Development of a System for Making Guide Maps Based on the Idea of the Cognitive Map

Kantaro Monobe, Graduate School of Informatics,Kansai University, Osaka, Japan
(mkkkm@aurora.dti.ne.jp)

Shigenori Tanaka, Faculty of Informatics,Kansai University, Osaka, Japan
(tanaka@res.kutc.kansai-u.ac.jp)

Furuta Hitoshi, Faculty of Informatics,Kansai University, Osaka, Japan
(furuta@res.kutc.kansai-u.ac.jp)

Summary

Digital maps are very easily applied as route guide maps. Route guide maps are provided through Web or a mobile phone services, and demand for such services is increasing. However, the production of a route guide map requires a great deal of time. Therefore, it is difficult for general users to make route guide maps. The purpose of the present research is the development of a system that can generate a route guide map using the Digital Map 2500 (Spatial Data Framework) published by the Geographical Survey Institute. This system will not require advanced equipment or expert knowledge. Therefore, anyone can produce route guide maps easily and quickly. By using the Digital Map 2500, the time and cost required in order to generate a map are reduced. Moreover, a useful route guide map can be created by simplifying the map form based on the human cognitive map.

1 Introduction

Several years ago, general users could not use digital maps because of low computer performance and the lack of maintenance of digital maps. However, due to the rapid increase in computer performance and improved maintenance of map data, at present, anyone can use digital maps.

The uses for digital maps are varied and include car-navigation systems, disaster prevention systems, and market research. Digital maps are now a part of our lives.

At present, digital maps are used for route guide maps that are provided by Web-based or mobile phone services. In order to produce a route guide map, out of the massive amount of geographic information, it is necessary to extract only the information required for guidance. Research has been performed to investigate an Internet interface for route guide maps and on a system for producing route guide map for mobile phones. In previously investigated systems, a system administrator must prepare data for a route guide map in advance, which requires a great deal of time and expense.

In the present study, the time and cost are reduced by using Digital Map 2500 (Spatial Data Framework) published by the Geographical Survey Institute. This system can support the production of an intelligible route guide map by simplifying the map form based on the concept of the human cognitive map.

The purpose of this research is to develop of a system to support the production of a route guide map by simplifying Digital Map 2500.

2 Outline of the System

In the present study, a system supporting the creation of a route guide map is developed. The proposed system can simplify and design route guide maps using Digital Map 2500. The concept of the proposed system is shown in Fig.1. This system consists of five processes: 1) extraction of map information, 2) deletion of unnecessary map information, 3) transformation of map form, 4) emphasis of map information and 5) output of a route guide map. A flowchart describing the proposed system is shown in Fig.2.

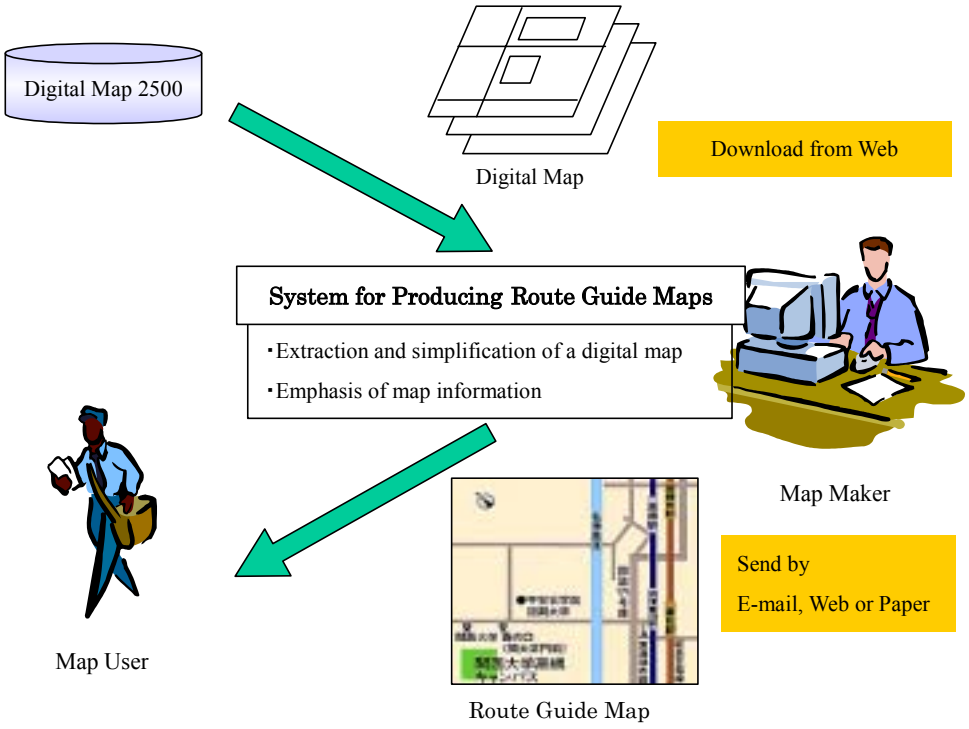


Fig.1 Concept of the proposed system

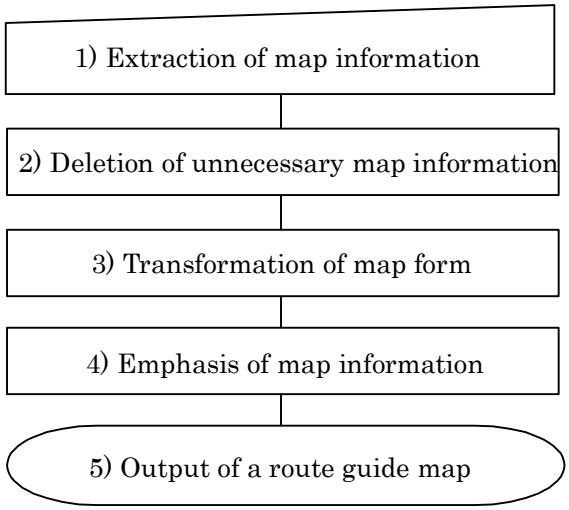


Fig.2 Flowchart of the proposed system

3 Details of the System

3.1 Extraction of Map Information

In this system, Digital Map 2500 is used as the base data of a route guide map. The reasons for using the Digital Map 2500 are that the data is maintained on a national scale, the data has high credibility, and the scale is suitable for use in creating a route guide map. Furthermore, from March 20, 2002, it became possible to download for free the map data via the homepage of the Geographical Survey Institute (http://www.gsi.go.jp). Digital Map 2500 is now easier to use. The data of Digital Map 2500 is separated and stored into individual areas. Thus, in the proposed system, map data used to create a route guide map is associated beforehand.

In this system, the indispensable data, such as a landmark for the map user indicating the destination, is extracted from Digital Map 2500. These data items include the "center line of the road", "railroads tracks", "train station", "building", and "river." After extracting the data, a map domain including two points is displayed. These points are the origin and destination of a route guide map.

3.1.1 Displaying a Node

In Digital Map 2500, since the center line of a road is expressed by two types of data, node data and the connection relation data between nodes, a node must first be arranged. In order to arrange a node, the data of the node stored in "ROADNTWK.NOD" is used. A node is displayed using the coordinate data of a node.

3.1.2 Displaying the Center Line of a Road

The center line of a road is displayed using the connection relation data between the nodes stored in the "ROADNTWK.TIE" file. The center line of a road is displayed by connecting each node. An example of displaying nodes and center lines of roads is shown in Fig.3.

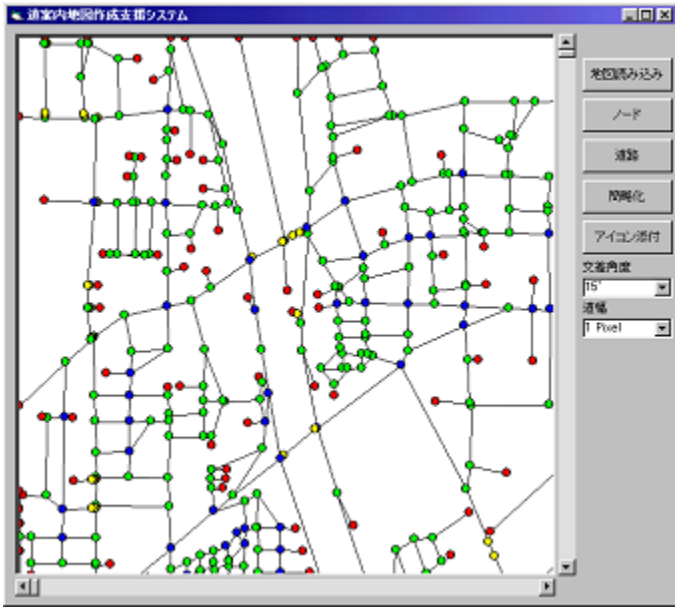


Fig.3 An example of displaying nodes and center lines of roads

3.2 Deletion of Unnecessary Map Information

In order to create a route guide map, in the worst case, three types of information are required: an origin and destination on the route, the best route connecting the origin and destination, and buildings which serve as landmarks along the route. In addition, the data may contain information that hinders the creation of the route guide map. Unnecessary information for a route guide map is deleted.

Unnecessary information in creating a route guide map includes dead end roads. A map becomes easier to understand and use when such unnecessary information undeleted.

In the proposed system, by using node records of area and the end tag, the road lines for which a node that is connected to only one other node is considered to constitute a dead end, and so the corresponding is deleted. An example of a map from which unnecessary roads have been deleted is shown in Fig.4.

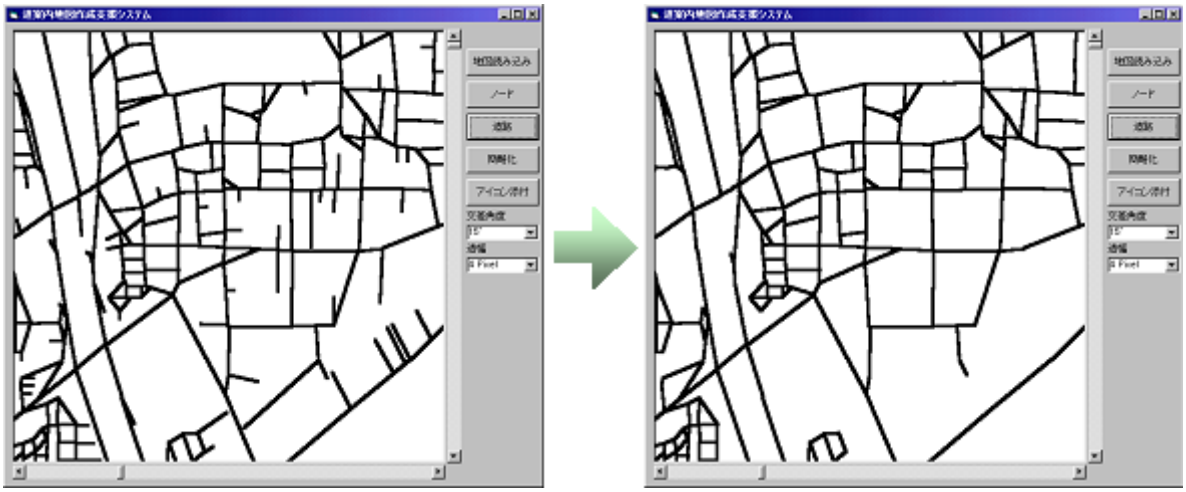


Fig.4 An example of deleting the unnecessary information from a map

3.3 Transformation of Map Form

In order to use the Digital Map 2500 data as a route guide map, the map form needs to be simplified. In this system, the map form is changed based on the idea of the cognitive map, which is one of the characteristics of human space cognition.

3.3.1 Cognitive Map

The cognitive map is made up of memories of large space structures and places that have been accumulated during the everyday activities of a human. Since human memory is limited, geographic information is simplified efficiently and memorized on the cognitive map. Therefore, a difference arises between the geographic information in the real world and the cognitive map in the brain. A typical example is road orthogonalization at intersections.

Road orthogonalization at intersections is space cognition that judges the angle of the intersection to be a right-angle even when the angle of the intersection is not a right-angle. According to a report by Byrne (1979) in Britain, most people remember intersection angles of 60 - 70 degrees and 110 - 120 degrees as 90 degree angles. His experiment results are shown in Fig.5.

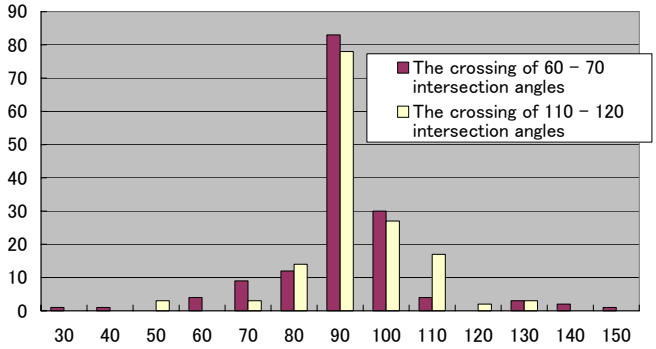


Fig.5 Frequency distribution of presumed crossing angle

A difference exists between the geographic information of the real world and the cognitive map generated by the human brain. Therefore, in order to make a route guide map easy to understand, it is necessary to take human space cognition into consideration.

The human being judges as straight road lines for them of slight bends. This is similar to road orthogonalization at intersections. Thus, in the present study, the map form is simplified by transforming all road lines with slight bends into straight lines.

3.3.2 Desegmentation of a Road Line

In the proposed system, in order to make a corner of a street with a slight bend into a straight line, a road line is desegmented by reducing an unnecessary node, and thus the map form is simplified. An example of desegmentation is shown in Fig.6.

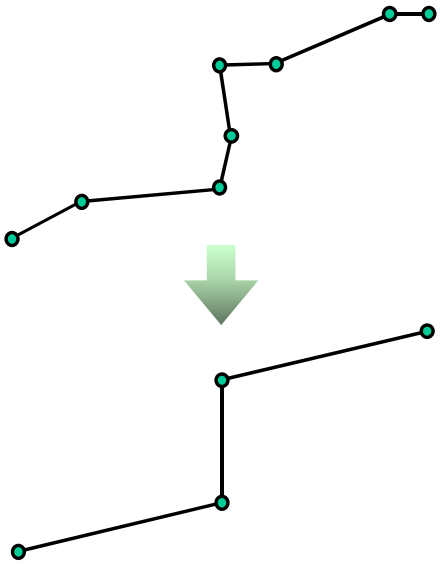
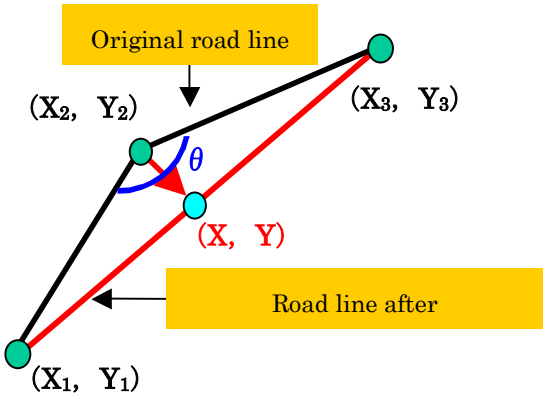


Fig.6 Example of desegmentation

In desegmentation, after extracting two continuous road lines, the corresponding intersection angles are calculated. Then, when an intersection angle is beyond a fixed value, a road line is made into a straight line by moving the node of a point of contact onto the line connecting the two remaining nodes. Movement of nodes is performed using the formula (1):

$$\left.\begin{aligned} X &= (a(Y2-Y1)+X2+a2X1)/(a2+1) \\ Y &= aX+Y1-aX1 \\ a &= (Y3-Y1)/(X3-X1) \end{aligned}\right\} \quad (1)$$

A map is simplified by repeating the processing (Fig.7) performed using this formula (1) for all road lines.



θ : Intersection angle of two road lines

Fig.7 Desegmentation of a road line

The optimal values of the intersection angle used as the standard of desegmentation differ from those of the simplified map form. Then, a few intersection angles are simplified, and the map maker chooses a simple route that best guides the viewer.

3.4 Emphasis of Map Information

In order to make a route guide map intelligible, important objects should be emphasized on the map. Thus, a process to make the width of the road line of the optimal route thicker and a process to emphasize important buildings are performed. The buildings to be emphasized are the origin and destination buildings, and buildings near crossings and stations. Icons representing important buildings are prepared and placed onto the map by the map maker. The designed route guide map is shown in Fig.8.

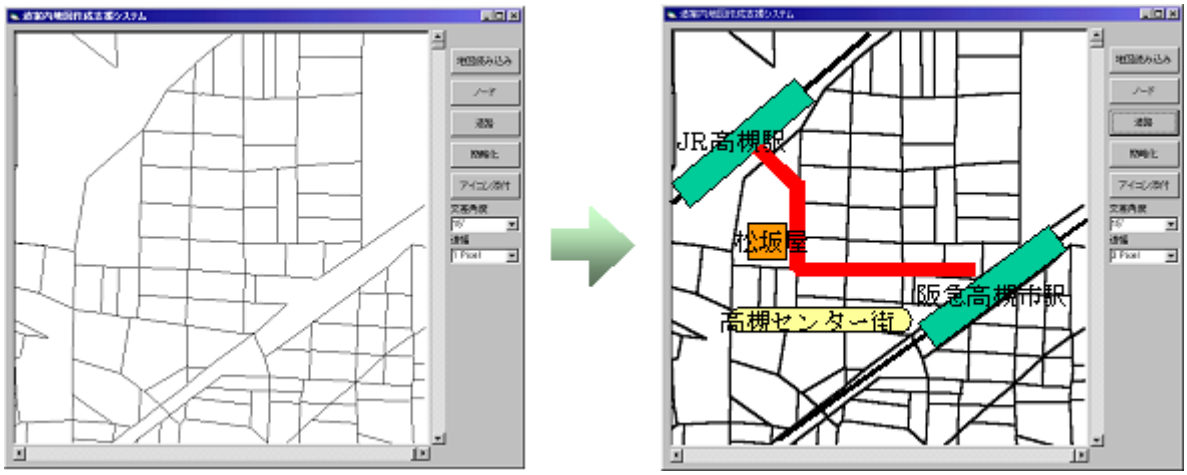


Fig.8 Designed route guide map

3.5 Output of a Route Guide Map

In this system, the route guide map is saved in JPEG form, making it possible to print the map, import it to a Web page, or to send it by E-mail, for example.

4 Verification Experiments

Two types of experiments were conducted in order to verify the usefulness of the proposed system: a route guide map creation experiment, in which the possibility of easy route guide map creation using the proposed system is confirmed, and a test experiment, in which the usefulness of the created route guide map is confirmed.

4.1 Map Creation Experiment

4.1.1 Experimental Method

In the map creation experiment, route guide maps were created both using the proposed system and by hand. The route guide map for the experiments describes how to reach JR Takatsuki station from Hankyu Takatsuki station. This experiment evaluates the map creation time and the questionnaire. The questionnaire questions had five levels of evaluation: "(5) I think so that it is strong", "(4) I think so", "(3) neither ", "(2) I do not think so" and "(1) I do not think so at all". The map creation time and questionnaire results were used as variables in a two sample t-test. Moreover, subjects were asked to explain their reasons for each answer.

4.1.2

The time of map creation and the questionnaire results for map creation are shown in Table 1 and Table 2.

Table 1 Map creation time

Item	By system	By handwriting	Significant difference by two sample t-test
(1)Average time of map creation	3'23	4'35	○

Table 2 Results of map creation questionnaire

Questionnaire item	Average of evaluation in the case of system	Average of evaluation in the case of handwriting	Significant difference by two sample t-test
(2)Could you make the map easily?	4.4	3.7	○
(3)Could you make a satisfactory map?	3.9	2.7	○

(1) Average time of map creation

The average time of map creation was 3 minutes and 23 seconds when the proposed system was used. When a map was created by hand, the average time of map creation was 4 minutes and 35 seconds. The significant difference was determined by a two sample t-test.

(2) Could you make the map easily?

The average evaluation score was 4.4 using the proposed system and was 3.7 for hand-drown maps. Significant difference was determined by a two sample t-test. Subjects of the experiment stated "The system creates a map automatically, decreasing the amount of work, so I can create maps easily."

(3) Could you make a satisfactory map?

The average evaluation score was 3.9 when this system was used and was 2.7 when maps were created by hand. Significant difference was determined by a two sample t-test. Subjects of the experiment stated that "Creating good maps does not require one to be a skilled designer. I created a beautiful map by simply appending icons."

4.2 Test Experiment

4.2.1 Experimental Method

In the test experiment, 20 university students used a route guide map created by the proposed system to find their way from Hankyu Takatsuki station to JR Takatsuki station. Subjects who had no prior knowledge of the area were selected. Subjects gathered at the Hankyu Takatsuki station and received the route guide map.

The usefulness of the map was evaluated based on the number which could have reached the destination within 15 minutes and a questionnaire. The evaluation items on the questionnaire are identical to those of the map creation experiment.

4.2.2 Experimental Results

The results of the test experiment is shown in Table 3 and Table 4.

Table 3 Number of subjects who reached the destination

Item	The number which could has reached	The number which could not has reached
(4)Arrival at destination	17 persons	3 persons

Table 4 Results of test experiment questionnaire

Questionnaire item	Average of evaluation
(5)Was the created map helpful?	4.1
(6)Would you want to use the created map again?	3.8

(4) Arrival at destination

Seventeen out of 20 subjects were able to reach the destination within 15 minutes.

(5) Was the created map helpful?

The average evaluation score was 4.1. A number of reactions to the map were positive. The subjects who were able to arrive at the destination stated that "the route and destination were intelligibly displayed on the map." The subjects who could not reach the destination stated that "more landmark were needed."

(6) Would you want to use the created map again?

The average evaluation score was 3.8. Positive statements about the map were "The system is convenient because new guide maps can be created for different purposes." and "Creating maps using the system is fun."

5 Considerations

The proposed system for producing route guide maps could realize the following:

・Reading of the Digital Map 2500

・Deletion of unnecessary map information

・Transformation of the map form based on the cognitive map

・Customization of the map placing icons on maps

Moreover, the following two points were confirmed experimentally:

・Route guide maps can be created easily.

・The created map is useful in guidance.

From the above results, it is clear that the system is effective for creating route guide maps.

6 Conclusions

The proposed system allows anyone to create effective route guide maps easily and without special technology or special apparatuses. In the proposed system, the time and cost of route guide map creation is reduced by using Digital Map 2500. Furthermore, effective simplification of a map was carried out by taking the human cognitive map into consideration.

The experimental results confirmed that the proposed system was useful for creating route guide maps, and the created map is useful in guidance. This information is considered to be useful in traffic or city planning.

In the future, we will develop the system which can use the data of G-XML and GML. Moreover, we intend to investigate the development of a system which can be used on the Web.

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