Fast calculation of average slope of river channel based on digital elevation model

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Abstract. The calculation of average slope drop is one of the important parameters of design flood calculation in engineering hydrology. Conventional calculation of average slope drop of river course is usually carried out by using CAD topographic map. The river length is divided section by section and the elevation of starting point is determined, and then the average slope drop of river course can only be calculated by single river course, which has low efficiency and great artificial influence. On the basis of the river basin DEM (digital elevation model), the elements and tools needed in the calculation are connected in turn in the ArcGIS, and the calculation program of the average slope drop of the river is run according to the specified process, and the calculation results are obtained successfully. By comparing the typical river calculation examples with the data of Zhejiang River Manual, it is shown that the average slope drop calculation model constructed by the ModelBuilder can realize the rapid calculation of the longitudinal slope drop of the river and ensure the calculation accuracy.

1. Introduction

Engineering hydrological calculation is an important preliminary work in water conservancy planning and water conservancy engineering design, and is the basic basis for determining the project scale. For hydrological calculation, a lot of work lies in the integration of the information of each watershed, including the calculation of the average slope of the river. Usually, the calculation of the average slope of the river channel in the middle CAD is combined with the density distribution of the contour line, the difference of height and the length of the river, which is input into the Excel worksheet in turn. There are a lot of repetitive work, and the results are greatly affected by human. There is no literature to use ModelBuilder modeling tools in the ArcGIS to realize the batch calculation of the average slope of multiple reach.

By using the combination of hydrological analysis tools, spatial analysis tools and data management tools in the ArcGIS, the calculation of the average slope of the river can also be completed, which has the advantages of convenient operation, patchwork and low artificial influence on the results. The only drawback is that the operator needs to run multiple tools in turn. Using Model Builder to establish the model, we can call a number of ArcGIS tools to analyze and calculate the elements in turn, realize the automatic flow of data processing, save time and effort. This paper uses the river basin DEM (or contour
line) and the river channel centerline elements as the basic data, with the help of ArcGIS hydrological tools, analysis tools and data management tools, constructs the river channel average slope drop calculation model, achieves the channel average slope drop fast calculation goal.

2. Calculation method
Slope refers to the ratio of the drop of the reach to the length of the corresponding reach. The drop of the unit river length is the average slope of the river (also known as the longitudinal ratio of the river). Usually, the slope of the river is constantly changing with the course of the river, so it is necessary to calculate the average slope in sections. Because the contour line is the most basic element to reflect the topographic change, the contour line is used as the basis for the division of the river [2]. Finally, the formula is as follows.

$$SL = \frac{\sum_{i=1}^{n} (h_i + h_{i+1}) \times l_i - 2 \times h_{n+1} \times l}{l^2}$$

In the formula, the SL is the average slope of the river; n is the number of the river reach; the $h_i$ is the starting elevation of paragraph i (i=1,2,... l, n+1); the $l_i$ is the length of the i reach; the l is length of the river.

3. Design process

3.1. Tool profiles
ArcGIS is a powerful set of GIS software developed by American ES R I Company, which provides a variety of spatial analysis and processing tools for processing geographic information data. Model Builder is a visual programming language used to build workflow in the ArcGIS, which can create a new set of tools and edit and adjust continuously with the purpose and effect of the application, and finally save and manage by the operator. In essence, the model combines the original data to the final result with geographical processing tools and data, and concatenates them in a certain regular order. The input of the next tool connects the output of the previous tool. After the tool set is built, running the application, the model will automatically execute the workflow in turn, get the final results needed by the user, and accelerate the design and implementation of the complex geographical processing model. In addition, the model builder can even integrate ArcGIS with other applications for application expansion.

3.2. Basic structure
ArcGIS model consists of four parts: input data, output data, geographic processing tools and connectors that connect the first three. where the input and output data can be vector data (.shp,.dwg), raster data (dem、remote sensing images, etc.) and data types such as table data, while geographic processing tools can be toolboxes, scripts, command lines, models, etc. The process of model building is to apply an operation flow to obtain new information or data on the basis of existing data.

3.3. Design Process
When using Model Builder model builder in the ArcGIS to build the calculation model of river course average slope, it consists of three parts: input data, output data and spatial processing tools (toolbox, script, command line or other models). The modeling process is to apply an operation to obtain new information or data on the basis of existing data [3]. When modeling, you need to add a tool to the Model Builder and set values for each parameter of the tool, complete a process construction, and then connect each process one by one. The general steps of the model design are as follows.

3.3.1. create new models
Start ArcMap, new or open already. mxd type map document. Click the Model Builder button on the ArcMap Standard toolbar to open the Model Builder interface.
3.3.2. Add tools and data to the model
There are three main ways to add tools and data to the model.

First: click Geography to open the search tool dialog box, enter the tool name, find the desired search item, and drag it into the blank area of the Model Builder canvas.

Second: in the arc toolbox and directory windows, find the required tools or data and drag into the "model builder ".

Third: on the Model Builder standard toolbar, click the add data or tool button, then navigate to the required tool or data, and then click add.

3.3.3. Insert tool parameters
When data or tools are added to the model, they are called model elements. contains three basic elements: variables (e.g., data sets), tools, and connectors. The variables are determined according to the function and execution intention of the tool, and then the variables are obtained from the parameters or environment. The variables will be used as input elements and can be interactively selected by the user through the graphical interface. At the same time, iterators (For, While, Multi-value, File, etc.) can be used to complete batch processing of files in folders.

3.3.4. Run and save the model
The model starts running and the output is added to the display. When the model is finished, the drop-down shadow is displayed around the tools (yellow rectangle) and output variables (green ellipse), indicating that the tools have been run. Finally, the model is named and saved according to the purpose of modeling for the next application.

4. Model building
A Model Builder modeling tool is used to construct the model to realize the rapid calculation of the average slope of the river. The river manual of Zhejiang province is a book officially published, and the calculation data of slope drop have certain reference, so the calculation results are compared with the data of Zhejiang river manual to verify the reliability of the calculation.

4.1. Data readiness
Based on the data of channel centerline and study area, the DEM data are taken as the basic input data.

4.1.1. Central River
Central river can be extracted from topographic map, combined with river range manual drawing, if the lack of topographic map data can also be generated by DEM.

For extraction from topographic maps, attention should be paid to the continuity of the central line of the river, and a calculated river section should be merged into one. Then change from CAD data to shapefile elements in the ArcGIS reference paper[4], data conversion, add name field and name separately. With the help of DEM generation is relatively cumbersome, need to be carried out with the help of hydrological analysis tools, in turn to complete the flow surface simulation process of filling, flow direction determination, cumulative flow calculation and grid water system generation, and vectorized into water system single line element.

| Hydrological tools | Execution order | Description |
|--------------------|-----------------|-------------|
| Fill Sinks         | 1               | remove small defects in the data by filling sinks in the surface grid. |
| Flow direction | 2 | Create a grid that flows from each pixel to its steepest downhill adjacent point. |
|----------------|---|----------------------------------------------------------------------------------|
| Flow Accumulation | 3 | Create a grid of cumulative traffic per pixel. The weight coefficient can be applied selectively. |
| Vectorization of grid river networks | 4 | Converts a grid representing a linear network to an element representing a linear network. |

4.1.2. DEM of study area
Other than the use of open data (ASTER GDEM 30m or SRTM 90m), it can also be generated by topographic contour lines, elevation points. Generated from topographic maps DEM include the following steps:

a) data conversion
Topographic map medium high line and elevation point layer extraction, CAD to ArcGIS data conversion, elevation data check and contour data repair.

b) create Tin
Click D Analyst /Data Management/Create Tin. menu 3 Input elements select elevation points and contours, height fields select Elevation”.

c) Tin the grid
3D Analyst /Data Management/Convert/Convert from Tin/Tin To Grid. Input element selection ”Tin “, sampling distance: cellsize, determined according to topographic map scale.

4.2. Flow chart design

4.2.1. Key tools
Complete the generation of DEM to isoline in 3D analysis tool; automatically complete the factor turning line, cutting, screening, summarizing statistical tool in analysis tool; in hydrological analysis model, automatically complete the calculation of river length and slope drop of river reach; in data management tool, automatically complete the addition, calculation and connection of fields.

4.2.2. Design ideas
a) Channel centerline treatment
Add and calculate each channel identification field and channel centerline identification field.

b) Isocline extraction
The contour line is generated by the DEM and the spacing is 5-30 m. In order to reduce the calculation workload, the buffer zone can be established with the reference of the channel centerline, and the DEM can be masked first.

c) Divide the center line of the river
The channel centerline is divided into several segments with isoline as the dividing factor.

4.2.3. Modeling flowchart
The results matrix is saved to the default geographic database. Model Builder modeling is shown in figure 1-3.
4.3. Comparative analysis

Based on the ASTER GDEM 30m data, 10 river channels such as Huxi and Songyinxi in Zhejiang Province were selected, and the results obtained by using the average slope drop calculation model were compared with the data in Zhejiang River Manual\(^5\). From Table 1, it can be seen that the difference between the two methods is less than 7%, and the absolute value of the average relative error is 4.12%. The calculation model of the average slope of the river course constructed by the ArcGIS modeling tool can meet the requirements of engineering hydrology.

| No. | River name     | Manual data (‰) | GIS results (‰) | Absolute difference (‰) | relative difference (%) |
|-----|----------------|------------------|-----------------|--------------------------|-------------------------|
| 1   | Huxi           | 7.6              | 7.96            | 0.33                     | 4.34                    |
| 2   | Gangkougang    | 8.2              | 7.88            | -0.32                    | 3.90                    |
| 3   | Longraoxi      | 2.6              | 2.75            | 0.15                     | 5.77                    |
| 4   | Zhongyuxi      | 5.9              | 6.28            | 0.38                     | 6.44                    |
| 5   | Shuangguyuan   | 13.2             | 12.83           | -0.37                    | 2.80                    |
| No. | River name | Manual data (‰) | GIS results (‰) | Absolute difference (‰) | relative difference (%) |
|-----|------------|------------------|-----------------|-------------------------|-------------------------|
| 6   | Guanchuan  | 23.1             | 22.77           | -0.33                   | 1.43                    |
| 7   | Lianxi     | 19.8             | 18.98           | -0.82                   | 4.14                    |
| 8   | Zhuxi      | 20.2             | 20.73           | 0.53                    | 2.62                    |
| 9   | Jincunxi   | 4.7              | 4.52            | -0.18                   | 3.83                    |
| 10  | Longxir    | 15.3             | 16.2            | 0.9                     | 5.88                    |
| Ave. |            |                  |                 |                         | 4.12                    |

5. Terminology
By using the Model Builder modeling tool, this paper constructs the calculation model of the average slope of the river course, which can quickly complete the flow and batch calculation of the average slope of many river channels, and is convenient to operate. At the same time, it can form the same calculation result and avoid human influence for the same data source. The paper proves that this method is feasible and efficient, and can meet the requirement of engineering hydrologic calculation. The method can save a lot of time for engineering hydrologists.

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