A NEW ALGORITHM FOR EXTRACTION OF CONTINUOUS CHANNEL NETWORKS WITHOUT PROBLEMATIC PARALLELS FROM HYDROLOGICALLY CORRECTED DEMS

Um novo algoritmo para a extração de redes de canais contínuos sem a problemática paralela a partir de MDEs hidrologicamente corrigidos

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ABSTRACT

One of the most popular flow-routing approaches to the extraction of channel networks from DEMs is the D8 approach. Several algorithms based on this method have been developed so far, but none provides a satisfactory solution to the problem of parallel lines. In this study, a new algorithm named *DR*ainage *A*xis *W*ay (DRAW) is developed. It has seven core routines, and three of them are similar to the *P*rofile Recognition and *P*olygon Breaking *A*lgorithm (PPA). It is a segment based computation system, but it uses flow accumulation data as well. It works on hydrologically corrected DEMs. In DRAW, the flow accumulation threshold value is determined automatically with respect to the occurrence of parallel lines depending on terrain forms. For experimental testing, two hydrologically corrected 5 m DEMs were used. Four sets of channel networks were extracted from the DEMs by using PPA, D8 with two different stream thresholds, and DRAW. For comparison, an existing channel network on a map with a scale of 1:5,000 was utilized as a ground-truth.

Keywords: DRAW; Accumulation; D8; PPA

RESUMO

Uma das abordagens mais populares para a extração de canais de redes de drenagem a partir de MDEs é o uso do D8. Vários algoritmos baseados neste método foram desenvolvidos, mas nenhum fornece uma solução satisfatória para o

problema das linhas paralelas. Neste estudo, um novo algoritmo, *DRainage Axis Way* (DRAW) é apresentado. Este algoritmo possui sete rotinas principais e três destas são similares às do *Profile Reconition and Poligon Breakin Algorithm* (PPA). É um sistema computacional baseado em segmentos, mas também usa dados do acúmulo de fluxo. Trabalha com MDEs hidologicamente corrigidos. No DRAW, o valor de acumulo do fluxo é determinado automaticamente em relação à ocorrência de linhas paralelas dependentes das formas de terreno. Para testes experimentais, dois MDEs com resolução de 5m , hidrologicamente corrigidos foram usados. Quatro redes de canis foram extraídas dos MDEs usando o PPA, D8 com dois limiares de drenagem diferentes, e DRAW. Para comparação, uma rede de canais existente em um mapa de escala 1:5000 foi utilizada como parâmetro da verdade.
Palavras-chave: DRAW; Acumulação; D8; PPA.

1. INTRODUCTION

The identification and mapping of stream channel networks is important for applications in cartography, geomorphology, hydrology, and water resources management. For example, fluvial geomorphological studies often involve the measurement of quantitative basin characteristics such as channel density and stream order from a channel network (Heine et al., 2004). Channel networks are also used to determine the characteristic points of contour lines in cartographic generalization (Gökgöz and Selçuk, 2004; Gökgöz, 2005). One of the most popular flow-routing approaches to the extraction of channel networks from Digital Elevation Models (DEMs) is the D8 approach which was first presented by O'Callaghan and Mark (1984) and Mark (1984). There are several algorithms based on the D8 approach, which are mainly distinguishable by the way they treat problematic cases (e.g. definition of flow directions over flat areas and pits) (Turcotte et al., 2001).

A local pit is defined as a point none of whose neighbors have lower elevations (O'Callaghan and Mark, 1984) and the lowest point of a pit is called a depression. Some depressions are data errors introduced in the surface generation process, while others represent real topographic features such as quarries or natural potholes. A few researchers have attempted to remove depressions by smoothing the DEM data (O'Callaghan and Mark, 1984; Mark, 1984). The smoothing approach removes shallow depressions, whereas deeper depressions remain. A second approach is to "fill" depressions by increasing the values of cells within each depression to that of the cell with the lowest value on the depressions boundary (Jenson and Dominigue, 1988). The filling approach removes all depressions and results in only flat areas. In a flat area, each cell has the same flow direction, and thus only parallel flow lines can be extracted instead of a single channel line. Consequently, parallel flow lines in flat areas are unrealistic and may be undesirable for some applications, such as cartographic representation (O'Callaghan and Mark, 1984). Flat areas are also the result of inadequate vertical

DEM resolution which can be further exacerbated by a lack of horizontal resolution (Garbrecht and Martz, 1997).

Thus far, many researchers have focused on flat areas, and as an inevitable consequence, on parallel lines. The proposed approaches are mainly based on (1) applying a stochastic function to the gradient determinations (Fairfield and Leymarie, 1991), (2) defining a main flow line through the flat area to an outlet, and directing the flow lines for nearby points in this area towards the main line (Tribe, 1992), (3) using a non-discrete flow direction and/or multiple flow directions (Costa-Cabral and Burges, 1994; Tarboton, 1997), (4) incrementing cell elevations of the flat area to include information on the terrain configuration surrounding the flat area, (Garbrecht and Martz, 1997), (5) combining the depression breaching and filling (Martz and Garbrecht, 1998), (6) using a digital river and lake network (DRLN) as input in addition to the DEM (Turcotte et al., 2001), and (7) using the priority-first-search weighted-graph algorithm (Jones, 2002). These approaches generally produce better results than the standard D8 approach, but they are still not satisfactory because of the remaining parallel flow lines, and the inconsistency between the model and the actual features of the terrain. Some of them may have additional disadvantages, such as eliminating the unimodal link between flow directions and the river network location (Costa-Cabral and Burges, 1994; Tarboton, 1997), or cutting through an area of higher elevation (Tribe, 1992).

In the D8 approach, parallel flow lines may not only arise in flat areas but also on uniform slopes approaching an inclined plain, depending on the chosen threshold for the flow accumulation data set as defined such that each cell receives a value equal to the number of cells that drain to it (Jenson and Dominigue, 1988). There are basically three approaches for calculating flow accumulation. One approach visits each cell and follows it downslope to the edge of the DEM or to a sink. All cells along the way have one unit of flow accumulation added to the flow accumulation already present. The second approach is iterative. The flow accumulation matrix is first initialized to value one and a temporary matrix is initialized to the number of drainage inputs to a cell. On each iteration, only those cells with zero values in the temporary array are examined. The accumulation values for these cells are added to those of the neighbor to which it drains, and the value for that neighbor in the temporary array is decremented by one. The procedure terminates when no cells with zero values remain in the temporary array. The third approach is also essentially iterative. However, a technique called "divide and iterate" is used to reduce the number of disk accesses on the flow direction (input) and the flow accumulation (output) grids. In this approach, instead of iterating over the entire area, the flow direction and the flow accumulation grids are divided into small blocks. For each cell within a block a candidate flow accumulation value is first calculated as the summation of the weights and the flow accumulation values of all neighboring cells that flow into the center cell, with an initial value of zero. This process iterates on a block until no change can be made.

The procedure continues with the next flagged block and terminates when there is no block that is flagged for update (Gao et al., 1996).

Naturally flat areas such as lakes are represented on a map by a polygon demarking their boundaries. In hydrological DEM analysis linear flow lines occur in these regions which are by necessity parallel to each other. Similarly, naturally uniformly sloped terrains have parallel flow lines, and in neither case do they have channel lines. Thus, flat or uniformly sloped areas can not include the starting point of channel lines. In this study, a flow line that starts parallel to another one is treated as problematic feature. In addition, these accumulated problematic features are treated as parameters that control the extent of the channel network.

In this study, a new algorithm named *DR*ainage *A*xis *W*ay (DRAW) is developed for the extraction of a continuous channel network from hydrologically corrected DEMs while eliminating problematic parallels. A hydrologically corrected DEM, for example, can be developed using topographic and hydrographic data from topographic maps with TOPOGRID in ARC/INFO (Hutchinson 1989).

TOPOGRID is based on an interpolation algorithm that uses a combination of point elevation, hypsography, and hydrography data to produce a hydrologically corrected DEM. The program requires that all stream arcs in the hydrograph to face in the direction of flow. The resulting DEMs are superior to existing ones because they allow for enforcement, or “burning in”, of known channel meander patterns (i.e., artificially lowering the elevations of known stream channel locations using another data source), and the elimination of inconsistencies in stream topology (i.e., ensuring that the stream network generated has no breaks because of depressions and/or disconnected stream segments) (Heine et al., 2004).

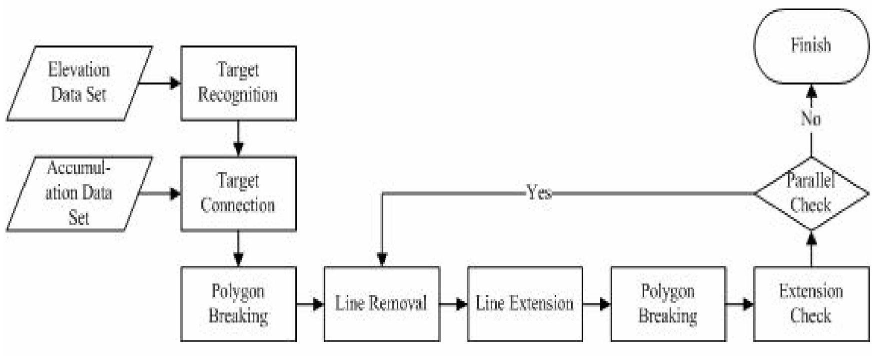
In DRAW, flow accumulation data based on the D8 flow directions is used, because it requires unimodal link between flow directions. Flow accumulation data based on a non-discrete flow direction and/or multiple flow directions (e.g., D-infinity) is not useful for some routines of DRAW.

The DRAW is implemented as a stand alone tool programmed with Microsoft Visual Basic. It has seven core routines, three of which (target recognition, target connection and polygon breaking) are similar to the *P*rofile Recognition and *P*olygon Breaking *A*lgorithm (PPA) developed by Chang et al. (1998). PPA is a segment based computation system which works on hydrologically non-corrected DEMs. Channel networks are extracted in four stages: (1) target recognition, (2) target connection, (3) segment check-out, and (4) line smoothing. Similar to the D8 based algorithms, PPA suffers from parallel flow line problems, but additionally is encumbered by unimportant short lines, hook-shaped features, and non-continuous networks.

2. THE NEW ALGORITHM: *DR*AINAGE *A*XIS *W*AY (DRAW)

The DRAW consists of seven routines as shown in Figure 1. They are explained in the following sub-sections.

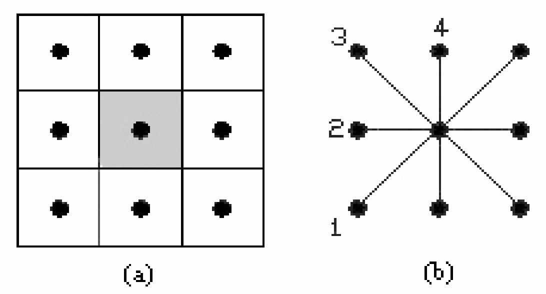
Figure 1 - Flow chart of DRAW.



2.1 Target Recognition

The purpose of this routine is to identify the target cells. Towards this aim, the elevation of each cell is compared to that of its eight neighbors (Figure 2a). This comparison is done in four directions: Southwest–Northeast, West–East, Northwest–Southeast or North–South (Figure 2b). If the elevation of a cell is less than or *equal* to both of its neighbors along at least one of the directional profiles, then this cell is chosen to be a target cell. As a result, all cells in flat areas are also recognized as targets in order to provide the continuity of the channel networks.

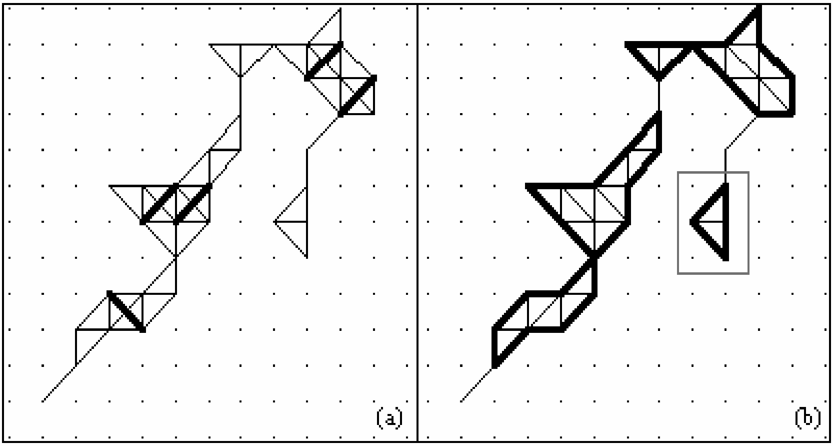
Figure 2 - (a) Eight neighbors of a DEM cell (grey) and their centers, and (b) four directions.



2.2 Target Connection

In this routine, a number of segments, some of which form triangles, are built by connecting all of the neighboring target cells *without considering flow directions*. It is natural that some crossing triangle edges, i.e., diagonal segments in a grid, occur. The segment with the lower weight in each such pair is eliminated when necessary (bold segments in Figure 3a). A triangle or a set of neighbor triangles are called closed polygons. They contain not only potential channel lines but also flow lines (Figure 3b).

Figure 3 - (a) Connected target cell centers and crossed diagonals to be eliminated (bold), and (b) initial closed polygons (bold).



The weight of a segment is defined as the total sum of the flow accumulation values at the endpoints of that segment. Accumulation values are obtained in accordance with the D8 algorithm, and hence are only as good as the assumption that the D8 algorithm reasonably reflects the flow pattern.

Accumulation data is a realistic representation of the draining characteristic. They show the relationship between cells in a basin. The accumulation value of a topographically lower cell is higher than that of a topographically higher one; hence the largest accumulation value in the basin reflects its depth. In short, the accumulation is relative depending on the broadness of the basin, while the elevation value of a cell is absolute. The accumulation value of a cell reflects the weight of that cell in the basin: the bigger its accumulation value, the more weight it gets.

2.3 Polygon Breaking

The aim of this routine is to generate a dendritic structure by eliminating the least important segment within each polygon, hence breaking it. It is an iterative procedure applied to the segments until no closed polygon remains. The outcome for each iteration on the highlighted closed polygon in Figure 3b is shown in Figure 4. The final stage of the procedure for the whole area is represented in Figure 5. The relative importance of a segment is determined in accordance with its weight, as is done in the target connection routine.

Figure 4 - (a) Initial closed polygon, the results of (b) the first, and (c) the second iteration of the polygon breaking routine (focusing on the boxed area in Figure 3b).

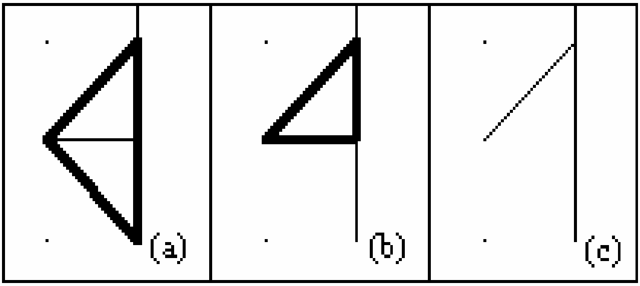
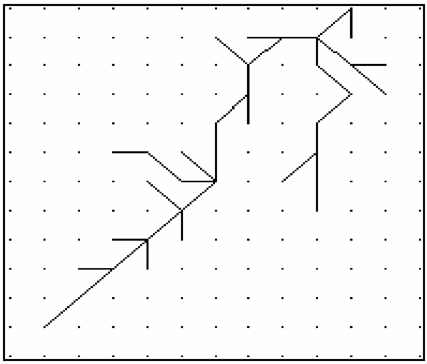


Figure 5 - Results of polygon breaking routine for the whole area.

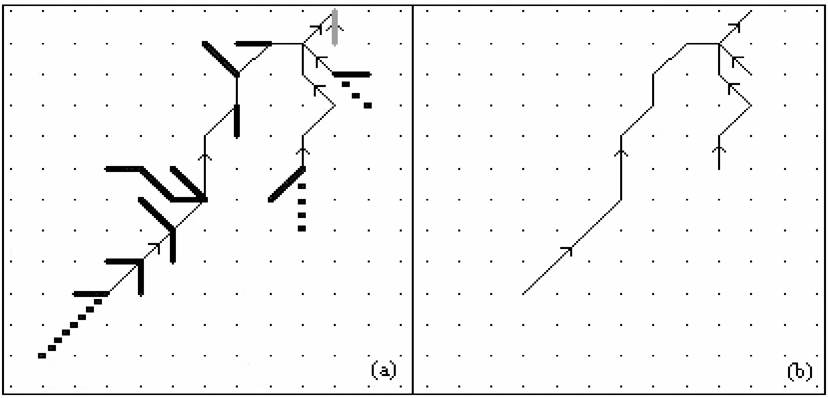


2.4 Line Removal

After polygon breaking, many short ancillary branches remain in addition to the real channel lines. Most of these are undesirable side effects of target recognition which generates some over-determined targets around the real channel lines. In this study, starting with the definition of channel lines, we propose a new criterion with the aim of preserving the real channel lines in the post-polygon breaking process. A channel line is defined as a common path of flow lines in a valley. In other words, among the flow lines in a valley it is the longest one with minimum slope (Finsterwalder, 1986; Aumann et al., 1991; Gökgöz and Selçuk, 2004). The evaluation of a potential channel line is done by taking its branch(es) into account: if it has at least one branch, it is assumed to be a channel line, as this means that there is a common path of flow lines. Otherwise, it is just a flow line, and so it should be eliminated. This criterion can also overcome the aforementioned parallel flow lines problem, if the eliminated flow line is parallel to another in the network.

Since the line removal routine works down-stream, it first determines the highest starting point among flow lines in the network. It then flows through the connected segment with the next-biggest accumulated value, proceeding until it reaches the endpoint of its path-defined largest accumulation value on the network. During this process, if the routine meets at least one junction point, it means that there is a common path of flow lines in a valley. The common path is the channel line that is being searched. The path between the highest starting point and the first junction point is just a flow line (dashed black lines in Figure 6a). Therefore, it is trimmed in order to obtain the channel line (thin black lines in Figure 6a). However, if the routine does not meet any junction point, the path is assumed to be a flow line or an unimportant channel line, and is eliminated (bold black lines in Figure 6a). This process is repeated for each flow line in the network: in each iteration, the line with the highest starting point among the remaining flow lines is processed. If a segment has been processed in any given iteration, it is not processed in further iterations. The result of the line removal routine is shown in Figure 6b.

Figure 6 - (a) The trimmed parts of the channel lines (dashed black), the common paths of the flow lines, i.e., channel line, (thin black), the flow lines (bold black), and the hook-shaped segment (bold grey), and (b) the result of the line removal algorithm.

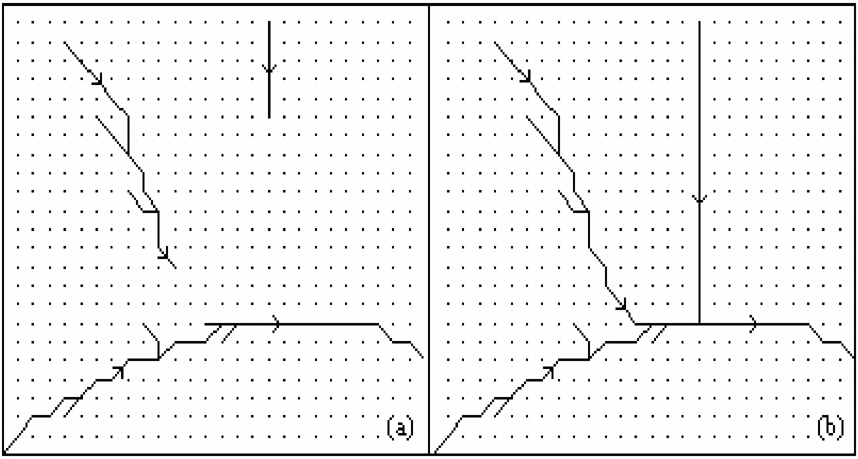


However, a resulting channel line at this stage may still not be ideal, because the accumulation value at its endpoint may be smaller than that at the preceding point. This is an inherent problem of the polygon breaking routine, and it gives rise to hook-shaped features (bold grey segment in Figure 6a). In these situations, DRAW removes the endpoint and preceding line segment, satisfying the principle that accumulation values of a channel line always increase towards the direction of flow.

2.5 Line Extension

Following line removal, individual lines which are not members of the network structure can be observed around the laterally extensive parts, i.e., planar slopes, because they do not reach to (1) a line in the network system, (2) a lake or sea, or (3) the rim of the model (Figure 7a). This routine extends these lines, making new connections to the cells with larger accumulation values until they reach one of the features mentioned above. As a result, a continuous network is obtained (Figure 7b). On the other hand, this process can also generate new closed polygons, flow lines and parallel lines in the network. In order to solve these problems, polygon breaking and following routines (i.e. extension check and parallel check) are invoked.

Figure 7 - (a) Individual lines, and (b) the result of line extension.

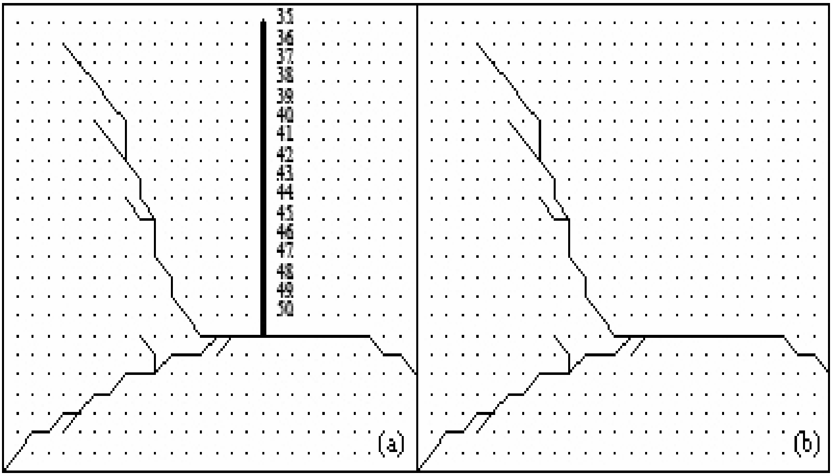


2.6 Extension Check

Some individual lines extended with the line extension routine may just be flow lines. Since line extension is a routine which extends all individual lines, flow lines are also extended and joined to the network. Extension check routine is developed in order to detect and remove the extended flow lines. They are not removed before joining them to the network, because determining their common paths is the explicit aim. Therefore, optimum contribution of flow lines to determination of channel lines is obtained.

Accumulation values are checked utilizing the extension check routine, beginning from the highest starting point of each line in the network. If the accumulation values of a line increase one by one in a part or all over the line (Figure 8a), it is assumed as a flow line and trimmed or removed from the network, respectively (Figure 8b). Accumulation values increase one by one only on uniform slopes. The bold line shown with its accumulation values in Figure 8a is the result of line extension routine and corresponds to the line in Figure 7b. It is clear that it is on uniform slope, because its accumulation values increase one by one.

Figure 8 - (a) A flow line with accumulation values (bold), and (b) the result of extension check.



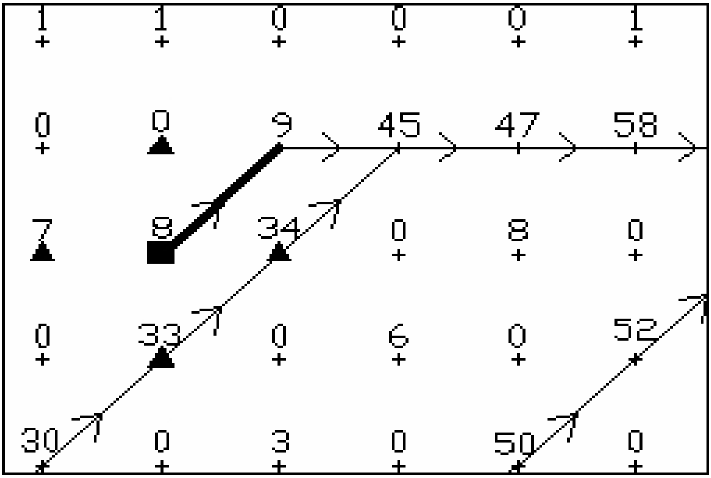
2.7 Parallel Check

In this paper, the term parallel lines refer to lines with the same flow direction spaced one grid interval apart from one another (i.e. the space between parallel lines may contain no points). In the D8 approach, points are connected with respect to their flow directions in order to obtain the channel network. Since the flow directions of the D8 approach are generally the same in flat areas or on uniform slopes, channel lines in the network may be parallel. In DRAW, the polygon breaking routine may also produce parallel lines in those areas, but many of these are removed during the line removal process. Moreover, the line extension routine may result in new parallel lines.

All parallel lines may not be flow lines. Some of them, in fact, may be channels, but it is not possible to distinguish them from flow lines because of poor DEM resolution. If there are not higher points between two parallel lines, channels can not be distinguished from flow lines. Consequently, all parallel lines are threaded as flow lines in this study.

The parallel check routine was developed in order to overcome this limitation using accumulation values, which are not the same in these problematic areas. It begins with the highest starting point of a channel line (square point in Figure 9) and checks four neighboring points that are one grid interval away (triangle points in Figure 9). If a check point is a point of another channel line with the same direction, then these two lines must be parallel. In this case, the channel line of the starting point is eliminated given that its accumulation is not greater than that of the check point (bold segment in Figure 9). Otherwise it remains. All channel line starting points are checked using this method. If DRAW finds any parallels, it goes to line removal routine. Otherwise, it ends processing.

Figure 9 - The starting point (square), the checked points (triangles), the eliminated segment (bold), and the accumulation values.



3. EXPERIMENTAL TESTING

For this study, two hydrologically corrected 5 m DEMs generated with 5 m contours and streams, i.e., blue and channel lines, on two digital topographic maps at a scale of 1:5,000 produced photogrammetrically (Figure 10) using TOPOGRID in ARC/INFO were used. TOPOGRID requires the flow directions of all stream arcs to generate a grid of elevations. However, we did not need to specify the flow directions manually, because the arcs were already oriented to point downstream while producing the maps photogrammetrically. On this map, 1,447,225 m^2 and 711,000 m^2 validation watersheds are chosen for experimental testing, which are represented by the grey areas in Figures 10a and 10b, respectively. The maximum elevations in the areas are 2,166 m and 2,051 m, with local relief of up to 319 m and 184 m. They contain three orders streams in accordance with orders of streams system (Horton, 1945) in several lengths and depths.

Figure 10 - Areas for experimental testing; the grey part of the maps are at a scale of 1:5,000 with selected 25 m contours.

Four sets of channel networks were extracted from the DEMs using PPA, D8 with two different stream thresholds, and DRAW. The primary limitation of the stream threshold method is selection of the minimum flow accumulation area that gives rise to a channel network. Selection of different flow accumulation areas produces radically different channel networks in terms of total channel length, stream order, and channel density (Heine et al., 2004). The first threshold (D8-583 and D8-287 for the first and second study area respectively) used in this study is 1% of the maximum flow accumulation, which is recommended by Arc Hydro (Maidment, 2002). The second one (D8-201 and D8-114 for the first and second study area respectively), which is based on the approach proposed by Heine et al. (2004), is the mean value of accumulations determined at the heads of the existing channel lines on the maps at scale of 1:5,000. The results of these methods are shown in Figures 11 and 12. For comparison, the existing channel networks on the maps at a scale of 1:5,000 are used as the ground-truth (Figure 10). Furthermore, some quantities using segment based hydrological parameters are given in Tables 1 and 2.

Figure 11 - Comparison of resulting channel networks from the first study area that are overlaid on a shaded relief using (a) PPA, (b) the mean flow accumulation (D8-201), (c) 1% of the maximum flow accumulation (D8-583), and (d) DRAW.

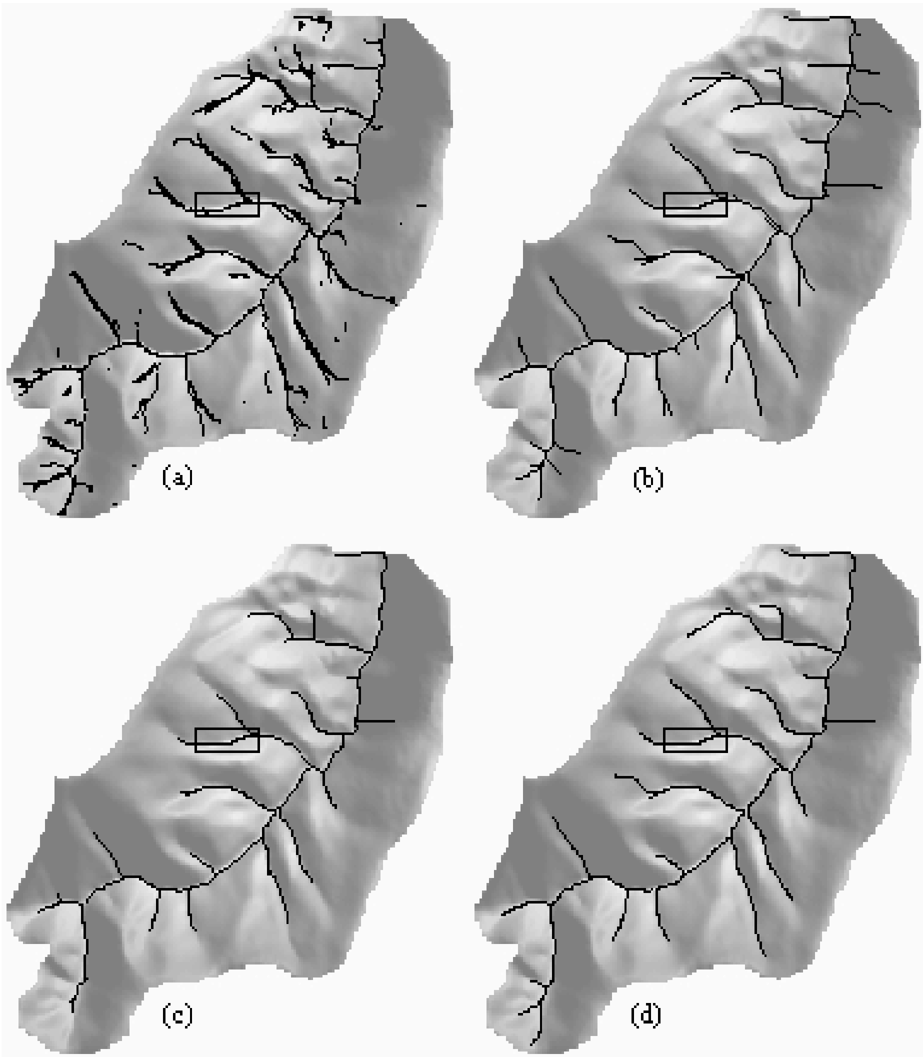
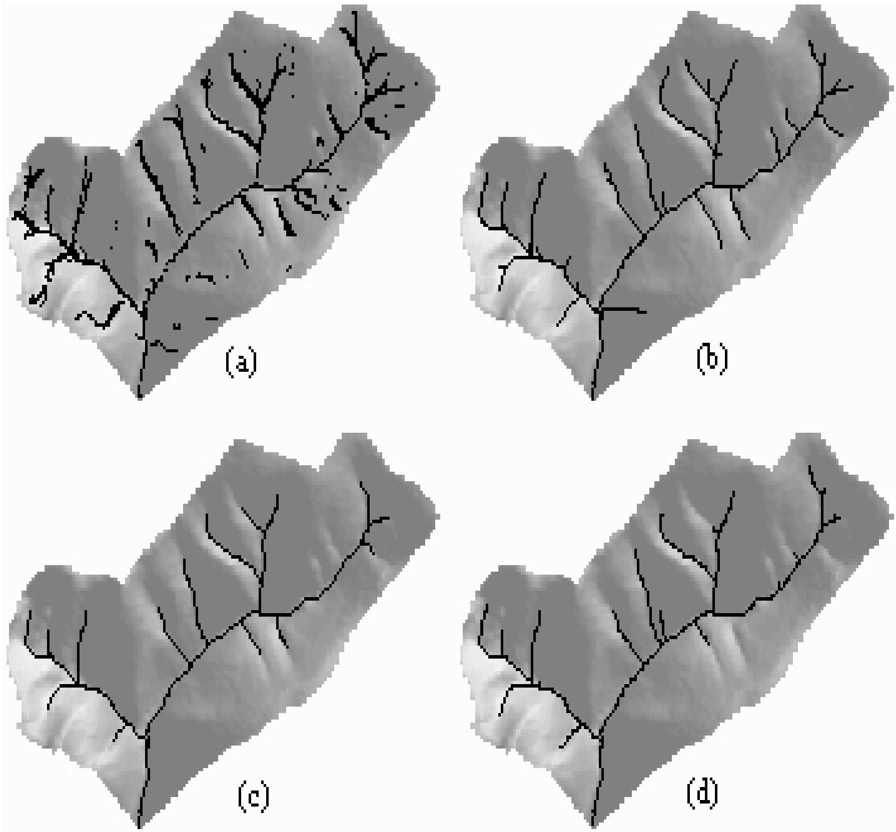


Figure 12 - Comparison of resulting channel networks from the second study area that are overlaid on a shaded relief using (a) PPA, (b) the mean flow accumulation (D8-114), (c) 1% of the maximum flow accumulation (D8-287), and (d) DRAW.



The PPA is not as definitive as the other methods, because it produces too many trivial and parallel lines which do not form a network (Figures 11a and 12a). Therefore, the results of PPA are not compared to other approaches. The other three extraction methods produce different results for first order lines, and nearly same for second and third order lines compared to ground-truth in the first study area (Table 1). The first order results of D8-201 and DRAW methods agree with 98.3% and 89.2% of the total length based on ground-truthing, respectively. However, D8-583 method is not satisfactory, because it gives worse results than the other two methods with respect to the ground-truth length.

According to ground-truth, D8-201 method derives almost all of the channel lines in the network, except the two shortest ones. However, DRAW and D8-583 methods cannot derive three additional lines that appear in ground-truth. Two of the three lines are common to both DRAW and D8-583 methods, and the third is unique. D8-201 method derives too many flow lines that behave like first order channel lines in the network. They are over-represented lines with respect to ground-truth. D8-583 method derives eight over-represented lines, all of which are also produced by D8-201 method. DRAW method derives eight over-represented lines and some of them are different than the ones derived by D8-201 and D8-583 methods due to the different computation system used in DRAW method. These evaluations are based on a visual inspection of the resulting channel networks.

When the total lengths of the derived network systems are calculated, we see that DRAW method gives the closest drainage density value to that of the ground-truth. Superfluous flow lines derived in D8-201 and D8-583 methods increase the channel density.

Table 1 - Hydrologic Parameters of Each Channel Network in the First Study Area.

Segment-Based Hydrologic Parameters				*Ground-Truth*	*D8 Threshold*		*DRAW*
					D8-201	D8-583	
Stream Order	1st	Numbers		22	32	20	20
Stream Order	1st	Length	[m]	4,419	4,344	2,918	3,941
Stream Order	1st	Length	%	(100)	(98.3)	(66.0)	(89.2)
Stream Order	2nd	Numbers		16	23	13	12
Stream Order	2nd	Length	[m]	1,848	1,854	1,847	1,809
Stream Order	2nd	Length	%	(100)	(100.3)	(99.9)	(97.9)
Stream Order	3rd	Numbers		6	14	8	6
Stream Order	3rd	Length	[m]	834	858	858	855
Stream Order	3rd	Length	%	(100)	(102.9)	(102.9)	(102.5)
Over Represented		Numbers		-	36	8	8
Over Represented		Length [m]		-	2,554	523	801
Under Represented		Numbers		-	2	5	5
Under Represented		Length [m]		-	111	494	461
Total		Numbers		44	105	49	46
Total		Length	[m]	7,101	9,610	6,146	7,406
Total		Length	%	(100)	(135.3)	(86.6)	(104.3)
Density (km / km^2)				4.91	6.64	4.25	5.12

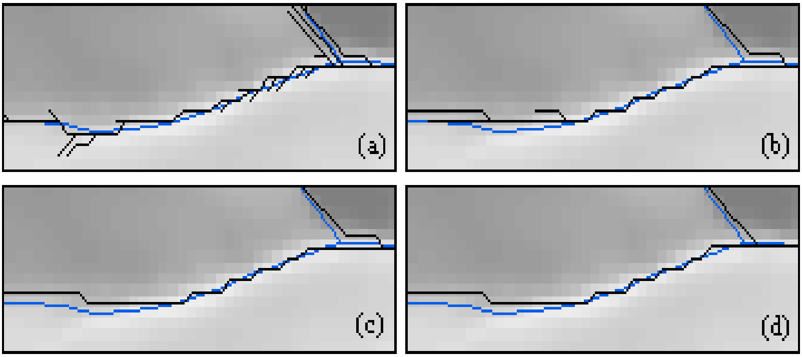
Table 2 - Hydrologic Parameters of Each Channel Network in the Second Study Area.

Segment-Based Hydrologic Parameters				*Ground-Truth*	*D8 Threshold*		*DRAW*
					D8-114	D8-287	
Stream Order	1st	Numbers		21	24	14	17
		Length	[m]	2,828	2,757	1,841	1,822
			%	(100)	(97.5)	(65.1)	(64.4)
	2nd	Numbers		9	18	9	11
		Length	[m]	771	818	823	824
			%	(100)	(106.1)	(106.8)	(106.9)
	3rd	Numbers		11	17	8	10
		Length	[m]	1,215	1,221	1,221	1,208
			%	(100)	(100.5)	(100.5)	(99.4)
Over Represented		Numbers		-	22	-	4
		Length [m]		-	623	-	112
Under Represented		Numbers		-	3	7	4
		Length [m]		-	100	456	341
Total		Numbers		44	81	31	42
		Length	[m]	4,814	5,418	3,885	3,966
			%	(100)	(112.6)	(80.7)	(82.4)
Density (km / km^2)				6.77	7.62	5.46	5.58

According to the second test results in Table 2, the evaluation of the methods is similar to that of the first test with respect to the four parameters: the second and third order lines, over and under-represented lines. However, based on the outcome for the total length and density, DRAW is not as good as the others, because DRAW extracted three of the first order lines shorter than that of the ground-truth.

As shown in Figure 13a-c (the highlighted areas in Figure 11), the three methods (i.e. PPA, D8-201 and D8-583) produce parallel lines on uniform slopes because of the cells with parallel flow directions. PPA does not have any criterion related to problematic parallel lines. In D8 approach, the number of parallel cells depends on the chosen threshold value for flow accumulation. Consequently, D8-201 method produces more parallel lines than D8-583 method. This is the main reason behind the high channel density in D8-201 method. However, DRAW does not extract any parallel lines similar to the ground truth (Figure 13d) in the entire domain of the channel network, because it has no threshold value for flow accumulation and it has a special function that deals with the removal of parallel lines.

Figure 13 - Channel lines of (a) PPA, (b)-(c) D8-201 and D8-583 methods with problematic parallel lines, and (d) DRAW that are overlaid on the ground truth (blue) (all focusing on the boxed areas in Figure 11).



4. CONCLUSIONS

DRAW combines the concepts of traditional channel extraction methods, which mainly deal with gravity flow behavior, and the mathematical techniques developed in PPA, especially the polygon breaking technique. One of the main limitations of the algorithms based on D8 approach is the parallel lines in problematic areas of hydrologically corrected DEMs. PPA has the same limitation in addition to the undesirable short lines, hook-shaped features, and non-continuous network outcomes. DRAW produces the continuous channel networks without parallel and hook-shaped flow lines.

However, DRAW has several weaknesses (e.g. over and under-represented channel lines), that are also present in D8 and PPA based channel extraction methods. The main reasons behind the weaknesses in DRAW are (1) the endeavor to obtain a continuous network structure, and (2) some channel lines which do not collect enough flow lines. In order to improve these weaknesses, it is necessary to develop two more criteria for line extension and line removal processes. For example, the length of the individual channel line and/or the extension distance may be used as the criteria for the line extension process. If the length and/or the distance are less than the threshold values determined for the criteria, the individual channel line is not extended anymore. Similarly, the number of flow lines draining to a channel line may be used as a criterion for the line removal process. In this case, it is assumed that the maximum number of iteration in the line removal routine is reached for that channel line. A hydrologically corrected DEM is necessary to view the data, which may be assumed as another weakness of DRAW. Lastly, flow accumulation data based on a non-discrete flow direction and/or multiple flow directions (e.g., D-infinity) is not useful for some routines of DRAW, because they eliminate unimodal link between flow directions.

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