WAVELET-BASED THE CHARACTER RECOGNITION IN MAP

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ABSTRACT:

The automatic recognition, including the character, annotation, contour line and so on, is very important in many fields. Here, we focus on the character recognition of the scanned map, because the digitizing map is an important resource data for GIS and automatic recognition character of scanning map is still a key problem, which needs to be solved seriously. In our investigation, which is about automatic recognizing characters in scanning map utilizing zero crossings of wavelet transform, we firstly transformed the gray map scanned to the binary image, which is pre-processed (noise filter, thinning, etc). The closed-contours in the binary image are constructed using morphology operators and the chain codes of the closed-contour are traced. Then, the closed-contours related to the characters are separated from the binary image by the special threshold. The three features (x, y, and tangential angle in the closed-contour of characters) are extracted, which is of great benefit to change 2D image to 1D signals. The feature signal related to x, y, and tangential angle is decomposed respectively by the discrete dyadic wavelet in 2^j scale, and the zero-crossings of the wavelet transform are extracted, because the zero-crossings represent sharp variation points of the feature signals. The dynamic time warping is used as the similarity measure for the purpose of realizing the feature match and character recognition.

1. INTRODUCTION

Recent years, many investigations related to automatically produce or update the database of GIS from remote sensed images or digitizing map have been introduced in a lot of literatures. Up to now, the automatic object recognition and feature extraction are still a challenging job for researchers in the fields of photogrammetry, remote sensing, machine vision, digitizing map, etc. Although the automatic updating map using satellite images or automatic and semi- automatic road extraction in gray image have been studied for many years, there exist still many problems which are not solved completely. Because the recognition character in digitizing map is one of key steps for automatically producing and updating database of GIS, we emphasize on the character recognition of the digitizing map. The character recognition is not only one of main tasks for the database of GIS, but also is a vital technique in the check verification, the signature identification, the vehicle number plate recognition, and so on.

The organization of this paper is as follows. Section 2 introduces the closed-contour extraction based on the morphology operators, the adaptive threshold selec- tion for the binarization of the gray-level image, the boundary tracing algorithm of the closed-contour, and the extraction of three items related to one dimension signal data. Section 3 describes zero-crossings of wavelet transform, derived from second derivative of the smoothing function, decomposing the signal of the closed-contour with the wavelet transform at resolutions of 2^j $(1 \leqslant j \leqslant J)$, and extracting the zero-crossings in the decomposed closed-contour for match in next step. The similarity measure established in the dynamic time warping, as well as the feature match approach is introduced in section 4. Section 5 is conclusion and analysis.

2. PRE-PROCESS OF SCANNING MAP

Firstly, one topographic map (scale of 1:5000) was scanned in ANATECH EVOLUTION Engineering Scanner, and the resolution is 300×300 dpi. For the sake of presenting expediently the approach of the character recognition in the digitizing map utilizing wavelet transform, the size of the gray-level image has been adjusted into 512×512. The median filter is used for retaining the edge details of gray image and diminishing the noise in the gray image, which is possible to blur the edge of digitizing map, and disturb the edge detection. Because object scale in image space is uncertain, as well as the contrast and the gray level in images vary with different conditions, the adaptive threshold has been chosen for transforming the gray-level image to binary image.

Mathematic morphology is a useful tool in digital image processing. In order to ensure the connectivity of the closed-contours extracted, we propose a 3×3 structure element to dilate the character, annotation and contour line in the binary image. Then, we choose the Minkowski operator (A[/](A(－－)B) to extract the edges of the closed-contour related to the character, annotation and contour line in the binary image, in which "A " denotes a binary value matrix of the original image, and "B" is a structure element matrix . One of advantages using the morphology operator to extract the edge of the closed-contour is that the boundary can be kept in the single pixel points.

One by one, the boundary in the closed-contour is traced in clockwise starting from every closed- contour's northwest corner. During the process of the tracing boundary, we record the boundary chain code (x-coordinate, y-coordinate and tangential angle) as one-dimensional signal, which will be decomposed in the dyadic wavelet transform in the different resolutions. Meanwhile, every closed-contour is numbered and its total pixel number is counted. Because of our emphasis on the character recognition of digitizing map, some of the closed-contours, in which total pixel number are out of the threshold, have been removed. We choose the total pixel number of the closed-contours between 60 and 150 as the threshold.

3. ZERO-CROSSINGS OF WAVELET TRANSFORM

Sharp variation points are among the most meaningful features for the character recognition in the closed- contour signal as the above mentioned. The position of the sharp variation points in the signal can be obtained by the zero-crossings of wavelet transform. We can obtain that a wavelet function $\psi(x)$ equals to the first derivative or the second derivative of the smoothing function $\theta(x)$.When $\psi(x)$ is chosen as the second derivative of the smoothing function, the zero-crossing of the discrete dyadic wavelet transform related to the closed-contour signal indicates the position of the sharp variation point.

3.1 Zero-Crossings of Wavelet Transform

If $\psi(x)$ is a real-valued function, and it satisfies the admissibility criterion

$$\int_{-\infty}^{+\infty} \psi(x)dx = 0 \tag{1}$$

then, $\psi(x)$ is called a basic wavelet or mother wavelet. A set of wavelet basis functions $\{\psi_s(x)\}$ can be generated by scaling mother wavelet, $\psi(x)$, as

$$\psi_s(x) = \frac{1}{s}\psi(\frac{x}{s}) \tag{2}$$

The wavelet transform of one signal $f(x)$ with respect to the $\psi_s(x)$ can be defined as

$$W_s f(x) = f * \psi_s(x) = \int f(t)\psi_s(x-t)dt \tag{3}$$

Let $\theta(x)$ is smoothing function, the second derivative of the smoothing function is

$$\psi(x) = \frac{\partial^2\theta(x)}{\partial x^2} \tag{4}$$

Substituting in equation (3) for $\psi(x)$ from equation (4) in scale s, we get

$$W_s f(x) = f * (s^2 \frac{d^2\theta_s}{dx^2})(x) = s^2 \frac{d^2}{dx^2}(f * \theta_s)(x) \tag{5}$$

If the smoothing function $\theta(x)$ is Gauss function,

$$\theta(x) = \frac{1}{\sqrt{2\pi\sigma}}\exp(-\frac{x^2}{2\sigma^2}) \tag{6}$$

equation (5) represents the well-known Marr-Hildreth edge operator. If B-spline function $\beta^{n+2}(x)$ is selected as the smoothing function at resolution 2^{-1}, we may get the B-spline wavelet of order n

$$\psi^n(x) = \frac{d^2}{dx^2}\beta^{n+2}_{2^{-1}}(x) = 8(\beta^{n+2})^{(2)}(2x) \tag{7}$$

and

$$\psi^n(x) = 8(\beta^n(2x+1) - 2\beta^n(2x) + \beta^n(2x-1)) \tag{8}$$

Here has (see (Wang and Cai, 1995))

$$\begin{aligned}\beta^n(x) &= \beta^0(x) * \beta^{n-1}(x) \\ &= \overbrace{\beta^0 * \beta^0 * \cdots \beta^0}^{n+1} \\ &= \sum_{j=0}^{n+1} \frac{(-1)^j}{n^j}(\frac{n+1}{j})\left[x + \frac{n+2}{2} - j\right]_+^n\end{aligned} \tag{9}$$

and

$$\beta^0(x) = \chi_{[-\frac{1}{2},\frac{1}{2}]}$$

where $\beta^0(x)$ is a feature function in [$-\frac{1}{2},\frac{1}{2}$]. It is valuably mentioned that when n equals 2 in equation (7), $\psi^n(x)$ is the B-spline wavelet defined by Mallat in (Mallat and Huang, 1992; Mallat and Zhong, 1992). Evidently, the zero-crossings in the second derivative of the smoothing function $\theta_s(x)$, equation (5), are at the same positions of sharp variation points in $f * \theta_s$.

3.2 Fast Algorithm of Decomposition and Reconstruction Based on Wavelet at Multi-Scales

The multiresolution representation of the wavelet transform provides a simple hierarchical framework for interpreting the signal information (the closed- contours). The multiresolution wavelet transform decomposes the signal into lowpass and highpass information. At different resolution, the details of the signal (highpass information) characterize different physical structures and describe the features of the sharp variation points. Lowpass information describes the main body of the original closed-contours.

In the experiment, we use the second derivative of one smoothing function as the wavelet function $\psi(x)$, and the first five coefficients of impulse response of the filters $H\{h_n\}_{n\in Z}, G\{g_n\}_{n\in Z}$, which are introduced by Mallat in (Mallat, 1991).

We have the fast algorithm of decomposing the one-dimensional discrete signal $S_1^d f$ into $W_{2^{j+1}}^d f$ and $S_{2^{j+1}}^d f$, at each scale 2^j,

j=0,
WHILE (j<J),

$$W_{2^{j+1}}^d f = S_{2^j}^d f * G_j,$$

$$S_{2^{j+1}}^d f = S_{2^j}^d f * H_j,$$

j=j+1,
END OF WHILE.

and the inverse wavelet transform algorithm recon- structs the discrete signal $S_1^d f$ from $\{ S_{2^{-j}} f, (W_{2^{-j}} f)_{1\leq j\leq J}\}$, at each scale 2^j,

j=J,
WHILE (j>0),

$$S_{2^{j-1}}^d = W_{2^j}^d f * \bar{G}_{j-1} + S_{2^j}^d f * \bar{H}_{j-1},$$

j=j-1,
END OF WHILE.

3.3 Decomposition of One-Dimensional Signals Related to The Closed-Contours

We have recorded three one-dimensional signals related to the closed-contours, of which are x coordi- nate, y coordinate and tangent angle. With the discrete dyadic wavelet transform, the one-dimensional signals $S_1^d f(n)_{n\in Z}$ of the three items may be decomposed into

$$\{(W_{2^{-j}} f(n)_{n\in z})_{1\leq j\leq J}\}, \quad \{ (S_{2^{-j}} f(n)_{n\in z})_{1\leq j\leq J}\},$$

corresponding respectively the highpass and the lowpass information of the three one-dimensional signals, at the 2^1, 2^2, 2^3, ..., 2^J resolutions. In other words, the sequence of the discrete signal $\{ S^d_{2^{-j}} f, (W^d_{2^{-j}} f)_{1\leq j\leq J}\}$ is called the discrete dyadic wavelet transform of the signal $S_1^d f(n)_{n\in Z}$.

It should be emphasized that the algorithm of feature extraction for the pattern recognition should be stable and retain the original signal characteristics. The simplicity and efficiency of algorithm are also very important for recognition pattern. Evidently, in the discrete dyadic wavelet transform, $\{W_{2^{-j}} f\}_{1\leq j\leq J}$ represents the detail information of the signal at different resolutions, which has the properties as the above mentioned. We extract the position parameter z_n of zero-crossing of the $W_{2^{-j}} f(n)$ as one features. Another features extracted are the value e_n of the integral between two consecutive zero-crossings (see (Mallat, 1991)).

4. THE SIMILARITY MEASURE ESTABLISHED IN THE DYNAMIC TIME WARPING

In addition to remote sensing data, the digitizing map is an important resource data for GIS database. Automatic recognition character in the scanning map is one of key techniques, which need to be investigated. An important problem in character recognition is how to measure similarity degree between feature vectors. Here, we apply the dynamic time warping as the similarity measure.

4.1 Similarity Measure-Dynamic Time Warping

As mentioned in section one, after the dyadic wavelet decomposition at 2^j scale, the feature vectors are extracted in zero-crossings of wavelet transform with respect to the close contour (x, y, tangential angle).

The dynamic time warping defines a similarity measure as follows. Let W be a warping function, which maps sample features from reference signal a(t) to sample features of testing signal b(t):

$$W=\{ w(1), w(2),..., w(k),..., w(K) \} \tag{10}$$

and $\quad w(k)= (i(k) , j(k))$

here i and j represent the time axis of reference and testing signals respectively *(i=1,2,...I and j=1,2,...,J)*. The distance d(w(k)) between two features is defined as following:

$$d(w(k))=d(i(k), j(k))= |[a(i(k))- \mu_a] -[b(j(k))-\mu_b] | \tag{11}$$

where μ_a and μ_b are the mean of signals a(t) and b(t) respectly. Then, distance between a(t) and b(t) is defined as:

$$d_{a,b}=g(I,J) \tag{12}$$

if $S=0$ *then*

$$g(i,j)=\min\begin{bmatrix} g(i,j-1) \\ g(i-1,j-1) \\ g(i-1,j) \end{bmatrix}+d(i,j) \tag{13}$$

……

$$j - \Gamma \leq i - \frac{(I-J)}{2} \leq j + \Gamma$$

and *g(1,1)=d(1,1)*

It is called as the algorithm of dynamic programming. Γ and S are the window and slope constrains respectly (see (Parizeau and Plamondon, 1990)). Dynamic time warping can nonlinearly expand or contract the time axis to match the zero crossing features between two corresponding closed contours.

Considering the attributes f in the set F, which include three elements (the x, the y coordinates, and tangential angle), the distance measure used to compare the zero crossings of two closed contours in DTW is defined as follows,

$$D_{a,b} = \sum_{s \in S} d_{a,b}^{R_i}(f) \tag{14}$$

here, R_i is the optimal resolution level related to highpass data in the closed contours.

4.2 Database Establishment for Reference Signal

For describing easily our method, the database of reference signal is firstly established among 0, 1,…,9 numbers and 26 English letters. The numbers and letters have been decomposed into the discrete signal sequence of { $S_{2^{-j}}f$, $(W_{2^{-j}}f)_{1 \leq j \leq J}$ } using the discrete dyadic wavelet transform, at the different resolutions. As the above mentioned, we extract the zero-crossings of the wavelet transform related to the signal. Those features have been stored as the template in the database of the reference signal for matching features.

5. CONCLUSIONS

Which one kind of features are chosen in the character recognition of scanning map, is very vital for pattern recognition successfully. At 2^j scale, we extract the zero-crossing of wavelet transform as features of the closed-contour in scanning map, because the sharp variation points of any signal are among the most meaningful features for the character recognition, and the positions of sharp variation points in a signal can be ascertained by the zero-crossing of its wavelet transform. It is a primary investigation that the zero-crossings of the discrete dyadic wavelet transform are as the features in the character recognition of scanning map. The efficiency and simplicity of the algorithm in the character recognition will be studied in future.

One of problems of character recognition is the scale, rotation, and translation invariant. The distance measure between two sample vectors established by the dynamic time warping algorithm is sensitive to scale. Because the distance measure is centered around the means, an offset on the total signal will not affect the last result (Marc Parizeau et al. ,1991) .
The related to figures are omitted here.

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