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Utilization of ancillary data in extracting drainage structure

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1. Introduction

Drainage structure of a watershed is the water course carrying water flow under gravity. It is also the path for the sediment and contaminated materials. Hydrological modellers, those who go beyond the lumped concept, need to determine accurate internal drainage structure to route locally generated flow, sediment and pollutants to their final destination. Grid Digital Elevation Models (DEM) are readily available and simple to use and hence have been widespread in application to the analysis of hydrologic problems (Moore et al., 1991). The ease with which such information can be processed, has stimulated the development of automatic procedures that alleviate the burden of some typical hydrological pre-requirements (e.g. drainage basin and subbasin delineation, drainage path calculation, drainage network extraction). Drainage network extraction algorithms, in particular, have been the object of intensive research activity owing to renewed interest in travel-time-based methods and to the wide availability of physically based distributed models (see, for example, Moore et al., 1991). However, the factors that determine the reliability of such procedures have not yet been fully analyzed. Most of the available algorithms (Tribe, 1992) automatically extract drainage information from the DEM.

Conventional approach to determine the internal drainage structure uses eight-flow direction matrix (D8) derived from raster DEM. The main demerit of this approach is lack of information on depression points and flat areas. Although different approaches have been applied to extract stream network by modifying original DEM, applicability of these methods are in question when applying to a large-scale watershed.

The objective of this study is to develop a suitable approach to determine drainage structure in large watersheds using available land use and elevation data sets. A Digital River and Lake Network (DRLN) is created using both the land use data. DRLN is used as an ancillary data source to remove the depression points in the DEM to generate watersheds' drainage structure.

2. Data set

Global elevation and land use data sets were used in the study. The U.S. Geological Survey's (USGS) Earth Resources Observation System (EROS) Data Centre, the University of Nebraska-Lincoln (UNL) and the Joint Research Centre of the European Commission (JRC) have jointly generated a 1-km resolution global land cover characteristics database. Land use data set derived from Biosphere-Atmosphere Transfer Scheme (BATS) was used to extract the water bodies such as lakes and rivers to create watersheds' DRLN.

GTOPO30 is a global DEM resulting from a collaborative effort led by the staff at the USGS Geological Survey's EROS Data. Elevations in GTOPO30 are regularly spaced at 30-arc seconds. Derived 1 – km and 3 – minute DEM data were used to extact dranaige stucute of the Mekong river basin.

3. Conventional (D8) Approach

The individual cells are connected to each other by their respective drainage directions and are thus organized into drainage basins. Each cell either drains into one of the eight neighbouring cells or into none if the cell represents an inland sink or a basin outlet to the ocean. In distributed hydrological modeling, continuous drainage network where each grid cell must be directly connected to one of its neighbouring cells, the eight flow directions (D8) is a valid approach to model the watershed drainage structure (Tribe,1992). Numerous algorithms based on the D8 approach have been reported to treat depression points and flat areas. In the study equation (1) and (2) were used to remove the depression points and flat areas in the DEM.

$$E(i,j)^{*} = E(i,j)^{m} + dh \qquad (1)$$

$$dh = C\left\{1 - \frac{(2*\mathrm{i}+\mathrm{j})}{(2*\mathrm{i}_{\max} + j_{\max}}\right\} \qquad (2)$$

Where i, j are the column and row number of a given cell;

$E(i,j)^m$: Minimum elevation of the surrounded eight points;

dh: elevation increment to the $E(i,j)^m$

C : Constant

$E(i,j)^*$: Modified elevation of the cell ;

Those algorithms were used to remove the flat areas and depression points in the DEM which used to exact the Mekong river basin. The best value for the C is 0.1 for the 3 arc minute resolution DEM (Table 1).

Depression free DEM can be used to exact the drainage structure of a watershed. It is difficult to obtain a good agreement between modelled river networks with the actual one especially for the large watersheds. This is a major draw back in distributed hydrological modeling where flow is transported via a modelled watersheds drainage structure. In the study

Table 1. Statistical variables from the result related to removal of depression points

Methodology	3 – minute (Algorithm 1 &2) – Method 1				1 – km - Method 2	
	C=1	C=0.1	dh=0.1	dh=1	D=0.1	C = 0.1
Original depression points	5144	5134	5134	5367	34082	39022
Total no of points changed	8851	8671	8807	14854	72734	132092
Average changed	6.52	5.94	6.12	13.68	10.8	25.76
Maximum changed	97.7	93.44	97.8	94	253.21	474.49

the used of available river and lake network was suggested for a better watershed delineation.

4. Watershed extraction with the help of ancillary data

To ensure a correct location of major rivers, Hutchinson (1989) proposed a technique called 'stream burning'. This technique makes use of additional information on the location of the main stream, derived from maps or from available data sets. Once the additional information is converted to a grid, it is used to lower the elevation in a DEM at the actual position of the main stream. The advantage of this method is that the main rivers are positioned correctly.

In this study, a methodology similar to stream burning was used to detect the watersheds drainage network. Land use map was used to create a DRLN (Figure 1). Grids within DRLN and outside of DRLN were treated in different manner to get rid of depression points and flat areas. Algorithm 3 was used to perform the operation outside the DRLN.

$$E(i,j)^* = E(i,j)^m + D\left\{1 - \frac{Dis}{Dis_{\max} + 1}\right\} \quad (3)$$

Where Dis is the distance between cell i,j and the nearest DRLN cell. According to the algorithm, perturbation coefficient takes a larger value for cells closer to the DRLN and it tends toward zero for cells far from the DRLN. The algorithm was tested for the 1 km resolution data set of Mekong river basin till Pakse gauging station. The comparison of results for C = 0.1 and the algorithm with D = 0.1 are shown in the Table 1 under method 2.

Since the flow direction of lake cell cannot be determined with a downstream cell, distance between a lake outlet and the lake cell was minimized to assign flow direction of a lake cell. Elevations of all DRLN cells are lower from arbitrary value (10 m). Depressions and flat points in the river segments were initially removed with the help of equations (1) and (2). Starting from the outlet, the algorithm goes along upstream following the outline of the digital river network (DRN) and assigns the flow directions of visited cells so that each cell flows into the cell located directly down-stream. When you meet with a depression point, equations (1) and (2) were used to modify the DEM. In this case $E(i,j)^m$ is the nearest

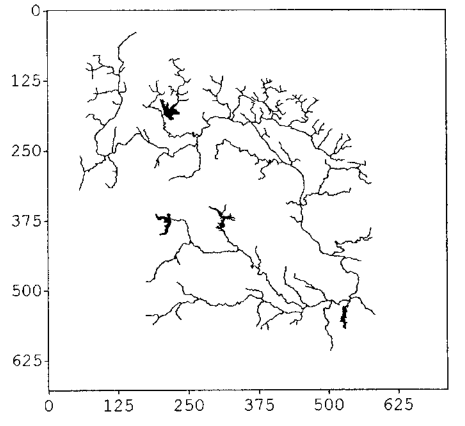

Figure 1. DRLN of the study region

downstream cell's elevation. Development of a watershed's drainage structure using ancillary data of DRLN not only minimize the disturbance to DEM while removing depression points and flat areas in DEM, but also produces a accurate drainage network.

5. Conclusions

The D8 approach is inappropriate for the identification of a drainage structure of large water watersheds. DRLN of the watershed is used to circumvent the fundamental errors of D8 approach due to lack of information in the DEM. The use of auxiliary data related to the locations of rivers and lakes appears to be an inevitable way to produce a better watershed drainage structure.

6. References

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