A THEMATIC MAP READING SYSTEM

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ABSTRACT

This paper presents a computer vision based thematic map reading system . It gets images from CCD camera with whole range of grey levels. A new methed for line extraction, called multi-criteria line following, is proposed. The procedure of data processing are described, such as arc vectorization, topological structure generation, vector data compression, geometrical rectification, mosaicing and so on. In this system, areas and lengthes are mearured automatically and spatial statistical information are generated for GIS data base. The results of experiments and a test production show that this system has get to a practical stage in the field of land source investigation.

KEY WORDS : Computer vision, Thematic map reading, Line following, Topological structure

1. INTRODUCTION

Thematic map digitizing is a important way for GIS data collection. At present, there mainly exist two means for map digitizing, one is manual operation by tablet, the other is scanning. The former has been widely used in productional units because of its simple operation, but it operates slowly and the accuracy and speed will decrease when the worker is tired. Most existing systems using the latter method are based on binary image processing techniques (Suzuki 1990, Musavi 1988) , such as binarization, thinning and so on. They avoid a lot of manual operation and work fast. But high quality map is requied in these systems and the binarization threshold is difficult to chose. Different results are obtained with different thresholds. Unsuitable threshold will lead to a lot of graphic editing tasks.

Drawing lessons from other systems, a computer vision based graphic reading system named CV2 is developed. It takes the whole range of grey levels. Its main function is to read topographical map, thematic map and engineering drawings (Lin 1991a). In CV2, the computer imitates the human eyes to recognize and follow lines based on computer vision techniques. This realizes the automation of line extraction. Data management and transformation, such as rectification, mosaicing and topological structure generation, are automatically performed based on photogrammetry and computer graphics. Efficient manual operations might be taken when automatic processing meets difficulty. Every effort is made to achieve the optimal combination of automatic processing and manual opertion. This paper describes the thematic map reading system in CV2.

2. SYSTEM COMPONENTS AND PROCESSING DIAGRAM

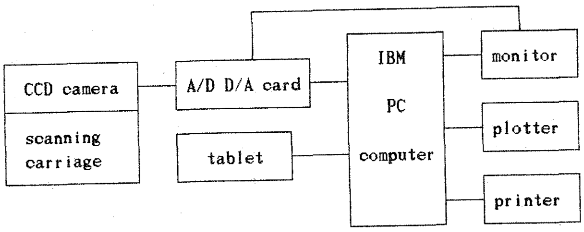


Fig. 1 System components

The system cmponents is shown in Fig. 1. CCD camera is adopted because of its high geometrical stability, high sensitivity and being easy to change scanning scale. The camera is mounted on a mechanical scanning carriage and driven by electric motors in X, Y drictions. Map sheet is scanned patch by patch. The monitor is used to display grey level image. The produced lines are overlaped on the image by a color. This makes manual interaction easy. The tablet is mainly used for interactive operations, e. g. selecting menu, editing graphics and inputing attribute codes. Therefore a small size tablet (say A3) is satisfying. The processing diagram is shown in Fig. 2.

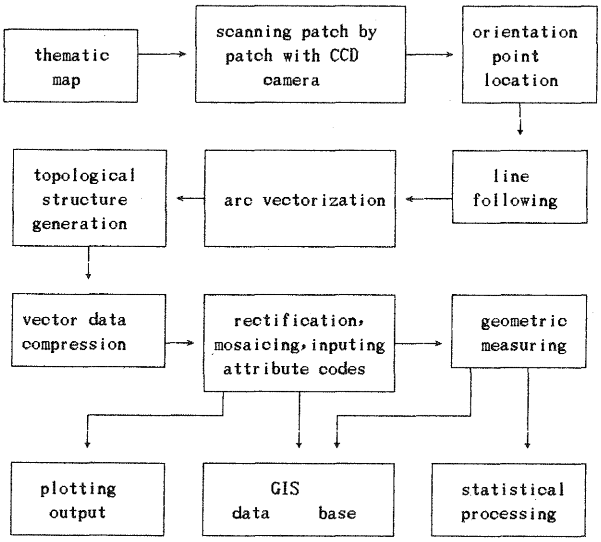


Fig.2. Processing diagram

3. MAIN PROCESSING LINKS

3.1 Orientation point location

In each patch, there are four cross shaped orientation points on the corners. They are the control points for rectification and mosaicing, so they need to be located with high accuracy. Approximately locating the orientation point by manual pointing, the system detects many feature points and locates the point accurately by least square fitting. The location accuracy reaches to subpixel level. The algorithm can prevents the disturbance of other lines because it uses the structural information of the cross.

3.2 Line following

Line following is a sequential line extraction method. It is performed in the multi-grey levels image. Comparing with the binarization method, its significant advantage is that it can use the information gotten in last following step. So it is easy to take the local feature into account and this prevents the effect of uneven light and of the change in line width and darkness. Also, its location precision is higher than that of binarization method.

The main procedures of line following are detecting start points and following lines sequentially according to some searching schemes and rules.

3.2.1 Detecting start points Start points are selected among the most reliable points on the line. When a start point is found on a continuous line, the whole line will be followed in two directions. So the criterion to distinguish start points should be more strict than that in line following process. According to the "from coarse to fine" principle, a number of candidate points are extracted based on the pixel grey value, then more strict criteria are added to detect start points. These criteria are local sum of grey values, the density of candidate points and so on. The start following direction is detected by some template matching operators.

3.2.2 Line following algorithm Following algorithm, namely the searching scheme and decision criterion, is the core of the line following procedure. A lot of algorithms can be used in line following. Groch (Groch 1982) proposed a local and a regional method for line following based on a profile analysis operater (PAO) . The local method detect points of the line by PAO sequentially in a arc shaped sample line with a variable length of the step. This method is mainly used in continuous line following. For every step in the regional method a rectagle area of interest (AOI) is defined straight in front of the last line segment increment. The AOI contains n samples which are perpendicular to the direction. In every sample line hint points are selected according to a confidence measure. A collinear measure is calculated to chose line points from the hint points. This method is mainly used in dashed line following. These two methods are combined to follow arbitrary lines. Joseph (Joseph 1989)used two thresholds to follow lines of uneven density. One is called fatal threshold at which a single pixel on the line terminates extension and another some what blacker threshold called provisional threshold at which the provisional end point of the line is marked. In addition, edge following (tracing) algorithms proposed by (Fishler 1981, Zamperoni 1982, Shu 1989, Ballard 1982) all can be used to follow lines by some modifications.

Theoritical analysis and experimental results indicate that each algorithm has its advantages and disadvantages. Segmentation algorithm can easily leap over the break point (Fig. 3a), but it needs too many manual operations when following a multi-curved line (Fig. 3b). As for recursive following method, it is easy to follow lines like Fig. 3b shows, but it is difficult to deal with the break point in Fig. 3a. Variable radius circular seaching method can deal with both situations in Fig. 3a and Fig. 3b (Fig. 3c), but it will cause some errors when lines occur desentily (Fig. 3d). On the other hand, the same seaching scheme with different criterion (such as grey value criterion, difference criterion, local sum of grey values criterion) will lead to different results. Therefore, there is no ideal following algorithm which is suitable for any situation.

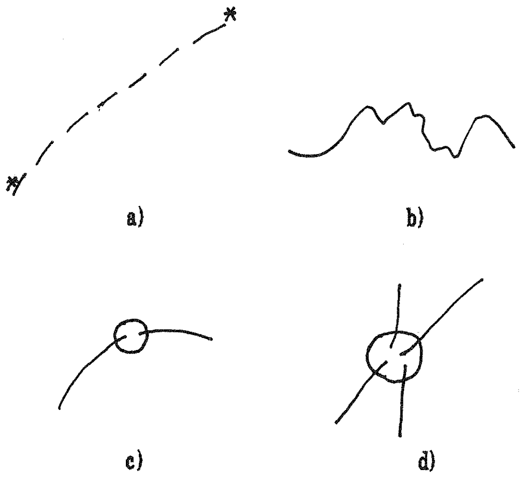


Fig. 3 Different algorithms

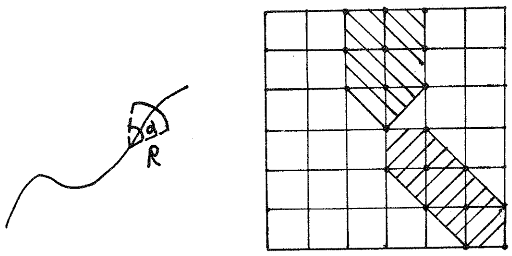
3.2.3 Multi-criteria line following In view of the differences of various algorithms, we think that the main way to improve line following procedure is to extract more information and apply multi-criteria. As for line following, there are a lot of information can be used, such as pixel grey value, first order difference, second order difference, local sum of grey values, curvature and so on. In addition, the knowledge about the line shaped objects can be used in the mean time.

The organization mode for multi-criteria can be divided into two kinds. One is to arrange the criteria to a decision tree according to their strengthenness and operating speed. The other is to make a unique criterion by a linear function which is similar to the consuming function of heuristic searching. Suppose that C_1, C_2, ……, C_n are criteria collected, the unique criterion can be defined as

$$C=k_1C_1+k_2C_2+\cdots\cdots+k_nC_n$$

where k_1, k_2, …, k_n are weighted coefficients. Desicion tree and unique criterion are constructed from a lot of experiments and can be adaptively modified when the program operates.

3.2.4 The line following algorithms in the system at present A. Fully automatic line following (FALF) That is to say, start point location and line following are automatically performed without any manual operation. Two kinds of searching scheme are adopted. The first is arc searching (Fig. 4a) , where the angle α and radius R are automatically modified in the process. The second is recursive following (Fig. 4b). Multi-criteria and decision tree form are adopted in each method. FALF is performed in the working window defined by the orientation points, also it can be peformed in a manually defined window. The two following methods are used individually or integrately. B. Line following with manual operation If some lines lose through FALF. Line following with some manual operation is performed. Manually pointing a start point on a line, the whole line will be automatically followed by



a) Arc searching b) Recursive following

Fig. 4 Line following

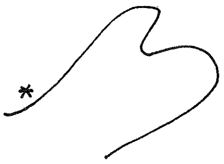


Fig. 5 Manually pointing a start point

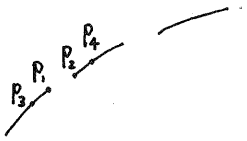


Fig. 6 Dashed line following

FALF. A small deviation of manual pointing is allowed, and it will be corrected automatically. C. Dashed line following Dashed line following procedure consists of two steps, segment following and segment linking. First, solid line segments are automatically followed by FALF, then segments belonging to a line are automatically linked according to their end points. Suppose p_1 and p_2 are the end points of two segments. The end point directions of the two segments are determined by the end points p_1, p_2 and the points p_3, p_4 which have some distance (e.g. 5 pixels) from p_1, p_2 respectively. The end point direction is represented by the angle (< or = 90) between straight line segment p_1p_3 (or p_2p_4) and the horizontal line. If the distance between p_1 and p_2 and the absolute difference of the two end point directions $|\alpha 1 - \alpha 2|$ satisfy the given thresholds, p_1 and p_2 are linked, otherwise, a cursor generates on one of the end points, manual operation is requested.

3.3 Arc vectorization and topological structure generation

3.3.1 Arc vectorization The result of line following is stored in raster form. It needs to be converted into vector form for saving the storage memory and making it convinent to perform rectification, poltting output and various succesive process in the information system. Vector data are recorded by arcs. Points between two nodes are defined to an arc. Vectorization are performed according to 8_neighbor connection. First, caculate connecting number C8 and crossing number CN.

$$C8 = \sum_{i=1}^{8} q_i$$

$$CN = 1/2 \sum_{i=1}^{8} | q_i - q_{i+1} |$$

where qi is the mark value of pixel i ,
q_i = 1 , if the point belongs to a line
= 0 , background
and $q_9 = q_1$
If CN > 2, the point is a node.
If CN = 1, the point is an end point.

End point is also called node in the following part if it does not cause any confusion. C8 is coorprated with CN to deal with node cluster (Musavi 1988).

4	3	2
5	X	1
6	7	8

Fig. 7 8_neighbor

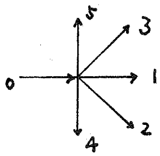
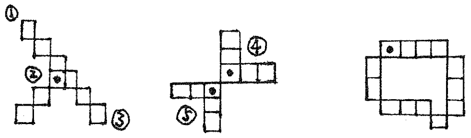


Fig. 8 Center first rule



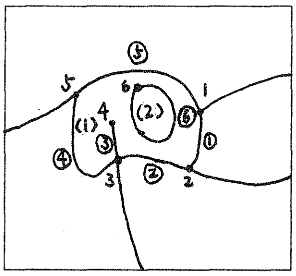
a) b) c)

Fig. 9 Some special situations in arc vectorization

Arc vectorization process begins at a node, traces the arc according to the center first rule and ends in another node. Fig. 8 shows the center first rule, 0 represents the present tracing direction, 1 to 5 are possible directions in next step. The searching order is from 1 to 5. Center first rule makes the tracing process fast because most lines change their directions smoothly. As shown in Fig. 9a, the arc from ① to ② will be lost and an arc from ① to ③ will generate if only the center first rule is used. Therefore, for every step in tracing, another identification is necessary to search nodes in the neighborhood of the present pixel. As shown in Fig. 9b, an arc from ④ to ⑤ should generate. After all the nodes are searched,

polygn NO.	interior point	outer-bounded rectangle	low address of arc	high address of arc	low address of hanging-up line	high address of hanging-up line	low address of hole	high address of hole	attributes
(1)			1	4	5	5	1	1	
(2)			6	6	0	0	0	0	

b) polygn file



a)

arc NO.
①
−②
−④
⑤
③
⑥

c) polygn arc file

polygn NO.
(2)

d) hole file

point coordinate X , Y

f) point file

arc NO.	start point	end point	low address of point	high address of point	left polygn	right polygn	attributes
1	1	2	1				
2	3	2					
3	4	3					
4	5	3					
5	5	1					
6	6	6					

e) arc file

Fig.10 Topological data structure

an additional search is performed to find holes (Fig. 9c). The point which is first detected on the boundary of a hole is also defined to a node. The hole is vectorized by tracing its boundary. The first point on the arc of a hole is the same with the last point.

3. 3. 2 Topological data structure

Topological data structure is adopted in the system to represent the objects and their relationships in the thematic map. Topological data structure saves the storge memory. And it is convinent to query the relationship of neighbor and connection. Objects on a map are devided into three categories : point, line, and plane. They are represented by point, arc, polygn respectively. In order to distinguish arcs of different type, the arc which starts or/and ends with an end point is called hanging up line (Fig. 10a, arc ③) . Topological data structure is composed of five files which are shown in Fig. 10b to f. In the polygn file, the interior point is used to mark the polygn in poltting output, and the outer-bounded rectangle is used to query the polygn fast. All files are stored in binary form.

3. 3. 3 Generation of topological data structure

Boundary tracing and region filling are performed to generate topological data structure. The system searches unmarked pixels from top to down and from left to right in the window. Detected points act as the original interior points. They will move to suitable locations by morphological erison after the topological structure generates. Starting at each original interior point, a search procedure is performed to left (or to right) until it meets with a boundary pixel. Then trace the boundary according to the right first rule (Fig. 11) and mark the traced pixels. In the course of tracing, arc number is sorted in the arc file and filled in the polygn arc file, and the polygn number is filled in the items of left or right polygn number in the arc file. As for the arc whose start and end nodes are the same as another arc (Fig. 12), an arbitrary point on the arc is cooperated with the two nodes to identify an arc number. When the tracing stops at the end of a hanging up line, a backforward tracing procedure is performed from the end point to the node, the arc number of the hanging up line is filled in the polygn arc file and the pixel marks are deleted. After a polygn is enclosed, the odd and even test algorithm is performed to fill the polygn. The points in the polygn are marked and holes are searched in the mean time. The data structure of a hole generates in the same way and the polygn number of the hole is filled in the hole file.

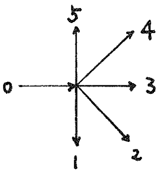


Fig. 11 Right first rule

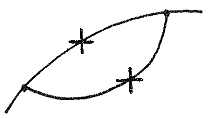


Fig. 12 Arc identification

3.4 Vector data compression, rectification and mosaicing

3.4.1 Vector data compression The vector data points gets from raster data are very dense. So it is necessary to compress the vector data. The system adopts the "local pixel logic" method (Hung 1983) . The compression procedure identifies critical points on an arc and keeps the node or end point. Critical points are defined as those feature points on a thin line such that the line can be approximated by a connected set of straight line segments. The algorithm traverses the chain code for each line and puts out a list of critical points after a set of caculation and identification. Since the computer can not "perceive" the lines in a global context like we do, this procedure may produce more critical points than that by manually collected.

3.4.2 Geometrical rectification It is necessary to rectify the arc points because of the deformation caused by the orientation of the CCD camera. According to the image orientation points in each patch and their map coordinates, the compressed vector data are rectified to a unique map coordinate system by affine transformation. Because the algorithm rectifies the lines directly and avoids the computation of background points, it operates fast.

3.4.3 Mosaicing Many processes are performed in patchs. The points on the border of the window may deviate after each patch to be rectified to the map. So mosaicing is necessary. A method like that in (Beard 1986) is used in the system. First, the nodes in the matching borders are extracted. If the distance of nodes in the two matching borders is little than a threshold, they are matched and their coordinates change to the same value in the arc and point file.

3.5 Attribute coding and geometric measuring

The attribute codes of polygns and arcs need to be input interactively. The areas and lengthes are automatically measusured according to some standards. Various statistics can be easily caculated according to the attributes. As a result, statistical tables are printed, areas and lengthes are automatically input to the thematic information base.

4. EXPERIMENTS AND CONCLUSIONS

Many pieces of thematic map are processed by the system. Fig. 13a shows the line following result of a kilometrer grid. An enlarged view of line following is shown in Fig. 13b. Fig. 14 shows dashed line following. Fig. 15 shows arc vectorization. Fig. 16 shows the filling result when generating the topological data structure. (only paints green points on the left and right sides of the polygn) Fig. 17 shows the elarged view of the unmosaicing result of two kilometer grids. Fig. 18 shows the mosaicing result corresponding to Fig. 17.

A test production for land source investigation is made using many pieces of land use map. These maps are processed to test the accuracy of area and length measuring. Comparing with the chinese land source investigation standards, the qualified ratio reaches to 100 percent. And this is not the highest accuracy of CV2. Reducing the working patch can increase the accuracy when higher precision is expecting.

A set of experiments show that the scheme of the thematic map reading system proposed in this paper is realizable. Optimal combination of computer visiov techniques and manual operation raises the global efficiency of the system. Multi-criteria line following improves the reliability and adaptibility of line extration. Topological data structure organizes the thematic map data efficiently and makes it easy to store and manage them. Using this system to land source investigation has get to a practical stage. On the other hand, the idea and some algorithms are suitable for the reading process of other line drawings. So this system can be developed further.

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Fig. 13a Line following

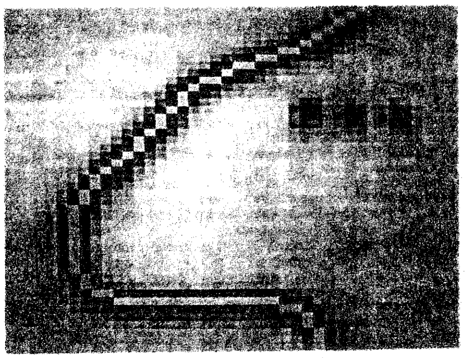

Fig. 13b Enlarged view of line following

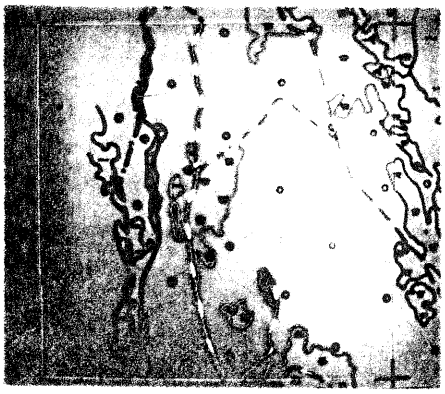

Fig. 14 Dashed line following

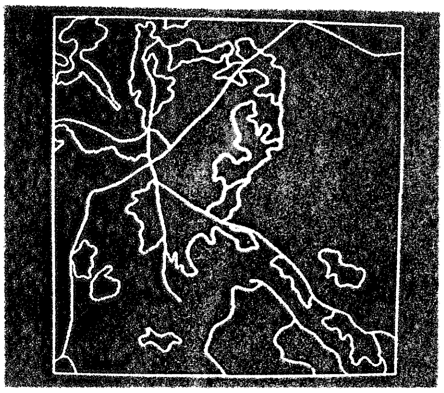

Fig. 15 Arc vectorization

Fig. 16 Filling result when generating the topological data structure

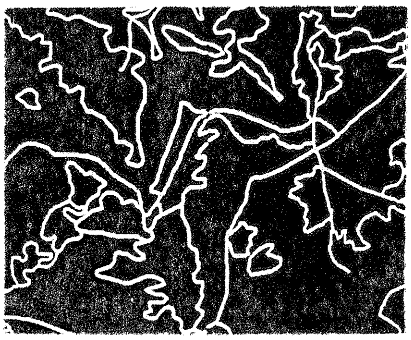

Fig. 17 Unmosaicing result of two kilometer grids

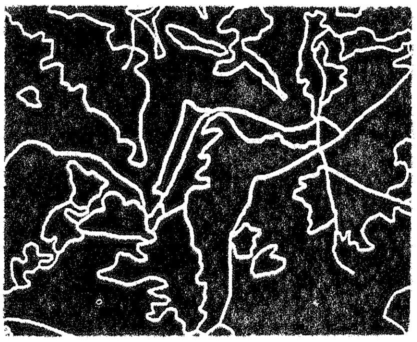

Fig. 18 Mosaicing result corresponding to Fig. 17