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ISSN (Online): 2455-7838
SJIF Impact Factor (2015): 3.476

EPRA International Journal of Research & Development (IJRD)

Volume:1, Issue:4, June 2016

Published By :
EPRA Journals

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SJIF Impact Factor: 3.476 ISSN: 2455-7838(Online)
EPRA International Journal of Research and Development (IJRD)
Volume: 1 | Issue: 4 | June | 2016

MODIFIED (BLD_8 AND $BLMD_8$) ALGORITHMS TO GENERATE DRAINAGE BASIN MAPS IN FLAT AREAS

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ABSTRACT

Generally, drainage basin maps are a very complicated process especially for flat area. These maps consider being very important issues that can be used in water resources management, agriculture, civil construction and civil defense. For this reason these maps consider to be vital source of information. There are many kinds of methods and algorithms that can be used to generate drainage basin maps such as Directional Eight (D_8) and Multiple Directional Eight (MD_8). However the challenge reveal in flat area where traditional algorithms (D_8 and MD_8) fails. For this reason three algorithms were suggested to generate drainage basin maps for flat area. Kind of area as well as what needed to implement these algorithms of processing like voids filling (information losing) in SRTM data by using mean value filters. The proposed algorithms were Bilinear Directional Eight (BLD_8), Bilinear Multiple Directional Eight ($BLMD_8$) and second neighbor algorithm. In this paper, drainage basin map was generated for Wasit province near Alhai district at southern Iraq; which is classified as flat area using the proposed algorithms. The result of BLMD8 algorithm was very distinct and very correlated with the ArcGIS9.2 results; in which one could quit of using ArcGIS9.2 software to produce flood hazard maps. BLD8 algorithm result was correlated with ArcGIS9.2 results but less than BLMD8 result. For last algorithm its performance was better than the traditional one.

KEYWORDS: *SRTM, Flow Direction, Flow Accumulation, Bilinear Interpolation, Drainage Basin*.

I. INTRODUCTION

Digital Elevation Models (DEMs) provides elevation information at regularly spaced grids over the certain area [1], which is having many derivatives, the simplest derivatives of a DEM are: slope, aspect, flow accumulation and drainage basin maps [2]. A DEM is described by three components: i.e. DEM resolution (grid cell, or called grain), DEM accuracy (error) and DEM spatial extent. DEMs can be obtained from various categories, these categories are topographic maps, ground surveyed elevation data and remotely sensed elevation data [3].

The Shuttle Radar Topography Mission (SRTM) elevation data is one of the remotely sensed categories. It was obtained on the space shuttle Endeavour in February 2000, and it coverage is available for 80% of the Earth's surface from 60°N to 60°S latitudes [4].

The SRTM elevation data contains voids pixels (areas without data) where the surface did not produce a good radar signal [5]. These pixels, it is unreliable to calculate height from the interferometric phase, which is almost entirely corrupted by noise [6]. There are several reasons for these voids:

1. Steep areas like canyons where the radar could not see the ground because of its 45° look angle [5].
2. Water bodies that did not reflect a radar signal back to the Shuttle [6].
3. Dry sandy areas that did not reflect a radar signal back to the Shuttle [6].

DEMs and their derivatives In particular, flow accumulation can indicate surface processes like lateral water flow [1]. DEMs are an important source of hydrology applications. It has been widely used for modelling surface hydrology including the automatic delineation of catchment areas [7]. All these computations are linked to the determination of flow direction and then to the calculation of flow accumulation and drainage basin [2]. Moreover, drainage basin is especially important to understand topographic controls on water [8].

II. CHOSEN SAMPLE OF SRTM ELEVATION DATA

The chosen sample of SRTM elevation data is located approximately (45) km south of (Wasit province) near (Alhai city) at the southern of Iraq. The sample enclosed area approximately (30) km^2, these data dominated by homogeneity of the elevation, in other words the sample area are with voids pixels; Fig -1 illustrate this area .

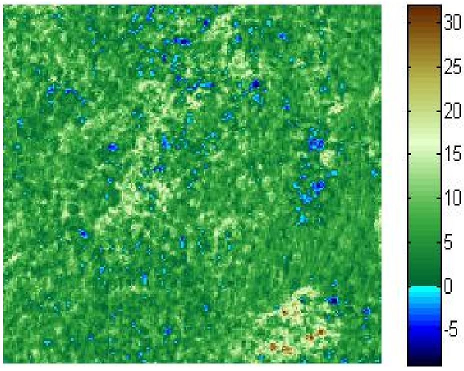


Fig -1: Two-dimensional SRTM elevation data with voids pixels.

From Fig-1, it can be seen that the area is a flat that drainage map cannot be generated especially when known methods are used. Special kinds of methods that can deal with such cases are needed. Therefore modified has been made to overcome such problem through BLD8 and BLMD8 algorithms. The voids pixels in Fig -1 are illustrated in Fig -2.

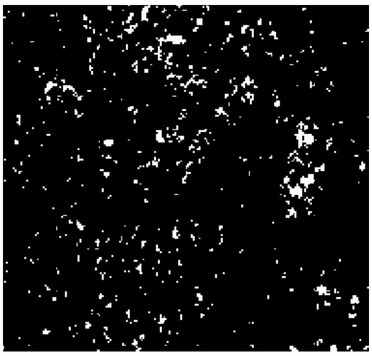


Fig -2: Voids pixels in Fig -1.

III. METHODOLOGY

Drainage basin map methodology proposed in this paper can be given by Fig-3. The basic steps include the following:

1. Read SRTM elevation data for study area; to convert this data into elevation matrix.
2. Detecting voids pixels; if there are no voids pixels in the elevation matrix, go to Step 4.
3. Fill voids pixels by using arithmetic mean filter.
4. Classification of the nature of the region into: detecting, flats and sinks area, if the area is the detected from area go to step 6.
5. Applying bilinear interpolation methods on flats and sinks area.
6. Generate flow direction matrix.
7. Generate flow accumulation matrix.
8. Extract drainage basin

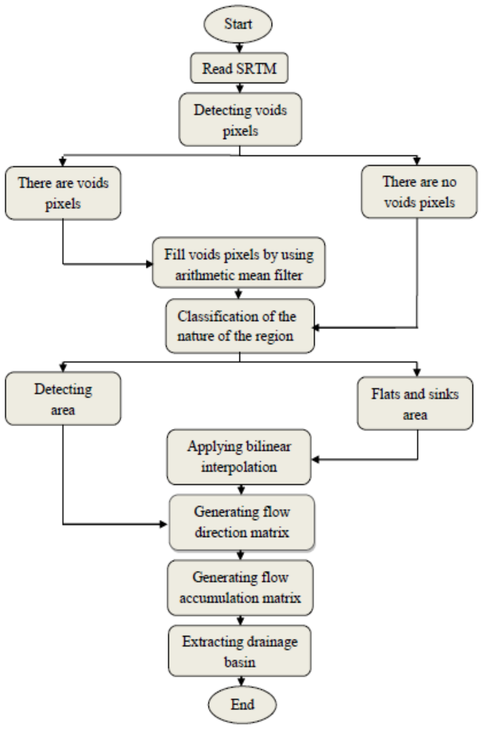


Fig- 3: Schematic diagram showing the basic method of drainage basin map methodology.

A. Voids-Filling Method

In order to fill-voids pixels the following steps were used:

1. Read SRTM elevation data.
2. Convert this data into a matrix.
3. he data voids in the matrix will be represented by Not a Number (NaN) value.
4. Two- dimensional low pass filter will be applied to overcome voids. Arithmetic mean filter with different sizes (e.g. 3×3, 5×5, 7×7, 9×9 and 11×11) pixels.
5. Finally, we will remove the data at the edges of the SRTM to eliminate filter artifacts.

Schematic diagram of voids-filling method, which are illustrated in Fig. 4.

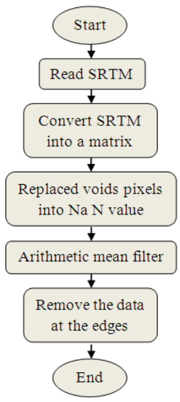
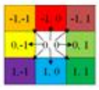


Fig -4: Schematic diagram showing the voids-filling method.

B. Flow Direction Algorithms

1. D₈ Algorithm

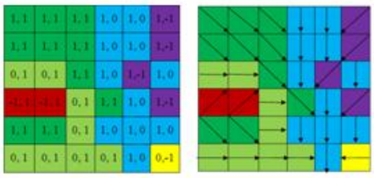
A single-direction flow (D8) is algorithm that is used to determine the water flow from point to its neighbor on the surface utilizing geometric characteristic like slope. D8 algorithm work with 8- neighbor (i.e. there are eight different direction can be found (see Fig- 5, (a)). Slope then determined for each neighbor points, selecting the largest one as the candidate direction of the current point. Fig- 5 show an example for D8 algorithm. The final output will be a map of flow accumulation (quantities of input, output of each cell (pixel) on the DEM).



a)

78	72	69	71	58	49
74	67	56	49	46	50
69	53	44	37	38	48
64	58	55	22	31	24
68	61	47	21	16	19
74	53	34	12	11	12

b)



c)

0	0	0	0	0	0
0	1	1	2	2	0
0	3	7	5	4	0
0	0	0	20	0	1
0	0	0	1	24	0
0	2	4	7	35	2

d)

Fig -5: The procedures of (D8) algorithm, a): Direction code, b): Elevation, c): Flow direction and d): Flow accumulation.

2. MD8 Algorithm

The multiple - direction flow (MD8) algorithm, distributes the flow to all neighbouring down-slope pixels weighted according to slope and tends to produce more realistic looking spatial patterns than the D8 algorithm by avoiding concentration to distinct lines [9]. MD8 algorithm is also more robust than D8. Using D8, a tiny elevation difference between two of the neighbouring cells can have a large effect as one of the cells receives all the area. Using MD8, such elevation differences have a less influential effect because both cells receive about the same portion of the accumulated area. In other words, what might be a question of a few percent when using MD8 can be a question of 0 or 100% when using D8. The elevation difference (?Z) from the centre pixel of the window to one of its eight neighbours is calculated as

:

$$\Delta Z = \frac{Z_{0,0} - Z_{i,j}}{\Phi_{i,j}} \qquad (1)$$

Where: ϕi = 1 for $Z2, Z4, Z6$ *and* $Z8$ (East, South, West, and North neighbors) and ϕi = 2 for $Z1, Z3, Z5$ *and* $Z7$ ((North - East, South - East, South - West, and North-West neighbors).

To determine of the orientation (flow direction) in this approach is as follows:

$$L = \Delta Z > 0 \qquad (2)$$

To determine of the orientation (flow direction) in this approach is as follows:

$$q = \frac{\Delta Z_{i,j}}{\Sigma \Delta Z_{i,j}} \qquad (3)$$

Fig- Illustration of source pixel and its eight neighbours.

$Z_{-1,-1}$	$Z_{-1,0}$	$Z_{-1,1}$
$Z_{0,-1}$	$Z_{0,0}$	$Z_{0,1}$
$Z_{1,-1}$	$Z_{1,0}$	$Z_{1,1}$

Fig -6: Illustration of source pixel and its eight neighbours.

3. Second Neighbor Algorithm

The Second neighbor algorithm can be used to determine flow direction in flats areas. This algorithm can be used for single flow direction or multiple - direction flow as show in Fig -7 and Fig -8 respectively.

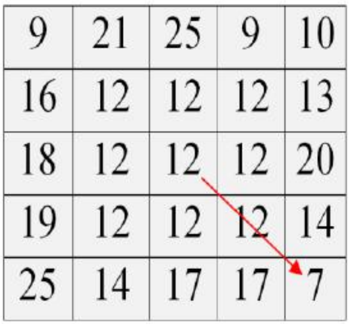


Fig -7: Example of second neighbor algorithm for single flow direction.

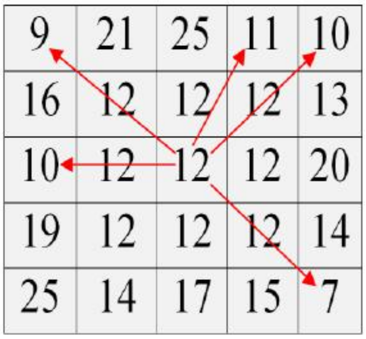


Fig -8: Example of second neighbor algorithm for multiple - flow direction.

4. BLD_8 and $BLMD_8$ Algorithms

The proposed algorithm is based on resize of SRTM elevation data, in other words doubling of SRTM elevation data resolution by using bilinear interpolation; the main purpose of the method is to improvement of the SRTM elevation data especially in flat areas. Bilinear interpolation is an extension of linear interpolation for interpolating functions of two variables (e.g., x and y) on a rectilinear two-dimensional grid [10]. The key idea is to perform linear interpolation first in one direction, and then again in the other direction. Although each step is linear in the sampled values and in the position, the interpolation as a whole is not linear but rather quadratic in the sample location [11], as illustrated in Fig - 9 below.

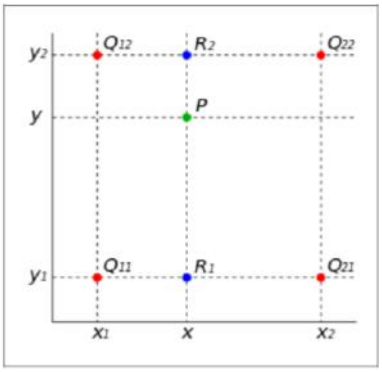


Fig -9: Illustrate the four dots (Q11, Q12, Q21 and Q22) which are used to estimate the P(x,y) dot, using bilinear interpolation criterion [11].

Suppose that we want to find the value of the unknown function f at the point (x, y), it is assumed that we know the value of f at the four points Q11 = (x1, y1), Q12 = (x1, y2), Q21 = (x2, y1), and Q22 = (x2, y2). Firstly, a linear interpolation should be implemented the x-direction; i.e.

$$f(R_1) = \frac{x_2 - x}{x_2 - x_1} f(Q_{11}) + \frac{x - x_1}{x_2 - x_1} f(Q_{21}) \quad (4)$$

And

$$f(R_2) = \frac{x_2 - x}{x_2 - x_1} f(Q_{12}) + \frac{x - x_1}{x_2 - x_1} f(Q_{22}) \quad (5)$$

Then, proceeding interpolation in y- direction; i.e.

$$f(P) = \frac{y_2 - y}{y_2 - y_1} f(R_1) + \frac{y - y_1}{y_2 - y_1} f(R_2) \quad (6)$$

This gives the desired estimation of $f(x, y)$; i.e [102].

$$\begin{aligned} f(x,y) = &\frac{f(Q_{11})}{(x_2-x_1)(y_2-y_1)}(x_2 - x)(y_2 - y) \\ &+ \frac{f(Q_{21})}{(x_2-x_1)(y_2-y_1)}(x - x_1)(y_2 - y) \\ &+ \frac{f(Q_{12})}{(x_2-x_1)(y_2-y_1)}(x_2 - x)(y - y_1) \quad (7) \\ &+ \frac{f(Q_{22})}{(x_2-x_1)(y_2-y_1)}(x - x_1)(y - y_1) \end{aligned}$$

After applying this type of interpolation methods, we will generate the drainage basin by using (D_8) algorithm, the new algorithm which is based on linear interpolation and (D_8) algorithm; we will call on this algorithm (BLD_8) algorithm. Also, we will generate the drainage basin by using (MD_8) algorithm, the new algorithm which is based on linear interpolation and (MD_8) algorithm; we will call on this algorithm ($BLMD_8$) algorithm.

C. Flow Accumulation Algorithm

Calculating flow accumulation map must have specific attention to calculate flow from all direction to the pixel under consideration. In this paper special procedure was used. This procedure accomplished by calculating flow accumulation from down-up as the first phase, while in the second phase flow calculated from top to down, keeping in mind the common flow direction. The important aspect in this stage is the execution time, which is resolution dependent process. The execution time for the propose algorithm is very practice.

D. Drainage Basin Extracting Algorithm

Flow accumulation data can be used to produce drainage basin when pixels with values greater than an assigned threshold value are selected. Fig - 10 illustrate the drainage basin extraction algorithm.

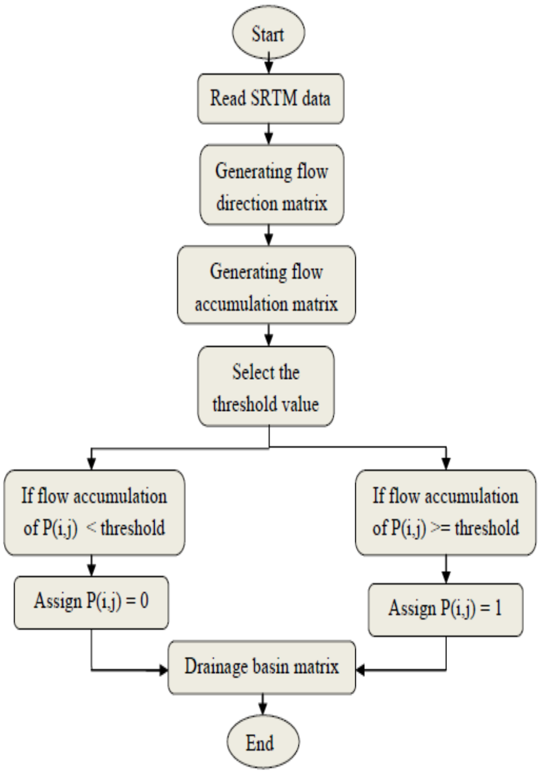


Fig -10: Schematic diagram showing drainage basin algorithm.

IV. RESULTT

The mean filter have been applied on SRTM elevation data contained will large number of voids clustered together as well as spread out as small regions making filling problem so hard. Therefore large mask size must be used like (3×3) till (11×11) size. Fig -11 and Fig -12 shows the results of this process. Table - 1 clarifies quantitatively the voids numbering and its corresponding area. It was found that this process is a very useful process when flat DEM under consideration. Flat SRTM is not useful data for drainage basin extraction as well as other process (median filter). Applying median filter instead filter is not practical because surface modification is so small that next process will not be practical

.

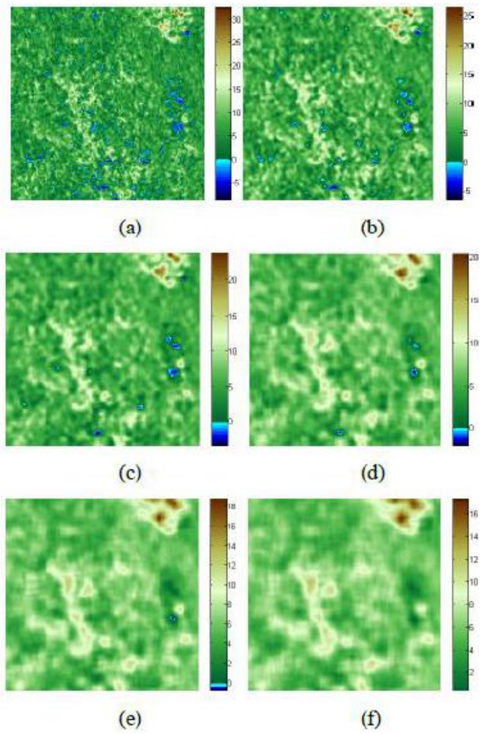


Fig - 11: Two-dimensional SRTM results by using mean filter. (a): Original data, (b): 3×3, (c): 5×5, (d): 7×7, (e): 9×9 and (f): 11×11.

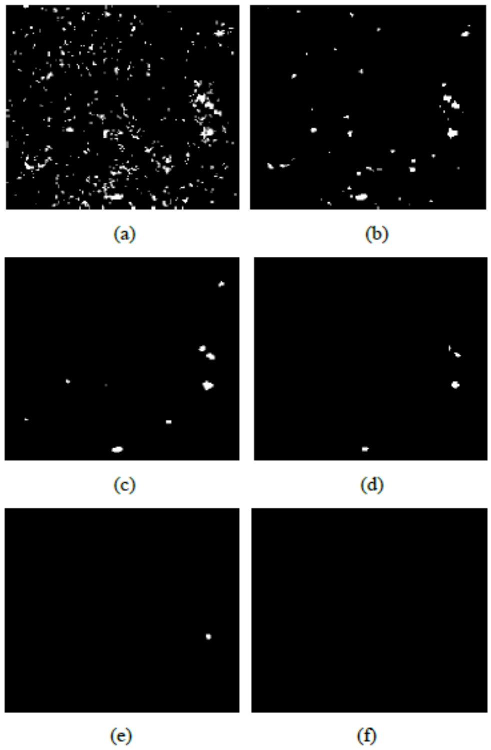


Fig -12: Voids pixels using mean filter. (a): Original data, (b): 3×3, (c): 5×5, (d): 7×7, (e): 9×9 and (f): 11×11.

No.	Processes	N_{voids} (pixels)	N_{voids}%	A_{voids} (m^2)	A_{voids}%
1	Original data	1479	4.62	44370	4.62
2	3×3 mean filter	368	1.15	11040	1.15
3	5×5 mean filter	149	0.47	4470	0.46
4	7×7 mean filter	57	0.18	1710	0.18
5	9×9 mean filter	16	0.05	480	0.05
6	11×11 mean filter	0	0	0	0

Table -1: The results of the fill-voids by using mean filter.

Drainage basin for the study area was obtained using different algorithms. For flat area (study area) D8 and MD8 failed to extract drainage basin see Fig-13(a), Fig-13 (b), Fig-14(a) and Fig-14 (b). The propose algorithms both (BLD8) and (BLMD8) shows a better result that the conventional comparing with Arc GIS 9.2 see Fig- 14 (e), Fig -14(f) and Fig -14(g). Fig- 15 shows magnified selected region for the sake of comparing, which indicate good agreement keeping in mind that Arc GIS 9.2 map is of continuous scale while the other is binary.

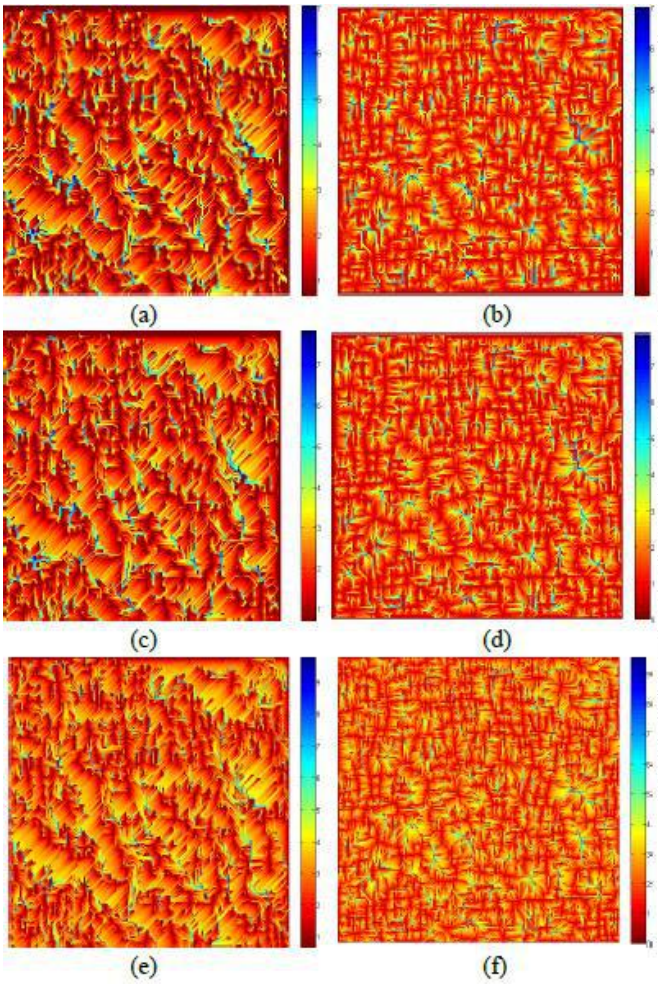


Fig -13: Flow accumulation map for study area (flat area) using (a): D8, (b): MD8, (c): single-directional second neighbor, (d): multiple-directional second neighbor (e):BLD8, (f): BLMD8 algorithms.

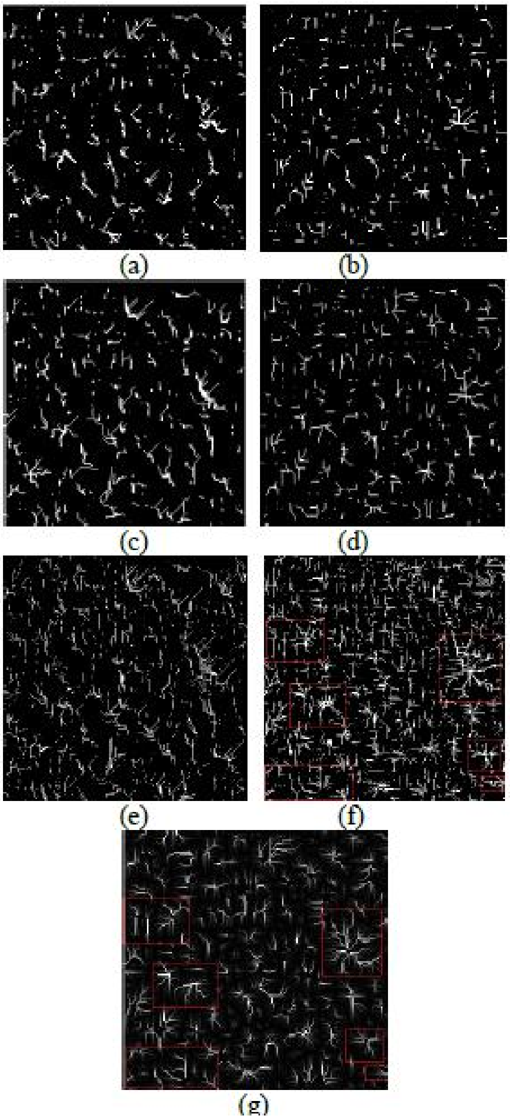


Fig -14: Drainage basin generated using (a): D8, (b): MD8, (c): single-directional second neighbor, (d): multiple-directional second neighbor (e): BLD8, (f): BLMD8 algorithms. (g): ArcGIS 9.2.

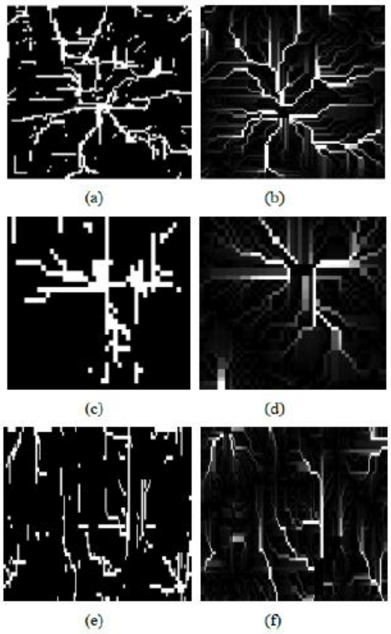


Fig -15: Compared to some of the results between BLMD8 algorithm result and ArcGIS 9.2 result.

V.CONCLUSIONS

Whenever voids pixels are large and multiple large size of mask is needed to get rid of them.MD8 algorithm gives better results than D8 for non-flat area because of the multi-directional flow is consider rather than single direction and both fail for flat area. BLMD8 algorithm result is very correlated and easiest when compared with Arc GIS 9.2 result. BLMD8 succeeded to extract drainage basin for flat area, where to traditional ones fails. Second neighbor algorithm is better than the traditional but less than quality than BLMD8 and BLD8 algorithms for flat area.

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