COMPARISON OF DRAINAGE NETWORKS EXTRACTED FROM DEMS AUTOMATICALLY USING ACCUMULATION VALUES AND PPA

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ABSTRACT

Digital elevation models (DEMs) are vital data in hydrological modeling and analysis such as automated catchments and watershed delineation processes that typically use the drainage lines as a network. Its simple matrix form makes the most efficient data type for processing with programming languages in GIS environment. There are several methods for extraction of drainage network from DEMs. The primary objective of this study is to compare the results obtained by two different methods. First, it is the most common approach that commercial GIS software offers. Second, it is a program based on the Profile recognition and Polygon breaking Algorithms (PPA) to automatically extract drainage networks. The results of two different methods were compared with drainage lines drawn by the operator in the stereo models of a test area. For comparison, cartographic and geomorphologic properties were used as the measurements i.e. the numbers, locations and lengths of lines, and relationships between the contours and extracted lines. Paper concludes with evaluation of results.

Key Words: Drainage network, Accumulation value, PPA, DEM, Comparison

1. INTRODUCTION

Terrain skeleton lines, i.e. drainage and ridge lines connecting the deepest and highest points of valleys and ridges respectively, are important cartographic and geomorphological objects on topographical maps. According to Finsterwalder (1986),

drainage/ridge lines are rain water collectors/separators. Aumann et al. (1991) define the skeleton lines as the common path of steepest slope lines with the following properties: "… the skeleton line is the one with minimum slope among the steepest slope lines in the surrounding, thus also the longest one…". Although drainage and ridge lines are complementary parts of terrain, many requirements make drainage lines and their network system more important than ridge lines.

A lot of scientists have studied on extracting drainage networks based on flow routes determined on each DEM points according to its neighbors for about three decades (Mark, 1984; Fairfield and Leymarie, 1991; Martz and Garbrecht, 1992; Tarboton, 1997; Jones, 2002). In these days, most of geographic information system (GIS) software also supports this approach.

2. DRAINAGE NETWORK EXTRACTION USING ACCUMULATION VALUES

Deterministic eight-node (D8) algorithm was proposed by O'Callaghan and Mark in 1984. On a 3×3 local window of a DEM, the slopes between the centre cell and its eight neighboring cells are computed. The flow direction of the centre cell points to the centre of the neighboring cell with the maximum downhill slope, and that single neighbor will receive all flow accumulated in the centre cell. The algorithm is the most popular one, particularly in commercial GIS software, because of its simple and efficient computation, and strong capability in dealing with local depressions and flat areas. Random eight-node (Rho8) algorithm recognizes that the flow over a grid DEM can be arbitrary thus introduced randomness into D8. It is a stochastic version of D8 that aims to break up parallel flow paths that may be resulted from D8, and produces a mean flow direction equal to the aspect. However, it still cannot model flow dispersion. Multiple flow direction (MFD) algorithms recognize flow divergence over a natural landscape (Gokgoz et al, 2006).

After decided to flow routes, the drainage network is derived from a flow accumulation grid. The derivation is based on a threshold accumulation value. Its choice can be arbitrary. Ideally, resulting drainage network from a threshold value should correspond to a network obtained from traditional methods such as high-resolution topographic maps or field mapping. There are two practical methods for defining flow

accumulation threshold. The first one is using the threshold value set as the mean accumulation value of all cells (Tang, 2000; Li et al., 2005). In the second approach, %1 of maximum accumulation value is given as default value while extracting the drainage networks (Olivera et al., 2002). Different accumulation threshold is varied the statistical results of drainage network such as number and total length of drainages lines (Gokgoz et al., 2006). According to Tang (2000) the results would be ideal if the threshold is set to the mean value of accumulation of all the cells.

3. DRAINAGE NETWORK EXTRACTION USING PROFILE RECOGNITION AND POLYGON BREAKING ALGORITHM

The other approach used in this study for comparison is Profile recognition and Polygon breaking Algorithms (PPA) developed by Chang et al. (1998) in order to derive drainage and ridge lines from DEM points by means of the profiles located on four directions at each point. In this study, PPA is considered as a program for only drainage depiction. Its ridge depiction approach is out of the scope of this study. The steps of PPA are in Figure 1.

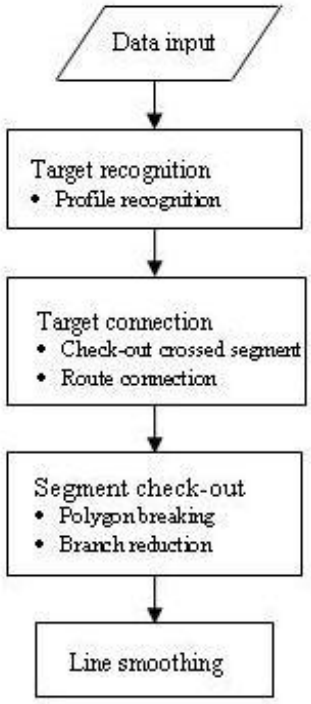


Figure 1: Flowchart of PPA

3.1. Target Recognition

Target recognition starts with profile recognition algorithm. The algorithm first takes the current processed DEM point as middle of the profile. If it can find at least one point higher than the middle one on both sides of the profile, the middle point is taken as a drainage target. Furthermore, the profile is switched from North-South, Northeast-Southwest, East-West, and Northwest-Southeast to check whether the point is a target or not. Profile length must be selected at least 3-point, but it is recommended to be more than 3 in order to obtain the results in network form (Chang et al., 1998).

3.2. Target Connection

Once target recognition has been accomplished, every two neighboring target points are connected into a segment. The program runs in every 9-point gridded cell, of which central one is a target point. The central point has eight neighbors which are memorized as number 1 for the northern point through number 8 for the other points in a clockwise direction. If any one of eight neighbors is a target in the clockwise direction, it is connected to the central target point. Under this approach, many diagonal connections cross each other and make many new junction points which are not located on grid points. Whenever such a situation occurs, the process automatically gets rid of the less important segments; for example, in a drainage search case, the segment with higher elevation is less important and eliminated. After the process of target connection, it is guaranteed that all possible axes are confirmed within the connected segment groups that makes closed polygons. In this step, the process of "check out crossed segments" determine and remove the less important one of the crossed segments in order to get rid of new junction points which are not located on the grid points. The process of "route connection" connects every two neighboring target points with a segment (Chang et al., 1998).

3.3. Segment Check-out

This step includes the two processes named "polygon breaking" and "branch reduction" as follows.

Polygon breaking

The purpose of polygon breaking is to find any closed polygon and break it by eliminating the most unimportant segment. It is a repeated procedure and is applied to segments until no closed polygon remains. The relative importance of the segments inversely correlates with their total elevation value of the endpoints. For example, the segment with higher elevation is less important than segments with lower elevation for drainage depiction. To avoid eliminating some more important segments before less important ones, each round of polygon breaking starts from the weakest segment of DEM. Whenever the tracing tour comes back to either end of this segment, the tracing stops and the segments are deleted because of a belt of closed polygons. After this process, many network structures occur and the remaining lines become pure dendritic patterns. All the axes are represented by continuous segment groups with many branches instead of a belt of closed polygons (Chang et al., 1998).

Branch reduction

After polygon breaking, many short branches remain besides the axes. At this stage, all the branches that are half the profile length are removed. The actions taken for this process are:

(1) all the endpoints are located,

(2) the connections of those endpoints are eliminated and

(3) *round* = *round* + 1; if the round is less than the (*profile length*) / 2; step (1) is repeated (Chang et al., 1998).

3.4. Line Smoothing

This process simply moves the position of the gridded DEM points to a new location. The shifting distance for the new position of DEMs is never more than a grid interval (Chang et al., 1998).

4. EXPERIMENTAL TESTING

For the experimental testing, a DEM that generated automatically from photogrammetric stereo models with 10 m. resolution in the middle Anatolian region of Turkey is used.

ArcGIS-ArcHydro and GeoMedia Grid software are used for the representation of the results of accumulation value approaches. For case study, %1 of maximum accumulation value is chosen. Figure 2 shows as a part of the resulting drainage lines extracted by using ArcGIS-ArcHydro and GeoMedia Grid software before raster-to-vector conversation. As it is seen in the figure, they give the similar results for drainage network derivation, since they use similar algorithms. Some small differences occur due to raster-to-vector conversion. Figure 3 shows overlaid drainage lines of ArcGIS-ArcHydro software after raster-to-vector conversation and operator's drawings for the comparison in whole study area.

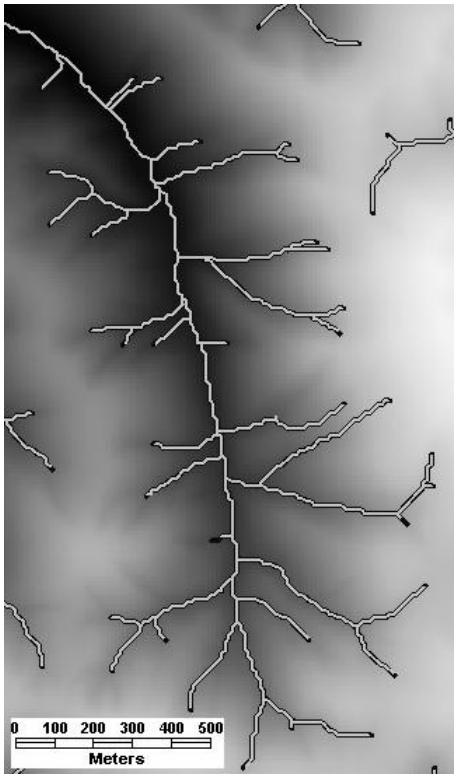


Figure 2: Drainage lines produced with ArcGIS-ArcHydro software (darker) and GeoMedia Grid software

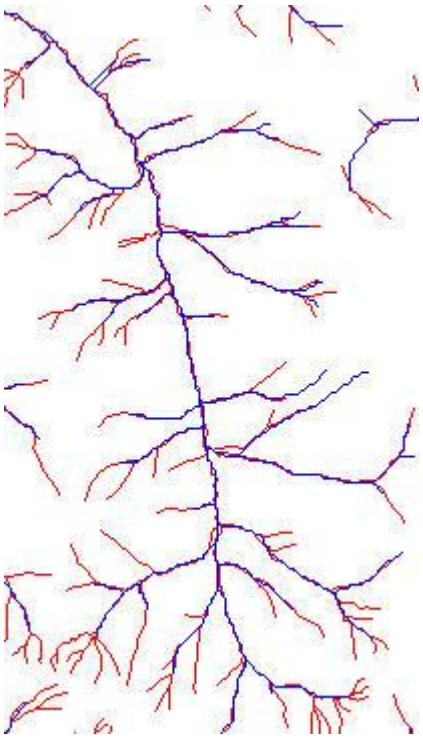


Figure 3: Overlaid drainage lines of ArcGIS-ArcHydro software (blue) and operator's drawings (red)

For PPA approach, profile length is selected minimum value (3-point) in case study, because of preventing to obtain too many unimportant segments. Figure 4 shows the results of PPA program. Figure 5 shows overlaid drainage lines of PPA program and operator's drawings.

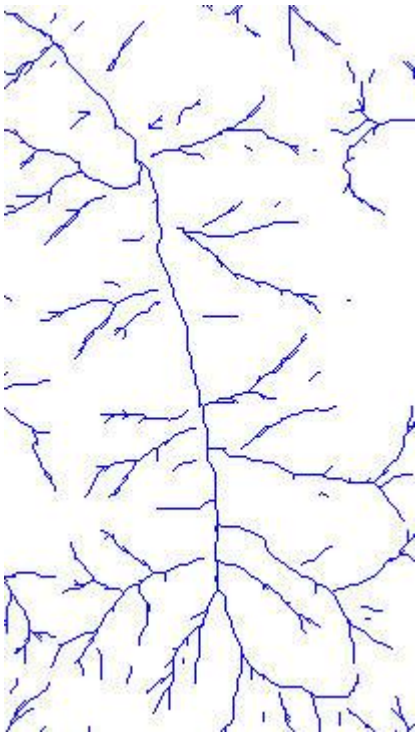


Figure 4: Drainage lines produced with PPA program

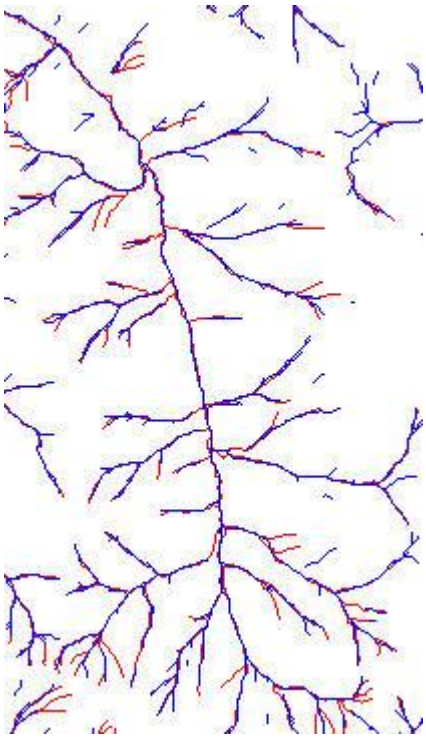
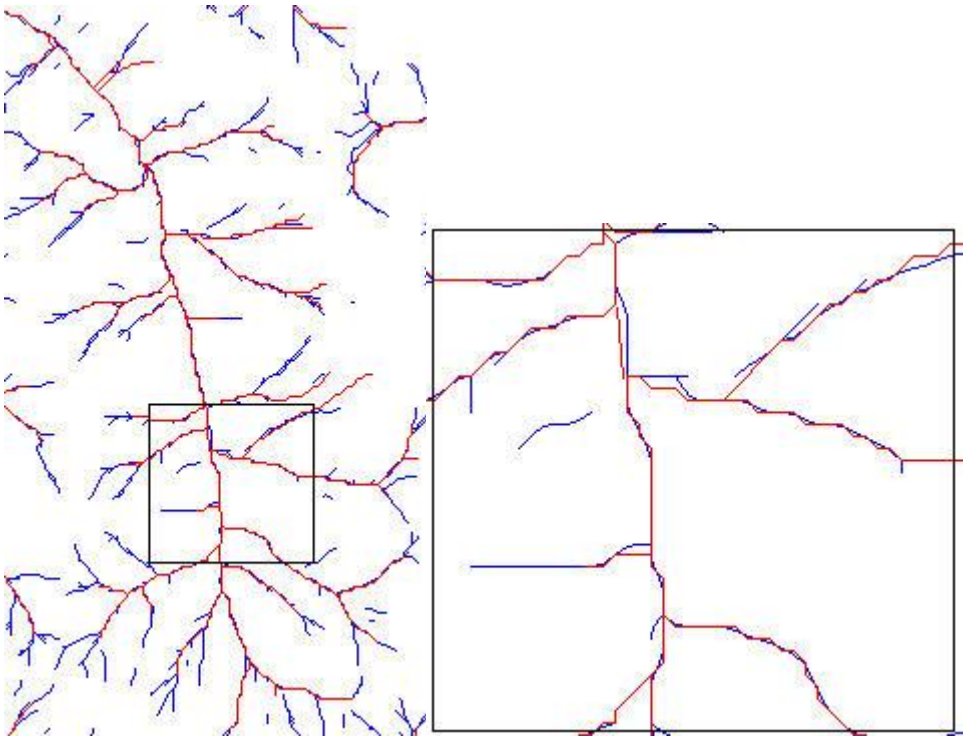


Figure 5: Overlaid drainage lines of PPA program (blue) and operator's drawings (red)

Figure 6 shows the overlaid drainage lines derived from using ArcGIS-ArcHydro software and PPA program.



(a) (b)

Figure 6: (a) Overlaid drainage lines of PPA program (blue) and ArcGIS-ArcHydro software (red), (b) Focused area

5. RESULTS AND DISCUSSION

In this study, two methods developed for deriving drainage lines of terrain from DEMs are compared in accordance with the results obtained from the same data set. The results with respect to the first method of GIS software are different from that of the second method developed by Chang et al. (1998) from several aspects such as numbers, lengths and locations of the drainage lines.

Figure 3 and 5 show the number of lines derived from a GIS software and PPA respectively are different from the operator's drawings. The reason of that they use insufficient parameters for derivation of terrain drainage networks. Besides, the numbers of lines are quite different from each other in Figure 2 and 4. However, if we change the accumulation threshold value, the results of the GIS software may become closer to the

results of PPA, despite there is no any criteria how much we change the value to obtain the same results. This is also valid for the length of lines.

Figure 6 shows that extracted lines do not cover each other, because (1) the results of PPA is smoothed, and (2) PPA has a different weighting approach which is described in polygon breaking process.

6. CONCLUSION

In this paper, the results of two approaches for derivation of drainage lines, i.e. accumulation value and PPA, are represented for the same study area. Although the results obtained with two different approaches give different information about the characteristic of terrain, they can be used in hydrological applications. However, PPA approach can be preferred to obtain more satisfied results because of the easy modification and rich results with regarding to number and length of drainage lines. On the other hand, accumulation value approach gives several results depending on the chosen threshold value.

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