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Application of mathematical morphology and rough set in target recognition of remote sensing image

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Abstract: This paper focus on the algorithm combining of the mathematical morphology and rough set. Firtly uses the rough set filtering to process the image, then uses morphology to extract the edge of the image, finally uses the geometric characteristics of image to remove the area which we don't need. The experiment of remote sensing image proves its feasibility.

Keywords: rough set; mathematical morphology; remote sensing image

I. Rough Set

Rough set theory was developed by Z Pawlak in the early 1980's. In the early 1890s, people gradually realized the importance of rough sets. Rough set theory don't need any preliminary or additional information about data—like probability in statistics, grade of membership in the fuzzy set theory. Rough set theory is a new mathematical approach to imperfect knowledge. The main goal of the rough set analysis is induction of approximations of concepts. It can be used for feature selection, feature extraction, data reduction, decision rule generation, and pattern extraction, etc. It can identify partial or total dependencies in data, eliminate redundant data, give approach to null values, missing data, dynamic data and others. In particular ,the rough set approach seems to be important for Artificial Intelligence and cognitive sciences, especially in machine learning, knowledge discovery, data mining, expert systems, approximate reasoning and pattern recognition.

II. The relationship between mathematical morphology and rough sets.

The lower approximation and the upper approximation can be obtained by corrosion and expansion operators. For a given structural element, the corresponding relationship is as follows:

$$xRy \Leftrightarrow y \in B_x$$

For R, it can be introduced:

$$\forall x \in U, r(x) = \{y \in U \mid y \in B_x\} = B_x$$

If the origin of U belongs to the structural element B, there is $\forall x \in U, x \in B_x$

Then: $\forall x \in U, xRx$

That R is reflexive, and if B is symmetric, there is

$$\forall (x, y) \in U^2, xRy \Leftrightarrow y \in B_x \Leftrightarrow y - x \in B \Leftrightarrow X - Y \in \tilde{B} (= B) \Leftrightarrow x \in B_y \Leftrightarrow yRx$$

That R is symmetric.

It can be obtained from the above relationship:

$$\forall X \in U, R_{-}(X) = \{x \in U \mid r(x) \subset X\} = \{x \in U \mid B_x \subset X\} = E_B(X)$$

By the same token,

$$\forall X \in U, R^{-}(X) = \{x \in U \mid r(x) \cap X \neq \phi\} = \{x \in U \mid B_x \cap X \neq \phi\} = D_B(X)$$

III. Grayscale image rough set filtering.

In order to eliminate the noise interference of the original image, the rough set theory is used in gray image filtering, that using the concept of rough set approximation set to determine the noise in the image, the edge points and the smooth area, and they are respectively filter processing.

When the image is digitized, the corresponding digital matrix is obtained, and

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each element in the digital matrix represents the luminance value corresponding to a point in the original image. For image $F(x,y)$, (x,y) represents the row and column values of each pixel in the image, and F is the brightness of the pixel. For binary images, $F=0$ or $F=1$;For grayscale images $0 \le F \le N$, is the grayscale level of the image. For color image RGB, $F \in \{(R,G,B)\}$, RGB represent the component values of red, green and blue base colors of the pixel.

Using the rough set theory method, the information of an image is presented as a knowledge system, and $K=(I,R)$ represents the approximate space of an image from image I and equivalent relation R. According to the rough set definition of the set X of the pixels selected in the image I , the lower approximation $R_{-}(X)$ of the X defined by the equivalence relation R is the full division of I which is completely contained in the X, and the upper approximation $R^{-}(X)$ is the full division of I that has at least one element contained in X.

For any digital image, it can be considered that the pixel points in the image are composed of smooth area point and edge charge noise point. Let X to be the pixel of one of the types, and if the two pixels in the image I are satisfied with the range of selected parameters, then these two points are related to R. We can determine the approximate set of X that meets our requirements in image I by determining a parameter range.

According to the above principle, we can consider a gray image as a knowledge system. $K=(I,(R_1,R_2,R_3))$ represents an image approximation space by the gray image I and the equivalent relation (R_1,R_2,R_3). When we consider a rotating window graph, we define $K=(W,(R_1,R_2,R_3))$ that represents an approximate space composed of the pixels in the window and the equivalent relation (R_1,R_2,R_3), and the 3×3 rotation window of the 9 pixel template is defined as follows:

$$W[x(i,j)]=\begin{bmatrix} x_1(i-1,j-1) & x_2(i-1,j) & x_3(i-1,j+1) \\ x_8(i,j-1) & x_0(i,j) & x_4(i,j+1) \\ x_7(i+1,j-1) & x_6(i+1,j) & x_5(i+1,j+1) \end{bmatrix}$$

If we define X to represent the pixels that are noisy in the image, R_1 is defined as: if each of the two pixels is within the range of selected noise parameters, the two pixels R_1 related, which belongs to the equivalence class, then we can define the upper approximation of R_1 are as follows:

$$R_1^{-}(X)=\{x \in W \mid ind(R_1):[x]_{R_1} \cap X \neq 0\}$$

Therefore, according to the relationship R defined by the noise equivalence class, there is at least one noise pixel in the pixel set obtained by R1.

If we define the pixels on the edge of the X, R is defined as: if each of the two pixels is within the range of the selected edge parameters, the two pixels are R related, which belongs to the equivalent class. So the lower approximation of our definition of R is:

$$R_{2-}(X)=\{x \in W \mid ind(R_2):[X]_{R_2} \subseteq X\}$$

Therefore, according to the relation R_2 defined by the selection edge, it must be the edge pixel by $R_{2-}(X)$.

If we define X represents the smooth area of pixels, R_3 is defined as: if two pixels in each an area are all in the choice of smoothing parameter range, the two pixels R_3 related, which belongs to the equivalence class. So we can define R_3 as follows:

$$R_3^{-}(X)=\{x \in W \mid ind(R_3):[x]_{R_3} \cap X \neq 0\}$$

Therefore, according to the relationship R defined by selecting smooth region parameters, one pixel in the pixel set obtained by R is located in the smooth region at least.

Suppose that there are two pixels A and B, and the grayscale of the pixels are respectively represented by $f(A)$ and $f(B)$, then the gray ratio $r(A:B)$ of A to B is defined as $f(A)/f(B)$. (If $f(B)=0$, set $f(B)=1$, which does not affect the quality of the image.) According to the actual test, the sensitivity of the human eye to the change of grayscale can be seen, When $0.9 < r(A:B) < 1.1$, the human eye basically does not feel the change of grayscale; when $r(A:B) < 0.9$ or $r(A:B) > 1.1$, the human eye can basically feel the change of grayscale.

Any image can be regarded as three types of pixels: smooth area, edge point and noise. For natural images, there should be a large correlation between adjacent points except noise. In a grayscale image, if the gray value of a pixel is very different from that of its neighborhood, which is likely to have been polluted by noise. If the gray value of a pixel is different from that of its neighborhood, it is likely to be located in the smooth region. If the gray value of a pixel is small compared to the two values in its neighborhood, it is very different from other values, so the point is likely to be the edge point of the image. It is proved by experiments that in an image, if a pixel has two values of gray ratio of other pixels in its neighborhood in the range of [0.9,1.1], it can be considered that the pixel point is polluted by noise. If the gray ratio of all points in the neighborhood of a pixel is three values in [0.9,1.1], it can be considered that the pixel point is the edge pixel point. In other cases, the pixel is considered to be in the smooth region.

Therefore, we define the parameter in the equivalence relation R_1: if the pixel point $x_0(i,j)$ in the center position of the rotating window has two values in the [0.9,1.1] interval of the other pixels in the rotating window, the center pixel of the rotating window can be considered as the noise point. The parameters in the equivalence relation R_2 are that if the pixel points in the center position of the rotating window have three values in the [0.9,1.1] interval of the other pixels in the rotating window, the pixel points can be considered as the edge points. The parameter in the equivalence relation R_3 is that if the pixel points in the center position of the rotating window are within the [0.9,1.1] interval of at least four values in the other pixels in the rotating window, the pixel points can be considered to be in the smooth region. For pixel $x(i,j)$, if it is noise, it can be replaced by the average value of other pixels in its neighborhood. If it is in the smooth region, it can be processed by the method in the neighborhood. If it is the edge pixel point, it can be replaced by the two points closest to the grayscale value in its neighborhood and the mean of that point.

IV. MATHEMATICAL MORPHOLOGY BASED ON ROUGH SET FILTERING

Based on the similarity between rough set and mathematical morphology, the target recognition process in this paper is as follows:

Step1 The original grayscale image is filtered by rough set.

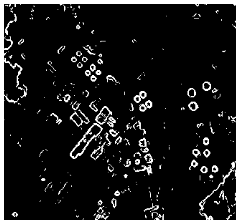
Step2 For image corrosion and expansion operations, the upper and lower approximations of the image are obtained. The boundary of the image is the difference between the upper and lower approximations.

Step3 Using the first sections, we can further process the images according to the geometric characteristics of the images so as to get the target images.

V. EXPERIMENTAL RESULTS AND ANALYSIS

Result 1:

Fig.1-a original image Fig.1-b the image after rough set filter



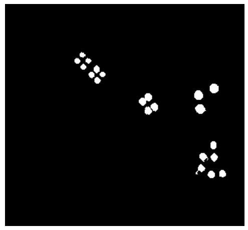


Fig.1-c the edge on morphology Fig.1-d the finally result

Result 2:

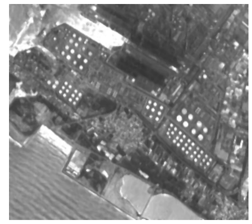
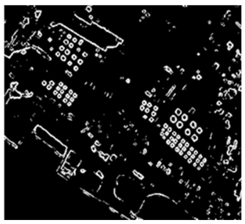


Fig.2-a original image Fig.2-b the image after rough set filter



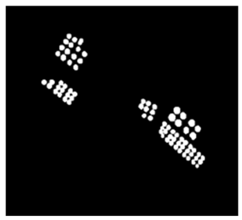


Fig.2-c the edge on morphology Fig.2-d the finally result

TABLE1 STATISTICS OF THE EXPERIMENTAL RESULT

	Visual target number	Recognition target number	Miss target number	Missing rate%	Error target number	Error rate %
Test1	**21**	**21**	**0**	**0**	**0**	**0**
Test2	**81**	**76**	**4**	**4.94**	**0**	**0**

For example, Figure 4-1 (d) and 4-2 (d) are the results of the method experiments in this chapter. The number of missed targets and the number of mistakable targets are significantly reduced, and the applicability of the method is further verified.

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