AUTOMATIC TECHNIQUES FOR IDENTIFICATION OF MINUTIAE'S IN MORPHOLOGY STUDY OF TERRAIN

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Abstract:

Morphological aspect of a terrain hosts different categories and different types of patterns. These patterns are represented in different color code for visual interpretation. These patterns are referred to as minutiae's. These identified minutiae's play pivotal roles by assisting researchers in making qualitative assessment of the terrain during various purpose specific inferential studies related to it. This work aims at design and implementation of efficient and effective procedures that assists researchers in extracting minutiae's from a reference data. In this work the reference data taken into consideration is a skeletonized binary images hosting the minutiae's.

Keywords: Minutiae, Morphological Aspect, Color Code, Reference Map, Visual Interpretation

1. Introduction

Minutiae's are different types of elementary morphological element contributing to different types of morphological features. Minutiae's are extensively used in finger print recognition system, retina identification system and GIS applications to name a few. It becomes very important to capture information regarding these elementary elements for performing qualitative assessment of subject of interest.

These elementary elements or better known as minutiae's can be of various categories and various types. The categories includes lines, bifurcations, enclosures, points and cross over's. It has been often observed that traditional way of manually extracting these minutiae's is highly ineffective and inefficient time consuming as well as the confidence of the results obtained is very poor and are often unreliable. This work focuses on developing efficient and effective procedures for identifying these minutiae's.

2. Minutiae's

There are various categories of minutiae:

Lines- Line better known as Ridge is linear feature that runs in the morphological terrain. Ridges in morphological study of terrain can be used for identification of contours, rivers and water bodies etc. There are different types of ridges namely

- *Complete Ridge* - Complete ridge is a ridge that runs through the terrain i.e. it starts from either of the edges and ends at the other, it can start and end in the same edge as well.
- *Ridge Ending* - Ridge ending is a ridge that starts at either of the edges but ends at a coordinate position that fall into neither of the edges.
- *Ridge Enclosure* - Ridge enclosure is a ridge that slits and again joins.
- *Short Ridge* - Short ridge is a ridge that starts and ends at non edge coordinates.

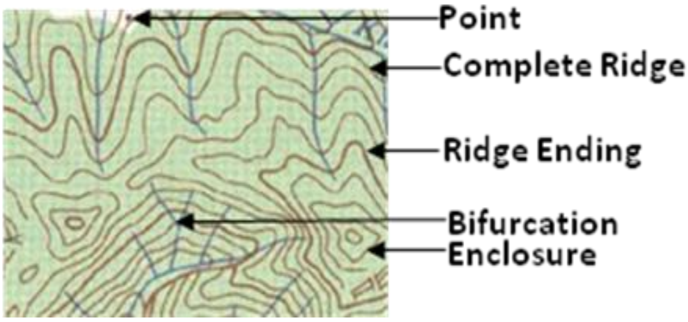

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Figure 1: Types of Minutaie's in topographical maps.

Bifurcations- Bifurcation or slit is a division of a ridge into two or more ridges. Bifurcation in morphological study of terrain can be used for identification of river convergence and divergence etc.

Enclosures - Enclosure or Island is a ridge that starts and ends at same point. Enclosure in morphological study of terrain can be used for identification of closed contour etc. An enclosure with a ridge extension is referred to as a lake.

Point - Point or dot is a feature that starts and ends at same coordinate without intermediate coordinates. Points in morphological study of terrain can be used for identification of landmark etc. Figure 1 shows the various types of ridges in a morphological pattern.

3. Related Work

Research on minutiae extraction is very popular in applications like finger print and face recognition algorithm to identify features like ridge termination or bifurcation for fast recognition. There are various techniques for extracting minutiae from skeleton of the images - thinned or un-thinned images (Roli Bansal, 2011).

Zhixin Shi et al. (2006) have used chain code processing based methods to extract finger print minutiae where the contour is traced counter clockwise and expressed as array of elements. Zenzo et al. (1996) and Hwan (2005) have used run based methods for fast minutiae extraction based on horizontal and vertical run length encoding scheme that does not require image skeleton of sing pixel width. Gamassi (2005) have proposed local pixel analysis based method based on average of pixel value in navigating square mask to decide upon minutiae as bifurcation or ridge termination.

Large number of research for minutiae extraction are based on the concepts of crossing numbers. Rutovitz crossing number (1996) is used to identify isolated points, ending point connective point, bifurcation and crossing point. However, this method requires skeleton of one pixel width. Zhao et al. (2007), Raju et al. (2012) and Iwasokun et al. (2011) have used Rutovitz crossing number to extract minutiae from finger print images .

4. Methodology Used

The schema used for minutiae’s extraction is shown in Figure 2. Extraction of feature in this work has been done by using thresholding technique taking into consideration the pixel intensity of feature of interest. The entire pixel within the range specified were set to a binary one and others were set to zero. Then morphological operators are applied to these patterns in order to thin it. After thinning the extracted patterns are represented using single pixel width. These single pixel width features are used for identifying different minutiae’s. In this work there are five identifiable modules namely:

- Design of an effective data traversal scheme
- Line (or ridge) detection
- Bifurcation detection

- Enclosure detection
- Identification of holes in an enclosure
- Identification of lakes
- Island or Point detection

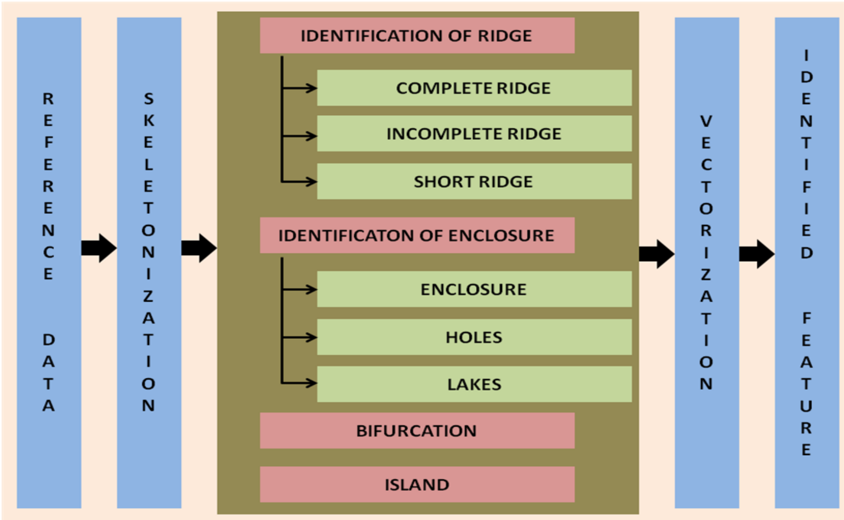


Figure 2: Proposed Schema for Minutiae's Extraction.

4.1 Design of an effective data traversal scheme

Before identifying the minutiae's it was important to design a scheme that is more effective than traditional row column traversal. This work implements a spiral traversal scheme that exhausts the data set in a clock wise direction. The advantages of this technique are that

- It aids in determining ridge ending effectively.
- The minutiae's may be detected in between 1 to O(n2) instead of O(n2) in case of row column approach. Upon encountering a significant value (i.e. 1) on traversing spirally, this one is traced using a mask of order three.

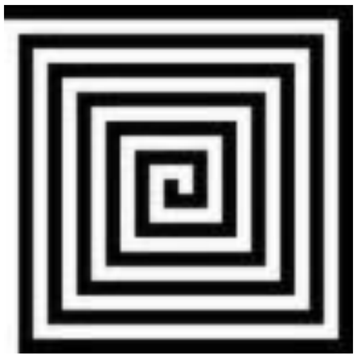


Figure 3: Spiral Traversal Technique.

The spiral traversal process resumes after the feature is identified. This process terminates after reaching the coordinates where the diagonal meet.

4.2 Line (or ridge) detection

While navigating the reference data spirally if a significant value (i.e. 1) is encountered

Complete Ridge

- In any of the four boundaries then the spiral traversal is put to halt temporarily and a recursive process is initiated that navigates the neighbor of the significant value till the terminating point is encountered. If the terminating point also is in any of the four boundaries then this feature is classified as complete ridge.

Ridge Ending

- Case 1: in any of the four boundaries then the spiral traversal is put to halt temporarily and a recursive process is initiated that navigates the neighbor of the significant value till the terminating point is encountered. If the terminating point is not in any of the four boundaries then this feature is classified as incomplete ridge.
- Case 2: in none of the four boundaries then the spiral traversal is put to halt temporarily and a recursive process is initiated that navigates the neighbor of the significant value till the terminating point is encountered. If the terminating point is in any of the four boundaries then this feature is classified as incomplete ridge.

Short Ridge

- In none of the four boundaries then the spiral traversal is put to halt temporarily and a recursive process is initiated that navigates the neighbor of the significant value till the terminating point is encountered. If the terminating point is not in any of the four boundaries then this feature is classified as incomplete ridge.

4.3 Bifurcation

While navigating the reference data spirally if a significant value (i.e. 1) is encountered then the spiral traversal is put to halt temporarily and a recursive process is initiated that navigates the neighbor of the significant value until a situation is encountered when there exist more than one neighbor that are not traversed. This point is considered to be the bifurcation point.

If the bifurcation later joins again then it will be classified as an enclosure and not bifurcation.

4.4 Enclosure detection

While navigating the reference data spirally if a significant value (i.e. 1) is encountered then the spiral traversal is put to halt temporarily and a recursive process is initiated that navigates the neighbor of the significant value until a situation is encountered when the starting coordinate is encountered as the next neighbor. This process is also capable of identifying lakes that might present in the reference data.

Most of the enclosure tracking algorithm implemented are either not capable of identifying the holes within an enclosure or does identify with greater complexity (such as, triangulation, minimum distance, interval scaling to name a few). One of the most significant achievement of this process is that it is efficiently identifies the holes. This has been possible because of the spiral scheme designed for data traversal. Hence with no additional complexity involved the holes can be detected.

4.5 Point or Island Detection

While navigating the reference data spirally if a significant value (i.e. 1) is encountered then the spiral traversal is put to halt temporarily and a recursive process is initiated. If the number of traversal is less than or equal to two nodes then this feature is classified as point or an island.

5. Results

For the proposed methodology, binary thinned image of the various feature in topographic map are considered for minutaie's extraction. These features are ridges, enclosures (holes and lakes), bifurcation and island. Figure 4-6 shows the results obtained for various test cases. Minutaie's and its location are also saved for vectorization of raster topographic maps.

A. IDENTIFICATION OF RIDGES AND ISLAND

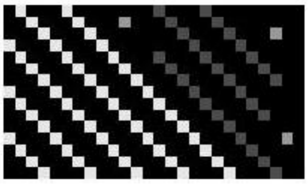
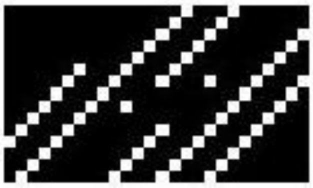
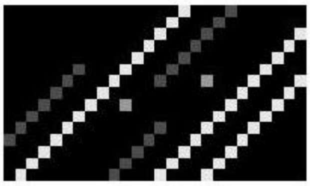
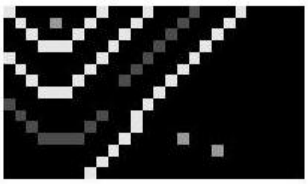
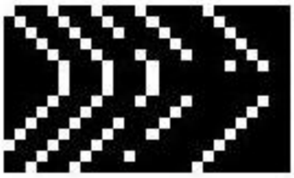
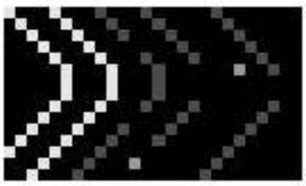
INPUT	OUTPUT	PATTEN EXTRACTED		
		START	**END**	**INTERMEDIATE**
		**COMPLETE RIDGE**		
		(0,1)	(14,15)	(1,2) (2,3) (3,4) (4,5) (5,6) (6,7) (7,8) (8,9) (9,10) (10,11) (11,12) (12,13) (13,14)
		(0,5)	(14,19)	(1,6) (2,7) (3,8) (4,9) (5,10) (6,11) (7,12) (8,13) (9,14) (10,15) (11,16) (12,17) (13,18)
		(14,11)	(3,0)	(13,10) (12,9) (11,8) (10,7) (9,6) (8,5) (7,4) (6,3) (5,2) (4,1)
		(14,7)	(7,0)	(13,6) (12,5) (11,4) (10,3) (9,2) (8,1)
		(14,3)	(11,0)	(13,2) (12,1)
		INCOMPLETE RIDGE		
		(0,13)	(9,22)	(1,14) (2,15) (3,16) (4,17) (5,18) (6,19) (7,20) (8,21)
		(0,17)	(6,23)	(1,18) (2,19) (3,20) (4,21) (5,22)
		(14,23)	(4,13)	(13,22) (12,21) (11,20) (10,19) (9,18) (8,17) (7,16) (6,15) (5,14)
		ISLAND OR A POINT		
		(1,10)	(1,10)	-
		(11,24)	(11,24)	-
		(2,23)	(2,23)	-
		**COMPLETE RIDGE**		
		(0,15)	(14,1)	(1,14) (2,13) (3,12) (4,11) (5,10) (6,9) (7,8) (8,7) (9,6) (10,5) (11,4) (12,3) (13,2)
		(2,25)	(14,13)	(3,24) (4,23) (5,22) (6,21) (7,20) (8,19) (9,18) (10,17) (11,16) (12,15) (13,14)
		(6,25)	(14,17)	(7,24) (8,23) (9,22) (10,21) (11,20) (12,19) (13,18)
		INCOMPLETE RIDGE		
		(0,19)	(6,13)	(1,18) (2,17) (3,16) (4,15) (5,14)
		(14,9)	(10,13)	(13,10) (12,11) (11,12)
		(11,0)	(5,6)	(10,1) (9,2) (8,3) (7,4) (6,5)
		ISLAND OR A POINT		
		(6,17)	(6,17)	
		(8,10)	(8,10)	
		**COMPLETE RIDGE**		
		(0,0)	(0,8)	(1,1) (2,2) (3,3) (3,4) (3,5) (2,6) (1,7)
		(0,12)	(4,0)	(1,11) (2,10) (3,9) (4,8) (5,7) (6,6) (7,5) (7,4) (7,3) (6,2) (5,1)
		(0,20)	(15,0)	(1,19) (2,18) (3,17) (4,16) (5,15) (6,14) (7,13) (8,12) (9,11) (10,11) (11,10) (12,9) (13,8) (14,7) (15,8) (16,7) (17,6) (18,5) (18,4) (18,3) (17,2) (16,1)
		INCOMPLETE RIDGE		
		(0,16)	(6,10)	(1,15) (2,14) (3,13) (4,12) (5,11)
		(8,0)	(9,8)	(9,1) (10,2) (11,3) (11,4) (11,5) (11,6) (10,7)
		ISLAND OR A POINT		
		(1,4)	(1,4)	
		(12,18)	(12,18)	
		(11,15)	(11,15)	
		**COMPLETE RIDGE**		
		(0,0)	(12,0)	(1,1) (2,2) (3,3) (4,4) (5,5) (6,5) (7,5) (8,4) (9,3) (10,2) (11,1)
		(0,4)	(14,2)	(1,5) (2,6) (3,7) (4,8) (5,9) (6,9) (7,9) (8,8) (9,7) (10,6) (11,5) (12,4) (13,3)
		INCOMPLETE RIDGE		
		(0,8)	(2,10)	(1,9)
		(0,12)	(4,16)	(1,13) (2,14) (3,15)
		(0,18)	(5,23)	(1,19) (2,20) (3,21) (4,22)
		(14,17)	(8,23)	(13,18) (12,19) (11,20) (10,21) (9,22)
		(14,6)	(10,10)	(13,7) (12,8) (11,9)
		SHORT RIDGE		
		(4,12)	(8,12)	(5,13) (6,13) (7,13)
		(11,13)	(8,16)	(10,14) (9,15)
		ISLAND OR POINT		
		(13,11)	(13,11)	-
		(5,20)	(5,20)	-

Figure 4: Minutiae Extraction from Skeletonized binary images (Ridges).

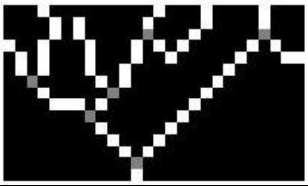
B. IDENTIFICATION OF BIFURCATION		
		BIFURCATIONS ENCOUNTERED AT
		(6,3) (5,9) (12,16) (10,17) (5,21) (5,14)
		(6,2) (9,7) (7,9) (2,12) (13,11) (2,22)

Figure 5: Minutiae Extraction from Skeletonized binary images (Bifurcations).

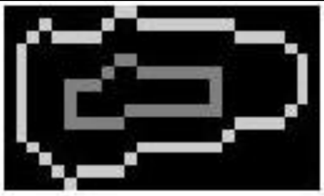
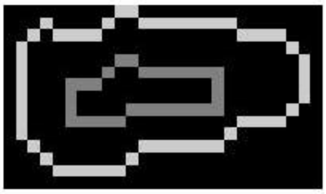
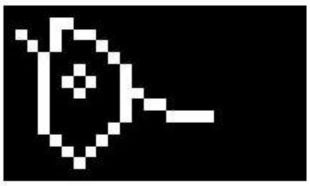
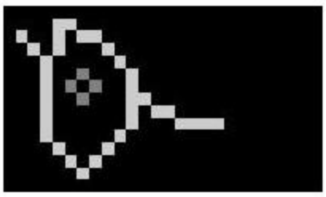
A. IDENTIFICATION OF ENCLOSURE AND LAKES		
		ENCLOSURE ENCOUNTERED AROUND
		(0-9) (0-10) (1-11) (1-12) (1-13) (1-14) (1-15) (1-16) (1-17) (1-18) (2-19) (2-20) (2-21) (2-22) (3-23) (4-24) (5-24) (6-24) (7-24) (8-23) (9-22) (9-21) (9-20) (9-19) (10-18) (11-17) (11-16) (11-15) (11-14) (11-13) (11-12) (11-11) (12-10) (13-9) (13-8) (13-7) (13-6) (14-5) (13-4) (12-3) (11-2) (10-1) (9-1) (8-1) (7-1) (6-1) (5-1) (4-1) (3-1) (2-2) (1-3) (2-4) (2-5) (2-6) (2-7) (1-8)
		(4-9) (4-10) (5-11) (5-12) (5-13) (5-14) (5-15) (5-16) (5-17) (6-17) (5-16) (7-17) (8-16) (7-17) (8-17) (8-15) (8-14) (8-13) (8-12) (8-11) (8-10) (9-9) (9-8) (9-7) (9-6) (8-5) (9-6) (9-5) (7-5) (6-5) (6-6) (7-5) (6-7) (5-8)
		(0-9) (0-10) (1-11) (1-12) (1-13) (1-14) (1-15) (1-16) (1-17) (1-18) (2-19) (2-20) (2-21) (2-22) (3-23) (4-24) (5-24) (6-24) (7-24) (8-23) (9-22) (9-21) (9-20) (9-19) (10-18) (11-17) (11-16) (11-15) (11-14) (11-13) (11-12) (11-11) (12-10) (13-9) (13-8) (13-7) (13-6) (13-5) (13-4) (12-3) (11-2) (10-1) (9-1) (8-1) (7-1) (6-1) (5-1) (4-1) (3-1) (2-2) (1-3) (2-4) (2-5) (2-6) (2-7) (1-8)
		(4-9) (4-10) (5-11) (5-12) (5-13) (5-14) (5-15) (5-16) (5-17) (6-17) (5-16) (7-17) (8-16) (7-17) (8-17) (8-15) (8-14) (8-13) (8-12) (8-11) (8-10) (9-9) (9-8) (9-7) (9-6) (8-5) (9-6) (9-5) (7-5) (6-5) (6-6) (7-5) (6-7) (5-8)
		(1-4) (1-5) (2-4) (1-5) (2-6) (2-7) (3-8) (4-9) (5-10) (6-10) (7-10) (6-10) (7-11) (8-10) (7-11) (8-12) (8-13) (9-14) (9-15) (9-16) (9-17) (9-10) (10-9) (11-8) (12-7) (13-6) (12-5) (11-4) (10-3) (9-3) (8-3) (7-3) (6-3) (5-3) (4-3) (3-2) (2-1) (3-4) (IDENDIFICATION OF LAKE)
		(5-6) (6-5) (7-6) (6-7)

Figure 6: Minutiae Extraction from Skeletonized binary images (Enclosures and lakes).

Conclusion

In this work, several effective and efficient preprocessing techniques are implemented for minutiae extraction from a reference data. The implemented minutiae extraction algorithms can detect all types of minutiae from skeleton images with greater computational efficiency. These algorithms are also capable of generating repository that maintains the state information of the minutiae's.

Minutiaes used in the proposed methodology can be used to extract different line feature like river, contour, roads and polygon feature contour enclosure or water body's enclosure efficiently from color or monochromatic topographic maps.

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