Imagemap simplification using mathematical morphology

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ABSTRACT

For a variety of mapping applications, images are the most important primary data sources. In photogrammetry and remote sensing, particular procedures are used for image and map data integration in order to perform change detection and automatic object extraction. The recognition of an object in an image is a complex task that involves a broad range of techniques. In general, three steps are used in this study. The first step is segmentation to object regions of interest. In this step, regions which may contain unknown objects, have to be detected. The second step focuses on the extraction of suitable features and then extraction of objects. The main purpose of feature extraction is to reduce data by means of measuring certain features that distinguish the input patterns. The final step is classification. It assigns a label to an object based on the information provided by its descriptors.
At the end of segmentation stage, the images are too still complex. So it is necessary to simplify image for further processes.
In this paper, investigation is made on the mathematical morphology operators for simplification of a gray-scale image or imagemap. Then an structure element, (L^4) , is applied on binary images to extract the skeletonized image. In this stage, there will remain lots of skeletal legs in the resultant image. Then in the next step, another structure element, (E^4) , is applied on skeletonized image to remove the remaining skeletal legs. The resulting thinned image may be extracted and then converted to vectors. The vector data may be input to a geographic information system (GIS) for further analysis. The program for this project is developed in visual c++ language under windows 98 operating system.

1 INTRODUCTION

One of the most fascinating promises of digital photogrammetry is the highly automated acquisition and updating of spatial data from images. Remarkable progress has been made in areas involving image and template matching such as automatic interior orientation, relative orientation, tie point selection, digital terrain model (DTM) generation and orthoimage generation. Although the current level of automation on most digital photogrammetric stations is still fairly low, a number of these developments are meanwhile available on some commercial systems (Gruen, 1996;Miller etal.,1996; Walker and Petri, 1996).
On the way towards automatic mapping or spatial data acquisition and update, automatic identification and localization of cartographic objects in aerial and satellite images has gained increasing attention in recent years. Despite the reports of some achievements, the automatic extraction of man-made objects in essence is still an unresolved issue. The recognition of an object (*i.e.* building, roads,etc.) is a complex task that involves a broad range of techniques. In this paper the analysis is organized into three steps: segmentation, features extraction and classification.
The first step which is the segmentation involves the identification of regions in an image that are homogeneous and dissimilar to all spatially adjacent regions.
The second step is feature extraction. The purpose of feature extraction is to reduce data by measuring certain "features" or "properties" that distinguish input patterns. In feature extraction we transform an input observation vector to a feature vector using some orthogonal or nonorthogonal basis functions so that data in the feature space become uncorrelated. A variety of approaches have been developed for feature extraction. Commonly used feature space techniques include the Fourier Transform(FF), Moment feature space and etc,. The last step is classification. It assigns a label to an object based on the information provided by its descriptors provided from

feature extraction step. Conventional classification techniques are grouped in two categories: supervised an unsupervised techniques. In a supervised method, classifiers learn with the help of training sets but in the case of an unsupervised method, classifiers learns without training sets.
During the man-made object extraction, there will be a lot of small unwanted regions after segmentation made. Some of the regions can be noise and some other are due to the unimportant effects that must be removed from the segmented image. In this paper, implementation of split and merge method for segmentation of image has been made, then morphological operations for image simplification have been investigated.

2 IMAGE SEGMENTATION

The objective of segmentation is to split an image into regions with similar properties. The grade of similarity is evaluated for each region by a homogeneity criterion.
It is required that the segmentation to be complete and segmented regions to be disjoint. That is, each pixel of the original image *f(x,y)* exactly belongs to one region R_j (Steudel,A., Glesner,M., 1996).

$$f(x,y) = \bigcup_{\forall j} R_j \quad and \quad R_j \cap R_k = \emptyset \quad \forall j \neq k \qquad (1)$$

There are different methods for image segmentation. Region splitting and merging is one of the methods based on a process which consists of split and merge operations to be applied on the square regions referred to the quadruplet tree(QPT). A split operation is started up whenever it is found that the homogeneity of the image data is insufficient. In this case the region is always split into four subregions in accordance with the four children of the corresponding node in the QPT. Likewise, four adjacent regions that share the same parent may be merge together if the homogeneity is sufficient.
A recursion of split and merge operations ends up when all regions found are homogeneous, and each quadruplet taken together would be inhomogeneous.

3 SPLIT AND MERGE ALGORITHMS

Various split and merge algorithms have been developed. In general, the split and merge technique proceeds as follows:

1- Define a homogeneity test. This involves defining a homogeneity measure, which may incorporate brightness, color, texture, or some other specific information. The definition determines a criterion that a region must meet to pass the homogeneity test.
2- Split the image into four equally sized regions.
3- Calculate the homogeneity measure for each region.
4- If the homogeneity test is passed for the region, then a merge is applied with its neighbor(s). If the criterion is not met, the region is split.
5- Continue this process until all regions pass the homogeneity test.

There exist many techniques for homogeneity measure.
a)-Pure uniformity
b)- Local mean vs. global mean
c)- Local standard deviation vs. global mean
d)- Variance
e)- Weighted gray level distance

4 MATHEMATICAL MORPHOLOGY

Based on set theory, mathematical morphology provides an approach to the processing of digital image continuing the geometrical structure of objects. Using appropriate sets known as structuring elements, mathematical morphology operations can simplify image data while maintaining their shape characteristics and eliminating irrelevancies. Serra(1982) introduced the basis and theory of mathematical morphology. Maralick, et al (1987) discussed the basic mathematical morphological operations and their relations in a N-dimensional properties of the basic binary and multi-level morphological operations with both 1D and 2D structuring elements.

4.1 Binary Mathematical Operations

4.1.1 Dilation, Erosion, Opening, and Closing. Consider a discrete binary image set *X* in an N-D distance grid Z^N.
Let $T \in Z^N$ denote a structuring element, $\breve{T} = \{-t | t \in T\}$ denote the symmetric set of *T* with respect to the origin, and $\emptyset$ denote the empty set.
The translation of *X* by a point $z \in Z^N$ is denoted by X_z and defined by $X_z = \{x + z | x \in X\}$. Then the four basic binary mathematical morphological operations of *X* by *T* are defined as follows:

$$
\begin{aligned}
&Dilation \quad X \oplus T = \{z | \breve{T}_z \cap X \neq \emptyset\} = \bigcup_{t \in T} X_t \\
&Erosion \quad X \Theta T = \{z | T_z \subseteq X\} = \bigcap_{t \in T} X_{-t} \qquad (2) \\
&Opening \quad X \circ T = (X \Theta T) \oplus T \\
&Closing \quad X \bullet T = (X \oplus T) \Theta T
\end{aligned}
$$

Dilation is used to fill small holes and fill narrow gaps in objects or expand image objects, whereas erosion shrinks the image objects. If we want to find the contours of objects in an image very quickly this can, for instance, be achieved by the subtraction from the original picture of its eroded version. Opening is used to eliminate specific image details smaller than the structuring element while closing connects objects that are close to each other, fill up small holes, and smoothes the object outline by filling up narrow gaps. Unlike dilation and erosion, opening and closing are invariant to translation of the structuring element. It means, if an image is eroded and then dilated the original image is not obtainable.

4.1.2 Hit/miss Transform. In addition to the four morphological operations, the hit/miss transformation is also an important morphological operation used to detect the occurrence of an exact pattern in the image. Let *T* be composed of two subsets T_1 and T_2; then the hit/miss transform of *X* by *T* can be defined as the set of all points where T_1 is included in *X* and T_2 is included in X^c.

$$X \otimes T = \{x : T_{1x} \subset X ; T_{2x} \subset X^c\} = (X \Theta T_1) \cap (X^c \Theta T_2) \qquad (3)$$

where X^c is the complement of *X* and $T_{ix}(i = 1,2)$ denotes the translation of T_i by x . When T_2 is chosen as the window complement of T_1 equation (3) can be written as(Serra, 1983)

$$X \otimes T = (X \Theta T) \cap (X^c \Theta (W \cap T^c)) \qquad (4)$$

where *W* is the window with finite support.

4.1.3 Thinning. Equation (4) identifies the areas which can be removed from the structure while maintaining the connectivity. Therefore thinning of *X* by *T* is defined as:

$$X \varnothing T = X / (X \otimes T) = X \cap (X \otimes T)^c \qquad (5)$$

where "/" is the set difference.
The operation $X \otimes T$ in equation (5) locates all occurrences of the structuring element *T* in *X* and the operation / removes from X those points which have been located.
Thinning transformations are very often used sequentially. Let $T_{(1)}, T_{(2)}$ denote a sequence of composite structuring elements $T_{(i)} = (T_{1i}, T_{2i})$. Sequential thinning can then be expressed as:

$$X \varnothing \{T_{(i)}\} = ((((X \varnothing T_{(1)}) \varnothing T_{(2)}) \ldots \varnothing T_{(i)}) \ldots) \tag{6}$$

There are several sequence of structuring elements $\{T_{(i)}\}$ that are useful in practice. Many of them are given by a permissible rotation of a structuring element in the appropriate digital raster (e.g. hexagonal, square). The 3*3 matrices will be shown in the first two rotations, from which the other rotations can easily be derived. The composite structuring element will be expressed by one matrix only. A value of *one* in the matrix means that this element belongs to T_1 (it is a subset of objects in the hit or miss transformations), and a value *zero* belongs to T_2 and is a subset of the background. An asterisk ‘ * ’ in the matrix denotes an element that is not used in the matching process, *i.e.* its value is not significant.
Thinning and thickening sequential transformations converge at one point. The number of iterations needed depends on the objects in the image and the structuring element used. If two successive images in the sequence are identical the thinning (or thickening) can be stopped.

4.1.4 Sequential Thinning By Structuring Element L. This sequential thinning is quite important as it serves as the homotopic substitute of the skeleton. The final thinned image consists only lines of one pixel width and isolated points. The structuring element L is given by

$$L_1^4 = \begin{bmatrix} 0 & 0 & 0 \\ * & 1 & * \\ 1 & 1 & 1 \end{bmatrix}, L_2^4 = \begin{bmatrix} * & 0 & * \\ 1 & 1 & 0 \\ 1 & 1 & * \end{bmatrix}, \ldots \quad L_1^8 = \begin{bmatrix} 0 & 0 & 0 \\ * & 1 & * \\ 1 & 1 & 1 \end{bmatrix}, L_2^8 = \begin{bmatrix} * & 0 & 0 \\ 1 & 1 & 0 \\ * & 1 & * \end{bmatrix}, \ldots$$

Assume that the homotopic substitute of the skeleton by element L^4 has been found. The skeleton is usefully jagged due to sharp points on the outline of the object. It is possible to smooth the skelton by sequential thinning by structuring element *E*. Using *n* iterations , points are removed gradually depending on the number of iterations from free-end lines and isolated points. If thinning by element *E* is performed until the image does not change, then only closed contours remain. The structuring element E is given by

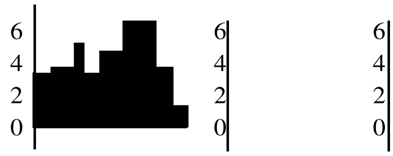
$$E_1^4 = \begin{bmatrix} * & * & * \\ 0 & 1 & 0 \\ * & 0 & * \end{bmatrix}, E_2^4 = \begin{bmatrix} * & 0 & * \\ 0 & 1 & * \\ * & 0 & * \end{bmatrix}, \ldots \quad E_1^8 = \begin{bmatrix} * & 1 & * \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}, E_2^8 = \begin{bmatrix} 0 & * & * \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \ldots$$

4.2 Gray Scale Morphological Operations

The binary morphological operations of dilation, erosion, opening and closing can be extended to gray scale imagery (Sternberg, 1982; Haralick, etal,1987). For such images, the minimum and maximu m values are found within neighborhoods represented by the structuring element. Let *F* and *T* be the domain of the gray scale image *f* and the gray scale structuring element *t*, respectively. The gray scale dilation and erosion can be computed by

$$\begin{aligned} &Dilation: \ (f \oplus t)(x,y) = \max_{(x-m,y-n)\in F,(m,n)\in T}\{f(x-m,y-n)+t(m,n)\} \\ &Erosion: \ (f \Theta t)(x,y) = \min_{(x+m,y+n)\in F,(m,n)\in T}\{f(x+m,y+n)-t(m,n)\} \end{aligned} \tag{7}$$

The adaptations can be better understood by considering dilation and erosion of an image intensity profile (figure 1.). A three pixel wide and four intensity unit high rectangle slides along the baseline of an image profile. The new intensity value of the center pixel is determined according to the following rules. 1) For dilation, if any pixel of the rectangle fits at or under the image intensity profile, the center pixel of the rectangle is given the maximum intensity of the pixel and its two neighbors in the original image; otherwise the pixel is set to zero intensity. 2) For erosion, if the whole rectangle fits at or under the image intensity profile, the center pixel is given the minimum intensity of the pixel and its two neighbors in the original image; otherwise the pixel is set to zero intensity.



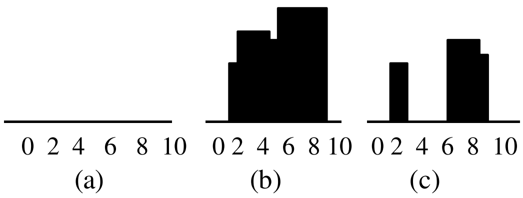


Figure 1.Gray scale morphological operations on a profile, a) Original image profile, b) Dilation of original image profile, c) Erosion of original image profile

5 EXPERIMENTAL INVESTIGATION

Figure 2a shows part of an aerial image (256*256). Results of applying gray-scale mathematical morphology operators on figure 2a , have been shown in figures 2b and 2c.

a b c

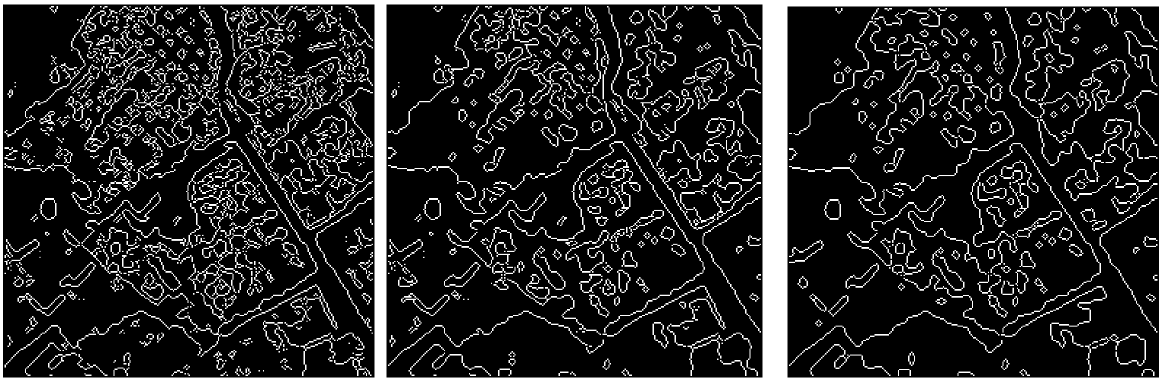
Figure 2. Gray scale mathematical morphology operations, a) Original image, b) Opened of image a, c) Closed of image b

Figures 3a, 3b and 3c represent the binary images of figures 2a, 2b and 2c after segmentation made by *"local standard deviation vs. global mean"* algorithm that is more efficient than the others based on the investigations made in this research.

a b c

Figure 3. Segmented images, a) Segmentation of 2a, b) Segmentation of 2b, c) Segmentation of 2c

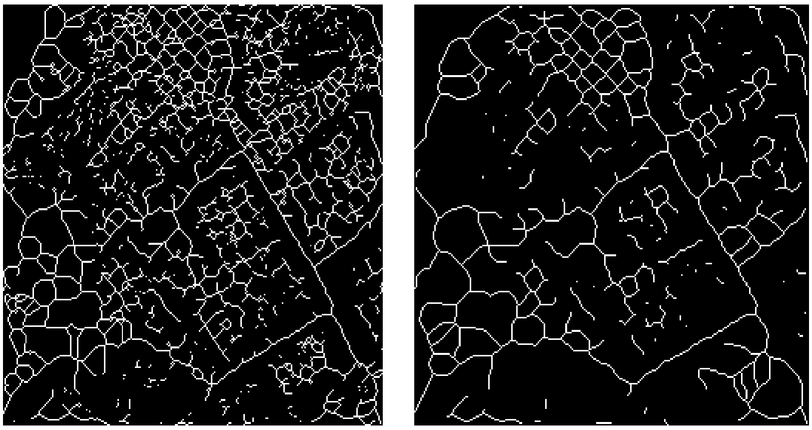
As it is seen in figures 3, the original image is simplified by doing of the closing operator on the opened image. Figures 4 show the edges of the figures 3 using the Canny operator.



a b c

Figure 4. Detected edges by canny operator, a) The edges of fig 3a, b) The edges of fig 3b,
c) The edges of fig 3c

Mathematical morphology provides a semi_automated technique for extraction of linear objects such as roads and rivers. These objects can be vectorized and input to a GIS. This idea has been shown in figure 5. The linear objects are identified by applying the structure element L^4 over the images of the figures 3a and 3c.



a b

Figure 5. Sequential thinning using element L, a) Original image
b) Opened-Closed image

In order to remove unwanted short skeleton legs from figure 5b, one or two end points of a longer line can be deleted by structure element E^4,. Figure 6 represents the result of smoothing with the structuring element E^4 over the thinned image of figure 5b.

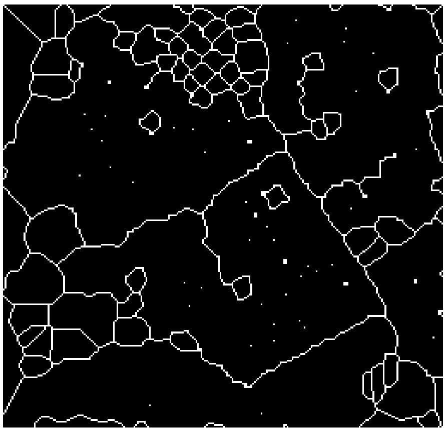


Figure 6. Smooth of 5b

As it is seen in figure 6, manual edition of the skeleton to some limited extend, can help extract linear objects in more efficient way.

6 CONCLUSIONS

Extraction of objects in aerial and satellite imagery is important in digital photogrammetry. There are many different types of objects in aerial and space images such as roads, bridges, buildings and so on. That require different algorithms for detecting objects of interest. In many applications, before the main process is started, it is necessary to simplify the image which contain important objects for our application.

This paper shows images could be simplified by using mathematical morphology operators. The application of structure element , (L^4) , on binary images, resulted in extraction of objects' skeleton from images, In the next step, the application of another structure element , (E^4) , resulted in removing skeletal legs.

The application of mathematical morphological operation to spatial data processing in photogrammetry and remote sensing can be considered as an extension of spatial analysis functions typical of GIS. The thinning operation makes it possible for spatial data in raster form to be vectorized and put directly into a vector_based GIS. Smoothing operations can be performed on binary images to delete short skeleton legs and isolated pixels (*i.e*., one or two end points of a longer line).

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