Contour Segmentation Based on GVF Snake Model and Contourlet Transform

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Abstract. A contour segmentation algorithm is proposed based on GVF Snake model and Contourlet transform. Firstly, object contours of images can be obtained based on Contourlet Transform, and those contours will be identified as the initial contour of GVF Snake model. Secondly, GVF Snake model is used to detect the contour edge of human gait motion. Experimental results show that the proposed method can extract the edge feature accurately and efficiently.

Keywords: Gait Recognition, Contour Extraction, GVF Snake models, Contourlet Transform.

1 Introduction

With the rising demand for intelligent monitoring system, the non-contact and long range identification technologies have attracted more and more research interest. Among them, the biometric identification technology identifies people by their inherent physiology or behavior characteristics. As a biometric identification technology, gait recognition identifies authentication by extracting human walking features [1]. Gait recognition is to analyze image sequences containing human motions primarily. Gait recognition mainly consists of three stages: the motion segmentation and classification, feature extraction and description, gait recognition [2]. Gait recognition conquers the limitation of other biological features such as Fingerprint recognition, Iris recognition, Facial recognition *etc*, and has been widely researched in recent years.

Currently, the main methods of motion segmentation include background subtraction method [3], frame difference method and approximate motion field method [4]. The frame difference method is the most commonly used method, which is fast but sensitive to noise. Some researchers have been done and have received good segmentation results through combining the background subtraction method and the frame difference method [5,6]. The feature extraction methods of gait recognition include ellipse model method [7] and graph model method [8] etc. The ellipse model method

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expresses different parts of binary image of human profile using ellipses. The graph model expresses different parts of human body using curves, and it tracks the angle-swing of every part of human body in the image sequence and takes the angles as the feature for gait recognition. The matching algorithms of gait recognition include Dynamic Time Warping (DTW) and Hidden Markov Model (HMM) etc. The DTW can complete pattern matching when the test sequences and reference sequences are not accordant. DTW is widely used in speech recognition fields. Hidden Markov model is a statistical model in which the system being modeled is assumed to be a Markov process with unknown parameters, and the challenge is to determine the hidden parameters from the observable parameters. The extracted model parameters can then be used to perform further analysis, for example for pattern recognition applications.

Feature extraction and description is the key steps for gait recognition. How to extract the motion contour effectively is most important in gait recognition, and it is the main point of this paper. This paper combines the background subtraction method with symmetric differential method to segment the motion human image, and then extracts the contour of motion human with improved GVF Snake model. The experimental results show that the proposed method can extract contour features effectively for the gait recognition.

2 Active Contour Model

Active contour model (snakes) was first introduced in 1988 [9], since then, it has been improved by many researchers. Snake models can move under the influence of internal forces within the curve itself and external forces derived from the image. The internal and external forces are defined so that the snake will conform to an abject boundary or other desired features within an image. Snake is parametric active contour model through curve and surface deformation. There are two key difficulties in Snake models, the first is the location of the initial contour setting, and the second is the bad convergence effect to concave boundary regions of image. On this basis of Snake models, there are many improved models, such as Balloon model, Ziploc Snake model, T-Snake, GVF Snake [10] etc.

Snake models minimize the energy functional to restrain the contour of target object. A traditional snake is a curve $X(s) = (x(s), y(s))$ $s \in [0,1]$, its minimizing energy function is as follows,

$$E = \int_0^1 \frac{1}{2}(\alpha |X^{'}(s)|^2 + \beta |X^{''}(s)|^2) + E_{ext}(X(s))ds \tag{1}$$

,

where α and β are parameters which control the snake's tension and rigidity respectively. The first term is the internal force, which controls the curve changes, while the second term Eextis is the external force, which pulls the curve to desired features. Different Eextcan be constructed in different models.

To analyze the movement of snake model curve from the aspect of force balance, the minimized E of a snake must satisfy the Euler equation:

$$\alpha X^{''}(S) - \beta X^{''''}(S) - \nabla E_{ext} = 0 \tag{2}$$

To add additional flexibility to the snake model, it is possible to start from the force balance equation directly, $F_{\text{int}} + F_{ext}^{1} = 0$, where $F_{\text{int}} = \alpha X^{''}(S) - \beta X^{''''}(S)$ and $F_{ext}^{1} = -\nabla E_{ext}$.

As the Snake contour is dynamic, the $X(s)$ can be viewed as the function of t and s, then,

$$X_t(s,t) = \alpha X^{''}(S) - \beta X^{''''}(S) - \nabla E_{ext} \tag{3}$$

Once getting solution of the equation (3), we will find a solution of equation (2).

3 Contourlet Transform

The limitations of commonly used separable extensions of one-dimensional transforms, such as the Fourier and wavelet transforms, in capturing the geometry of image edges are well known. In 2002, Do and Vetterli proposed a ‘true’ two dimensional transform, contourlet transform, which called pyramidal directional filter bank. The resulting image expansion is a directional multiresolution analysis framework composed of contour segments, and thus is named contourlet. This will overcome the challenges of wavelet and curvelet transform.

Contourlet transform is a double filter bank structure. It is implemented by the pyramidal directional filter bank (PDFB) which decomposes images into directional subbands at multiple scales. In terms of structure the contourlet transform is a cascade of a Laplacian Pyramid and a directional filter bank. In essence, it first uses a wavelet-like transform for edge detection, and then a local directional transform for contour segment detection. The contourlet transform provides a sparse representation for two-dimensional piecewise smooth signals that resemble images.

Contourlet coefficients of natural images exhibit the following properties:

1. Non-Gaussian marginally.
2. Dependent on generalized neighborhood.
3. Conditionally Gaussian conditioned on generalized neighborhood.
4. Parents are (often) the most influential.

The contourlet transform expresses image by first applying a multi-scale transform, followed by a local directional transform to gather the nearby basis functions at the same scale into linear structures. In the first stage of contourlet transform, the Laplacian pyramid (LP) is used for sub-band decomposition. The resulting image is subtracted from the original image to obtain the bandpass image. This process can be iterated repeatedly on the coarser version of the image. The LP decomposition at each step generates a sampled lowpass version of the original image and the difference between the original and the prediction, resulting in a bandpass high frequency image. Directional filter bank (DFB) is used in the second stage to link the edge points into linear structures, which involves modulating the input image and using quincunx filter banks (QFB) with diamond-shaped filters.

4 Contour Extraction Based on GVF Snake and Contourlet Transform

In the GVF field, some points have an important influence to the initial contour setting. When these points within the target, the initial contour must contain these points; and when these points outside the target, the initial contour do not contain these points, otherwise it will not converge to correct results. We call these points the critical points. The creation of critical points has the following factors: (1) critical points are associated with the image gradient Δf. By minimizing the energy functional, Δf will be spread out, the impact of noise generated by the local minima will produce the critical points. (2) critical points are associated with the smoothing coefficient μ. The higher the value μ is, the greater the smoothing effect is. The critical points will reduce, and GVF performance will reduce. Choosing a large-scale Gaussian smoothing and a smaller μ value will get good results. (3) critical points are associated with iterations number of solving equations. When the number of iterations is more than a thousand times, GVF field has changed dramatically. Although we require the final converged solution, but in the actual image processing applications, an intermediate result is acceptable. Therefore, the initial contour should contain the critical points as much as possible. So we can reduce the need of capture and reduce the amount of computation.

Contourlet transform offers a much richer sub-band set of different directions and shapes, which helps to capture geometric structures in images much more efficiently. The Laplacian pyramid (LP) is first used to capture the point discontinuities, and then followed by a direction filter banks (DFB) to link point discontinuities into linear structures. In particular, contourlets have elongate supports at various scales, directions, and aspect ratios. The contourlets satisfy anisotropy principle and can capture intrinsic geometric structure information of images and achieve better a sparser expression image than discrete wavelet transform (DWT).

In order to solve the initial active contour problem of Snake model, In this paper, Contourlet transform is introduced into the GVF Snake model, which will provides a way to set the initial contour, as a result, will improves the edge detection results of GVF Snake model effectively. Firstly, the contours of the object in images can be obtained based on Contourlet Transform, and this contours will be identified as the initial contour of GVF Snake model. Secondly, then GVF Snake model is used to detect the contour edge of human gait motion.

5 Experimental Results

This section shows several experimental results achieved using MATLAB 7.0. Images are from the database of the Biometrics and Security Research Center [11].

In experimental results, we can see that the gradient force field locates in the real contours and points to the real contours in the direct neighborhood of the real contour. The GVF force field smoothly spreads and points to the real contour in the homogeneous regions of image. In the GVF, the center is the neighborhood of real contour, and the force field smoothly diamond diffuses out according to the number of iterations. The direction of diffusion is same as the gradient force field center and the diffusion area is proportional to the number of iterations.

Fig. 1(a) and Fig. 1(b) are the rough contour segmented from the background in a continuous images, and the extracted body contour using the improved GVF Snake model (μ= 0.1, the number of iterations is 80 times).

Experimental results show that using GVF Snake model cannot detect accurately the crotch position of body. While the improved anisotropic GVF Snake model can produce better Concavities fitting effect.

(a) (b)

Fig. 1. (a) The rough contour segmented from the background. (b) The extracted body contour using the improved GVF Snake model.

6 Conclusions

The background subtraction method and the symmetry differential method can be effectively combined for the moving target detection. The moving target detection is the key step in gait recognition. This paper combines the background subtraction method with symmetric differential method to segment the motion human image, and then extracts the contour of motion human with improved GVF Snake model. The experimental results show that the proposed method can extract contour features effectively for the gait recognition. But the computation based on is complicated and time-consuming, so how to effectively combine GVF Snake model with gait recognition is also an open topic need of further research.

Contourlet transform can be used to captures smooth contours and edges at any orientation. In order to solve the initial active contour problem of Snake model, Contourlet transform is introduced into the GVF Snake model, which will provides a way to set the initial contour, as a result, will improves the edge detection results of GVF Snake model effectively. The multi-scale decomposition is handled by a Laplacian pyramid. The directional decomposition is handled by a directional filter bank.

Firstly, the contours of the object in images can be obtained based on Contourlet Transform, and this contours will be identified as the initial contour of GVF Snake model. Secondly, then GVF Snake model is used to detect the contour edge of human gait motion.

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