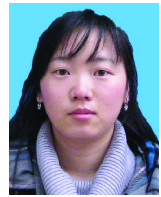


岷江上游流域 DEM 的河网提取



李旭娇¹, 杨武年¹, 曾超², 邬莉莎¹

(1. 成都理工大学 地质灾害防治与地质环境保护国家重点实验室/遥感与 GIS 研究所, 四川 成都 610059;

2. 四川师范大学 地理与资源科学学院, 四川 成都 610101)

摘要: DEM 中包含了丰富的地质地貌、水文等信息, 是流域分析的主要数据来源之一。详细介绍了利用 DEM 数据提取流域水系信息特征的方法, 并以岷江上游为例, 对 DEM 进行预处理, 然后采用 ArcGIS 9.3 软件平台下 Hydrology 模块提供的 D8 算法来确定水流离开 DEM 栅格单元的方向, 并计算流向各栅格单元的水流累积量, 再根据给定的集水面积阈值, 提取岷江上游水系。实验结果表明, 根据 DEM 生成的水系与实际基本相符。

关键词: 数字高程模型; 岷江上游; 河网提取

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DEM 包含了丰富的地形地貌信息, 如高程、坡度、坡向、山脊、山谷、洼地等。因此根据这些地形地貌信息, 借助恰当的模型, 可以自动提取适当范围内的自然水系。基于 DEM 提取数字水系的方法有很多, 常用的有 3 种: Band 和 Jianzhong Qian^[1-2] 用一个窗口扫描 DEM 矩阵来确定数据中存在的洼地, 水系的组成部分则由位于洼地内的栅格单元来标记; 此法存在一定的缺点, 水系标记过程中所产生不连续的水流线, 需通过一定方法的处理将不连续的水流线连接起来, 尤其在地形平坦及地形较复杂的地方, 为了产生合理的自然水系还需对其进行修饰, 如修剪、细化。O'Callaghan 等 (1984)^[3] 提出了地表径流漫流模型, 通过模拟地表径流在地表的流动来产生水系; 其后有许多研究者 Jenson 和 Dominique (1988)^[4]、Martz 和 Garbrecht^[5] 等都使用了该方法。这种方法原理是: 首先根据 DEM 格网 8 个相邻单元格中最大坡度来确定水流方向, 再计算流向此单元格的所有水流累积量, 由此确定一个合理的汇水面积阈值, 根据此阈值将不低于这个值的单元格标记为水系的一部分, 这样可以直接产生一个连续的水流线。由于它基于一定的模型基础来模拟地表径流, 因而被认为是较好的方法^[6]。该方法的缺陷是洼地和平坦栅格单元的水流方向无法确定。阎国年^[7] 等通过研究黄土沟壑地貌的具体特征, 采用形态学与水文学相结合的方法, 提取了黄土丘陵地区的沟谷网络, 取得了很好的效果。此方法在应用时具有很强的针对性, 不同地貌形态需重新设置地貌参数, 因此其适用性受到一定限制。目前利用 DEM 自动提取水系的软件主要有: ArcGIS 软件中的 Hydrology 水文处理模块、MapGIS 的 DTM 分析中的水文表面流

域分析和基于 IDL 开发的 RiverTools 软件等。本研究所采用 ArcGIS 平台提供的 Hydrology 水文模型是基于地表径流漫流模型算法。本文详细介绍利用此模型进行 DEM 预处理、水流方向确定、汇流累积量计算、河网生成等流域水文特征信息提取的处理过程及相关算法, 并将该模型运用于岷江上游流域, 取得了较好的结果。

1 研究区概况及数据源

岷江上游地处四川盆地丘陵山地向川西北高原的过渡地带, 属青藏高原东缘高山峡谷区。区域位置在北纬 30° 45' ~ 33° 09', 东经 102° 35' ~ 103° 56' 之间, 流域内部海拔高程范围变化在 740 m ~ 6 190 m 之间, 平均海拔 3 440 m。都江堰区首以上松潘、黑水、理县的全部以及汶川、茂县的部分地区, 流域干流全长 337 km, 流域面积约为 212 万 km²。1 月份平均气温 -4.13, 7 月份平均气温 14.15, 年平均降水量 730 mm ~ 850 mm; 主要有鱼子溪、杂谷脑河、黑水河、大姓沟、寿溪五大支流^[8]。

本研究所采用的 DEM 数据是由 SRTM 获得, SRTM (Shuttle Radar Topography Mission) 是由美国航空航天局、美国图像测绘局 (NIMA)、德国及意大利航天局共同实施的航天飞机雷达地形测量任务^[9-10]。SRTM2 DEM 数据是人类史上第一次从地球轨道高度对地球表面进行雷达三维成像并获取数字高程模型数据^[9-10]。SRTM2-DEM 以独立的栅格像元文件组织数据, 并用规则格网像元的灰度值来表征地形高程值。采样间隔为经纬方向各 1°, 即 1° × 1°, 像元采样间隔为 1 弧秒或 3 弧秒。以此为基础, SRTM2-DEM 采集的数据

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分为 2 类 SRTM21 和 SRTM23, 这两类数据分别为 30 m 和 90 m 分辨率。因仅有 SRTM23 是对外实现共享, 故本文采用 90 m 分辨率 (见图 1)。



图 1 经裁剪后的岷江上游 DEM(水平分辨率 90 m)

2 DEM 数据预处理

DEM 在生成过程中由于数据噪声、内插方法的影响, 常存在凹陷洼地、平地以及陡变的高峰, 这些都会给水流线的跟踪带来困难, 使水系提取过程复杂化, 流域网络间断或不连通。所以在计算水流方向前要先对洼地进行填平, 平地进行抬升。

2.1 洼地填平

DEM 数据中, 洼地是被高程值较高的栅格所包围的地形单元格, 它影响着地表流水过程。大自然中, 水由高向低流, 遇到洼地就将其填满, 再从洼地最低出口处流出。洼地本身就是一个局部地形的最低点, 水流填满洼地后就无法确定水流方向。因此, 洼地对水流方向的确定起到重要的作用。所以在进行水系提取过程前, 要先对 DEM 数据中存在的洼地根据一定方法对其进行去洼地化处理。无洼地化处理的常用方法为“洼地填平处理”^[11], 主要过程是: 首先确定一个 3×3 窗口或 5×5 窗口, 用这个窗口扫描 DEM 栅格数据, 相邻的 8 个单元格中, 将高程不低于本单元格高程的单元格标定为洼地单元格; 再以此洼地单元格为中心, 扫描位于窗口内的单元格, 在下坡处和平地处都能流向洼地单元格的栅格, 标定为洼地集水区; 然后检测每个洼地集水区, 从中找出最低的潜在的水流出流点, 将这个潜在出流点高程和洼地单元格的高程进行比较, 则洼地出流点高程高的确定为凹地。对于这个凹地, 对其填平过程是通过将洼地集水区所有低于出流点的

单元格高程赋值为出流点高程。洼地的填平是一项复杂的工作, 在一个洼地填平后可能生成新的洼地, 所以要重复上述扫描过程, 直到所有的洼地都被填平。

2.2 平地抬升

DEM 栅格数据中的平地有原始 DEM 数据获取时本身存在的, 也有洼地填平过程中产生的平地。无论是何种平地, 对水流方向的计算都会产生一定的影响, 因此要对平地进行处理。平地处理的常用方法为“高程增量叠加法”^[12], 该方法的基本原理是: 对平地范围内相邻 8 个单元格的每个单元格都增加一个不同的微小增量, 这个增量值不能超过 DEM 的分辨率, 本文中不超过 90。平地单元格经过增加增量后, 每个单元格都会有一个明确的水流方向, 以便水流汇流累积矩阵的计算, 最终为合理的水系的生成奠定了重要基础。

3 河网提取

河网的自动提取主要有 3 个步骤: 计算 DEM 栅格网的水流方向; 计算格网的上游水流累积矩阵; 河流网络的提取。

3.1 水流方向确定

水流方向是指水流离开格网时的流向。水流方向的确定是地表径流漫流模型的基础, 目前有单流向和多流向 2 种, 因单流向算法简单方便而得到较为广泛的应用, D8 算法作为最为常用的单流向算法, 在水流方向计算过程中, 结果较为精确情况下运算速度较其他方法更理想。D8 算法的基本原理是: 首先假定每个单元格的水流只有 8 种流向, 即东、东南、南、西南、西、西北、北和东北, 再用有效特征码来表示这 8 个方向, 即 1、2、4、8、16、32、64 和 128。每个格网与相邻格网间存在一定的距离权落差, 2 个格网间距离权落差越大, 其越有可能为水流流出的格网。所以, 通过计算中心格网与相邻格网间的距离权落差, 可以有效地得到中心格网最终的水流方向。距离权落差的含义为中心格网和相邻单元格间的高程差与 2 个单元格间的距离比值。距离权落差的计算为: $S = AZ/D$ 其中, AZ 为 2 个单元格间的高程差; D 为 2 个单元格间的距离差。图 2 为 DEM 计算后的水流方向。

3.2 水流累积矩阵生成

水流方向确定后, 对于 DEM 数据中的每个格网就有了相应的水流方向。那么汇入某一单元格的水流量就为汇入此单元格的所有上游单元格所产生的水流累积总量。由此可见, 水流累积量反映的是单元格汇水能力的强弱程度, 即汇流累积量越大, 单元格汇水能力越强, 则该单元格所代表的地形信息可能为河谷;

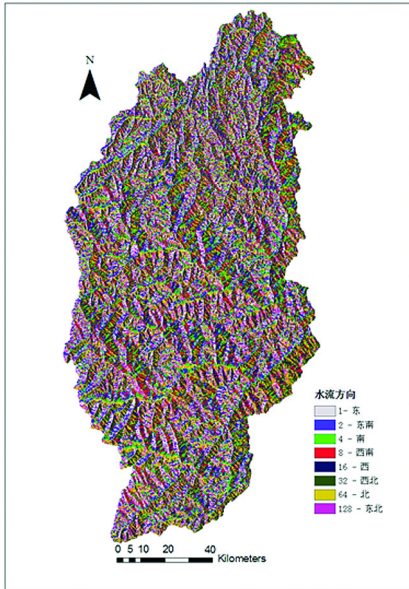


图 2 水流方向计算

反之，代表分水岭特征的单元格，其水流累积量近乎于零。所以河网的提取是以汇流累积量为前提和基础的。如前所述，DEM 网格中，每个格网都有对应的水流方向。假定每个 DEM 单元格初始都有一个单位的水量，那么根据水流方向可以计算流入各单元格的所有上游的水量，则每个单元格就有了相应的汇流累积量值。由此计算得出的结果表明注入水量越多的单元格，其栅格单元的单位水量值越高。

3.3 水系提取

河流网络是在水流累积矩阵基础上生成的，根据汇流累积量计算后的数据，汇入该单元格的单位水量由每个单元格的汇流累积量来表征，则当这个汇流累积量值达到某一特定阈值时，就确定此格网出现在水道之上，然后给这些出现在水道上的栅格赋值为 1，那些小于这一特定阈值的栅格赋值为 0。其中阈值设定的大小影响着河网密度、子流域大小范围等。该研究选取集水面积阈值为 2000 提取河流网络，将各水道按有效水流方向连接起来从而形成流域河网，划分出河流网络系统。

4 实验结果与分析

本文所有的研究过程，均基于现有的 ArcGIS 软件平台。从实验结果（见图 3）上看，从规则格网 DEM 数据中流域河网，对河网提取效率较传统地形图矢量化有了较大提高，且与基础河网相比结果较为准确。但同时也存在一定的问题，如 ArcGIS 软件所包含的水文处理模块本身设计计算的算法的不完善性、集水面积阈值选取的主观性以及 DEM 元数据的精度等问题，都会对最终生成的河网准确度产生影响。因此对上述因

子在河网提取中的影响还有待更深层次的探索。

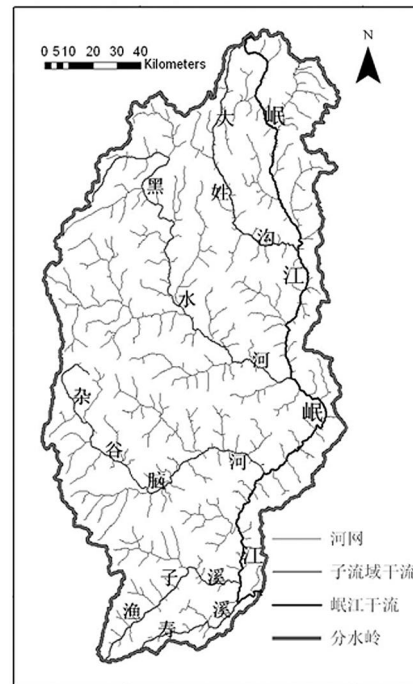


图 3 河网提取结果图

本研究选取岷江上游流域的 DEM 数据，经过数据预处理、水流方向计算、水流累积量计算以及流域网络提取主要的 4 个步骤，在保证水系信息提取较为准确的同时提高了实际工作效率；并将提取的河流网络利用 Google Earth 对其进行空间分布的对比，结果表明与实际较为吻合。本研究成功实现了快速提取河网信息，为进一步研究该地区地形地貌特征奠定了基础。

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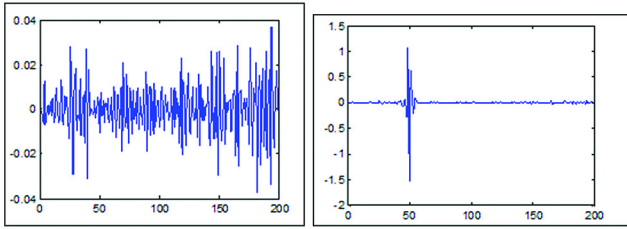


图7 无周跳的电离层残差值 图8 含周跳的电离层残差值

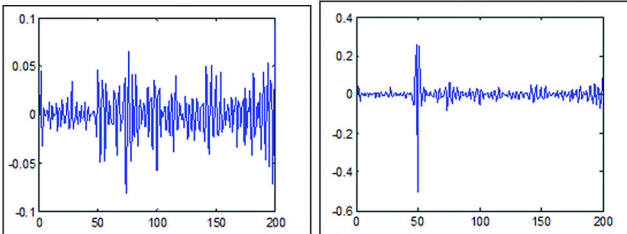


图9 无周跳双频伪距残差值 图10 含周跳后双频伪距残差值

在卫星 PRN5 上第 50 历元的 L_1 、 L_2 载波上加入相同的周跳值,由图 8、图 10 可以看出,图 8 探测的周跳值比图 10 的值大,说明经过小波处理的无电离层残差探测的周跳值比双频伪距组合观测 (Melbourne-Wbena) 探测的好。

4 结 语

首先分析了 GPS 周跳产生的原因及其特性,继而提出了周跳探测的检验量;然后在此基础上,采用小波分析的方法对实测数据进行多方面实验,并与常规方法做了一定地对比,从而说明了小波方法用于 GPS 周跳探测及修复的效果及优点。

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作者简介:毋利娜,硕士,研究方向为 GPS 数据处理。

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第一作者简介:李旭娇,硕士,研究方向为 3S 技术与数字国土。

grid pixel. We discussed upper and lower approximation of neighborhood particle from rough set. This research could provide a new method for grid data reclass and data analysis.

Key words grid data , neighborhood particle , rough set , distance measure (Page:31)

Research and Implementation of WebGIS Based on Silverlight by GUO Weipeng

Abstract Based on the user's increasing demand of powerful client and rich user experience, as well as the more strong consciousness about the importance of code portability, this paper used Silverlight a cross-platform and cross-browser technology for front port of the web application, the WebService interface supplied by BingMaps, and added in the the MiniMap and Magnify tools contained in DeepEarth, to complete this WebGIS Online Service System. This System used silverlight design UI and used some WebService to do some work about GIS. The research showed that the rich client and network service applied in Internet Map Service is feasible.

Key words Silverlight, GIS, Bing Maps, WebService (Page:34)

Automatic Extraction of Coastline Using Remote Sensing Technology by DING Yajie

Abstract Using remote sensing technique to determine coastline's position has been a problem received long attention. The paper present the development of research on this problem at home and abroad firstly. By using wavelet edge detection operators to extract the coastline of the Yellow River delta river estuary based on Landsat TM in 2004 and got more precise coastline through non-maximum depression, the paper illustrated the advantages and disadvantages of edge detection operators. Results showed that wavelet edge detection operators were more functional than traditional operators to extract precise coastline. The research emphases in future were also pointed out .

Key words coastline , RS image , wavelet transform , edge detection , non-maximum depression (Page:37)

Research of Using Scattered Data Interpolate DEM in Plain Areas by WANG Meng

Abstract A case study is given at the area of Qian Yingzi coal mine in China's eastern plains, which compared and analyzed the spatial interpolation results from the method of ANUDEM with those from GIS conventional interpolation methods for interpolation of spatially measured scattered data. This paper used statistical cross-validation and visual characteristics method to compare interpolation results from different methods. Comparisons showed that, in the plains, the DEM which was generated by TIN had higher accuracy, the DEM which was generated by ANUDEM method accurately reflect the hydrological landscape.

Key words Geographic information system , DEM , ANUDEM , Scattered data , Plain (Page:40)

Design of the School GIS Network Share System by WEN Chengjie

Abstract School GIS research is the main force of the GIS research in China, so the share of the school GIS network is the certain trend of the times. In this article, a solution, that how to use computer science to satisfy the request that the resource and technology's share between different schools or the inside network and outside network, was brought forward. From the view of a user, and according to the idea of software engineering some requirement was analyzed, and the whole syllabus and function modules of the school GIS network share system was analyzed and researched, and the key technologies referred by the implementation were explained in detail.

Key words school GIS , share , network , model (Page:42)

GIS Three-dimensional Visualization and Application of Terrain and Geology by SHEN Yongli

Abstract GIS has the function of powerful three-dimensional modelling and visualization analysis. By using areal geology achievement of Chongyang, Huhei Province for example, DEM was created by using terrain data and the three-dimensional terrain map was created by merging im-

age with Digital Elevation Model (DEM) based on geographical vector data, geological vector data and image data. The three-dimensional visualization model was created by integrating terrain data, geological data and image to solve the problem that three-dimensional geology could not be described intuitively by two-dimensional geological map and advanced spatial analysis capability.

Key words GIS, remote sensing image, DEM, three-dimensional visualization (Page:45)

The solution of converting CASS data to ArcGis by ZHANG Shuai

Abstract As we all know, the software CASS has a large number of versions, and some functions are always designed for the government according to their requirements, because of the data from different versions, it causes a lot of trouble for us in converting the unified ArcGis data format. The article is devoted to this kind of problems, and it depends on Visual C++ , as well as ObjectARX, discussing and researching the problem, finally, find a solution and making the different data totally customized to adapt to the varied data formats.

Key words CASS; ArcGis; data converting; user-defined; ObjectARX (Page:48)

Soil and Water Loss Dynamics in Brahmaputra River Basin by ZHANG Lin

Abstract Brahmaputra River basin was chose as a study area in this paper. Remote sensing and GIS technology were used to process remote sensing image of three periods in 2000, 2005, 2009 and extract soil and water loss factor. Soil and water loss dynamics in Brahmaputra River basin were studied deeply through the transition probability matrix. Markov model was used to predict dynamic changes of soil and water loss in Brahmaputra River basin. The result showed that the tend of soil and water loss was gradually increasing from 2000 to 2005, but the intensity was gradually reducing from 2005 to 2009. It indicated that the situation of soil and water loss had significantly improved since 2005. From the predicted results, soil and water loss in Brahmaputra River basin will be controlled.

Key words Markov model , soil and water loss , transition probability matrix (Page:51)

Visualization of Seabed Real-time Observed Data by Matlab Hybrid Programming by HE Zhiyuan

Abstract By analyzing the characteristics of data from seabed observing instruments, the author explored a way of using the Matlab based MATCOM Hybrid Programming to implement visualization of seabed real-time observed data in this paper. The author used ADO.NET technology to remotely access the intraday log tables in a SQL Server database for obtaining the seabed real-time observed data, and used the developer-friendly environment of VC ++. NET with Matlab powerful drawing functions to implement the functions of graphic display of seabed real-time observed data such as physical, chemical and energy data and it was expected to be used into the implement of real-time observation for seafloor observatory network.

Key words seafloor observatory network , seabed observed data , ADO.NET , Matlab, hybrid programming , real-time display (Page:54)

Extraction of River Network in the Upper Reaches of Minjiang River DEM by LI Xujiao

Abstract DEM contains a wealth of geological features, hydrology and other information, is the watershed of one of the main sources of data. This paper described the method of extraction feature river basin using of DEM data, and upper reaches of Minjiang , for example, pretreatment of DEM. And then used the platform of Hydrology module which provided algorithm by ArcGIS to determine direction of flow in the DEM grid cell for each . Calculated for each grid cell of the upstream catchment area, according to the given threshold, reached the river grid network diagrams, generated water system map. The results show that the water system in accordance with the DEM generation is basically consistent.

Key words DEM ; Minjiang River Upper Reaches ; extraction river network (Page:58)