Environmental Modelling & Software 38 (2012) 101–107

Contents lists available at SciVerse ScienceDirect

Environmental Modelling & Software

journal homepage: www.elsevier.com/locate/envsoft

Short communication

DEM Explorer: An online interoperable DEM data sharing and analysis system

Weiguo Han, Liping Di*, Peisheng Zhao, Yuanzheng Shao

Center for Spatial Information Science and Systems, George Mason University, 4400 University Drive, MS 6E1, Fairfax, VA 22030, USA

ARTICLE INFO

Article history:
Received 5 January 2012
Received in revised form
7 May 2012
Accepted 24 May 2012
Available online 15 June 2012

Keywords:
Digital Elevation Model
Geospatial data sharing and interoperability
Geospatial Web service
On-demand DEM retrieval
Terrain analysis
Hydrological analysis

ABSTRACT

Digital Elevation Model (DEM) data products are freely downloadable in tiled files from providers. But for most application needs, the area of interest does not exactly match the original spatial coverage of one DEM tile. After users obtain the files, they must mosaic, sub-set, and/or re-project them using geospatial software to generate the customized data that meet their requirements. It would be best if users could obtain the required DEM data directly. DEM Explorer is designed to share and explore the common DEM datasets in a publicly accessible online environment. It offers an intuitive and interoperable way to customize, download, visualize, and analyze DEM data in an Ajax-enabled Web interface. Via DEM Explorer, users are able to not only retrieve the original DEM files directly, but also obtain on-demand DEM data for any area of interest in a preferred format and projection. Deviations of terrain information are integrated as Web geoprocessing services in DEM Explorer to generate detailed terrain characteristics. DEM based hydrological models developed as Web services are aggregated to discover hydrological features. DEM Explorer has been adopted by the NASA Land Processes Distributed Active Archive Center to distribute the ASTER Global DEM to global users.

Software and data availability

Name	DEM Explorer
Developer	Center for Spatial Information Science and Systems (CSISS), George Mason University
Contact information	4400 University Drive, MS 6E1, Fairfax, VA 22030, USA
Hardware required	General-purpose computer
Software required	Internet browser (later versions are recommended)
Program language	Java, C and C++ (server side), JavaScript (client side)
Availability and cost	Any user can access DEM Explorer freely to visualize, customize, download, and analyze on-demand DEM data. DEM Explorer is at http://ws.csiss.gmu.edu/DEMExplorer/.

1. Introduction

Digital Elevation Model (DEM) data is used as the fundamental topographic data in a wide range of applications. DEM products such as Global 30 Arc-Second Elevation Data Set (GTOPO30) can be freely downloaded in tiled files with predefined spatial coverage from data providers. However, the targeted areas in most applications do not match the spatial coverage of the tiled DEM files exactly.

The normal data processing procedure is described as seen in Fig. 1. The user must calculate which DEM files should be downloaded according to the extent of the area of interest (AOI) and the spatial coverage of the DEM files. After acquiring these files, the user should perform several operations, like uncompressing, mosaicking, sub-setting, rasterizing, reformatting, and re-projecting to generate the required DEM data. Obviously, this typical process is laborious and inefficient. Increasingly, new data and processing services are needed to streamline the process of acquiring and using DEM data.

A Web geospatial application called DEM Explorer is developed to share and explore the DEM products in an interoperable and straightforward way. Using standard Web geospatial data and processing services integrated into DEM Explorer, users can avoid unnecessary bulk data transfers and inefficient data processing in GIS software, retrieve on-demand DEM data directly, explore DEM data interactively, and discover terrain patterns and hydrological characteristics.

* Corresponding author. Tel.: +1 703 993 6114; fax: +1 703 993 6127.
E-mail address: ldi@gmu.edu (L. Di).

1364-8152/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.envsoft.2012.05.015

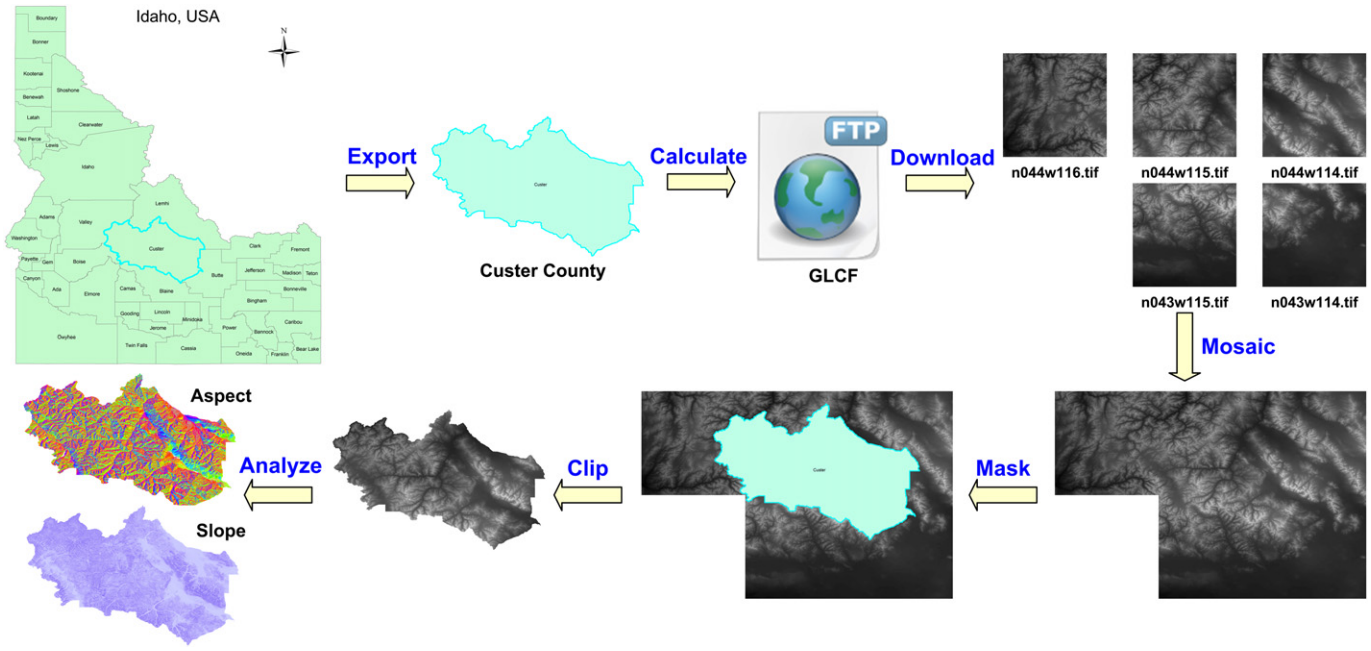

Fig. 1. Typical process of DEM data processing and analysis.

The remainder of this paper is organized as follows. Section 2 introduces DEM data products, Web geospatial data and processing services, and system architecture. Section 3 presents the implementation of DEM data sharing, dissemination, and exploration. Section 4 discusses the system's applications and promotions. Finally, Section 5 considers possible future developments.

2. Material and methods

2.1. DEM data

The DEM products integrated in DEM Explorer include Shuttle Radar Topography Mission (SRTM) 90 m (Jarvis et al., 2008), SRTM 30 m (USGS, 2006), Advanced Spaceborne Thermal Emission and Reflection Radiometer Global DEM (ASTER GDEM), Global Land Survey Digital Elevation Model (GLSDEM) (USGS, 2008), GTOPO30, and SRTM30_PLUS (Becker et al., 2009).[1] The information on these DEM datasets is listed in Table 1.

Data providers of these datasets provide Web interfaces or tools to search, select, order, and download original DEM data from their FTP or HTTP servers.

2.2. OGC Web services

The Open Geospatial Consortium (OGC) has built a series of specifications to discover, visualize, and analyze geospatial data. The Web Map Service (WMS) offers map rendering over the Web (de la Beaujardière, 2006). The majority of geospatial software can use maps from WMS (Iosifescu-Enescu et al., 2010). Coverage data can be retrieved from the Web Coverage Service (WCS) providers in a customized form (Whiteside and Evans, 2008). Geographic features can be queried and retrieved from Web Feature Service (WFS) servers (Vretanos, 2005). The server output is always encoded as a feature collection in Geography Markup Language (GML) or other vector format. These standard OGC services are widely used in the geospatial information science communities.

2.3. Geoprocessing Web services

Geoprocessing Web services provide standard interfaces to publish, discover and invoke geospatial functions (Baranski, 2009; Zhang et al., 2010). The World Wide Web Consortium (W3C) defines a series of standards of Web services such as the Web Services Description Language (WSDL), the Universal Description, Discovery and Integration (UDDI), and the Simple Object Access Protocol (SOAP). In the NASA-funded GeoBrain project (Di, 2004), a series of Web geoprocessing services derived from Geographic Resources Analysis Support System (GRASS) have been developed using W3C Web service standards to display, analyze and process raster, vector, and image data (Li et al., 2010). These standards-compliant and self-contained services can be discovered and composed into a workflow with other geospatial Web services to construct new modeling services using the Business Process Execution Language for Web Services (BPEL) (Han et al., 2011). Moreover, the services can be easily integrated using standard HTTP GET/POST or SOAP protocols in the Service Oriented Architecture (SOA) environment. Therefore, W3C Web service standards are also adopted to develop geoprocessing Web services in DEM Explorer.

2.4. Ajax

Because of its interactivity, no requirement on browser plug-ins, and low learning curve, Ajax (Asynchronous JavaScript and XML) is used to develop the browser client of DEM Explorer (Han et al., 2009). Many open-source Ajax frameworks can be downloaded to construct Web application easily. Moreover, some frameworks have been successfully integrated with JavaScript mapping libraries such as OpenLayers and Google Maps. Ajax provides a set of techniques to develop data-rich and service-centric Web geospatial applications.

2.5. System architecture

SOA is changing the way that geospatial data and information are delivered (Granell et al., 2010). It greatly extends the portfolio of Web geospatial data and processing services and permits easier development of customized geospatial applications (Goodall et al., 2011). DEM Explorer is implemented as a Java 2 Platform Enterprise Edition (J2EE) Web application based on SOA. The general framework is shown in Fig. 2.

In this framework, the *Application Layer* includes the browser client and other geospatial applications. The *Service Layer* offers OGC standards-compliant WCS, WFS, and WMS, along with Web geoprocessing services to visualize, customize, and analyze DEM data and other geospatial data. The *Data Layer* includes the boundary files, the color relief ASTER GDEM data, various types of DEM data, and the tile coverage files of DEM data. These data are served and processed by data and processing services in the *Service Layer*.

The data flow of DEM customization and analysis in DEM Explorer is showcased in Fig. 3.

3. Results

3.1. Web graphical user interface

In the implementation of DEM Explorer, ExtJS and OpenLayers are adopted to develop an Ajax-enabled browser client. The client

[1] Copyrights of all shared DEM data in DEM Explorer belong to the original owners.