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DYNAMIC LAYOUT ADJUSTMENT AND NAVIGATION FOR ENTERPRISE GIS BASED ON OBJECT MARK RECOGNITION

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ABSTRACT: In this paper a new method is developed to make a dynamic layout adjustment and navigation for enterprise Geographic Information System(GIS) based on object mark recognition. The extraction of object mark images is based on some morphological structural patterns, which are described by morphological structural points, contour property, and other geometrical data in a binary image of enterprise geographic information map. Some pre-processing methods, contour smooth following, linearization and extraction patterns of structural points, are introduced. If any special object is selected to make a decision in a GIS map, the all information around it will be obtained. That is, we need to investigate similar object enterprises around selected region to analyse whether it is necessary for establishing the object enterprise at that place. To further navigate GIS map, we need to move from one region to another. Each time a region is formed and displayed based on the user's focus. If a focus point of a map is selected, in terms of extracted object mark image, a dynamic layout and navigation diagram is constructed. When the user changes the focus (i. e. click a node in the navigation mode), a new sub-diagram is formed by dropping old nodes and adding new nodes. The prototype system provides effective interfaces that support GIS image navigation, detailed local image/map viewing, and enterprise information browsing.

KEY WORDS: layout; navigation; geographic information system; shape description and recognition; image processing

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1 INTRODUCTION

There are lots of Geographic Information Systems (GISs) that provide facilities for viewing and navigating GIS images(KOST, 1998; LAI and EADES, 1995) and there are also some systems that support enterprise information browsing. But there are a few systems for conveniently navigating and viewing both kinds of information. One of critical problems is how to develop effective interfaces for users to conveniently navigate and view both geographic images and enterprise information together. Also, to view GIS images/maps, current approach of using scrolling bars, windows (i. e. multi-views), zoom-in and zoom-out operations to show a huge GIS image is not convenient for the user's navigation, because it is difficult to obtain whole and detailed views of a huge image.

This paper presents an efficient method for dynamic layout adjustment and navigation for enterprise geographic information system based on object image recognition. The term "enterprise information" here refers to the information of those organizations that have geographically distributed branches, including each branch's resources (e. g. personnel) and product sales record. The information can be used for decision support on establishing (or closing) a branch or restructuring a branch (e. g. increasing/decreasing personnel) based on the operation record in a region. The diagram of the system processing is shown in Fig. 1.

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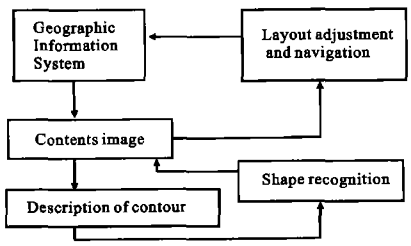


Fig. 1 The diagram of system processing

2 EXTRACTION OF OBJECT MARK IMAGE

In order to know if an enterprise should be established in a suitable site or not, the decision makers have to research all related information that concerns GIS, especially all the same enterprises around the selected site in any area size. If there are many object mark images in a huge geographic map, we can find how many object mark images are in each given region of a huge geographic map based on the pattern recognition of image processing. Our approach is a new method of structure recognition, that is, the description of shape is based on some morphological structural points. Some preprocessing methods are used to extract a binary image of geographic map. Let the starting point of image be the upper-left corner. The k-th contour of a binary image is represented as:

$$C_k = \{c_0, c_1 \ldots c_i, \ldots c_{n-1}, c_n\} \quad (1)$$

where C_k is the direction chain code set of contour k, and i is the index of the contour pixels. The difference code is defined as:

$$d_i = c_{i+1} - c_i \quad (2)$$

In the smoothed contour, d_i equals 0 or 1 (YU and YAN, 1997).

The smoothed contour can be converted to a set of line that consists of ordered pixels. Suppose that the direction chain code set of the smoothed contour is

$$c^l[i] \quad (i = 0, \ldots (n^l - 1)) \quad (3)$$

where l is the l-th line of a smoothed contour and n^l is the number of points of the l-th line.

A linearized line has the following property (YU and YAN, 1997): if

$$d_{ij} = c^l[i] - c^l[j] \quad (i = 0, \ldots n^l - 1), \quad (j = 0, \ldots n^l - 1) \quad (4)$$

then

$$|d_{ij}| \leqslant 1 \quad (i = 0, \ldots n^l - 1), \quad (j = 0, \ldots n^l - 1) \quad (5)$$

Therefore a linearized line contains only two elements whose chain codes meet Equation (5). These linearized lines need to be merged or split, and new linearized lines and their critical starting points are extracted based on their linearity, length and curvature.

Furthermore, the morphological structural points (critical points) are extracted based on extending Freeman codes and their difference codes. The extending Freeman codes are defined as the average code of a linearized line, and it is represented as $C_e{}^l$.

$$C_e{}^l = \sum_{i=0}^{n-1} c^l[i] \quad (6)$$

The definition of different structural points is based on pattern models (as shown in Fig. 2) and extending Freeman codes between two neighbouring linearized lines, and sixteen different characters in these figures are used to represent these structural points (YU and YAN, 1997).

These structural points are the convex point in the code 4 ("^"), the concave point in the code 4 ("m"), the concave point in the code 0 ("$"), the convex point in the code 0 ("v"), the convex point in the code 6 ("["), the concave point in the code 6 ("]"), the convex point in the code 2 (")"), the concave point in the code 2 ("("), the convex point in the code 5 ("F"), the concave point in the code 5 ("f"), the concave point in the code 1 ("O"), the convex point in the code 1 ("o"), the convex point in the code 3 ("T"), the concave point in the code 3 ("t"), the concave point in the code 7 ("S"), and the convex point in the code 7 ("s") (YU and YAN, 1997). The structural points describe the convex or concave change in different chain code directions along the contour (YU and YAN, 1997). For example, points "^" and "m" represent the convex and concave changes in the chain code 4 for the linearized lines respectively (Fig. 2). They can therefore be used to represent the morphological structure of a contour region (HU and YAN, 1996; MUSSELMAN, 1998; YU and YAN, 1997; YU and YAN, 1998).

For example the original object mark images are shown in Fig. 3a and Fig. 4a, their smoothed followed contours are shown in Fig. 3b and Fig. 4b and extracted structural points in Fig. 3 and Fig. 4 are represented with character which are defined based on the pattern models in Fig. 2.

Some shape structural rules can be got based on the series of structural points of shape contours, contour properties (being outer contour or inter contour and their geometrical position) and the geometrical position of structural points. Any shape can be divided into some basic shapes such as polygon, loop and wave shapes. Some basic shapes are described as follows:

Rule1: Octagon (Fig. 3)

(1) It consists of eight convex structural points, no

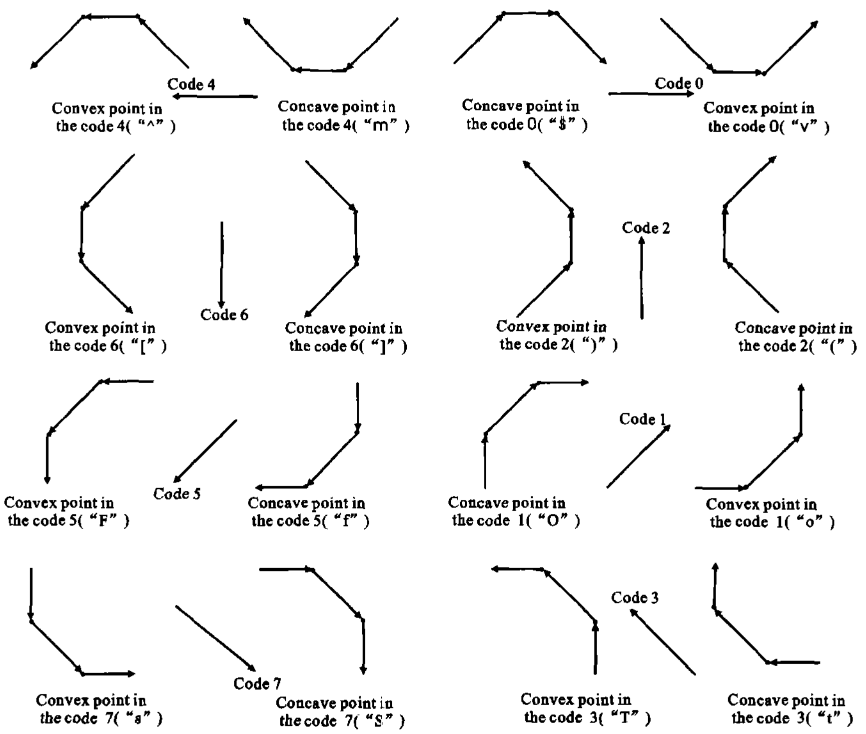


Fig. 2 The pattern models of structural points

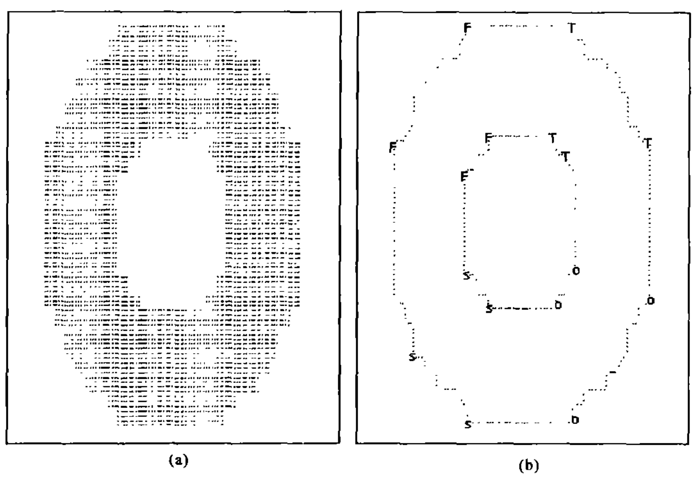


Fig. 3 The original image mark and its structural points of example 1

concave structural points and eight convex structural points are two "F", two "s", two "o" and two "T" in the series of structural points. There is a series of structural points, "F"→ "F"→ "s"→ "s"→ "o"→ "o" → "T"→"T".

(2) It has no inter contour.

(3) Different octagons are defined based on different groups together of lengths between two neighbouring structural points.

Rule2: Octagon loop (Fig. 3)

(1) It consists of two octagons, that is, it has an inter contour.

(2) Different octagon loops are defined based on different groups together of two octagons.

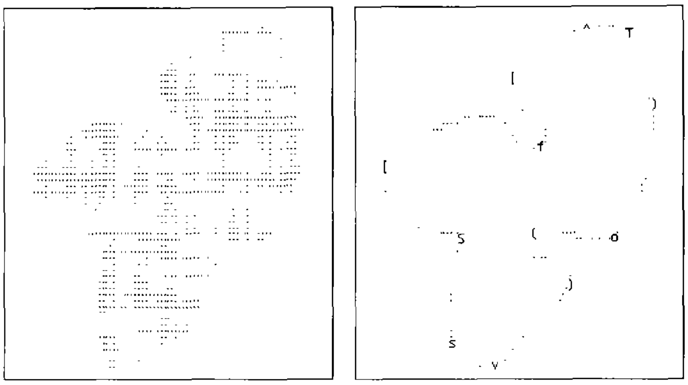
Rule3: The shape of digit 1

(1) It is an octagon.

(2) The lengths between structural points "F" and "s" and between structural points "o" and "T" are greater than that between other two neighbouring structural points.

Rule4: The shape of example 2 (Fig. 4)

(1) There is a series of structural points, "^"→ "["



(a) (b)

Fig. 4 The original image mark and its structural points of example 2

→"f"→"["→ "S"→"s"→"v"→ ")"→"("→"o"→ ")"→ "T".

(2) It can be divided into three polygons:

The first polygon consists of the series of structural points, "^"→"["→"o"→")"→"T", the second polygon consists of the series of structural points, "^"→ "[" → "v"→")", and the third polygon consists of the series of structural points, "^"→"s"→ "v"→")".

(3) There is no inter contour.

We can construct many rules to describe and recognize different shapes with their structural points based on priori knowledge and their morphological structure. Based on the above rules, the example 1 is an equal octagon. The shape of example 2 in Fig. 4 consists of three polygons, and there are three concave structural points ("f", "S" and "("). Therefore the binary object mark images can be found based on the above method.

3 DYNAMIC LAYOUT ADJUSTMENT AND NAVIGATION FOR ENTERPRISE GIS

The effective interfaces are developed to support GIS image navigation, detailed local image/map viewing, and enterprise information browsing. If any special object is selected to make a decision in a GIS map, the all information around it should be obtained. Especially all related mark images should be searched in any special region and some relations are set up. For example, we want to set up an object enterprise by selecting a place. We use this place as a central point to find a sub-GIS map as shown in Fig. 5. We need to investigate similar object enterprises around selected region to analyse whether it is necessary for establishing the object enterprise at that place.

To search similar object enterprises around selected region, we need to use the related mark image as a pattern. In this example we use the mark image shown in Fig. 4 as a pattern for scanning this map, six mark images have been found. We use arrows for pointing these six mark images in Fig. 5. In our prototype system, these mark images are flashed with red colour.

We use a graph for GIS image navigation. It is shown in Fig. 6. Each node in the graph represents a mark image. Each edge between two nodes represents a relationship between two nodes; it is represented as a neighbourhood relation. Each node is also related to the enterprise information in a region. The intention of using the graph for GIS image navigation is to give the user a global view of a huge GIS image and whole enterprise information.

The GIS user interface has three underlying views: a graph navigation view, an image layout view, and an enterprise information view. The graph navigation view shows a sub-graph corresponding to the current user's focused image displayed in the image layout view. The crossing line mark in Fig. 6 indicates our initial intention at that place to establish an object enterprise.

To further explore similar object enterprises around this region, we can navigate this graph by selecting a node in this graph to change the focus point. For example, if we select the node on the left-bottom of the graph, a new sub-GIS map is displayed (Fig. 7). The navigation graph is shown on the upper right to help the user track back to the original focus. After searching all surrounding areas by selecting the nodes in the graph, we can obtain the information of surrounding enterprises. In the mode of EnterpriseInfoShow, we can get enterprise information for each surrounding enterprise by selecting the corresponding node in the graph. The enterprise information can be shown with such information as population, sales records, distance between this node

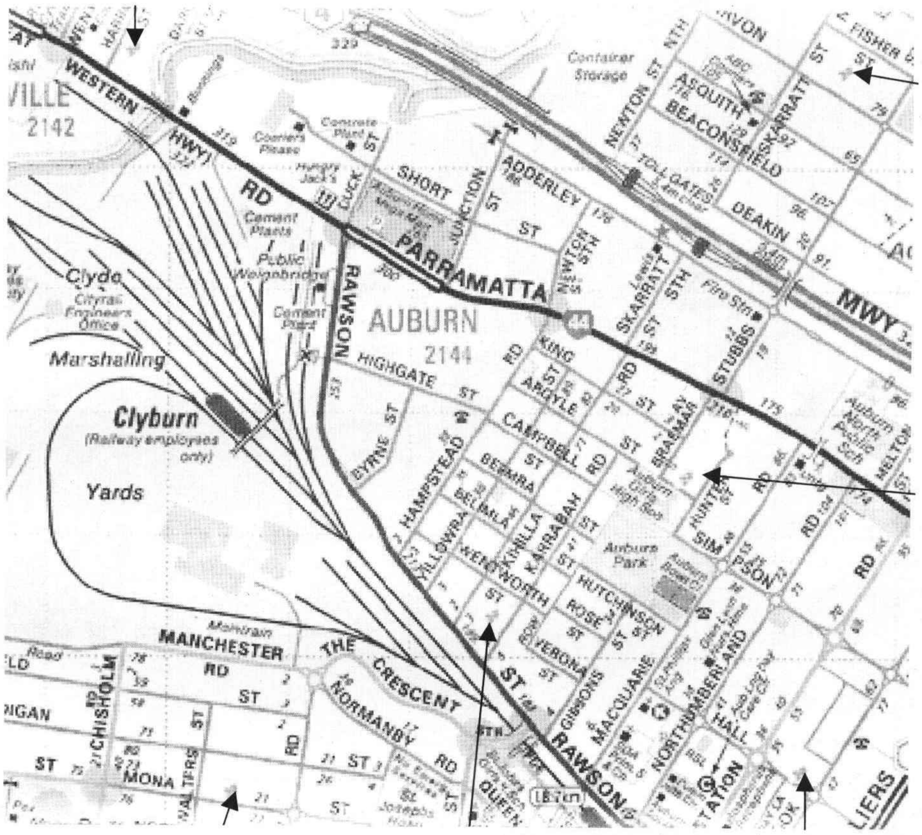


Fig. 5 A GIS map and its mark image

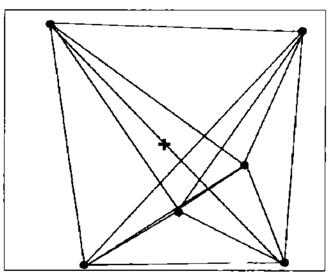


Fig. 6 The diagram of linked nodes based on the extracted mark images

and other nodes, and so on. This can help us to make a decision. That is, we can know whether the selected place is suitable for establishing an enterprise.

Three kinds of modes are provided in the graph navigation view: Navigation, ImageShow, and EnterprisInfoShow. In the mode Navigation, if the user selects a node, a new sub-graph with this node as its central node is displayed. In the mode ImageShow, when the user selects a node, the corresponding GIS image is shown in the image layout view. In the mode EnterprisInfoShow, after the user clicks a node, the corresponding enterprise information of an organization's branches in this region is shown in the enterprise information view, and the locations of the branches are highlighted in the image layout view. Thus, a decision may be made based on the above information. Also, each view has its own layout and layout adjustment operations. For example, the image layout view should provide some functions operating on its displayed image, such as zoom-in and zoom-out operations for image viewing.

The graph navigation view maintains the user's orientation for GIS image and enterprise information exploration and it also reduces the cognitive effort required to recognize the change of views. This is done by connecting successive displays of the subset of the graph and by smoothly swapping the displays via animation. In other words, a sub-graph is changed smoothly to another sub-graph during the user's navigation. This change from one subset to another should preserve the user's mental map (EADES *et al.*, 1991; 1995) for GIS image navigation. The navigation graph is based on the link direction between the selected node and the central node. We have developed a dynamic method on extending the CIGRAPH model (LAI and EADES, 1995) for GIS image navigation and giving a formal specifica-

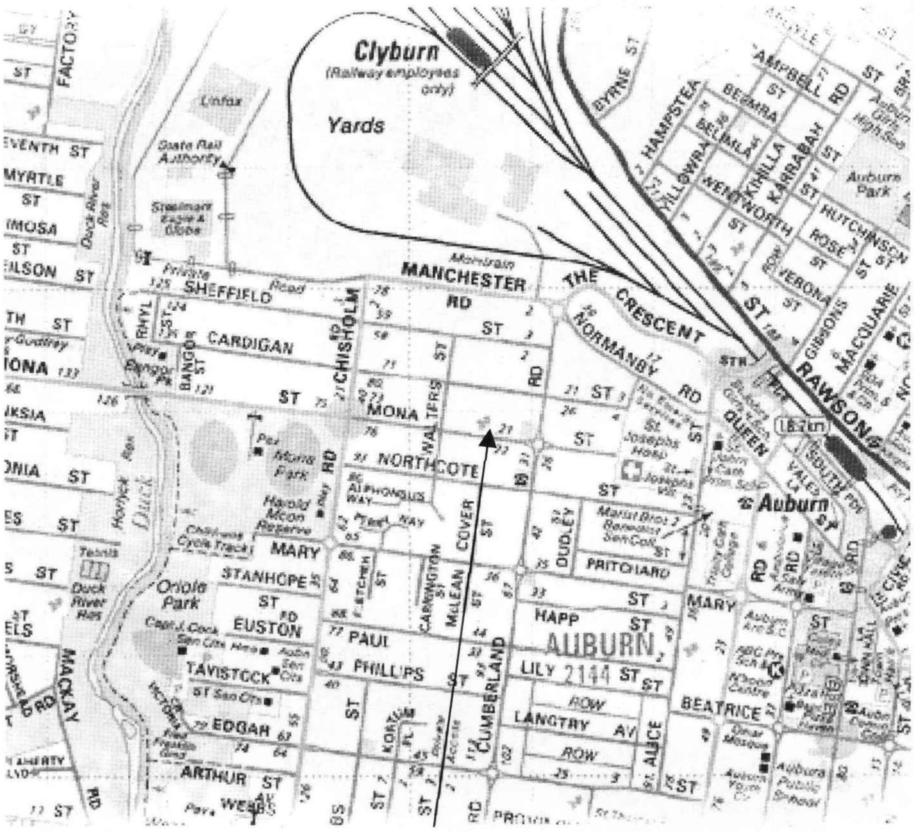


Fig. 7 The dynamic layout and navigation of decision processing

tion for the graph structure. The dynamic linkage mechanism can be set up among the logical part of the model, GIS abstract mark image areas and their connections, and enterprise information.

4 CONCLUSION

A new algorithm is developed to extract mark images in GIS map based on some morphological structural points, contour properties and geometrical features. We have developed dynamic methods for the communications among sub-graphs, GIS image views and enterprise information for a specific application. A site and its surrounding region size can be selected and changed in terms of enterprise strategy. A dynamic layout and navigation for Enterprise Geographic Information System is given based on the navigation graph which consists of mark images and three underlying views (a graph navigation view, an image layout view, and an enterprise information view). The method can be used for any special object decision which is related to GIS if there are mark images in GIS map.

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