AUTOMATIC RECOGNITION OF BRIDGES OVER WATER AND REGISTRATION IN REMOTELY SENSED IMAGES WITH GIS DATA

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KEY WORDS: Automatic Object Recognition, Bridge Recognition, Image Registration, Remote Sensing, GIS

ABSTRACT:

Bridges over water are one of the most important geo-spatial objects and military objects. Automatic recognition and extraction of bridges from remote sensing images is very important and urgent for map updating and military application. In this paper a new algorithm for simultaneously recognizing bridges and registering image is presented. The basic assumption for new algorithm is that the bridges and the water have no big changes between remote sensing images and GIS data. The main idea of new algorithm can be parted into four steps: the extraction and recognition of water areas, the extraction and recognition of bridges from remote sensing images, the extraction of unchanged features between recognition results and GIS data, image registration using corresponding features. Some effective image processing algorithms including the so-called OTSU image segmentation algorithm, the mathematical morphology algorithms are applied for features extraction of bridges and the water. Considering the different properties of image and GIS vector data, the shape-based feature matching is employed for image registration with old GIS data. The primary experiments results show new algorithm is effective.

1. INTRODUCTION

Bridges over water are one of the most important geo-spatial objects and military objects. Automatic recognition and extraction of bridges from remote sensing images is very important and urgent for map updating and military application. Although a very limited number of articles exist in this particular direction, there still are some methods for recognizing bridges. It can be seen different recognition algorithms for bridges are presented using different data sources, for example, Wu et.al presented an bridge recognition algorithm by integrating satellite SAR and optical imagery (Wu, 2005), Hou et.al segmenting and recognizing bridges in high resolution SAR images (Hou, 2001), Chen et.al presented a method for selecting bridge in IR image (Chen, 1997). And these recognition algorithms for bridges include knowledge-driven method, template matching, ROI detection and analysis, image segment and so on (Liu, 2004; Yuan, 2003; Wu, 2003; Wang, 2001).

Although these algorithms can obtain good results, they are only suitable for some special cases. And in general they focus on the recognition of bridges and don't care whether remote sensing images are registered (Hou, 2001). Even if some recognition algorithms need image registration, image registration is often finished before or after recognition operation. However, in some special application such as automation control, object surveillance and other military application automatic object recognition (ATR) and image registration need to be simultaneously finished with object recognition. Obviously single recognition algorithms or image registration algorithms can't satisfy with the requirement. Aiming at this, this paper emphasize on a new automatic algorithm for simultaneously recognizing bridges and registering image.

The rest of the paper is organized as the follows. In the next section, the basis idea and strategies of new algorithm for simultaneously recognizing bridges and registering image are presented. In section 3 how to extract and recognize water and bridges is introduced. And in section 4 relative methods for feature description, feature extraction and image registration with GIS data are proposed. Some experiments and results are given in section 5. The last section summarizes and concludes with a discussion of future work.

2. THE BASIC IDEA AND STRATEGIES OF NEW ALGORITHM

The basic assumption for new algorithm is that the bridges and the water have no big changes between remote sensing images and GIS data. And it is very lucky that generally this requirement can be satisfied because the bridges and the water always keep unchangeable. The basic idea of new algorithm can be parted into four steps: the extraction and recognition of water areas from remote sensing images, the extraction and recognition of bridges from remote sensing images, the extraction of no-change features between recognition results and GIS data, image registration using corresponding features.

Firstly some effective image processing algorithms including the so-called OTSU image segmentation algorithm, the mathematical morphology algorithms and other methods are applied for features extraction of water areas and bridges. For the automatic recognition of bridges over water the knowledge-driven strategies are applied. That means the prior information (length, width and etc.), context information and the features of bridges, rivers and land in remote sensing images are sum up for recognizing bridges. Because the image is not registered, the initial registration using extracted feature points (mainly including those feature points in bridges and water areas) in image and possible corresponding features in GIS data is necessary for comparison. Then the iterative feature detection and comparison is applied. The unchanged features can be extracted after comparing. And the image can be registered with GIS data through so-called Least-Square method.

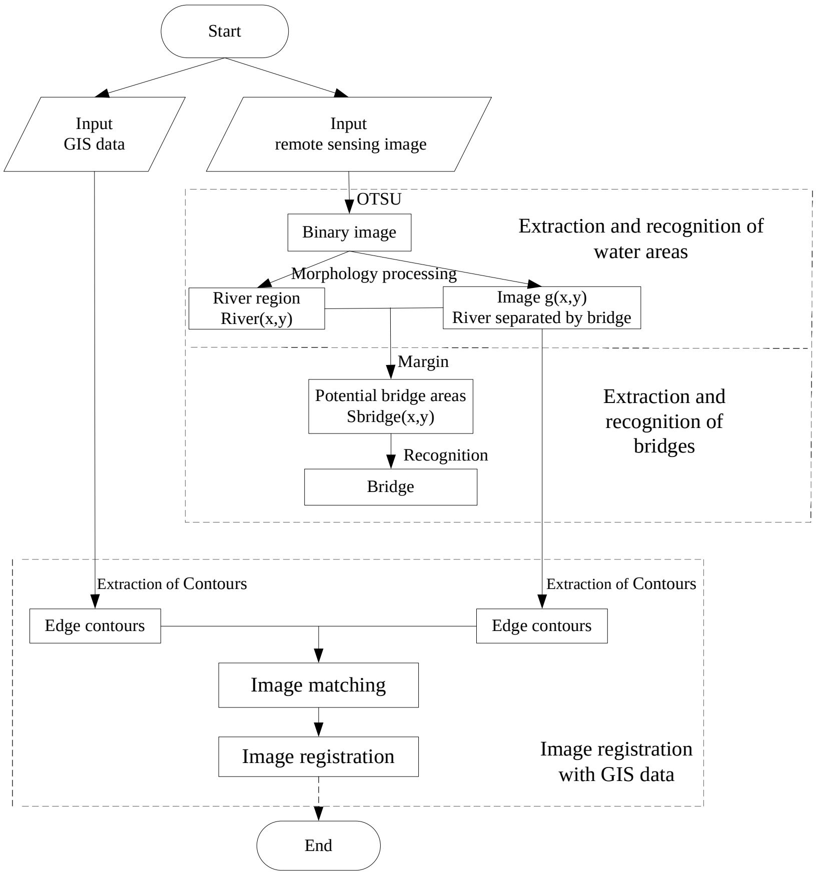


Figure 1. The processing flowchart of new algorithm

3. AUTOMATIC EXTRACTION AND RECOGNITION OF WATER REGION AND BRIDGES

3.1 Extraction of water areas

Image segmentation is an important step in the processing of remote sensing image, which directly influenced on the following recognition. In general, water areas, wetlands have the low reflection in near infrared bands of remote sensing images, but vegetation has the high reflection. So water areas are always dark areas in the near-infrared images, gray value is the smallest; the gray value of vegetation is the greatest; the rest values of land area are higher than the river and lower than vegetation. Therefore in order to extracting water area from images, the so-called OTSU image segmentation algorithm (Nobuyuki, 1979) is employed. Using this kind of segmentation method two thresholding values are selected and image is classified with three categories: the water areas, vegetation and land area. To obtain complete river region, the result images are further processed. Firstly vegetation and land area are united and segmented images will be created (see Fig.2 (b)).

Although the water areas have been separated from bridges and land in binary image, there are still many noises in the land area caused by the buildings shadow and tree shadings. So it is necessary to further process the binary image. Generally the grey values of water are relatively homogeneous and the variance is smaller. On the other hand, the grey values and variance of the water area inside land in original image is relatively larger. So the grey value variance and area are chosen as thresholding values. Under ideal situation, the grey variance of the water body should be 0. But taking into account the reflection of water and sand, here variance threshold is set as 6. Considering the water body is generally not small in original image, area threshold is set as 2500 square meters. After processing with these two thresholds, binary image only including water areas are created (see also Fig.2(c)).

3.2 Extraction and recognition of bridges

After extracting of water areas, three steps are necessary for extraction and recognition of bridges: connection of water areas, extraction of candidate bridges points, creation of candidate bridges using Hough transformation, recognition of bridges.

Because in binary image the water areas are always cut off by bridges & other objects and this affects accurate extraction of candidate bridge information, it is important to remove these factors and connect all water areas. The processing procedure includes two aspects: one is to remove noise caused by the shadow of the land bridge in the image; another is to connect the same region of river. For the latter, mathematical morphology of dilations and erosions operators are employed for eliminating rivers & land borders burr and restoring rivers contours (Flusser, 1992).

Taking into account the noise and bridges' size, we define the structuring elements of dilations and erosions as the following:

$$B = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \tag{1}$$

In order to remove noise & eliminate the gap between the adjacent waters and connect a complete river, the following steps are necessary: firstly n times dilations operations to pixels those gray level is 0 in binary image g(x, y). Then n times erosions operations for complete closings operations. After those procedures, the river regions are completely connected, and the rivers' borders are smooth. After the closing operations, the borders of waters are basically unchanged, the only difference is that the gap between the original adjacent waters were eliminated, the entire waters is connected (see Fig.2 (d)). After a lot of experiments, n=12 is the best result.

It is obvious that candidate bridges image can be obtained using the image (Fig.2(c)) including water areas & other information and the image (Fig.2(d)) only including water areas .The processing result can be see in Fig.2(e). Because bridges in images are always straight lines, the classical Hough transformation (Kang, 1992) is employed for extracting straight lines from the candidate bridges image. Candidate bridges can be obtained from the extracted results. However, real bridges need to be further recognized by prior information and knowledge about bridges.

Here we will divide bridge into two categories: one is simple bridge and another is complex bridge. The property of the so-called simple bridge is that all bridge parts are all above the water areas. On the contrary some parts of the complex bridge are above the water areas and other parts fall in the islands in the river. For complex bridge recognition, our strategy is to first recognize simple bridge then connects these parts as a whole one after recognition.

The recognition of bridges can be finished by all kinds of prior information about bridges structure, shape, topological relationship with water areas. Generally the edge lines of bridges are two parallel lines and the length of the bridge is much longer than the width. There are big angle between the bridge borders and water borders. Using these knowledge of bridge, we can detect whether these lines are bridges' edge lines or not. And real bridges can be recognized (see Fig.2 (f)).

4. AUTOMATIC IMAGE REGISTRATION WITH GIS DATA

Because the image is not registered, it is necessary to register image with GIS data using recognized water areas and bridges. The image registration method consists of two steps: the first step is to obtain homologous points, the second step is to geometric rectification for image using so-called Least-Square algorithm.

4.1 Feature matching

It is necessary to define feature description when comparing GIS data with extracted water areas and bridges remote sensing image. Here area description by shape matrix (Flusser, 1992) is employed. The basic idea of shape matrix is: for any given area object G, we construct its shape matrix S(G) of size (2n+1)*(2n+1). Every object G has its own shape matrix. On the assumption that every object's maximum radius is exclusive, so object's shape matrix is unique. And two different area objects can be distinguished by comparing their shape matrixes.

For every object we establish their shape matrix for GIS data and remote sensing images. And base on the shape matrix using feature-matching algorithm (Zhang, 2004), we can obtain some pairs of matched feature area. For every area, we take its gravity center as homologous points.

4.2 Geometric correction

We choose affine model for our image registration. Suppose the geometric distortions relations between image coordinate and GIS coordinate can be described by equation as follow:

$$x' = h_1(x, y) \tag{2}$$

$$y' = h_2(x, y) \tag{3}$$

Usually h_1(x, y) and h_2(x, y) can be described by binary equation. Here we choose more accurate quadratic:

$$\begin{aligned} x' &= a_0 + (a_1 X + a_2 Y) + (a_3 X^2 + a_4 XY + a_5 Y^2) \\ y' &= b_0 + (b_1 X + b_2 Y) + (b_3 X^2 + b_4 XY + b_5 Y^2) \end{aligned} \tag{4}$$

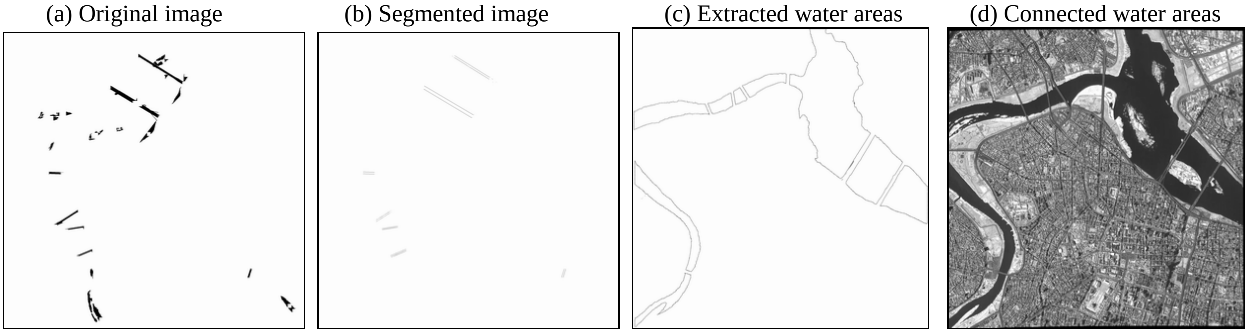
where *x', y'* = image pixels coordinates
X, Y = homologous points' coordinates of GIS data

Therefore, we can utilize this formula and resample the original remote sensing image to final rectified image.

5. EXPERIMENTS

Here we use IKNOS image (see Fig.2 (a)) with fourth band. The GIS data (only including bridges and river, see Fig.2 (g)) is extracted from origin digital map. It is obvious that there are 8 important and visual bridges, including one bridge does not over water. The implementation platform is finished by using VC++ language. Experimental result shows in Figure 2.

(a) Original image (b) Segmented image (c) Extracted water areas (d) Connected water areas



(e) Candidate bridge information (f) Recognized Bridge (g) GIS data including bridges and river (h) Rectified image

Figure 2. One example of automatic extraction and recognition of bridges and image registration with GIS data

6. DISSCUSION AND FUTURE WORK

The proposed algorithms take full advantage of the water and bridges in the characteristics of remote sensing image. The experiments show that the algorithm is feasible and effective. Because it is not enough that only water and bridges information are utilized in image registration. And there exist still possible recognition errors and this is dangerous for latter image registration. So it is necessary to use other GIS information including road, buildings for obtaining unchanged features for image registration. Obviously this is an iterative verifiable and confirmable course. On other hand, other image data sources should also be experimented. It should be pointed that our algorithm is design for the bridge over waters, if rivers are dry and bridge over land, then our algorithm is helpless.

ACKNOWLEDGEMENTS

The work described in this paper was substantially funded by the conversion mechanism from spatial surveying data to spatial information and to geometrics knowledge (No.2006CB701300).

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