PHYSICAL BARRIER DETECTION FOR UPDATING OF NAVIGATION DATABASES FROM HIGH RESOLUTION SATELLITE IMAGERY

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ABSTRACT:

Updating of navigation databases is an important task to ensure a high level utilization of navigation data. For example, in fundamental topographic databases roads are often represented as a single line without detailed connectivity and traffic flow information, but for a navigation database, roads separated by physical barriers should be represented as two roads with different traffic flow directions. Updating navigation database of this kind is mainly carried out by field investigation at present. In this paper, we present a process integrating high resolution satellite imagery with a national fundamental topographic database for updating of navigation data. This paper presents the first step of our work focused on the physical barriers consisting of vegetation. Firstly, road information in the topographic database is used to select corresponding areas in the image. Secondly, the Burns algorithm is adopted for extracting directional edge segments. The next stage is detecting two parallel straight edges by Hough Transform, as physical barriers consisting of vegetation can be described by two anti-parallel edges. Some constraints on edge width and intensity are used for the final recognition of the objects. Some results of tests show the applicability of the proposed method.

1. INTRODUCTION

GIS-T is the application of geographic information systems in transportation. It is now one of the most important application areas of GIS technology (Waters, 1999). Vehicle navigation is currently the most widespread and successful consumer application of GIS-T, with huge profit already in the developed countries and huge market potential in the developing countries as China (Jiang, 2002). Building a navigation database and keeping it up-to-date is an important task to ensure a high level utilization of navigation data.

With the responsibility for providing the fundamental geographic information and related service, the National Geomatics Center of China (NGCC) tries to establish a navigation database for vehicle navigation. Navigation-related data in the national fundamental topographic database need to be upgraded and updated for navigation use. For example, in fundamental topographic databases roads are often just represented as a single line without detailed connectivity and traffic flow information. But for a navigation database, roads separated by physical barriers should be represented as two roads with different traffic flow directions. Updating databases of this kind is mainly carried out by field investigation at present, which is very cost and time consuming. High resolution satellite images make it possible to do some of the work partly automatically, namely the detection of these physical barriers from high resolution imagery.

Walter (1999) examined data from different sensors regarding their potential for an automatic change detection approach. For the topic of geospatial object extraction, most research is focused on roads and buildings. An overview of object extraction can be found in (Baltsavias, 2004).

In this paper, we present a process for detecting physical barriers from panchromatic IKONOS imagery using existing data of a fundamental topographic database for the updating of a navigation database. A short summary of the approach is given in section 2. Our three-stage process on physical barrier detection is described in detail in this section. Section 3 contains some results of experiments. The last section gives a summary and draws some conclusions for the presented work.

2. APPROACH

In our approach, we model physical barriers consisting of vegetation as an elongated homogeneous area. We extract two parallel boundaries of the physical barriers. This process is divided into three stages: image area selection, directional edge segment extraction, and parallel straight edge extraction. Finally, some constraints on distance between parallel edges and intensity are used for the final recognition of the objects.

2.1 Model

The physical barriers which are located in the center of the road are of clear appearances in high resolution satellite images. They are represented as long homogeneous areas with comparatively dark gray values. Their borders are approximately parallel. The resulting employed physical barrier model is depicted in Fig. 1.It also shows the simulated objects parts in the image.

As physical barriers usually separate a road along the centre axis, road data in the fundamental GIS database naturally provide information on direction and position of the physical barriers. Thus, we regard the search space and the direction in which the barrier is to be detected as given information which comes from the fundamental database.

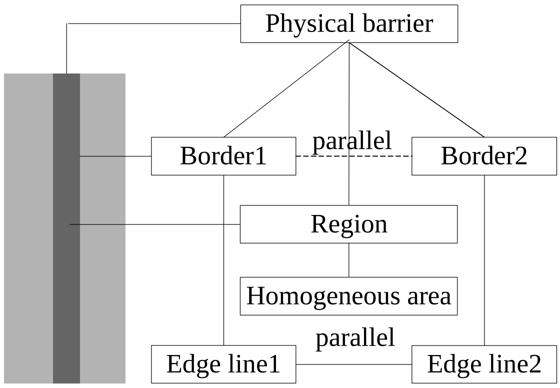

Figure 1. Physical barrier model

2.2 Burns Algorithm for Edge Extraction

The Burns algorithm for edge extraction[1] is used in our approach. This section explains the ideas of Burns' straight edge algorithm. A detailed description of this method can be found in (Burns, 1986; Beveridge, 1996).

The key idea of Burns algorithm is to group pixels into edge-support regions by their gradient orientation. The basic steps for straight edge detection are divided into two parts: grouping pixels into edge-support regions and detecting straight edges from these edge-support regions.

The image is first convolved by the Roberts mask to calculate pixel gradient magnitude and orientation. Adjacent pixels with similar gradient orientation are then grouped into one edge-support region in the first step. This is done by labelling the pixel gradient orientation into different partitions. The 2π radiant range of gradient orientations is quantized into 8 equal intervals, each of which is $\pi/4$. Each pixel gradient orientation belongs to one interval and each pixel is labelled according to the partitions in which it falls. For pixels in a straight edge may have the same orientation partitions, adjacent pixels falling in the same partitions are then connected into one edge-support region. Each edge-support region represents a candidate for a straight edge.

The fixed partition of the orientation may result in some problems. For example, if an edge lies nearly on a partition boundary, the gradient orientation may fall into different partition intervals. As a consequence, this straight edge will produce fragmented edge-support regions, which represent different candidates for the straight edge. To solve this problem, two overlapping sets of partitions are used in the Burns algorithm (Fig. 2).These two kinds of partitions are rotated with respect to each other by $\pi/8$. Also edges lying across one partition boundary in $\pm\pi/8$ can thus constitute one edge-support region, which avoids fragmented edge-support regions.

Each pixel is a member of two regions and a voting strategy is adopted to select the right edge-support region. For each edge-support region representing a candidate of a straight edge, a straight edge is then extracted in the next step (see Burns, 1986). In our approach, we use the idea of the Burns algorithm for grouping the pixels in similar gradient orientations. For detecting straight edges from the edge-support region, we use the Hough Transform instead (see below for a justification).

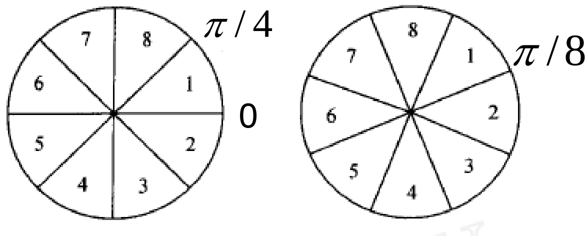

Figure 2. Gradient orientation partitions

2.3 Strategy

The goal of our research is to detect physical barriers for updating of a navigation database. As mentioned before, the road information in the fundamental database is important information for the detection of physical barriers: it provides prior information on position and orientation. Our process contains three stages: grouping edge-support regions, detecting parallel straight edges and verifying the detected region.

2.3.1 Grouping Edge-support Regions: We use the Burns algorithm described above. Firstly, we create a road buffer wide enough to define an area of interest in the image. Secondly, we calculate gradient magnitude and orientation with a convolution mask. We use the Prewitt mask instead of Roberts mask, for the Roberts mask is not symmetric and cannot be generalized to detect edges that are multiples of 45 degree (Gonzalez, 2005).

Then, we label the pixels with similar direction. Here, the road direction information provides some prior information: we do not have to group pixels in the whole radiant range. Instead, we calculate the road direction θ from the database. The physical barrier direction is usually parallel to the road direction. Using the Burns algorithm, the direction of physical barriers is selected in the domain $\theta \pm \pi/8$. The gradient orientation of the pixels in the barrier border should be almost perpendicular to the physical barrier, so we select the adjacent pixels whose gradient orientation is perpendicular to the physical barrier direction. The grey value changes in two parallel borders are of opposite direction for a physical barrier. So, for there are two parallel borders, the gradient orientation of the two border edges differs by π.

These pixels are then connected to regions. Some small regions are created in this process. In general, one road may only have one physical barrier. The small regions taken together may constitute an edge-support region. This combined region may thus contain the wanted straight edge, while in Burns method each small region will contain a separate edge. We believe that it is easier to combine the regions prior to edge extraction, which is why we have chosen the Hough Transform for detecting parallel straight edges.

2.3.2 Detecting Parallel Straight Edges: The Hough Transform (Hough, 1962) is used in this stage for the parallel

[1] In the original paper Burns uses the term „line-support regions"and talks about line extraction. However, the Roberts operator delivers gradient information, which actually yields edges instead of lines. Therefore, we use the term "edge" as opposed to "line" throughout this paper.

edge extraction from the edge-support region grouped in the last step.
The Hough Transform is a global method for detecting features of a particular shape in an image. A straight line in x-y plane can also be represented in $\rho-\theta$ parameter space (see Eq.1), which represent a line on the normal equation.

$$x \cdot \cos\theta + y \cdot \sin\theta = \rho \tag{1}$$

Where x , y are the pixel coordinates, θ is the orientation with respect to the X-axis. ρ is the length of the normal.

Dividing the $\rho-\theta$ parameter space into accumulator cells, each pixel in the x-y plane is transformed into a discretized function in $\rho-\theta$ space. Accumulator cells with a large number of hits are then strong indicators for a straight line in x-y space.

In our research for detecting parallel straight edges of physical barriers, we can use some database information: For one thing, the two parallel straight edges have the same direction. For another, the edge direction is in the direction of the physical barrier, which is defined in the first stage as $\theta \pm \pi/8$. Thus, when transforming the edge pixels from x-y plane to $\rho-\theta$ space, there is no need to calculate θ in all ranges of 2π for accumulating.

Road length is also information we can use for the Hough Transform. This is because in the edge-support region, many pixels are located in the border of the physical barrier. The longer the physical barrier is, the more pixels in the edge can be taken for the accumulation in $\rho-\theta$ space. Usually, the physical barrier has nearly the length of the road. For a 1 meter resolution IKONOS image, we define a third of the road length as the minimum number of pixels for a valid edge-support region.

In this stage, if there is a physical barrier, two parallel straight edges would be detected in the results. The next step is verifying the extracted region composed by two parallel edges.

2.3.3 Verifying the Detected Region: Two constraints are used for verifying the physical barrier. As mentioned above, physical barriers covered by vegetation appear as long homogeneous areas in the image with comparatively dark gray values. Thus, we require the average gray value of the barrier to be lower than the surrounding region by a pre-defined threshold. In addition, we require the standard deviation of the gray values in the region to be relatively small.

The second constraint is geometric in nature. The vegetation barriers are often more than 2 m wide and less than 10 m. The distance between two detected parallel edges can thus also be used to check the result.

3. RESULTS

The following experiments test the approach described in this paper. We had access to pan-sharpened RGB IKONOS orthophotos with a resolution of 1 m per pixel, but we used only the intensity channel, because the colour channels are originally not of a sufficient resolution for our task. The research area of the images and the fundamental database is located in a built-up area in Beijing, China. The position differences between the orthophotos and the data in the fundamental database are small enough for the given purpose. The fundamental database contains road data sets with coordinate information and name attributes so that we can obtain the roads of interest for physical barrier detection.

Three different roads have been investigated. Fig. 3 shows the first example. There is a physical barrier in the centre of the road. Fig. 3 (a) shows the image superimposed with the road of the fundamental database (in white). Fig. 3 (b) is the result of our approach. The result in Fig. 3 (b) shows that two parallel straight edges along the border of the physical barrier are successfully detected. The region composed by these two edges is of a lower intensity compared to the neighbouring area. The width of these two edges is approximately 5 meters.

Fig. 4 shows the second example. Here, no physical barrier is present. As a consequence, no straight edge is detected by our approach. This result also shows the benefit of using database information as prior information. In the Hough Transform, there are many alternatives for straight edges. The road direction and the road length are of much use in restricting the edge detection in this case.

Fig. 5 shows the third example of our test. Again, no physical barrier is present in the image. In this test, we are able to extract two parallel straight edges, nevertheless. However, the homogeneous area is brighter than the surroundings and the distance between the two straight edges is too small, therefore the region is rejected as a physical barrier in the verification step. Observing the detected edges in the area, we may guess that the detected edges represent a road marking in the center of the road.

4. CONCLUSIONS

This paper presents a process for detecting physical barriers consisting of vegetation from high resolution panchromatic satellite imagery by integration with fundamental GIS databases for the updating of navigation database.

We develop a three-stage approach. In the first stage, we use the Burns algorithm to group pixels according to their gradient direction into edge-support regions. In the second stage, parallel straight edges are detected from the edge-support regions. In the last stage the extracted regions are checked for brightness, homogeneity and width.

Some test results show the applicability of the proposed method for detection of vegetation barriers. The GIS data provide important information to facilitate our task.

This paper presents the first step of our work focused on detecting physical barriers on roads. The next steps include the detection of other kinds of physical barriers such as slim fences in the road centre, or the extraction of traffic flow direction from satellite images, etc. We will also investigate multi-spectral images and especially make use of the near-infrared channel in order to separate vegetation from non-vegetation areas.

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REFERENCES

Baltsavias, E.P., 2004. Object extraction and revision by image analysis using existing geodata and knowledge: current status and steps towards operational systems. *ISPRS Journal of Photogrammetry & Remote Sensing*, 58, pp. 129– 151.

Beveridge, J.R., Graves, C., Lesher, C., 1996. Some lessons learned from coding the Burns line extraction algorithm in the DARPA image understanding environment. Report CS-96-125, Computer Science Department of Colorado State University, USA.

Burns, J.B., Hanson, A.R., Riseman, E.M., 1986. Extracting straight lines. *IEEE Trans.on Pattern Analysis and Machine Intelligence*, PAMI-8(4), pp.425-455.

Gonzalez, R.C., Woods, R.R., Eddins, S.L., 2005. *Digital Image Processing Using MATLAB*, Prentice Hall, China, pp.389

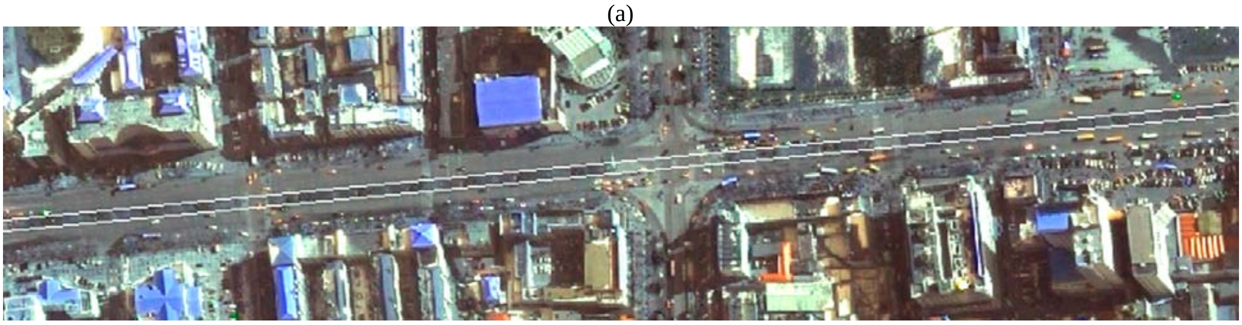
Hough, P.V.C, 1962. Methods and means for recognizing complex patterns. U.S.Patent 3069654.

Jiang, J., Gang, H., Chen, J., 2002. Modeling turning restrictions in traffic network for vehicle navigation system. The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. (34), Part 4, pp. 106-110.

Walter, V., 1999. Automated GIS data collection and update. In: *Photogrammetric Week '99*, Fritsch, D. and Spiller, R. (Eds.), Wichmann Verlag, Heidelberg, pp. 267-280.

Waters, N.M., 1999, Transportation GIS: GIS-T. In: Longley, P.A., Goodchild, M.F., Maguire, D.J., and Rhind, D.W. (Eds.), *Geographical Information Systems: Principles, Techniques, management and Applications*, Wiley: New York, pp. 827-844.

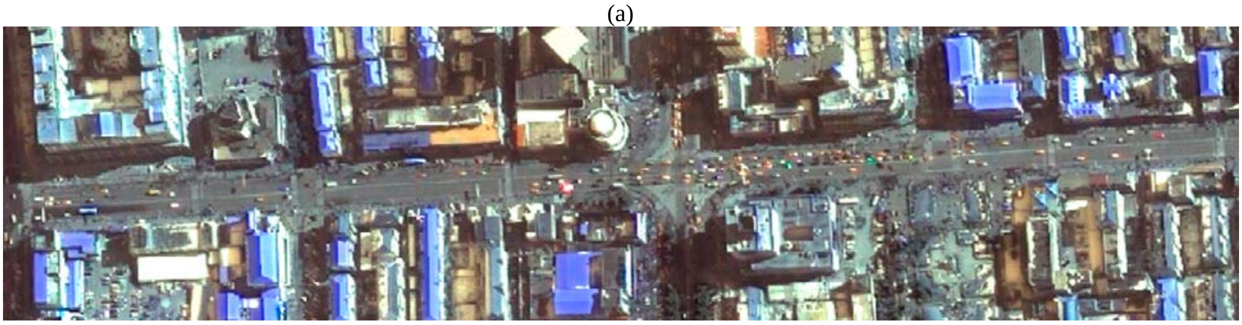
(a)



(b)

Figure 3. Physical barrier detection, first test: (a) image and database information, (b) detected physical barrier

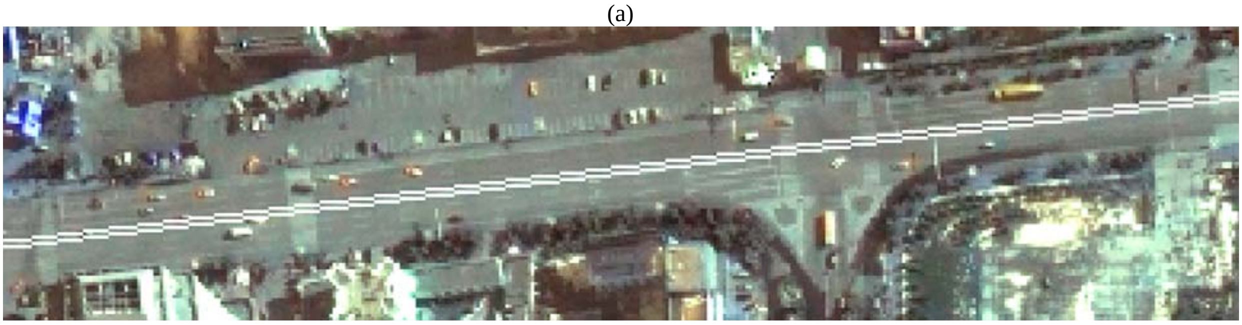
(a)



(b)

Figure 4. Physical barrier detection, second test: (a) image and database information, (b) detected physical barrier

(a)



(b)

Figure 5. Physical barrier detection, third test: (a) image and database information, (b) detected physical barrier