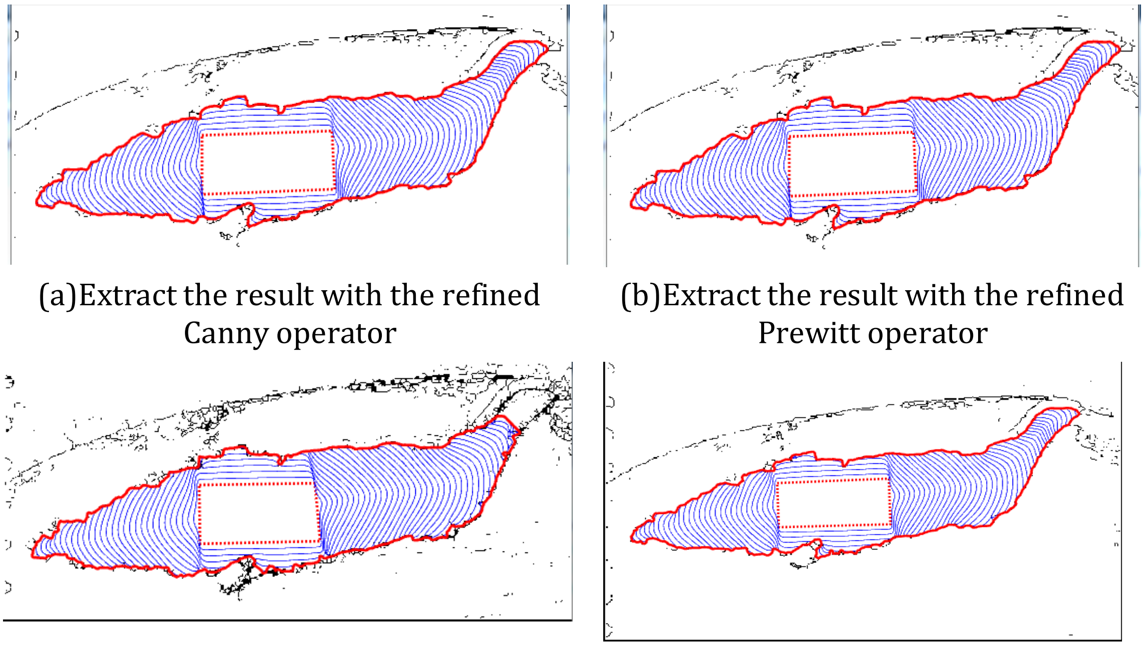
convergence result. Edge detection is performed on the damage of the steam pipe compensator. The detection result is shown in Figure 3:



(a)Extract the result with the refined Canny operator

(b)Extract the result with the refined Prewitt operator

(c)Extract the result with the refined Roberts operator

(d)Extract the result with the refined Sobel operator

Figure 4 GGVF Snake model and operator combined results (a) (b) (c) (d)

In the detection of the damaged target image of the same steam pipe compensator, by comparing the four extraction results in Figure 4 (a) (b) (c) (d), the GGVF Snake model and the refined Canny edge detection The method of combining operators can better make the initial contour converge to the edge contour of the damaged part of the steam pipe compensator, improve the anti-noise ability of the GGVF Snake model, and overcome the problem of active contour sensitivity to weak edges.

7. Conclusion

For the complexity and particularity of the image, when the image contains high noise, it is difficult to extract the edge contour of the target by applying the generalized gradient vector flow model (GGVF), which affects the accuracy of convergence. A method of combining the GGVF Snake model and the refined edge operator is proposed. The experimental simulation results show that the method combined with the refined Canny edge detection operator can better converge to the target edge. This is for high noise More important for complex images.

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