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THE CONTOUR TREE - A POWERFUL CONCEPTUAL STRUCTURE FOR REPRESENTING THE RELATIONSHIPS AMONG CONTOUR LINES ON A TOPOGRAPHIC MAP

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Abstract: *This paper presents a method for recognizes the relationships between neighboring contours and utilizes the contour tree structure to establish topological relationships among the contour lines.*

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1. INTRODUCTION

Topography reflects the shape of the earth's surface and plays a very important role in shaping or mediating many other environmental flows or functions [1].

The contour lines is one of the most important mode to represent geomorphological information on analogical or digital maps. However, it is known that conversion from analogical format in vector data with automated algorithms is difficult task. Only the position of contour is got automated and elevation of contour lines to be input manually. One of the major processes is elevation assignment. The traditional approach is to manually identify elevation of contours from existing topographic maps. The last time looking for solutions to automate this process.

The contour tree is a automated approach that efficiently utilizes a minimum set of elevation information from the topographic maps to automatically identify the contour lines and create DEMs. Elevation and/or user input information includes spot heights and contour indexes. A conceptual model, in the form of a contour tree, is adopted to express the relationships of the contour lines, in particular the contour topology. The topology of contour lines is derived by examining their neighborhood relationships. A set of rules are employed to identify the contour tree. In this process, human-machine interaction will provide the relevant feedback messages to guide the operator to provide further information to continue the automated process.

2. CONSTRUCTING THE CONTOUR TREE

The algorithms for constructing the contour tree can be grouped into two kinds: the ones based on raster that employs image dilatation or erosion and the ones based on vector data which uses polygon in polygon test algorithm to determine the relation between contour lines [2]. However, both need much manual preprocessing that can be reduced further and cannot ensure the consistency when there are broken contour lines which is often appeared in topographic maps.

Is necessary that human operator to introduce a minimum set of elevation information to automatically construct the contour tree. Figure 1 illustrates the process flow of the proposed approach.

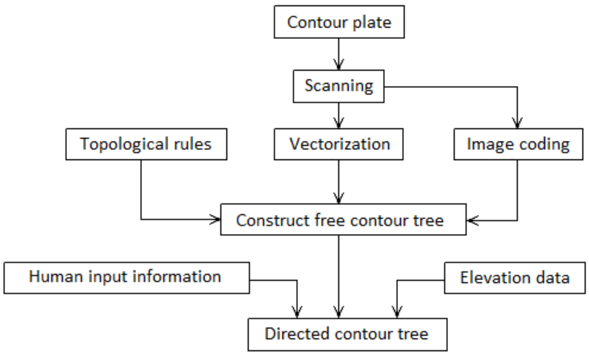

Fig. 1 Process flow of automated contour identification

In figure 1, a contour plate is produced for topographic map reproduction. It may be a negative or a positive, depending on the reproduction procedure, and is on large format developed film.

The tree structure is a graph with nodes and edges where nodes symbolize the contour lines and edges symbolize relationships among contour lines. A tree without any directional information is called a free tree, whereas a tree with contour elevations attached to the edges (thus providing directional information) is called a directed tree. An adjacency matrix can also be used to represent the same structure. The spatial relations of the contours shown in figure 2 can be mapped as the tree shown in figure 3.

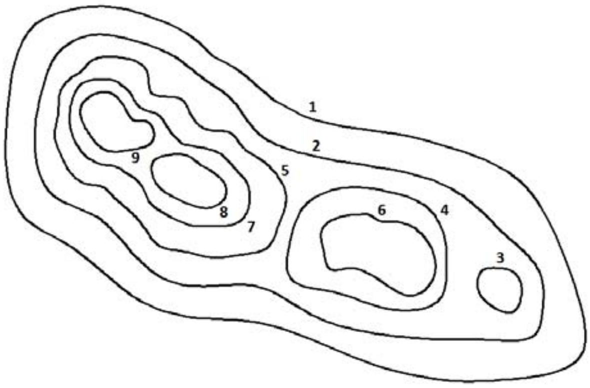

Fig. 2 A contour map

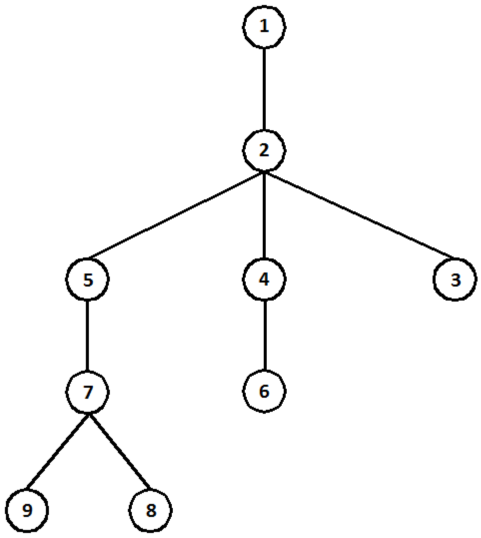

Fig. 3 The tree representation of the relations of contours line

The relative height ordering relationship between contour lines and inter-contour regions can be intuitively realized from the tree structure [3]. Each contour line may have many neighboring contours, but may have only one enclosing neighboring contour. A branch in a tree represents a divergence where there exist two or more contour lines of the same elevation that are enclosed by a common neighbor.

Free Contour Tree/Directed Contour Tree. A contour tree is called free if the edges values, namely the elevation and the direction to the next contour (up, down or same) are unknown. A tree is called a directed contour tree if those values are known. The direction of the elevation difference is based on the topological relationship of the neighboring contours.

Closed/Non-Closed Contour. A contour on a map is a set of points that have the same elevation (isoline) . If terrain is a continuous surface every contour line should be a closed line. In a raster image, closed line means that every pixel has at least one pixel connected in one of its four (eight) directions. When the contour line ends at the map edge, it will be "cut" and becomes a non-closed contour.

Neighboring Contours. When two contour lines are adjacent to each other, they are called neighboring contours. Neighboring contours can have two forms. One contour may contain the other. In such a case, two contours are closed contours and the outer contour contains the inner one. The elevation difference of these two contours is the equidistant contours. The other form of neighboring is that these two contours are separate. For example, a saddle consists of two separate but neighboring contours. The elevation difference of these two contours is zero.

Enclosing Contours. If contour A and B are closed contours. If A and B are neighboring contours, and if B is inside A, then A is enclosing B. If contour A encloses contour B, then the elevation of contour A is one equidistant contours lower than B. This property is used in determining the relative elevation differences between two closed contours.

Unique/Ambiguous. If the elevation value of a contour in a contour tree can be uniquely determined, it is called a unique contour. Otherwise it is an ambiguous contour. Once a contour is unique, its elevation can be used to aid defining elevation of neighboring contours.

Monotonic. If the elevations of a set of contour lines are step increasing/decreasing, this set of contour lines are called monotonically increasing/decreasing. When a branch is proved to be monotonic, the relative elevation differences among the contours in this branch becomes unique.

Key nodes. Higher degree nodes, by definition, have more than one connection to other nodes. In this case, the elevation of connected nodes can also be defined. Any saddle can be found in a tree where a node connects to at least two equal elevation nodes. These connected nodes are key nodes, too.

From a contour tree, many knowledge or information about the terrain can be obtained. The following items deduced from contour tree can be used to obtain some useful information about the terrain.

The number of nodes of the tree. This item represents the number of contour lines. When the area of contour map is given, the higher the number of contour lines at the more rugged terrain.

The number of leaf nodes. This item represents the number of local peaks or pits.

The level of the tree. This item represents the range of elevation. When the contour interval is given, the more levels of the tree, the more difference level of the terrain.

There are four basic rules that guide contour elevation ordering [4]:

a) Truncate rule (figure 4.1). The elevation of a closed contour, which has a spot height enclosed, is the truncated elevation of the spot height.

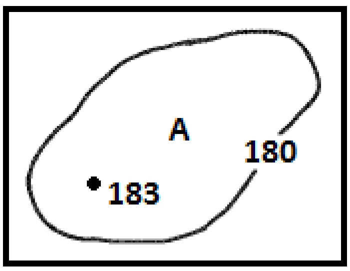

Fig. 4.1 Spot height rule

b) Equal height rule (figure 4.2). If two neighboring closed contour lines A and B are both enclosed by a common closed contour C, then A and B are of the same elevation.

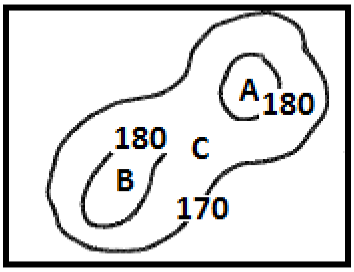

Fig. 4.2 Equal elevation rule

c) Enclosing rule (figure 4.3). If there exists two neighbored closed contours A and B, and if A is enclosing B, then elevation of B is one contour-interval higher than elevation of A. Note that in case of depression, which is symbolized with many regular short line segments perpendicular to the contour line, the elevation is one contour interval lower.

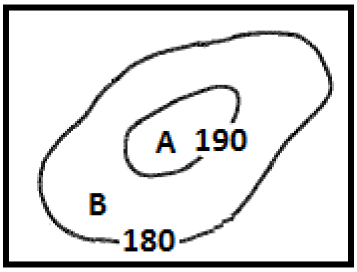

Fig. 4.3 Enclosing rule

d) Local peak rule (figure 4.4). A local peak has only one neighbor.

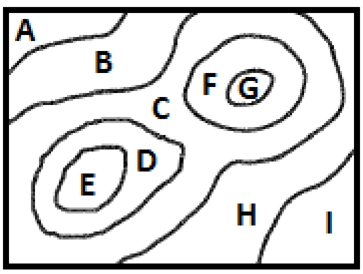

Fig. 4.4 Local peak rule

Contour labeling is basically an iterative process. In the first iteration, it starts at the most simplest contour relation such as the peak rule, enclosing rule, or equal elevation rule, to derive a unique solution for the contour. Unique solution means that the elevation of this contour can be uniquely defined. The second iteration will use the elevation derived from the first iteration and so on. A consistency check of the elevation is done at this level. A search path of the contour tree from a high elevation node to a low elevation node (or vice versa) supports the consistency check. Finally, unsolvable contours are highlighted at this level. Unsolvable contours are mostly caused by the non-closed nature of the contour.

3. CONCLUSIONS

A contour tree is a graphical tool for representing the topological relations of contour lines. From a contour tree, many knowledge or information about the terrain can be obtained.

After labeling and identifying contour lines with unique solutions, the system should be capable of highlighting ambiguous contours. For organizations that have large amounts of existing analogical maps and who wish to build a GIS, this approach provides a partially automated solution. This approach is able to establish height ordering for closed contours, whereas for non-closed contour, the topological rules are not applicable. The interaction between system and operator will guide the process until all contours are labeled.

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