AUTOMATIC RECOGNITION OF ROAD INFORMATION ON MEDIUM SCALE TOPOGRAPHICAL MAPS

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Commission Number : III

Abstract

Acceleration in digitizing various information on medium scale topographical maps requires automatic recognition of such symbols as roads, houses, railways and so forth. Automatic recognition with image processing techniques, however, does not seem practical because of its time consuming processes and the expensive hardwares needed.

In order to make the processing time shorter and to make the things practical, a new method for automatic recognition of road symbols drawn with parallel lines on 1:25,000 topographical maps of Japan is proposed. The processes of the method deal with vectorized map information data and,therefore, can be executed in ordinary computers.

The experimental results indicate that about 90% of road symbols can be recognized automatically, although about 10% of others are incorrectly extracted.

Another method is also presented to reduce the number of the incorrectly extracted symbols.

1. Introduction

After the completion of the whole coverage of Japan with 1:25,000 topographical maps in 1983, the Geographical Survey Institute (GSI) started a new project, Basic Map Digitization Project (BAMDIP), in 1984 (Yaguchi et al., 1987). The project aims at constructing a data base of those maps, Digital Cartographic Data From 1:25,000 Scale Map, in order to automate the cartographic processes, and also aims at offering digital map information to the people.

The digitization is carried out with three separates which correspond to three colours (black, blue and brown) on printed maps. Among those separates, the ones for blue and brown include only a few kinds of information, so they do not require highly intelligent digitizing systems. As for the separate for black colour, however, it includes many kinds of information, and at the same time each kind has a lot of information, as indicated in Figure 1.

Therefore the digitization of the information on the black colour separate requires a new automatic recognition method with a computer. As the first step of research, the GSI focused on the road information on the topographical maps which is symbolized as parallel lines. Because these symbols are considered as one of the most important kinds of information on the maps .

There have been several studies on the automatic recognition of parallel line road symbols with image processing techniques (Miyatake et al., 1985 ; Nagao et al., 1987). In this paper, however, a new method is presented aiming at less processing time and the development of a software which is available with any computers.

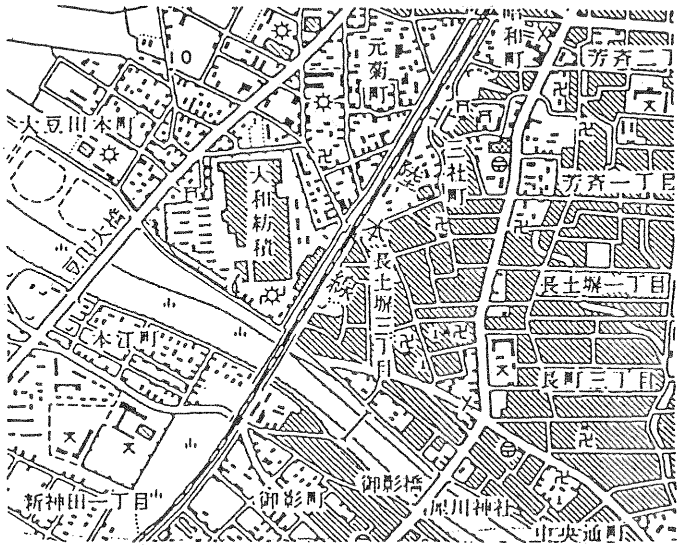

Figure 1. Separate for black colour of a 1:25,000 topographical map.

2. Method of Parallel Line Recognition

2.1. Flow of Processes

The flow of the recognition processes of parallel line road symbols is shown in Figure 2.

The separates for black colour, mentioned above, are used as manuscripts to be measured with a drum-scanner. The scanned image data is converted into two-value data with an appropriate threshold level, as shown in Figure 3a. The data of this type, raster data, requires long time to be processed with a computer. Therefore instead of direct processing of the data with image processing techniques, it is vectorized before starting recognition processes.

The present specifications of the 1:25,000 topographical maps, however, require small house symbols (small black rectangles) to touch parallel line read symbols when the former is close to the latter as shown in Figure 1. This means that the vectorization with thinning method, which is now common in vectorization (Leberl and Olson, 1982), causes to lose the information of parallel line as shown in Figure 3b.

Therefore in order to preserve the parallel line feature, boundary lines of the two-value image are traced (Ohsawa and Sakauchi, 1984) instead of the thinning method. Then as indicated in Figure 3c, the boundary lines inside a parallel line are completely independent of house symbols attached to the outside of the parallel line.

Input with Scanner
↓
Tracing Boundary Lines
↓
Extracting Linear Features
↓
Detection and Tracking of Parallel Lines
→
Detection and Analysis of Intersections
↓
Supplementary Process for Incompletely Analyzed Intersections
↓
End

Figure 2. Flow of automatic recognition of road symbols.

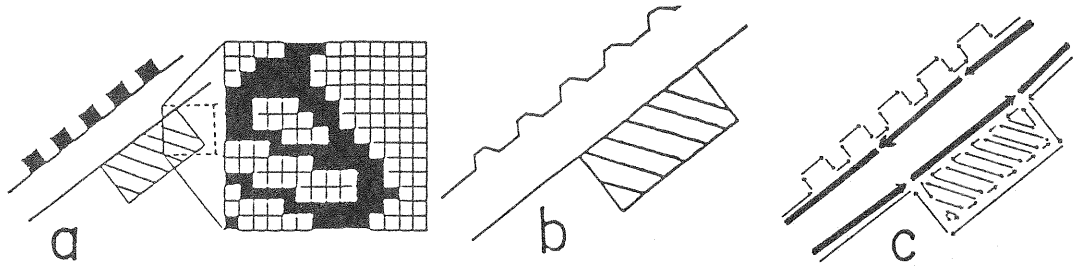

Figure 3. Input data from a scanner and the boundary lines.
a. Input data.
b. Vectorized data with thinning method.
c. Boundary lines.
➡ : Boundary lines inside a parallel line road symbol.
→ : Boundary lines outside a parallel line road symbol.

After tracing the boundary lines, those lines are classified into two groups, according to the size and the shape of the circumscribed rectangle of each boundary line, in order to distinguish linear feature from small symbols and to reduce the amount of data.

Next, for the longest vector in the linear feature data, a vector which makes a parallel line with the longest one, 'pair vector', is searched. Then the recognized parallel line is tracked along the boundary lines. These processes are explained in detail in the section 2.2.

When an intersection is detected in the course of tracking process, the process is stopped and the intersection is analyzed to understand its shape and the number of parallel lines directly connected with it. After the analysis, detected parallel lines are tracked in the opposite direction of the intersection. These processes are explained in the section 2.3.

If the length of the longest vector becomes less than a certain threshold, correction process is triggered for intersections which have not been successfully analyzed.

2.2. Detection and Tracking of Parallel Lines

As mentioned above, the boundary lines inside a parallel line are used to recognize parallel line road symbols. In addition to the fact that the vectors inside parallel lines are almost parallel, their directions are opposite with each other because of the clockwise tracing rule of boundary lines (Ohsawa and Sakauchi, 1984). The length of vectors which belong to the boundary lines of parallel line road symbols are considered significantly long in comparison with other features. Therefore parallel line road symbols can be effectively detected with long vectors in the linear feature. The pair vector of the long vector is searched in an area of appropriate size set in the left hand side of the long one. This searching process may be executed very fast because of the tree structure of the boundary vector data (Ohsawa and Sakauchi, 1985).

There are, however, several groups of data which cause errors in the result of recognition with this method. They may be divided into two categories. One of them is a group of data which has parallel line structure but is not a road symbol.

There are two examples of it. One is a hatched area indicated in Figure 4a and the other is an area between two linear structures indicated in Figure 4b. The former case can be basically distinguished from true road symbols with information of inner boundary lines, which are traced counterclockwise (Ohsawa and Sakauchi, 1985), but such an area is sometimes invaded by letters of names and becomes outer (i.e. clockwise traced) boundary lines.

Therefore the data of this category causes errors in the recognition result. If the result includes many errors of this kind, human inspection is required to eliminate them. But in that case the automatic recognition method may be considered impractical. This problem is discussed later in this paper and one solution is presented.

The other category is a data which can not be recognized only with the knowledge of parallel line structure. For example, the road symbols with a median strip, indicated in Figure 4c, are recognized as not one road but two parallel line roads. Another example is a road symbol with a revetment. The road symbols of this kind, as indicated in Figure 4d, do not have parallel line structure, or rather the boundary vectors inside the road symbols are not parallel.

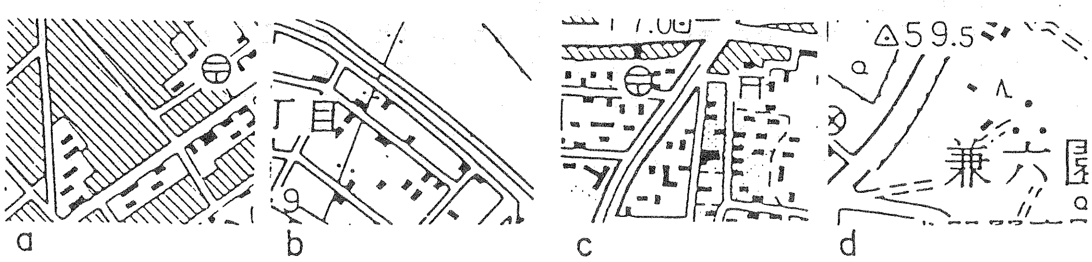

Figure 4. Examples of incorrectly recognized symbols.
a. Parallel line structure of densely populated area.
b. Parallel line structure between two linear symbols.
c. Road with a median strip.
d. Road with a revetment.

The road symbols of these types are also difficult to be recognized with the method mentioned above. AI techniques may be useful to overcome this difficulty. Another solution may be the introduction of a human-friendly interactive correcting system (Takishima et al., 1987). As perfect automatic recognition of map information is almost impossible, the result of the recognition should be followed by a good correcting system. Therefore in order to minimize total digitization time, a human-friendly interactive correcting system, which effectively compensate the inability of automatic recognition, is desirable.

Once a pair vector is detected, the parallel line symbol is tracked along with the boundary lines. In the course of tracking, the center line of road symbols is traced and the width of the symbols is also detected.

2.3. Detection and Analysis of Intersection

The method of Parallel Vector Tracer (Nakajima et al., 1984) is applied for the detection and analysis of intersections. The intersections can be detected when the parallel line nature between pair vectors becomes not clear. Namely, when the angle between pair vectors is Θ, and a threshold value is Θth, the condition can be expressed as follows,

$$|\Theta| \leq \Theta th \text{ --- } (1).$$

Once an intersection is detected, it is examined whether it has already been analyzed or not. If it has not yet, the following analyses are carried out to examine its shape and the number of parallel line road symbols flown into it (Yaguchi et al., 1988).

The analysis of the intersection type focuses on one of the last pair vectors which do not satisfy the equation (1), and examines whether there is a corner on the boundary line on the focused vector's side when the vector is tracked on the line. If the pair vectors are named V and W, respectively as shown in Figure 5, and the vector V is focused, then the nature of the boundary line on the V's side can be defined with the following three factors,

L : the length between V and Vi measured along with the boundary line,

A : the angle between V and Vi,

D : the distance between line V and the start point of Vi,

where Vi is a vector on the boundary line obtained when the line is tracked from V, including V.

If A and D are larger than certain threshold values, Ath and Dth respectively, it is recognized that there is a corner on the V's side, as shown in Figure 5a. On the other hand, if A is smaller than Ath and L is larger than a certain threshold value Lth, no corner is recognized on the V's side, as shown in Figure 5b.

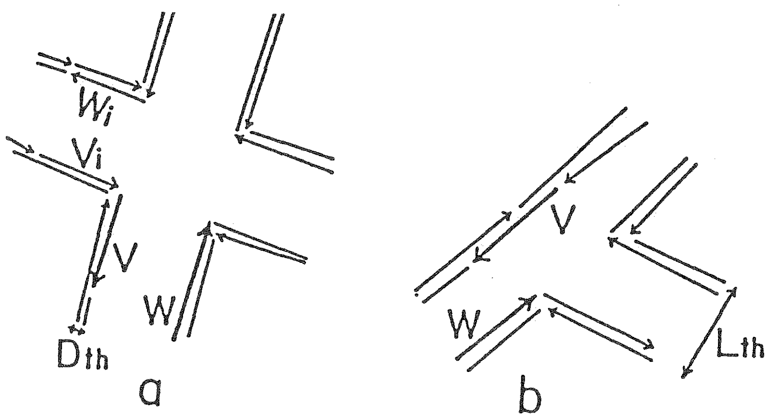

Figure 5. Analysis of intersection.
a. With a corner on V's side.
b. Without a corner on V's side.

Once the shape of the intersection on the V's side is understood, the vector Vi is considered as one side of a new road symbol which also flows into the intersection. Then the vector on the other side of the road symbol,Wi, is searched in the same way as in the case of searching the first pair vector in the area set on the left side of the Vi.

If the vector Wi is found, it is considered as a new V, and these intersection analyzing processes are iterated until the Vi becomes equal to the vector W. If Wi is not found in these processes, the intersection analyses are stopped and those intersections of incomplete analyses are reviewed at the last stage.

If an intersection is analyzed completely and understood successfully, those pair vectors recognized as flown into the intersection are recorded and the tracking process is carried out for each pair.

The recognition processes are continued until the memory for pair vectors becomes empty and the length of the longest vectors in the remaining vectors becomes less than a certain threshold value.

2.4. Experiment-1

An experiment to recognize road symbols was carried out with the method described above on the following two 1:25,000 topographical maps in Japan.

1:25,000 topographical maps used,

'KANAZAWA' : urban area,
'ZAOSAN' : mountainous area.

The former map was used as an example of complicated roads in urban area, and the latter one was used as an example of winding roads in a mountainous area.

The results of the experiment are shown in the Table 1. In this table the processing time means the CPU time of the computer, Apollo DN660, for processing the whole map. The extraction rate means the percentage of the extracted number of road symbols out of the number of all the parallel lines between the road intersections, but the errors are not included.

The threshold values used in this experiment are as follows,

$Oth = 160$,
$Lth = 30$ pixels,
$Ath = 20$,
$Dth = 8$ pixels,

where the pixel corresponds to the sampling pitch of scanner and in this case it is 50 microns on a map.

The examples of extracted road information are shown in Figure 6. The errors in the hatched area in Figure 6b were caused by the invasion of names which made those inner boundary lines of the hatched area into outer ones. There are also some errors of Figure 4b type. It may take a lot of time to find and correct them, because the inspector has to check every arc of the result to know whether it is an error or not.

In this sense, this recognition method is still impractical.

Table 1 Processing time and extraction rate of the experiment.

MAP NAME	Processing time* (CPU time : min)				Extraction rate (%)
	Boundary line extraction	Linear information extraction	Parallel line structure extraction	Total	
KANAZAWA	47	28	57	132	89.7**
ZAOSAN	10	4	3	17	92.2

* : Ability of the CPU is about 1MIPS.
** : Examined only in the area of 10cm by 10cm on the map including that of Fig. 6a

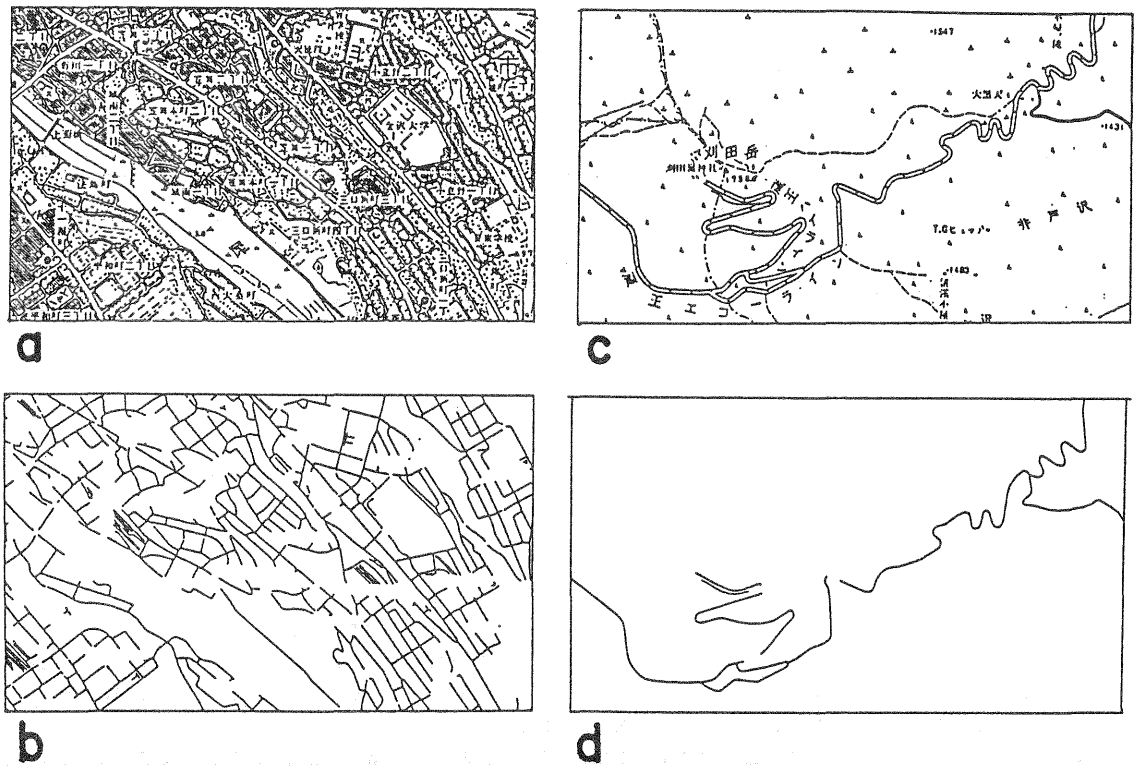

Figure 6. Results of automatic recognition of road symbols.
a. Input data : 'KANAZAWA'.
b. Extracted road information from a.
c. Input data : 'ZAOSAN'.
d. Extracted road information from c.

3. Reduction of errors in automatic digitizing systems

3.1. Usage of coarse data

As long as there are errors in the result of automatic recognition without any aid for an inspector to find them, the recognition method as a digitization system may be considered impractical.

The cause of the errors in the above experiment stems from the fact that the method uses the 'longest vector' in the data as a key to find one of the boundary lines of parallel line road symbols. After all this idea is useful to find parallel line features, but can not distinguish road features from others.

In order to improve this defect, it is easily understood that the usage of already digitized road data, even if it is coarse, is very useful. Fortunately, principal roads of Japan have already been manually digitized with digitizers by the GSI as the Digital National Land Information (DNLI) (Matsuda, 1980). The accuracy of the data is within one mm on a printed 1:25,000 topographical map. Although the accuracy is not so good, it may still be useful to find one of the boundary lines of parallel line road symbols. Because once a correct vector of a road symbol is found, most of the road symbols connected to the first one can be digitized as long as the symbol tracking and the analyses of intersections work well.

Therefore it can be expected that roughly digitized existing road data helps finding correct road symbols and that if some are found, most of all road symbols can be automatically and accurately digitized without errors. Actually as indicated in Figure 7, the number of the first vectors necessary to find parallel line symbols is not large in the automatic recognition method mentioned in the section 2.

The processes of finding a road symbol with DNLI data are described in Figure 8.

1). One of the DNLI road vectors, R, is extracted.

2). Two short vectors p and q are considered at several points with constant interval of length along R. Both of them are perpendicular to R and have their start points on it, but their directions are opposite with each other. The length of them is slightly larger than the width of road symbols on a map.

3). For p and q, two boundary vectors v and w, which satisfy the following conditions, are searched.

p crosses v and q crosses w, and

$$(p \times v)\cdot\hat{z} > 0 \text{ and } (q \times w)\cdot\hat{z} > 0$$

in a right-hand coordinate system --- (2)

where $\hat{z}$ is a unit vector of the z-coordinate.

4). If both v and w are found, they are considered as pair vectors of a parallel line road symbol and tracking processes described in the section 2.2 are started.

Figure 7. First vectors needed to find parallel lines.
: Position of first vectors.

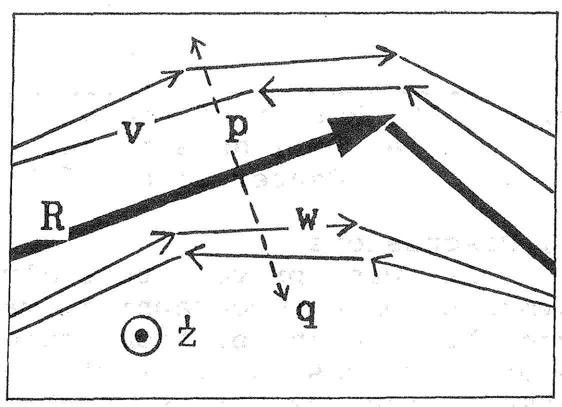

Figure 8. Detection of road symbols with DNLI data.
: DNLI vector.
: Boundary vector.

3.2. Experiment-2

Automatic recognition experiments were carried out with both methods for a small area of 3.5x2.5 cm on the 1:25,000 topographical map of 'KANAZAWA'. The results are shown in Figure 9b and 10b, respectively. In Figure 9b, there is an error in the center of the figure. On the other hand, there are no errors in Figure 10b. As indicated in Figure 10a, DNLI data has only one arc in the area, but most of the road symbols are recognized. The difference of processing time between both methods is only a few seconds for the area of Figure 9a. Therefore the usage of DNLI data does not increase the processing time too much.

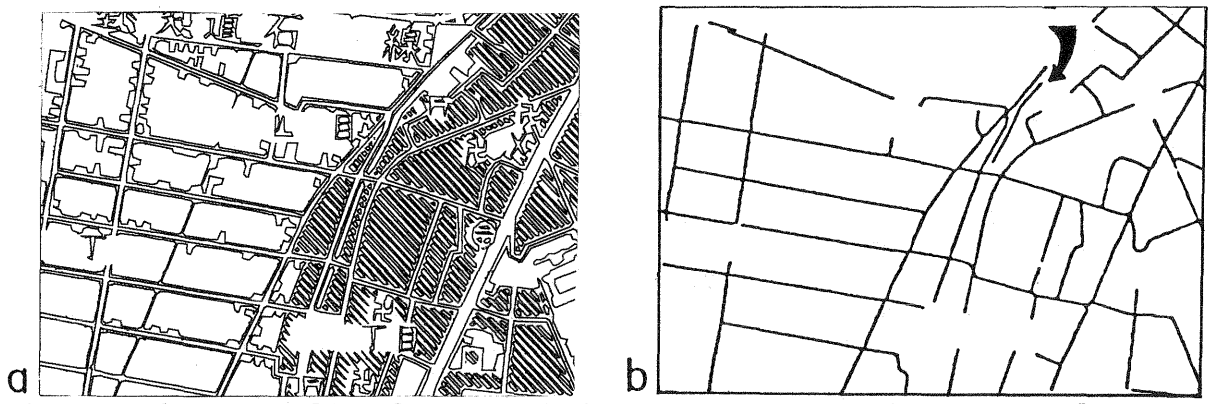

Figure 9. Result of recognition experiment with the longest boundary method.
a. Boundary lines of the test area.
b. Center lines of the recognized road symbols. The arrow indicates the error.

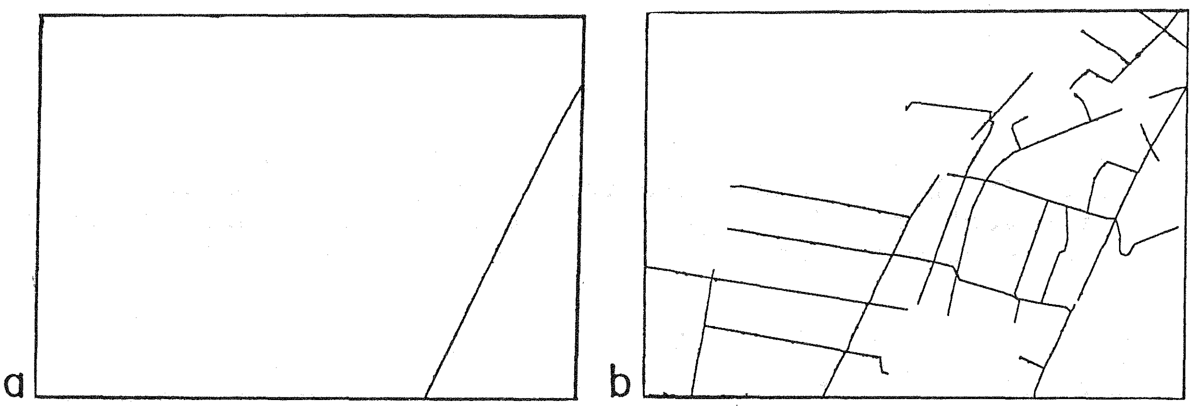

Figure 10. Result of recognition experiment with the DNLI data.
a. DNLI data in the test area.
b. Center lines of the recognized road symbols.

4. Discussions

It was proved that almost 90% of parallel line road symbols on a topographical map and the width of road symbols can be recognized from boundary lines of a scanned image in short processing time with an ordinary computer, though the results include errors which amount to about 10 per cent of the total parallel line road symbols. The usage of coarse data, such as DNLI road data , was proved useful to get rid of these errors. However, it assumes that few roads are isolated from others, namely most of roads are connected with each other through intersections. This assumption is not inappropriate in the real situations, but on maps, road symbols sometimes suffer from the invasion of names or other features, or even from cutout by neat lines. It is possible that a certain part of a road network is completely isolated from others without any DNLI data. In that case, such an isolated area is not at all digitized. Therefore it may be impossible to find out all the road symbols drawn on a map only with the usage of the DNLI data. For those road symbols that are not recognized with the DNLI data, the first method, the usage of the longest boundary vector, should be applied. The result of the latter method is likely to include errors. However it is possible to distinguish the result with the former method from that with the latter one. Namely the inspection of the result is necessary only for the result obtained with the longest boundary vector method. Therefore it can be said that the usage of the DNLI data may contribute to reduce the time spent on inspection and interactive correction.

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