A New Method of DEM Drainage Extraction Based on Geoprocessing Service

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Abstract - DEM-based drainage extraction is a hot spot in digital hydrology research. This paper has analyzed the method of drainage extraction based on DEM, used Hydrology tools in ArcGIS software to build the model of drainage extraction and published the model to geoprocessing service. Taking Jiulong River basin DEM as an example, this paper used geoprocessing service to realize drainage automatic extraction in the network environment. The comparison of GP-based drainage extraction and actual drainage system shows that using this GP-based drainage extraction method to extract Jiulong river basin in general can objectively reflect its space distribution .

Index Terms - DEM, geoprocessing service, automatic extraction, Jiulong river basin

1. Introduction

Drainage extraction is an important part the digital hydrological studies. High-quality drainage extraction can greatly improve the accuracy of entire digital hydrological studies. Digital elevation model (DEM) contains abundant terrain information which is suitable for the description of complex surface morphology and drainage networks extraction. Using computer technology to extract drainage network is always focused as the research highlights in the field of hydrology.

The main method of DEM-based drainage extraction is calculated each grid flow direction of DEM, based on grid flow direction calculate upstream catchment areas of each grid and then obtain the stream line [1]. Many commercial GIS software (e.g. ArcGIS, Hydro Tools, River Tools et al.) use this method to extract drainage characteristics. The processing process in these commercial softwares is straightforward, but a single step process in it would bring the inconsistencies of the data processing chain. At the same time, the traditional method extraction operation based on the the stand-alone environment would carry out the inadequate to the network resource utilization.

With the rapid development of computer technology and information technology, more and more applications and data are publishing in the network, which is the same mean of Web service. As one kind of web service, Geoprocessing service (GP service) takes geoprocessing as complex and professional GIS (Geographic Information System) applications to publish it in the network and provides it as the form of services to the web users [2]. In this paper, a drainage extraction model a GP service has been published in the environment of ArcGIS Server and used this GP service to realize drainage automatic extraction in the network environment, which has improved the efficiency of drainage extraction.

2. The analysis of geoprocessing service

Consider the relevant degree of spatial data, GP service can be divided into data processing service and data analysis service [3]. Data processing service mainly for spatial data management and often results in a reduction in the amount of data transferred to the client. Data analysis service is designed to combine data from multiple distributed servers or services to create derived information. In this paper, GP service is a kind of data analysis services that a geographic data processing model or a map document in it has been published in the environment of ArcGIS Server. It emphasizes the interaction between geographic data and users, fully digs the hidden geographic information and provides analysis capabilities as the basis for users' decision-making [4]. Equivalent to general network information system model library, GP services in ArcGIS software are advanced applications and core module of geographic information web services [5].

GP services refer to the external interfaces provided by geo-processing function. These interfaces conform to the general web-service protocol specifications and allow three access modes as REST (Representational State Transfer), SOAP (Simple Object Access Protocol) and OGC WPS (Open Geospatial Consortium Web Processing Service). Taking geoprocessing information that is about to be shared on the server as the resource, REST confirms a identifier for each resource and provides the operation geared to the demands of geoprocessing resource through GET, PUT, POST and DELETE interfaces of HTTP, SOAP mainly calls geo-processing in the long distance through the approaches and variable names acquired from WSDL files, As to OGC WPS, it provides users with metadata profile of GP service, and such descriptions of metadata in service function as the name, parameters, form and output result, as well as the operation of assigned GP service through three interoperable interfaces-Get Capabilities, Describe Process and Execute respectively. Among these three modes, the OGC WPS shows the most satisfying performance in the interoperability of GP service and has received the support from a limited number of open source software (OSS), such as GRASS and 52° North, REST and SOAP have been extensively applied in the operation of various kinds of services. REST is applicable to situations of

limited bandwidth and resource, stateless operation and where processing procedure cache needs to be considered, SOAP is applicable to formalized agreement and stateful operation.

This paper realizes geoprocessing function encapsulated by GP service through the abundant supply of tools and mechanisms offered by ArcGIS. Then, it publishes external interfaces through the mode of REST, which saves network bandwidth and resource. To be more specific, there are two methods of publishing GP service. One is through "ArcCatalog" client-side and the other is through the webpage-side of "ArcGIS server manager". Both of them choose "Add new service" on the webpage navigation bar to add new services, name the services and describe their properties, categorize the type of published services to GP Service, select suitable execution mode and storage path of GP services, and finally click "Finish" to complete the publish of GP services. Publishing service steps are shown in figure 1. In the process of publishing GP services, the execution mode can be "Synchronous Service" or "Asynchronous Service". After being processed by the synchronous server, the result, which will not be stored by the server, will be delivered to the client-side and shown on it. "Synchronous Service" is suitable for analysis function with light data. As to "Asynchronous Service", after requests from the users are sent out, the client-side is enabled to continue to other operations without waiting for the processing. When processing is finished, the server will restore the result. This type of service is more suitable for geoprocessing with large data. Since the Drainage extraction processing service based on DEM published in this paper includes heavy data and relatively complicated processing procedure, the author determines to publish it as "Asynchronous Service". In addition, in publishing the service, the storage mode of the server means to set up the pooled and non-pooled management of the service target. In the non-pooled management, the target of service will not be published until users finish their dialogues. The excessive use of non-pooled service target will lead to redundant data to the target and reduce system performance. However, under the "pooled" management mode, after the server fulfills the task, its target will return to the shared pool and wait for the next access request. These facilitates the mechanism of garbage collection by destroying targets that are no longer usable via background programs and re-creating new targets. Due to the complexity in processing, it is necessary for the drainage extraction processing service based on DEM published in this paper to be set as the "pooled" mode. In this way, garbage can be better collected in the execution of service and the service processing can witness an improvement in its efficiency.
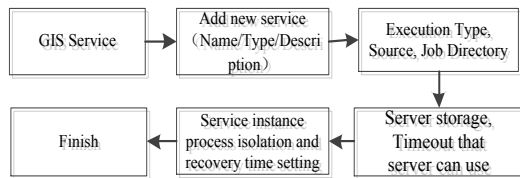

Fig. 1 The publishing process of Geoprocessing Services

3. The Construction of Automatic Drainage Extraction Processing Model

3.1 DEM-based Drainage Extraction Method

Hydrology tool of ArcGIS software is applied in this paper to construct drainage extraction. The main steps include pre-processing of DEM data, calculation of flow direction and accumulated confluence, and the generation of drainage.

1) Pre-processing of DEM data: Fill up depression in the existing DEM data and generate depression-free DEM. Apply "FILL" tool in Hydrology to scan each cell. Provided the result shows sink, the value of elevation is set as the minimum elevation among the eight adjacent cells. Finally, achieve depression-free DEM.

2) Calculation of flow direction: flow direction inside the raster is calculated with the help of pre-processed DEM data. D8 algorithm is the most commonly applied in the determination of flow direction. Its principle goes like this: the flow direction of each raster cell is the cell that shows the maximum distance level difference (the maximum gradient descent) among the eight adjacent raster cells. "Flow Direction" tool in Hydrology is applied to determine the flow direction of cell in this paper.

3) Calculation of accumulated confluence: the calculation of accumulated confluence is based on flow direction data. The bigger the accumulated confluence number is, the easier it is to form the form surface runoff. "Flow Accumulation" tool in Hydrology is applied to calculate the accumulated confluence of basins.

4) Generation of drainage: set a threshold value to the accumulated confluence, and this value decides how precise and detailed the extraction of river net can be. The built-in "Greater Than" tool in ArcGIS software is applied in this paper to extract the raster river net under regions with assigned threshold value. Then, "Raster to polyline" tool in the conversion tool is applied to convert raster river net into a vector for better analysis and operation.

3.2 ArcGIS-based Drainage Extraction Model

As a brief description of objects or phenomenon in the real world, model is a data flow diagram which can establish bath processing process, associated data and tool geared to complicated GIS tasks to generate editable and reusable workflow [6]. ArcGIS software provides abundant tools and mechanisms which enable Model to combine a series of processing steps pursuant to certain operation sequence, thus accomplishing the automatic operation of workflow processing. In accordance with the method and procedure of drainage extraction, the built-in model generator of ArcGIS software is used to set up an automatic drainage extraction model. See the detailed steps below:

1) Add spatial processing tools: add tools involved in the above-mentioned drainage extraction procedure to the editor model in a sequence like this: Fill, Flow Direction, Flow Accumulation, Greater Than, Raster to Polyline.

2) Set connection parameters: refer to the drainage extraction flow diagram and connect elements of spatial

processing tools correspondingly. In the meanwhile, set Raster Layer, Output polyline feature and Input raster or constant as the parameter model.

See the model diagram finally achieved in figure 2. The correspondence between this model diagram and DEM drainage extraction method includes: "Fill" tool-DEM pre-processing, "Flow Direction" tool-calculation of flow direction, "Flow Accumulation" tool-calculation of accumulated confluence, "Greater Than" and "Raster to Polyline"-generation of vector river net.
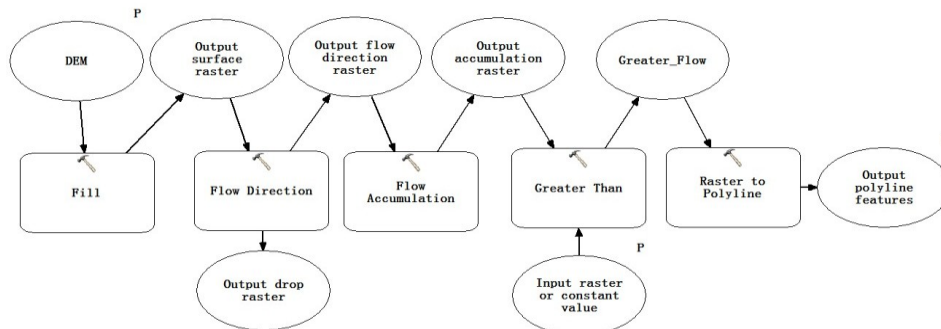

Fig. 2 ArcGIS-based drainage automatic extraction model

4. Realization of ArcGIS-based Drainage Extraction GP Service

Firstly, the automatic drainage extraction processing model introduced in Chapter 2.2 is published as GP service through the method of publishing GP services described in Chapter 1. Then, the automatic drainage extraction is completed through the call of GP service in the system. The published GP service includes three main parameters: DEM data, input raster or constant value (threshold value of accumulated confluence), and Output polyline features (the result of output vector drainage). See REST interfaces of the published GP service in figure 3. The interface document includes the name, description, assistance, and the execution mode, the name of different parameters, data types and data flow directions of GP services.

Fig. 3 REST interfaces of the published GP service

The system realization procedure calls GP service with ArcGIS Server JavaScript API, sets model parameters and executes the model, and finally, superpose the extracted drainage result with the original DEM data (Figure 4).
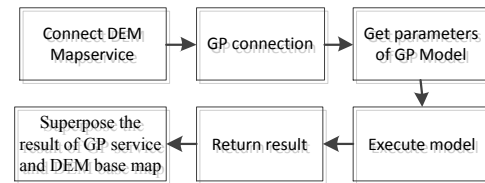

Fig. 4 The implementa process of GP service

It is necessary to add "esri.map", "esri.tasks.gp" and "esri.graphic" to such realization. The published DEM map service in the flow diagram mainly adopts "esri layers.ArcGIS Dynamic Map Service Layer (demUrl)" and "addLayer ()". "DemUrl" is the site of the published DEM map service, GP connection mainly adopts "esri.tasks and Geoprocessor (gpUrl)",define GP = "esri.tasks .Geoprocessor (gpUrl)" and "gpUrl" is the site of the published GP service, the parameters of GP model are the same as the threshold value of the accumulated confluence. The parameters of this model can be acquired from "GPserver Port", and the unit of these parameters are set as meters, On the basis of the mode of publishing GP service, "Asynchronous Service" is selected, therefore "gp.submit Job (parms, jobResult)" is applied to execute the model, among which, "parms" is the parameter of the GP model and "jobResult" is the result after the GP model is executed. Since "Asynchronous Service" is selected to execute this model, function logic must be added to check the status of the task and return the result of processing after the execution is completed. "If (status === esri.tasks.JobInfo.STATUS_SUCCEEDED)" can be used to check the status of tasks in the model. Then, "gp. getResultData(jobId,"Output_polyline_features",addResults)" can be used to attain the result of processing, among which, "jobId" is the serial number of the execution process, "Output_polyline_features" is the output parameter of the model, "addResult" means to load drainage data extracted by the model to the self-defined function parameter of DEM base

map. Superposed the result of processing and the original DEM base map is realized through the self-defined "function addResults(results)". The function includes signified parameters of the map, the size and extent of loaded map. Then, the map is loaded on DEM base map through "map.graphics.add(feature)", among which, "feature" refers to the signified drainage extraction data result.

5. Testing of GP Service-based Drainage Extraction Processing Model

5.1 Data Preparation

Data used in this model testing comes from DEM data (30 m resolution ratio) of Jiulong River basin in Fujian Province. Firstly, finish the definition projection of DEM data. Then, publish it as map service via "ArcGIS Server Manager".

5.2 Result Analysis

The precise and detailed the extraction of drainage can be depends on the size of assigned threshold value. It is suggested by paper [7] that 8500 m is the value correspondwith the point where drainage fractal dimension tends to be mild, and using this value as the drainage fractal dimension in the extraction of Jiulong River basin can fit the objective circumstances well. Therefore, the threshold value is set to be 8500 m directly in the extraction of DEM drainage. Call GP service, and the result of drainage processing is shown in figure 5 (set the threshold value as 8500 m).

Superpose the result of drainage extraction with the practical digitalized water, as you can see in figure 6. The red part is digitalized water, and the blue part is drainage automatically extracted by GP service (threshold value: 8500 m). It can be found out through visual interpretation that Jiulong River basin extracted automatically on the basis of the above-mentioned GP service basically accords with the practical drainage condition, and that rivers in the majority of regions show satisfying consistency, but the places with slow elevation changes show slightly bigger errors. As a whole, it can objectively reflect the spatial distribution of Jiulong River basin.

6. Conclusion

With the help of Hydrology tool built in ArcGIS software provided by ESRI Company, a drainage extraction model is constructed. Moreover, this model is published as GP service that enables the call of GP service under network environment, which successively realizes the automatic formulation of drainage extraction. It is suggested by studies that this GP-based drainage extraction method enables users to fully utilize processing service resources published via the network to extract drainage. In this way, an improving efficiency but decreasing cost can be expected in drainage extraction.
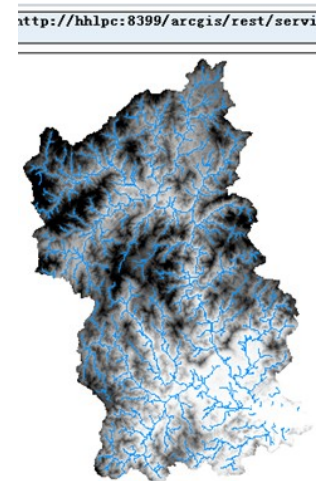
Acknowledgment

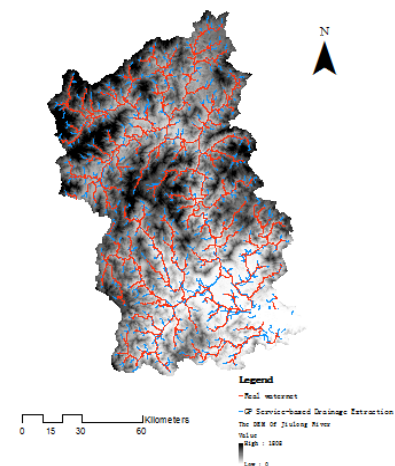Fig. 5 The drainage extraction result based on GP service

Fig. 6 Superpose the result of GP service and DEM base map

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