Extraction of River Network Information in Heihe Basin Based on HEC-GeoHMS

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***Abstract*—Based on the HEC-GeoHMS module, this paper extracts the river network information of the Heihe River Basin effectively by using the Digital Elevation Model (DEM) obtained free of charge. By the steps of filling the sinks, determining the flow direction, flowing accumulation and streaming definition, we get the river network density corresponding to the thresholds of different confluence accumulations in the basin. By fitting the curve of the relationship between the threshold of sink flow and the density of the river network, we conclude that the most suitable threshold for the accumulation of the Basin is 42.3km^2. In addition, the river network density decreases with the increase of the confluence accumulation threshold. But when the confluence accumulation threshold increases to a certain value, the change of the river network density becomes stable. According to the value of which the density tends to be stable, the river network information in the Heihe River Basin can be extracted effectively, which provides basic data for the establishment of the hydrological model in the region.**

Keywords—river network information, optimal confluence accumulation, HEC-GeoHMS, Heihe river.

I. INTRODUCTION

River network information is the basic skeleton, which reflects the characteristics of the river basin, and it is also an important parameter for constructing a distributed hydrological model of the river basin[1]. There are two traditional ways to obtain the river network information, the one is field measurement, and the other is manual extraction from topographic maps and satellite images. However, the main disadvantages of these two methods are time-consuming and the accuracy problem by subjective speculation. In recent years, the application and research of hydrological model systems based on DEM have become the main development trend of modern hydrological models. With the wide using of geographic information system technology, DEM has become the most convenient type of terrain information for operation and storage of which is feasible to extract terrain parameter information effectively. Therefore, extracting of water system and sub-watershed features automatically by DEM has become a convenient way. What's more, Geographic Information System (GIS) is currently widely used in data management, spatial analysis and visualization. Extracting hydrological terrain parameters by DEM is the basis for combining hydrological models with GIS. And we can use DEM to extract topographic features related to the watershed automatically, such as slope, current direction, and convergence grid, et al.

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The digital model of hydrological process is an important content in the field of engineering hydrology, and it is also an important means for water resources planning management, utilization, and reduction of flood and drought disasters[2]. Hydrological model simulation methods can be divided into physical models and mathematical models. Among them, mathematical models are divided into deterministic models and random models. The deterministic models mainly include lumped models and distributed models. With full consideration of the characteristics of rainfall and uneven spatial distribution of the underlying surface, the physical process represented by the distributed model is closer to the objective world. Due to the organic combination of remote sensing technology and geographic information system, the distributed hydrological model has a unique role and advantages in the study of regional water resources generation. In this paper, we use the extension module named HEC-GeoHMS provided by the ArcView to establish a basin model, which provides basic data for the establishment of the hydrological model in the area.

II. DATA AND METHOD

A. Study Area and Data Source

This research takes the Heihe River Basin as the study area, and the data used in this paper is the middle and upper reaches of the River. The middle reaches (ASL 1300m-1680m) is the interval between Yingluo Gorge and Zhengyi Gorge. the river is 185 kilometers long and the watershed area is 25 600 km^2. The transportation of water has an important impact on the improvement of the ecological environment in the downstream. Figure 1 shows the geomorphological information of the study area.

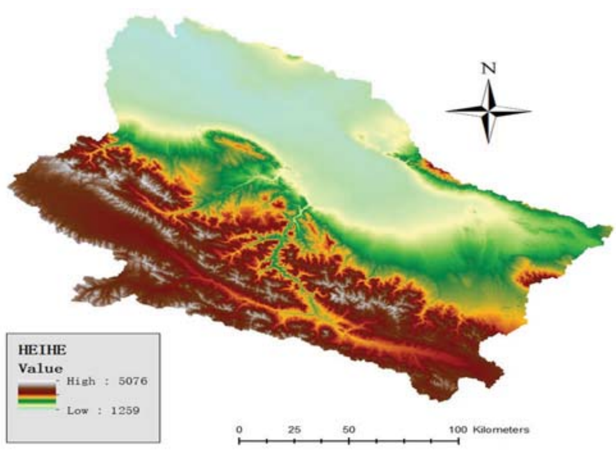

Fig.1: Heihe River Basin.

The DEM data which derived from National Aeronautics and Space Administration (NASA) in this paper is based on detailed observation results of the new generation of Earth Observation Satellite TERRA in the past decade. The TERRA satellite was launched in December 1999 and is equipped with an advanced spaceborne thermal radiation and reflectometer (ASTER) manufactured by ME-TI (Ministry of Economy, Trade and Industry). It acquires stereo image pairs through its vertical infrared imaging sensor and rear-view imaging sensor in the near-infrared band, and finally generates DEM data. Table Ⅰ provides detailed information on DEM.

TABLE Ⅰ: Characteristics of the DEM.

Variables	*Values*
Coverage	About 99% of land area
Spatial resolution	30m*30m
Accuracy	Error is less than 20m
Invalid value	-9999
Data Format	GeoTIFF
Data Sources	TERRA
Reference geographic coordinates	WGS 84

B. Method

The algorithm processing for extracting digital water system from DEM generally includes the following steps: Firstly, the depression should be filled of the DEM data. Secondly, we should determine the flow direction of all grids and then count the flow accumulation of each grid. Thirdly, the minimum area threshold should be set and the grid whose flow accumulation is greater than the minimum area threshold should be set as the river channel. Finally, the digital water system is obtained by connecting the river channels. Figure 2 shows the detailed processing steps.

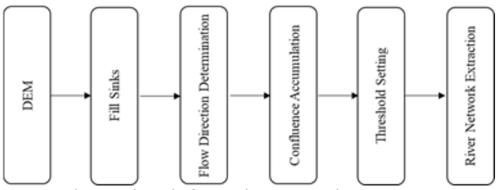

Fig.2: River information extraction process.

III. HYDROLOGICAL INFORMATION EXTRACTION

A. Data Preprocessing

Due to the influence of some special terrain (karst landforms), interpolation process, and horizontal and vertical resolution, the number of cells in the depression will occupy 5% of grid cells[3]. As for small or undulating watersheds, depressions can often be ignored due to the high terrain drop. However, the existence of depressions can cause a large error in the large or flat watersheds. Therefore, before determining the direction of the water flow, it is necessary to fill the DEM. The results of the filling operation in the hydrological analysis module under the Spatial Analyst tool set in ArcGIS are shown in Figure 3.

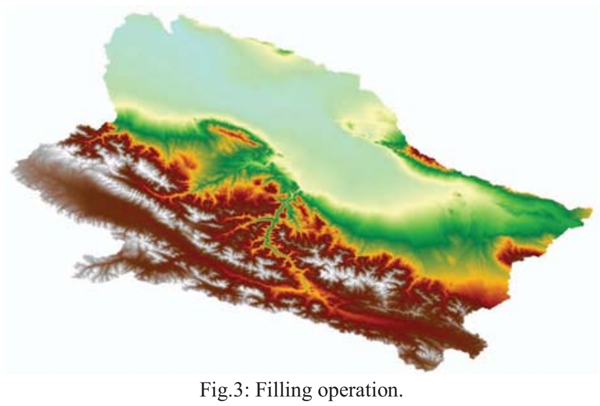

Fig.3: Filling operation.

By comparing figure 1 with figure 3, it can be concluded that the altitude of the lower-lying areas in the high-altitude area was increased after the filling operation.

B. Flow Direction Determination

In DEM, each grid has a definable flow direction value. The direction of flow of a grid cell is the direction in which water flows away from the cell[4]. In HEC-GeoHMS, the D8 algorithm is used to calculate the direction of the water flow, which assumes that the water flow in each cell may flow to 8 adjacent cells. The water flows in the direction of the steepest slope. The slope (S_{max}) can be calculated according to formulas (1)-(2).

$$S_{(i,j)\to(i+m,j+n)} = \frac{Z_{(i,j)} - Z_{(i+m,j+n)}}{\sqrt{m^2+n^2}\Delta l} \tag{1}$$

$$S_{max} = \max(S_{(i,j)\to(i+m,j+n)}) \tag{2}$$

In the two functions, $Z_{(i,j)}$ is the central grid unit, $Z_{(i+m,j+n)}$ is the adjacent grid unit, and Δl is the width of the grid.

The flow direction of each cell can be determined according to the slope calculated by the D8 algorithm. The algorithm determines the flow direction by calculating the maximum slope from the central grid to the adjacent 8 grids. Figure 4 shows the flow of each cell. Different colors indicate different flow directions of the grid. And we use 2 to the power of N for encoding which is convenient for computer identification.

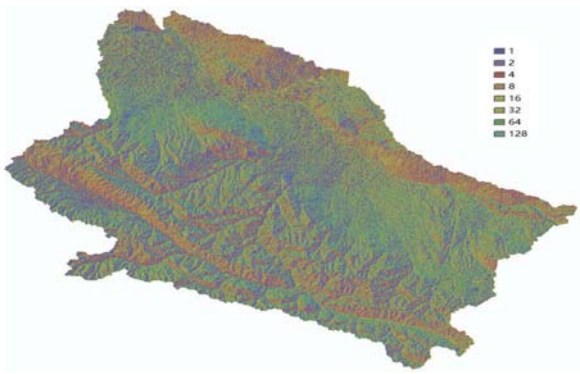

Fig.4: Flow direction determination.

C. Determination of Confluence Threshold

In the process of river network extraction, it's the most critical step to choose a suitable confluence threshold. The selection of the threshold is usually determined by the river network density. The theoretical basis is that with the increment of the threshold value, the position of the starting point course will retreat to the flat terrain, the length of river will be correspondingly shortened, the extracted river level will be higher, and the number of the river course will be smaller and smaller. However, when the confluence accumulation threshold increases to a certain threshold value, the change in river network density tends to be gentle, and the value is the most appropriate confluence accumulation threshold.

This paper selects 40 grid points from 500 to 100,000 to draw the relationship between river network density and grid points. The calculation results are shown in Table Ⅱ.

TABLE Ⅱ: Results of threshold and density.

Grid Points	*Threshold(/km²)*	*River Density(km/km²)*
500	0.45	0.017
1000	0.90	0.013
1500	1.35	0.010
…	…	…
85000	76.50	0.001
90000	81.00	0.001
95000	85.50	0.001

Based on the table data above, the scatter plot of river network density and its fitted curve are shown in Figure 5.

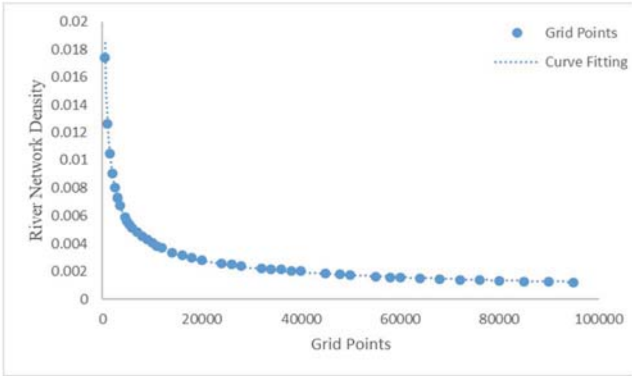

Fig.5: Flow direction determination.

The formula obtained by fitting the scatter plot can be described as:

$$y = 0.446x^{-0.513} \quad (3)$$

We can get the formula (4) after the first derivative of the fitting curve, and the relation curve is shown in Figure 6.

$$y' = -0.229x^{-1.513} \quad (4)$$

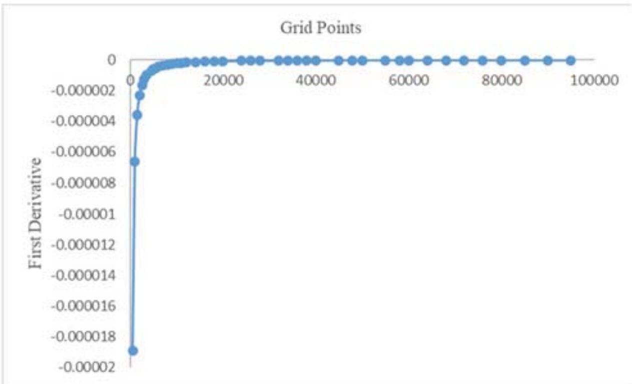

Fig.6: The first derivative of the fitting curve.

From Figure 5 and 6, We can conclude that when the number of grids is less than 47000(that is, when the threshold value of the accumulation amount is less than 42.3km^2,) the river network density shows a large downward trend. However, when the grid number exceeds 47000, the first derivative of the river network density approaches zero. Therefore, setting the confluence accumulation threshold to 42.3km^2 can get a better result.

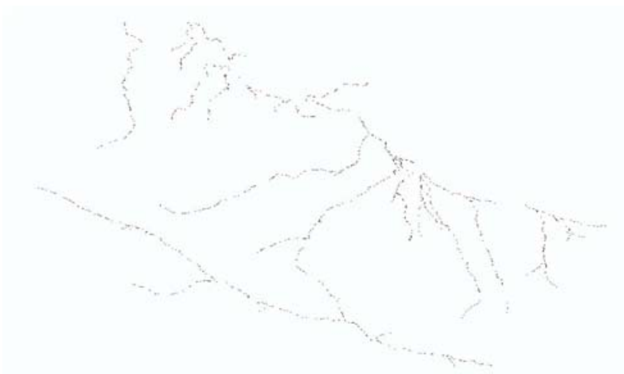

Fig.7: Result of the threshold 47000.

After the optimal confluence accumulation threshold was determined, the upper reaches were selected as the input of the HEC-GeoHMS model and the Yingluoxia was selected as the watershed exit. As is shown in figure 8.

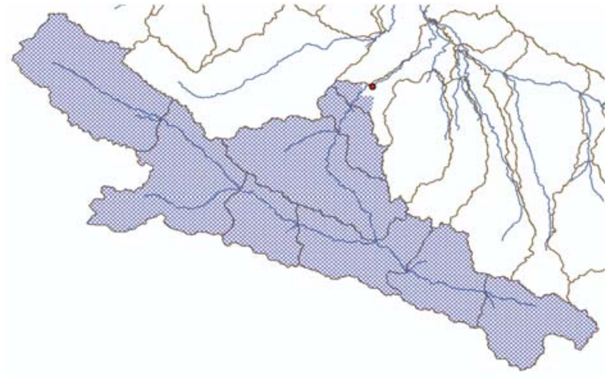

Fig.8: The study area of Heihe river.

D. *Extraction of River Network*

The information from DEM to river network is based on the following assumptions: If the accumulation of a unit is greater than the threshold, the unit is part of the river network [5]. Therefore, when a threshold for the cumulative accumulation is determined, any accumulation above the threshold is considered to be a part of the river network, so that we can connect these cells together to creates a river network. Furthermore, as is shown in figure 8, the river can be extracted based on the threshold value. and finally, the river network information can be extracted through operations such as river classification and river network quantization. It can be seen from the figure 9 that the river network in the selected area is mainly divided into three levels, and the selected area has a drainage basin exit.

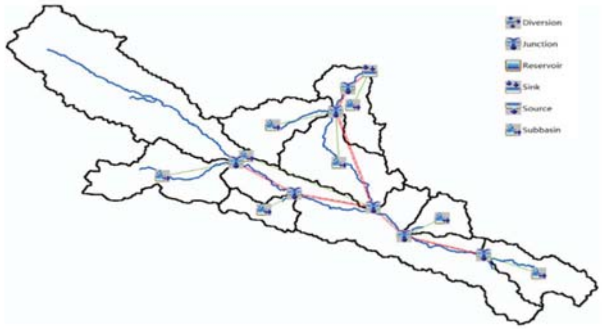

Fig.9: The Result of River Network.

IV. CONCLUSION

This paper uses DEM as the basic data and uses the HEC-GeoHMS module to complete the pre-processing of the DEM, and the calculation of the river network density with different thresholds. And we get the optimal threshold of the research basin which valued 42.3km^2. Finally, we extract the river network effectively. It can be concluded the flowing points: (1) DEM data can be effectively applied to the extraction of Heihe River water system and sub-watershed information, which not only saves the cost of acquiring expensive digital topographic maps, but also provides an efficient and feasible data source for water systems in arid and semi-arid areas. (2) The accuracy of watershed parameter extraction depends on the quality and resolution of DEM. (3) This paper uses the HEC-GeoHMS to extract the river network information of the Heihe River Basin, which provides basic data for the establishment of the hydrological model in the region.

V. FUTURE WORK

At present, HEC-GeoHMS can only be used to describe natural surface water systems, not artificially constructed water flow systems. This is because the flow direction simulated by HEC-GeoHMS is based on natural topography, that is to say, it simulates the river network under the condition that human activities have not changed the natural flow direction. Therefore, in the future, when dealing with the areas greatly affected by human activities, further manual correction is needed for the results.

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