

# PRELIMINARY STUDIES ON CONTOUR TREE-BASED TOPOGRAPHIC DATA MINING

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## ABSTRACT:

After many years of intensive investigation and mapping of the topography, a large number of topographic maps were produced by national mapping agencies. The explosive growth and wide availability of topographic data has created a data-rich environment for a variety of GIS users. How to make the best use of such topographic data has become a basic but daunting task. The research challenge now is to develop and use suitable approaches to discover new and interesting patterns, trends and relationships that might be hidden deep within the very large national topographic datasets. Among the digital topographic data, contour line is the most fundamental element. The shape and relationship of contour lines play a key role when human beings recognize topographic features from a contour map. A contour tree is a good graphical tool for representing the spatial relations of contour lines. In this paper, some preliminary researches are introduced, in which contour tree is used as a tool to find some implicitly information hidden in the contour lines that represent several typical kinds of landform. Firstly, the spatial relations of contours are classified as multi-order enclosure relation, parallel relation and multi-order disjoint relation, and tree method for representing spatial relations of contours are briefly introduced. Then, several items deduced from contour tree are analysed, i.e. the number of nodes, the number of leaf nodes, and the level of the tree. After comparing the values of these items of the trees of the contours representing mesa, loess ridge and Karst hill in 1:50 000 scale, some preliminary results are obtained which can be used to assist characterize the three landforms.

## 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 (Mark and Smith, 2001). After many years of intensive investigation and mapping of the topography, a large number of topographic maps were produced by national mapping agencies. These have been converted into digital formats in the last 20 years. How to make the best use of such topographic data has become a basic but daunting task. The research challenge now is to develop and use suitable computational tools to discover new and interesting patterns, trends and relationships that might be hidden deep within the very large national topographic datasets (Malerba et al., 2001).

The contour lines on the topographic maps play important roles in the process of human cognizing landform. When people read topographic map, they use different knowledge deduced from contour lines.

Among these knowledge, the spatial relations of contour lines play a key role when humans recognize topographic features from a contour map even without knowing the detailed elevation of the contours (Kweon and Kanade, 1994). A *contour tree* is a good graphical tool for representing the spatial relations of contour lines where contour lines are mapped as edges and interstitial spaces as nodes (Boydell and Reston, 1963; Freeman and Morse, 1967).

In this paper, some preliminary researches are introduced, in which contour tree is used as a tool to find some implicitly information hidden in the contour lines that represent several typical kinds of landform.

## 2. SPATIAL RELATIONS OF CONTOURS AND TREE REPRESENTATION

Thus far, there is still not a formal description of these relations. Based on spatial relation theory and the geometry characters of contour lines, Qiao (2003) classified the spatial relations of contours into three kinds, i.e. *k*-order enclosure relation, parallel relation

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and  $k$ -order disjoint relation. For instance, in Fig. 1, contour  $L_4$  1-order encloses  $L_3$ , and 3-order encloses  $L_1$ .  $L_2$  and  $L_5$  are the ‘children’ of  $L_4$ , which have parallel relation. In addition,  $L_1$  holds 1-order disjoint relation with  $L_3$ , and holds 2-order disjoint relation with  $L_6$ .

In order to model and represent the relationships among contour lines, in 1963 Boyell and Reston proposed a contour tree generated by mapping contour lines as edges and interstitial spaces as nodes (Boyell and Reston, 1963). This tree structure has found applications in many geo-science related areas, such as finding of terrain profiles (Freeman and Morse, 1967), automated labelling elevation of contours (Wu, 1993; Liu and Ramirez, 1995), modelling of topographic changes (Kweon and Kanade, 1994), automated reasoning with contour maps (Cronin, 1995), etc. The spatial relations of the contours shown in Fig.1 can be mapped as the tree shown in Fig. 2.

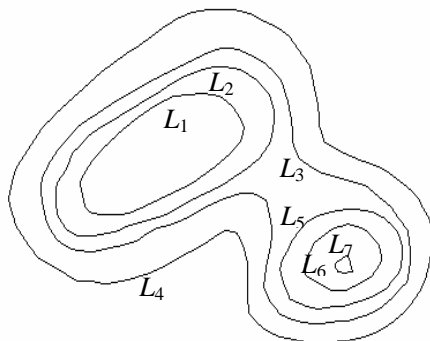


Fig. 1. A contour map.

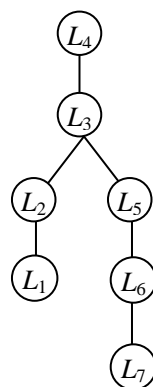


Fig. 2. The tree representation of the relations of contours shown in Fig.1.

To construct a contour tree, the identification of the enclosure relation is a crucial issue. There are some deficiencies in existing two methods, i.e. the point-in-polygon-based method and the region growing-based method. Chen et al. developed a new method for the computation of a contour tree using the immediate interior adjacency set ( $IAS_1$ ), which is based on the Voronoi 1-order neighbors (Chen et al., 2004).

### 3. CONTOUR TREE-BASED TOPOGRAPHIC DATA MINING

The interpretation of contour maps requires abstraction processes and deep domain knowledge that only human experts have (Cronin, 1995). Since the contour tree is a good graphical tool for representing the spatial relations of contour lines, the authors believed that it could serve to represent basic geographic facts and rules for deducing information from the very large national contour databases.

#### 3.1 Items deduced from contour tree

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.

4. The number of nodes of the tree

This item represents the number of contour lines. When the area of contour map is given, the bigger the number of contours, the less intact the terrain.

5. The number of leaf nodes

This item represents the number of local peaks or pits.

6. The level of the tree

This item represents the range of elevation. When the contour interval is given, the more the level, the more the range of elevation.

The values of these items can be used to discover new and interesting patterns, trends and relationships that might be hidden deep within the large topographic datasets.

#### 3.2 Preliminary test

In this section, a test is given in which the values of above items are used. In this test, contour maps portraying three kinds of landforms, a mesa, loess ridge and a Karst hill, are used. The contours, which are at the scale of 1:50,000 and are all 5km × 5km in size, were obtained from the National Geomatics Center of China (NGCC). The contour intervals are 20m, 20m and 40m, respectively. The immediate

interior adjacency set-based method is applied to the three contour maps. The trees generated are shown in Figs.3 to 5.

The statistical results of the contour trees corresponding to the three kinds of landforms shown in Figs.3 to 5 are shown in Table 1 and Fig. 6. It can be observed that the tree of the Karst hill has the largest values of all of the items, except for the item 'the level of the tree.' This indicates that the Karst hill is the most cracked of the three kinds of landforms. By contrast, the loess ridge is the most intact landform.

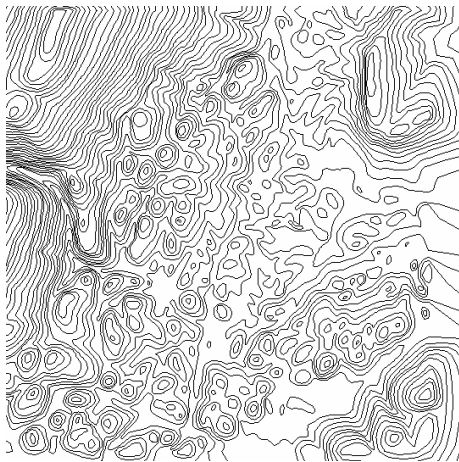


Fig. 3. Contour map of a mesa and the corresponding tree.

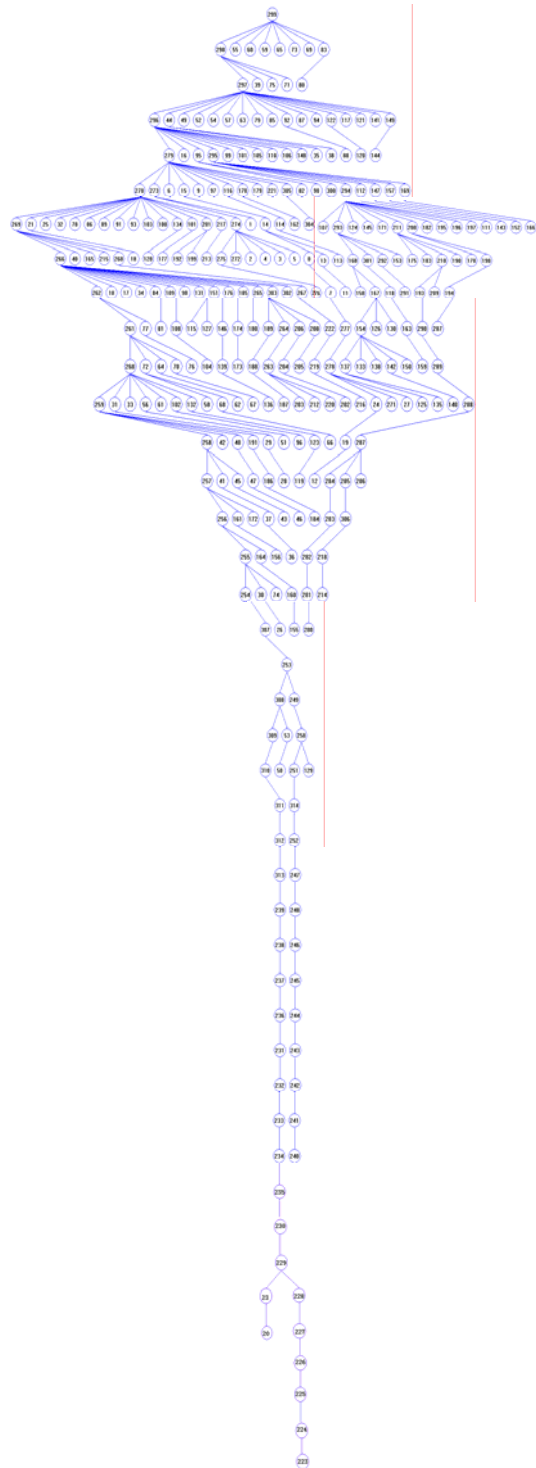


Fig. 3. (Continued).

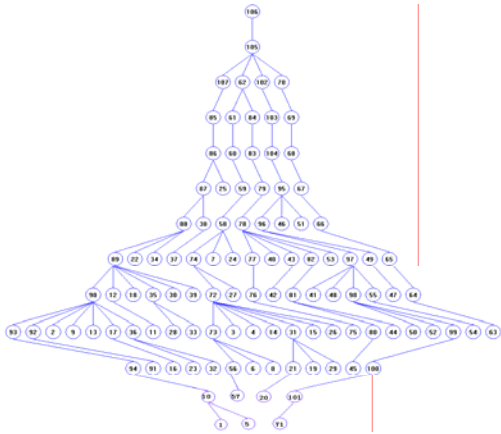
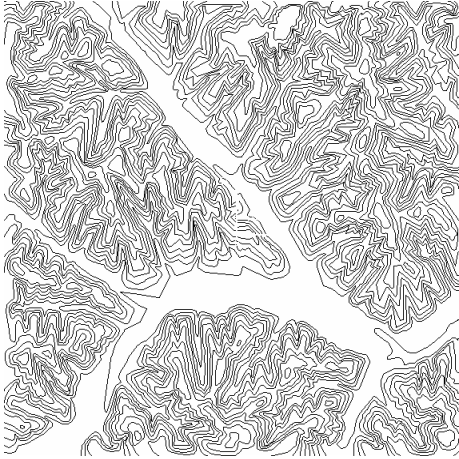


Fig. 4. Contour map of a loess ridge and the corresponding tree.

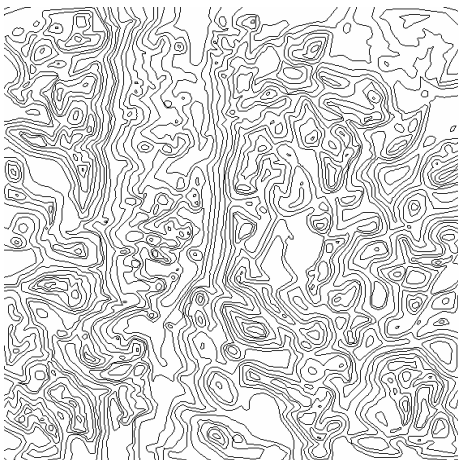


Fig. 5. Contour map of a Karst hill and the corresponding tree.

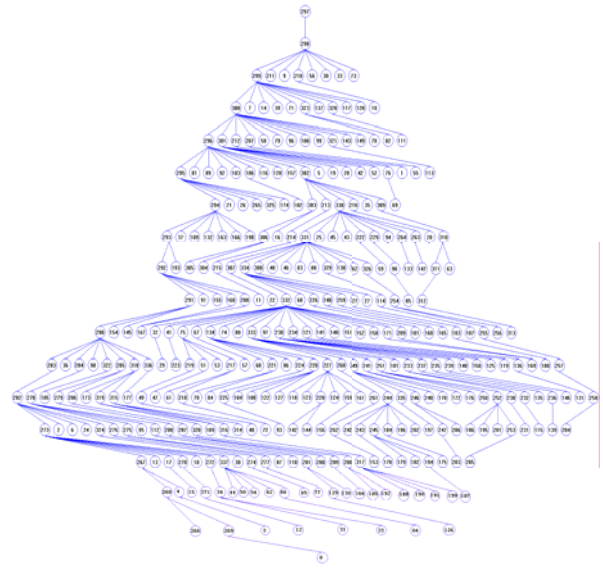


Fig. 5. (Continued).

Table 1. Statistical results of the contour trees of different kinds of landforms.

Landform Item	Level of the tree	Number of nodes	Number of leaf node
Mesa	42	314	152
Loess	13	107	48
Karst hill	18	337	193

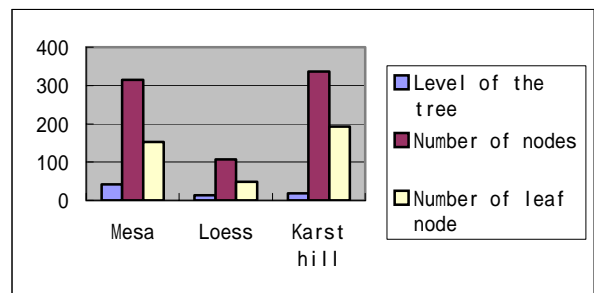


Fig. 6. Chart of the statistical results of the contour trees.

## 7. CONCLUSIONS AND DISCUSSIONS

A contour tree is a good graphical tool for representing the spatial relations of contour lines. From a contour tree, many knowledge or information about the terrain can be obtained. In this paper, several items deduced from contour tree, i.e. the number of nodes of the tree,

the number of leaf nodes, and the level of the tree, are used in the process of topographic data mining. The result of a preliminary test shows that contour tree is a good tool for topographic data mining.

However, there are still much to be done to better use contour tree in data mining. The data used in the test is limited. The result is qualitative and not quantitative. Further research into how a contour tree can be used in geographic knowledge-based applications such as landform classification is now being carried by the authors.

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