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Automatic Association of Stream Order for Vector Hydrograph using Spiral Traversal Technique

Mohan P Pradhan[1] and M K Ghose[2]
[1]*Department of CSE, Sikkim Manipal Univeristy, India*
[2]*Department of CSE, Sikkim Manipal Univeristy, India*

ABSTRACT: *In the field of RS and GIS, automated information extracted from topographic sheet or reference map plays a pivotal role in assisting researchers in performing various inferential analyses that aids in making qualitative as well as quantitative assessment of the features. Such automated procedures tremendously reduces time and effort requirement compared to that of traditional manual techniques. This work aims at associating stream order for vector hydrograph using spiral traversal technique that reduces time complexity from O(n2) to o(n).*

Keywords: *Digitization, Horton's stream order, Spiral Traversal, Stream, Vector hydrograph.*

I. INTRODUCTION

A stream net is the inter-connected drainage pattern formed due to flow of drainage system over a terrain. These patterns have several identifiable features such as junction, interior link and exterior link. A junction is a point in drainage system where two streams meet. A link is an unbroken stretch of the river between two junctions. An exterior link is link between the source and the first junction where as all other links are interior links.

Quantitative analysis of the stream network with Horton [1] was done in order to perform comparison among different drainage basin and to establish relationship between different aspects of drainage system. It has been observed that manual extraction of rivers from topographic sheet demands greater effort and times as well as confidence of the results obtained through these procedures are often unreliable. This work focuses on developing an efficient procedure for associating each stream with Horton orders in the river pattern.

II. STREAM ORDERING

Strahler's ordering for the detected segment is done to ease the process of ordering using Horton's Scheme. It also helps in determining the main outlet segment and determines the maximum order in the drainage pattern. In Strahler's [2] system, the headwater streams that receive no tributary are first order systems. Two first order streams meet to gives a second order stream. Two second order streams meet to give a third order and so on. When two streams of different order meets, the combined stream retains the order of the higher order stream.

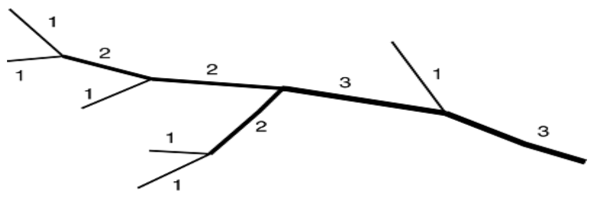


Fig 1: Strahler's ordering system.

After the Strahler's ordering, the segment with highest order was taken which then proceeds for Horton's ordering. According to Horton, the main stream in the river net should be denoted by the same order number all the way from its mouth to its headquarters. Thus, at every junction where the order change, one of the lower order streams is renumbered to the higher order and the process repeated. It can be immediately realized that a certain amount of subjectivity is involved in the ordering of streams according to Horton's method.

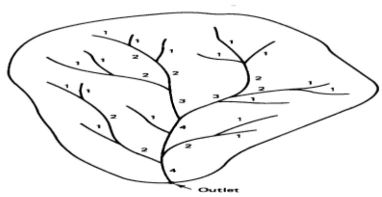


Fig 2: Horton numbering system

III. RELATED WORK:

Very few research has been carried out in past for automatic digitization even though it consumes most of the time in field of Remote sensing and GIS application. More work are focused on extraction of drainage pattern from topographical maps automatically [3, 4] but association of attribute to vector hydrograph also plays important role in remote sensing application for example study of river morphology, forestry, fisheries etc. Gleyzer et al. [5] have proposed recursive stream ordering framework for vector hydrography for braided river pattern. Their method have presented linear stream ordering procedure. Ratika et al. have used recursive graph based method to traverse a dentritic river pattern for assigning Strahler's ordering to each stream. Their method requires starting point to be fed by the user for the traversal and was applicable only for dendritic river pattern [6]. Suzanne et al. have come up with NHDplus SCSV solution for calculation of Stream Order for the drainage systems [7].

IV. METHODOLOGY USED

In this paper a novel approach of spiral traversal for vector hydrograph is suggested where each streams is characterized by the attribute vector (start, end, length, order, bifurcation ratio, length ratio). The various attribute are defined by

- *Start*: Location in vector hydrograph form where the stream starts
- *End*: Location in vector hydrograph to which the stream ends
- *Length (L)*: Length of the stream.
- *Order (u)*: *it* is a measure of the relative size of streams.
- Bifurcation ratio:

It is defined as the number of streams of order u divided by number of streams of order (u-1), i.e. N_u / N_{u+1}.

- Horton's Length ratio:

It is defined as the ratio of mean length of the streams of order *u* and *u-1* i.e. L_u^* / L_{u-1}^*, where $L_u^* = L_u/N_u$.

Spiral Traversal Technique:

The traditional traversal technique use to exhaust the data set to be traversed in a row major fashion i.e. in order to traverse a Two dimensional array of size n * m both O(f) and o(f) would be m*n. On analyzing the input set pertaining to a river pattern it was observed that the leaf or the peripheral streams were oriented in a manner that it converges inwards, hence here the traditional technique would prove ineffective.

In order to overcome this lack of traditional technique this work proposes a traversal technique based on spiral model that exhaust row column in sequence either in clock wise and anti clock wise direction till the center coordinate is not reached. In this case the O(f) would remain the same that is m *n, o(f) can be much less than m * n.

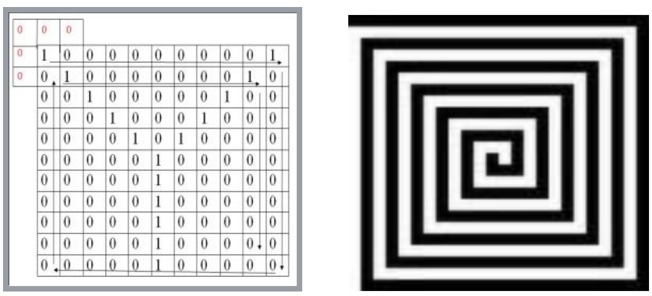


Figure 3: Spiral Traversal Technique

Here in this process in order to perform complete traversal, the data set to be traversed was made an odd order matrix by appending additional rows and columns if required.

This process has four sub modules

Traverse right, Traverse down, Traverse left, and Traverse up

Traverse right

This process was used in order to traverse right by keeping the row intact and incrementing the column by one until and unless a significant value is not encountered or the column bound is not reached.

Traverse down

This process was used in order to traverse down by keeping the column intact and incrementing the row by one until and unless a significant value is not encountered or the row bound is not reached.

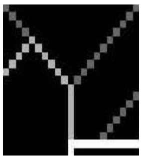
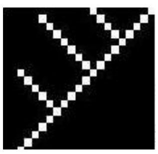
Traverse left

This process was used in order to traverse left by keeping the row intact and decrementing the column by one until and unless a significant value is not encountered or the column bound is not reached.

Traverse up

This process was used in order to traverse up by keeping the column intact and decrementing the row by one until and unless a significant value is not encountered or the row bound is not reached.

Table1: Association of Stream order and attribute for Vector Hydrograph

Input Image	**Output Image**	**Sl. No.**	**Segment**	**Count**	**Order**	**Bif. Ratio**	**H.L. ratio**
		1	(0,0),(1,1),(2,2),(3,3),(4,4)	5	1	1.0000	0.8696
		2	(0,20),(1,19),(2,18),(3,17) (4,16),(5,15),(6,14),(7,13) (8,12),(9,11), (10,10)	11	1	1.0000	0.8000 0
		3	(11,20),(12,19),(13,18), (14,17), (15,16),(16,15), (17,14)	7	1	-	-
		4	(17,20),(17,19),(17,18), (17,17),(17,16),(17,15), (17,14)	7	3	-	-
		5	(20,10),(19,10),(18,10),(17,10)	4	3	-	-
		6	(8,0),(7,1),(6,2),(5,3),(4,4)	5	2	-	-
		7	(17,14),(17,13),(17,12),(17,11) (17,10)	5	3	-	-
		8	(17,10),(16,10),(15,10),(14,10) (13,10),(12,10),(11,10),(10,10)	8	3	-	-
		9	(4,4),(5,5),(6,6),(7,7),(8,8), (9,9),(10,10)	7	2	-	-
		1	(0,12),(1,13),(2,14),(3,15), (4,16)	5	1	0.3333	0.7949
		2	(0,20),(1,19),(2,18),(3,17), (4,16)	5	2	-	-
		3	(20,0),(19,1),(18,2),(17,3), (16,4),(15,5),(14,6),(13,7)	8	2	-	-
		4	(1,5),(2,6),(3,7),(4,8),(5,9), (6,10),(7,11),(8,12)	8	1	-	-
		5	(8,2),(9,3),(10,4),(11,5),(12,6), (13,7)	6	2	-	-
		6	(4,16),(5,15),(6,14),(7,13), (8,12)	5	2	-	-
		7	(13,7),(12,8),(11,9),(10,10), (9,11),(8,12)	6	2	-	-
		8	(8,12)	1	2	-	-

On traversing in either direction in 4 neighborhoods if a significant value is encountered that had not yet been traversed, then the encountered significant value is considered to be the leaf. Once a leaf is encountered the leaf is traversed until an intersection is encountered. Moment an intersection is encountered the information of the traversal is stored in a data structure and then the initial spiral traversal resumes. At the end of spiral traversal all the leaf nodes are detected and their information is stored in the data structure. In order to efficiently use the storage, this process implements a jazzed array in order to store the information of the various leaf as the segment length are not same.

Determining Strahler's order

Upon identifying all 1 order streams, Strahler's stream order 1 is assigned to each. The entries in the jagged array holding 1 order streams having same termination vertex represents an intersection. All such intersections are detected and then each of the intersection is traversed till further intersection is encountered or any of the four bounds is reached. Upon identifying all 2 order streams, Strahler's stream order 2 is assigned to each. The process of traversing the intersection is repeated for higher order streams until and unless all the streams are detected.

Determining main stream

At the end of the previous process we will be able to determine the main stream along the drainage pattern by selecting the stream segment that has the Strahler's order.

Determining length of segment

The jagged array used for maintaining the segment information can be used for determining the length of the segment. As it keeps track of the coordinate pattern, this coordinate count will be the length of the segment. The actual length of the river segment can be determined by finding the product of the coordinate count and the resolution of the topographic map.

Determining Horton's order

Upon encountering the main stream in the drainage pattern the Horton ordering scheme assigns highest order and traverses backwards. On encountering an intersection either of the intersecting segment may be continued with the same order and the remaining intersecting segments are assigned order one less than the order of the main stream. This process is repeated recursively until and unless the leaf segments are reached.

V. RESULTS AND DISCUSSION

In this section the proposed technique is used to digitize vector hydrograph is shown in Table 1 given below. Each table has input images and output image hydrograph and its attribute fed automatically to the database. In output images, each of the streams are assigned unique color code to represent Horton's order.

VI. SUMMARY AND CONCLUSION:

Association of stream order in vector hydrograph is tedious and time consuming task. This paper suggests a novel approach to locate streams in vector hydrograph and assigns orders to it. In addition to order information it also maintains database for other attribute like bifurcation ratio, length, length ratio etc. The time complexity of proposed traversal scheme is minimized to o(n).

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