Web Service for Extracting Terrain Openness from DEM Data

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***Abstract*— This paper discusses the implementation of the Terrain Openness parameter as a Web Service. Terrain Openness is a new morphology parameter that emphasizes surface concavities and convexities (Yokoyama et al., 2002) and can be derived directly from a digital elevation model (DEM). It is essentially an angular measure of the relation between surface relief and horizontal distance and can be used as a proxy for topographic curvature. It is not sensitive to noise in the data and has spatial scale built in its definition. However, the Terrain Openness parameter has not been widely used, perhaps because of limited software availability. Implementing it as a Web Service will ensure widest possible accessibility, because the only requirement for the user is an Internet connection and a standard web browser. This is made possible with recent advances in Service-Oriented Architecture (SOA), geospatial Web Services, and interoperability technologies. It is implemented within the framework of GeoBrain, an open, interoperable, distributed, standard-compliant, multi-tier web-based geospatial information services and knowledge building system.**

Keywords-Web Service; Terrain Openness; DEM

I. INTRODUCTION

Digital Elevation Models (DEMs) in the form of grid data have become common place nowadays and many parameters such as slope, aspect, convexity and concavity can be derived directly from DEM. These parameters are widely used in the fields of civil engineering, geology, geomorphology and hydrology, e.g., for modeling erosion, providing watershed information and mapping land components [1]. Terrain Openness is a recently developed terrain morphology parameter that emphasizes surface concavities and convexities [2] and can be used as a proxy for topographic curvature. Comparing with the traditional curvature measure, terrain openness has the following advantages: (1) its computation is more straightforward as no derivatives are involved and thus makes it less sensitive to noise; (2) it incorporates the line-of-sight principle but does not require light sources in its computation; (3) spatial scale dependency is built into its definition, which allows the user to calculate openness at varying scales to show fine- or course-scale features [2]. However, the Terrain Openness parameter has not been widely adopted, perhaps because of limited software availability. This paper presents a free Web Service that allows a user to extract the Terrain Openness parameter from DEM data easily. The only requirement is an Internet connection and a standard web browser.

II. TERRAIN OPENNESS

Terrain Openness is essentially an angular measure of the relation between surface relief and horizontal distance [2]. It incorporates the terrain line-of-sight principle but does not require light source and is calculated from zenith and nadir angles along eight azimuths. Openness has two viewer perspectives (see Figure 1). Positive values, expressing openness above the surface, whereas negative values describe this attribute below the surface.

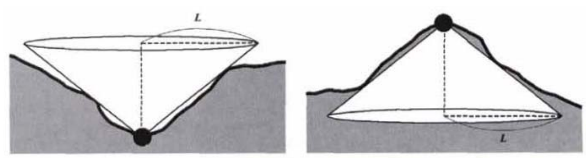

Figure 1. Positive (left) and negative (right) openness. Heavy lines indicate terrain surface; L is the scale of calculation for point under consideration (big black dot) on a DEM (after [2]).

The calculation of openness at point A in DEM grid with spatial scale L is illustrated in Figures 2-3 and involves the following steps:

1) for each azimuth direction D (D = 0º, 45º, 90º, 135º, 180º, 225º, 270º, and 315º), calculate the elevation angles along the profile from point A (double circle in Figure 2 and big black dot in Figure 3) out to length scale L. In Figure 3, there is an elevation angle for each grid point along the profile represented by the small black dot. The elevation angle is positive if the distant point is higher than A; negative if distant point is lower than A. These angles form a set ${}_{D}S_{L}$ for each azimuth direction D.

2) calculate maximum elevation angle: ${}_D\beta_L = \max({}_DS_L)$;

3) calculate minimum elevation angle: ${}_D\delta_L = \min({}_DS_L)$;

4) calculate zenith angle: ${}_D\phi_L = 90° - {}_D\beta_L$;

5) calculate nadir angle: ${}_D\psi_L = 90° - {}_D\delta_L$;

6) obtain positive openness: $\phi_L = ({}_0\phi_L + {}_{45}\phi_L + \ldots + {}_{315}\phi_L)/8$

7) obtain negative openness: $\psi_L = ({}_0\psi_L + {}_{45}\psi_L + \ldots + {}_{315}\psi_L)/8$

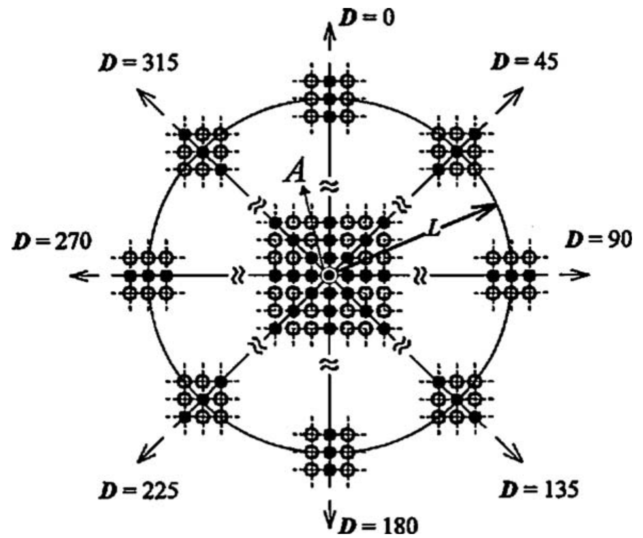

Figure 2. Plan view of selected cells in a DEM grid illustrating openness calculation. Double circle shows the point of origin (A) for the calculation of openness; solid points show heights outward from point A along each of the eight azimuths; azimuth angle *D* is measured clockwise from north. *L* is radial limit of the calculation (after [2]).

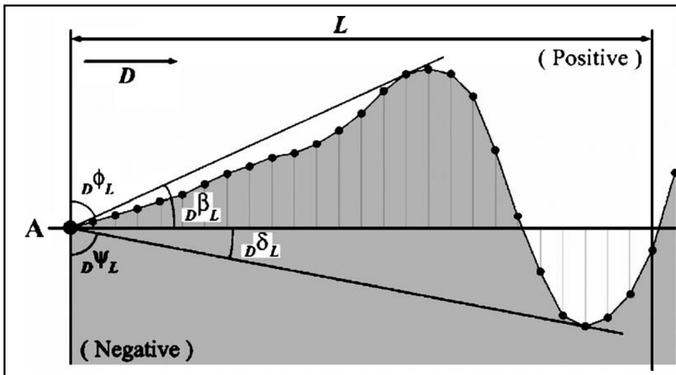

Figure 3. Profile view along azimuth *D* (D = 0º, 45º, 90º, 135º, 180º, 225º, 270º, and 315º) as shown in Fig. 1. ${}_D\beta_L$ is the maximum vertical angle subtended by point A and any point along the azimuth *D* up to distance *L*. ${}_D\psi_L$ is the minimum counterpart (note: angels formed between horizontal and the point below A are negative). Positive openness is the mean value of zenith angle ${}_D\phi_L$ (= 90° - ${}_D\beta_L$) along the eight sampling directions; negative openness is the corresponding mean value of nadir angle ${}_D\psi_L$ (= 90° - ${}_D\delta_L$) (after [2]).

III. GEOBRAIN AND WEB SERVICES

With the recent development of Web Service technology, we are witnessing a paradigm shift in scientific analysis of geospatial data, from "everything locally owned and operated" environment to "Web-and-Service-Centered" environment [3]. Service-Oriented Architecture (SOA), geospatial Web Services and interoperability technologies have made it possible for researchers to access data residing on a remote server without having to download them physically to their local machine and to string Web Services available over the Internet together to complete their own analysis tasks. The new paradigm makes analysis and application of geospatial data very inexpensive and efficient, as researchers do not have to spend money on the software licenses and time to preprocess the large volume of geospatial data in the format compatible with the software.

A Web Service is defined by the World Wide Web Consortium (W3C) as "a software system designed to support interoperable Machine to Machine interaction over a network." GeoBrain is a Web Service based geospatial knowledge system for providing value-added geospatial service and modeling capabilities to geosciences user community [4]. Funded by NASA, GeoBrain is developed to make petabytes of NASA's Earth Observing System (EOS) data and information as easily accessible as possible to higher-education users, both professors and students. In other words, through the Open GIS Consortium (OGC) standard compliant Web Services in GeoBrain, users can not only easily access NASA data as if the data are residing on their local machine, greatly streamline the preprocessing, but also access existing tools or necessary building blocks to build new tools to analyze large amount of geospatial data. GeoBrain has ported many functions of the open source GIS software GRASS [3][4]. Taking advantage of the existing infrastructure of GeoBrain, the Web Service for extracting Terrain Openness from DEM data is implemented as part of the GeoBrain and incorporated into the Web Service-based Online Analysis System (GeOnAS, http://geobrain.laits.gmu.edu:81/OnAS/), a fully extensible online analysis system for using GeoBrain Web Services to discover, retrieve, analyze, and visualize geospatial and other network data. With this implementation, all that is needed for the user is an Internet connection and a standard Web browser, both readily available nowadays.

IV. IMPLEMENTATION OF OPENNESS WEBSERVICE

The core code to derive the "openness" from DEM data is written in Fortran. This openness program can be executed in command line mode. Three parameters need to be entered by the users: (1) Input DEM file in ESRI ASCII grid format, (2) Input spatial scale *L* in number of cells, (3) Input vertical unit ("m" (meter) or "ft" (feet)). The outputs of the openness program are two raster maps containing the positive openness ϕ_L and negative openness ψ_L in ESRI ASCII grid format.

To expose an existing algorithm as a Web Service, we first write a WSDL (Web Services Description Language)[1] file for describing the Web Service interface. WSDL is an XML-based language for supporting interoperable machine-to-machine interaction. Corresponding to three inputs of the Fortran program, three request parameters are described in the WSDL schema: (1) DEM data URL with name "sourceURL" defined as the xsd:anyURI type, (2) spatial scale with name "scale" defined as xsd:int type, and (3) vertical unit with name "zunit" defined as the enumeration type "ZunitType" that represents required vertical unit (there are two options: m, ft). We specified the input and output data formats as GeoTIFF format because GeoTIFF is an open standard image format and widely supported by many different tools. One more request parameter with name "outputGeoTiffType" is defined as an enumeration type "GeoTiffFileType" for specifying output data format (there are eleven options: Byte, Int16, UInt16, UInt32, Int32, Float32, Float64, CInt16, CInt32, CFloat32, and CFloat64). Two pairs of parameters are used to define the response parameters: the xsd:anyURI type "phiReturnURL" that represents the URL of output raster map containing the positive openness and the xsd:string type "phiReturnFormat" that represents format of output raster map containing the positive openness. In like manner, "psiReturnURL" and "psiReturnFormat" represent the URL and format of output raster map containing the negative openness.

Many Web Service toolkits are available to make creating Web Service easy. Apache Axis[2] is such a toolkit for building, deploying and using Web Services, while the developers and users do not need to learn SOAP (Simple Object Access Protocol)[3] or other low-level Internet protocols. To create the openness calculation Web Service, we use a "WSDL2Java" tool in Axis to read WSDL file and automatically generate server-side stub Java code for the Web Service, then fill the actual algorithm implementation in generated Java code. The exec() method of java.lang.Runtime class is used to execute external command line applications from within a Java program. Since the specified input and output formats are not compliant with the requirements of openness algorithm program, the open source GDAL/OGR[4] "gdal_translate" utility is used to convert data formats between GeoTIFF and ESRI ASCII grid format. The "gdal_translate" utility can also be executed with the inputs on the command line. Once the service code has been compiled successfully, the Axis within a Web application server such as Apache Tomcat[5] can publish the Web Service automatically.

[1] http://www.w3.org/TR/2001/NOTE-wsdl-20010315
[2] http://ws.apache.org/axis/
[3] http://www.w3.org/TR/2001/WD-soap12-part0-20011217/
[4] http://www.gdal.org/gdal_translate.html
[5] http://tomcat.apache.org/

V. Interface of Openness Web Service and Example Usage

The Terrain Openness Web Service is a standard SOAP-based service that anyone can invoke it directly with their own client applications. Its WSDL file can be retrieved from the service address URL so that the users can develop their own clients from the WSDL description. In this paper, we took advantage of the existing framework of GeoBrain and implemented the Openness Web Service in "GeOnAS", an OGC-compatible Web client. This client provides an interoperable way of discovering and accessing geospatial information resources that are distributed on the Internet, such as Web Services, data sets, data descriptions, and their associations [5]. The GeOnAS system is a browser-centric online analysis system that can be called within a standard Web browser.

GeOnAS uses "Project" to manage a group of data files, including coverage data, feature data, and map data in the same spatial reference system and geospatial bounding box. Figure 4 shows the interface for defining the geographic bounding box of an area of interest in Cascade Range, Oregon, where a contrast in dissection exists [6].

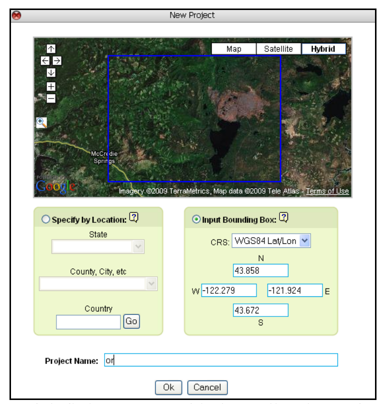

Figure 4. Interface of defining geographic bounding box of area of interest.

Geospatial data are added into the left "Project Panel" (See Figure 5) by using the "add new layer" icon on the Tool bar. This operation will connect to the data server. Added data can be displayed in the right Map Panel. Figure 5 shows an example of the SRTM DEM data being displayed. The user can control the map display by using tools such as zoom, pan, refresh, and change palette. Five data operation functions can be found at the left bottom toolbar of the Project Panel, "Add Layer", "Remove Layer", "Export data", "Export image" and "Properties". "Properties" is very useful tool for showing metadata information to users.

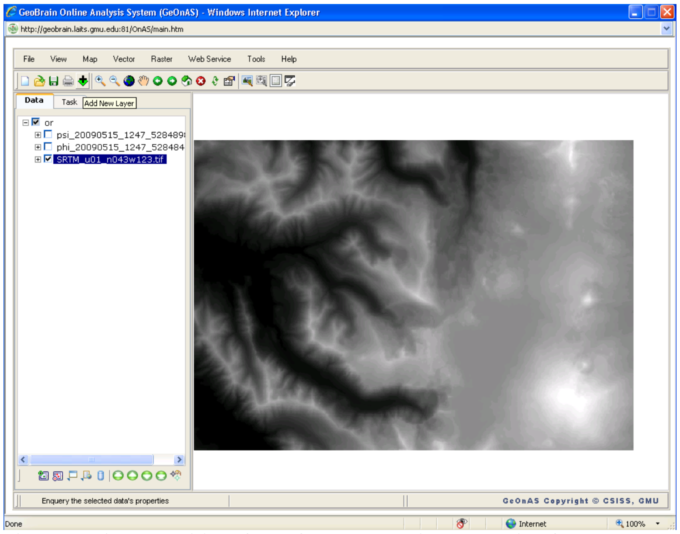

Figure 5. The general interface of GeOnAs and an example of SRTM DEM data.

The Terrain Openness calculation Web Service has been registered in the Catalog Service for the Web (CSW) and categorized according to OGC standard service type taxonomy, so that it can be easily searched and invoked. Figure 6 shows the interface for Terrain Openness Web Service. The user can simply click on the "+" button to add currently displayed DEM for the sourceURL. Once the scale, zunit and output data type are specified, clicking on "Invoke" button will start the calculation. GeOnAS supports asynchronous invocation. The users can continue to work on other things while the invoked calculation is being processed in the background. This feature is especially useful for processing large geospatial datasets.

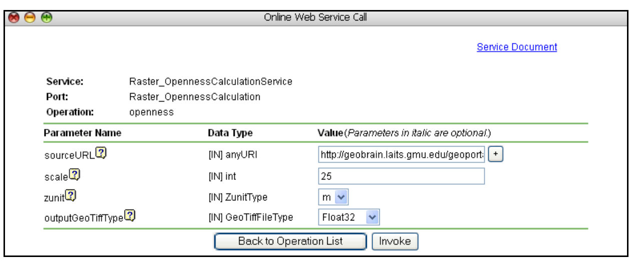

Figure 6. The Terrain Openness Web Service interface in GeOnAs.

The results of the positive and negative openness at the spatial scale of 25 cells are shown in Figures 7 and 8. Comparing with the original DEM (Figure 5), high values (bright areas) of positive openness correspond to ridges, low values (dark areas) valleys (Figure 7). On the other hand, high values (bright areas) of negative openness correspond valleys, low values (dark areas) ridges (Figure 8). Thus Terrain Openness can be used to extract stream lines and ridge lines. In addition, Terrain Openness can help visualize the topographic dominance or enclosure of any location on an irregular surface represented by a DEM [2] and reveal subtle differences in dissection patterns. It is also interesting to note that the lake (black area) shown in Figure 4 has a perfect 90 degree openness in both negative and positive openness results.

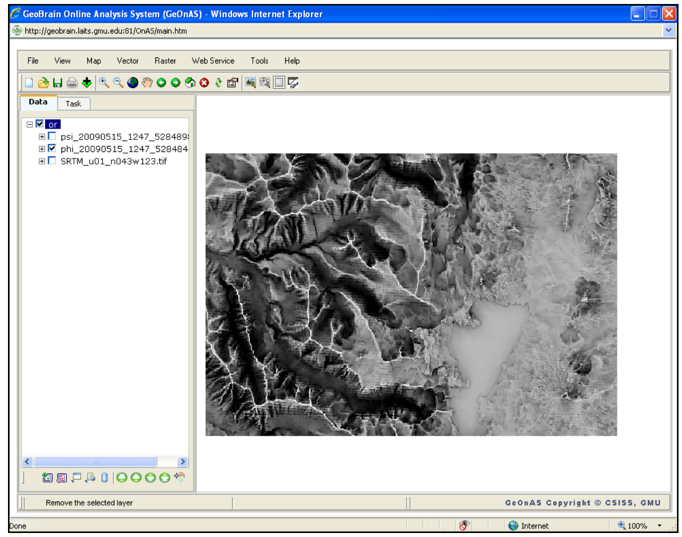

Figure 7. The result of positive openness ϕ_L at the spatial scale of 25 cells.

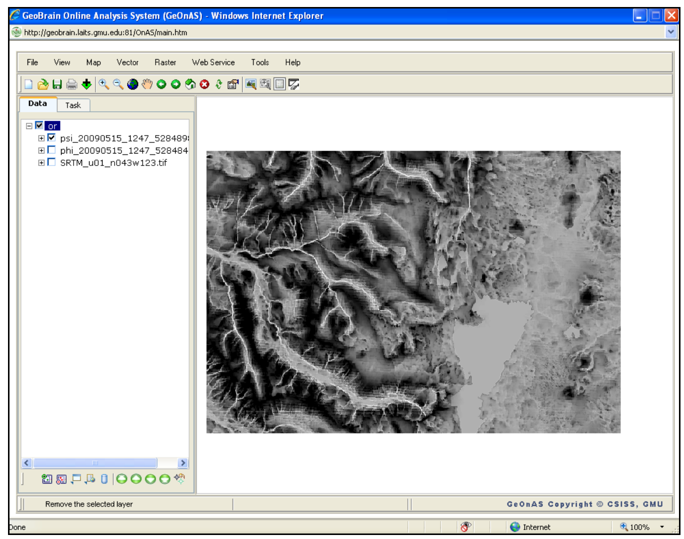

Figure 8. The result of negative openness ψ_L at the spatial scale of 25 cells.

VI. CONCLUSIONING REMARKS

Terrain Openness is essentially an angular measure of the relation between surface relief and horizontal distance and can be used as a proxy for topographic curvature that emphasizes surface concavities and convexities [2]. It is not sensitive to noise in the data and has spatial scale built in its definition. In addition, it incorporates the line-of-sight principle and helps to visualize the topographic dominance or enclosure of any location on the topographic surface [2]. It can be used to extract stream lines and ridge lines from DEM data. However, the Terrain Openness parameter has not been widely used, perhaps because of limited software availability. Taking advantage of the existing framework of GeoBrain and GeOnAS, we implemented a free Web Service that allows a user to extract the Terrain Openness parameter from DEM data via a standard web browser. The Web Service will ensure widest possible accessibility, because the only requirement for the user is an Internet connection and a standard web browser. This is made possible with recent advances in Service-Oriented Architecture (SOA), geospatial Web Services, and interoperability technologies.

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