TerraEx – a GeoWeb app for world-wide content-based search and distribution of elevation and landforms data

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Abstract

Terrain Explorer (TerraEx) is the first world-wide content-based search application for landscapes. Using 3" resolution world-wide DEM as an input it finds and displays, in the form of a similarity map, locations in the world where landscapes are similar to a user-selected query. TerraEx is a freely available, full service GeoWeb application. It also doubles as the most convenient distributor of global 3" DEM data, the global map of geomorphons, and the global map of terrain relief. TerraEx opens a possibility to utilize publicly available DEM archives in their entireties for world-wide exploration through content-based search.

1. Introduction

Digital Elevation Model (DEM) is one of the most useful data types in geosciences with applications in multiple disciplines from geomorphology through civil engineering to virtual reality and entertainment. Popularity and broad adoption of DEMs follows in part from the fact that medium and low resolution DEMs are freely available for download; examples include the Shuttle Radar Topography Mission (SRTM) world-wide DEM and US-wide National Elevation Dataset (NED). Users can access DEMs by selected region, coordinates, or administrative regions. However, until now, these vast resources could not be explored in their entirety due to the lack of search tools for content-based retrieval of topographic information.

In this paper we report on development of Terrain Explorer (TerraEx) – the first application for content-based retrieval of topographic information. TerraEx is a GeoWeb application (http://sil.uc.edu/webapps/terraex) that enables the world-wide search for topographic landscapes similar to a user-selected query landscape. It uses a world-wide 3" (90m) DEM (see next section for details) for elevation data. The search is not performed directly on the DEM; instead it is performed on the DEM classified into the ten landform elements using the geomorphon method (Jasiewicz and Stepinski 2013a). TerraEx also doubles as the most convenient source of world-wide, geographically registered topographic data. A user can navigate to a location of interest (with or without a prior exploration using the search) and download (in GeoTIFF format) a 3" resolution DEM, a map of geomorphons, and a map of terrain relief.

In the process of constructing TerraEx we developed the following new products and concepts: (a) a new, adaptively smoothed version of world-wide, 3" DEM that removes artifacts in the flat areas, and (b) a methodology for comparison of spatial patterns in a globe geometry

2. Content-based search

Input data is the world-wide 3" DEM (Ferranti, 2014) – a compilation of the SRTM DEM with DEMs from other sources for areas not covered by the SRTM. This dataset covers 215000 × 420000 16bit integer cells, in the WGS84 lat-lon projection with vertical resolution of 1m. We fill all the gaps in the Ferranti data, convert it to floating point, de-noise, and adaptively smooth while preserving elevation values in Ferranti DEM to within 1 m. This removes terrace-like artifacts in the flat areas (30% of lands surface) – an important improvement, especially when classifying DEM into landform elements. This new world-wide DEM is classified into ten landform elements yielding the 3" world-wide map of geomorphons which is used for landscape search.

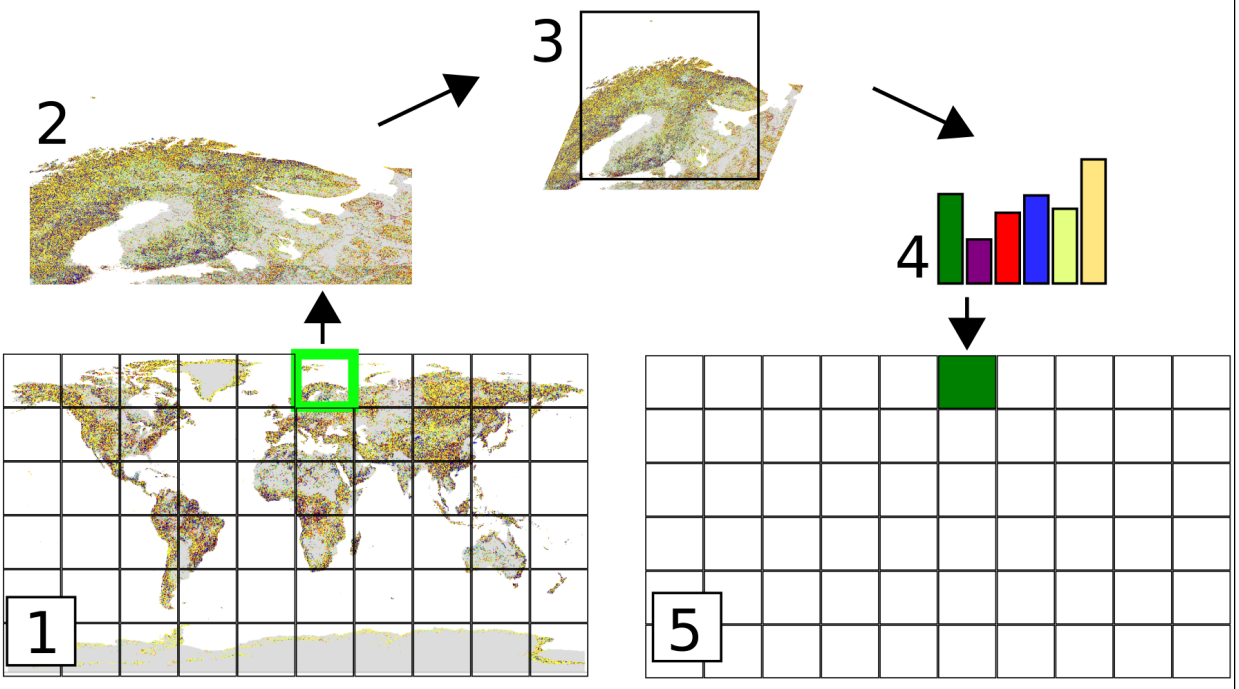

Figure 1: On-the-fly reprojection from WGS to UTM during grid calculation

The content-based search of topography is based on the same general principle as our earlier search for similar land cover patterns across the US (Jasiewicz and Stepinski, 2013b; Stepinski et al., 2014) but with modifications to accommodate the globe geometry. The geomorphons dataset is divided arbitrarily into a regular grid of local blocks of cells; each block (referred to as a motifel) contains a local pattern of the ten landform elements which serves as a proxy for the local landscape. For the purpose of calculating similarities between motifels (local landscapes) we represent them by the co-occurrence histogram of landform elements. In TerraEx a motifel has a size of 160 cells (~14km) and the global grid of all motifels has dimensions of 10800×5400 (motifels are arranged in a grid with a significant overlap).

The major difference from our previous US-wide search is that in the lat-lon grid of global extent the topography is severely distorted at high latitudes but search requires a comparison of undistorted landscapes. Fig.1 illustrated schematically how this problem is addressed in TerraEx: (1) lat-lon geomorphons dataset is divided into motifels; (2) for each motifel an appropriate

UTM zone is determined and a region of the geomorphon map large enough to cover a motifel after transformation to this UTM zone is selected; (3) the region is transformed to the local UTM; (4) co-occurrence histogram is calculated from the transformed map; (5) histogram is saved in the appropriate position in the lat-lon grid. The steps 1-5 are all calculated offline with the resultant grid of histograms saved in the server memory.

The landscape search starts with a user selecting a location; the histogram describing a local landscape in this location (a query) is set aside to be compared one-by-one with histograms from all motifels in the world-wide grid. We use the Ruzicka similarity measure (Deza and Deza 2014) between two histograms; it yields a value between 0 (not similar at all) to 1 (identical). The result of this comparison is the spatial layer containing values of similarities between a query and local landscapes. This layer – a similarity map – is displayed in TerraEx with a color gradient indicating similarity values. Visual examination of the similarity map provides information on where in the world are the landscapes similar to the query. The time from issuing a query to displaying a similarity map is about 10 sec. Such short wait time is achieved by an efficient computational engine (GeoPAT 2.0, a stand-alone extension of an original, GRASS GIS-based GeoPAT toolbox for pattern-based geoprocessing (Jasiewicz et al., 2015)), which is written in C and uses parallel computation based on the OpenMP library.

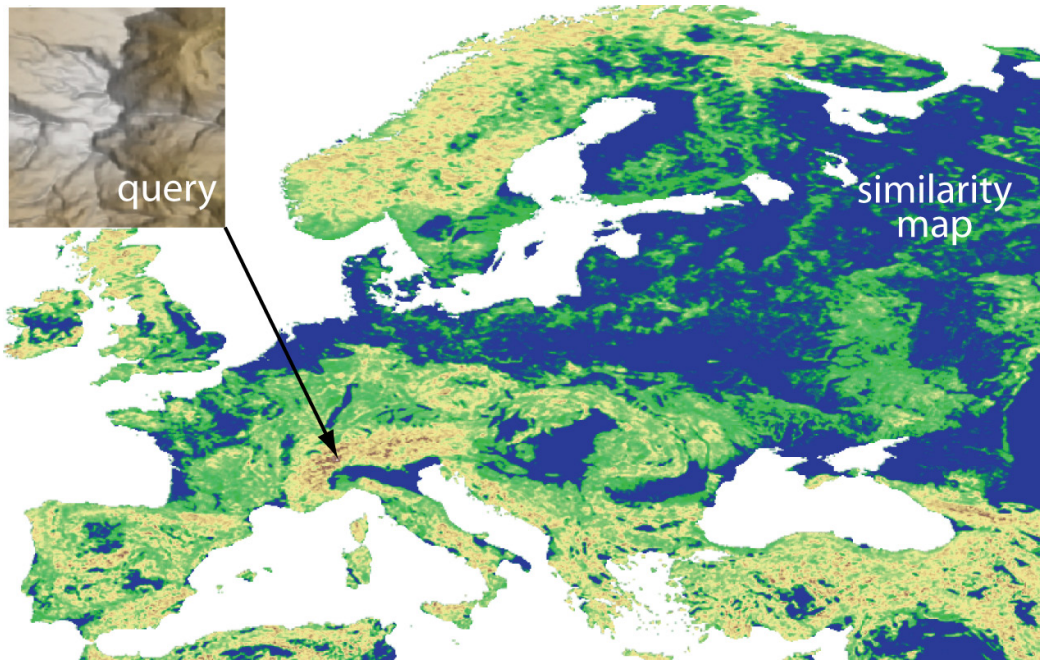

Figure 2: Example of landscape search using a specific alpine landscape as a query.

4. Example of landscape search

It is not possible to fully convey in the paper how TerraEx – an interactive, web-based application – works; one needs to use it to fully appreciate its functionality. Fig.2 illustrates

partial results of a particular search. As an example, we have chosen a location in the central Alps as a query. This location is indicated by an arrow in Fig.2 and a landscape in this location (spatially restricted to the scale of a motifel or ~14km) is shown in the inset in the form of a hillshade. The main panel of Fig.2 shows the similarity map for this query restricted to Europe (so some details could be seen). Brown colors indicate high similarity to a query; decreasing similarities to a query are shown by a yellow-green-blue gradient. As expected, TerraEx indicates that other locations in the Alps, as well as locations in Caucasus Mountains have largest similarities to a query, while central and eastern European planes have the smallest similarities to the query.

5. Conclusions and future work

TerraEx is a novel tool that enables, for the first time, content-based, world-wide exploration of topographic landscapes. Behind the scenes TerraEx is a modern, standards-compliant GeoWeb application, details of which could not be described here due to the lack of space. It also doubles as a very convenient distributor of world-wide 3" DEM and the map of geomorphons.

The major novelty of TerraEx is its ability of identifying places in the world having landscapes "similar" to a query. Note that what actually is calculated is similarity of patterns of landform elements as given by the geomorphon method. As with all content-based searches there is a possibility of the semantic gap – a difference between similarity as calculated by an algorithm and similarity as perceived by an analyst. Geomorphons are not the only way to define landform elements, co-occurrence histogram representation of landscape is one of many possible heuristics, and similarity between histograms can be calculated by a number of methods. In addition, TerraEx currently implements search of landscapes only on a single scale of ~14km. Future research will address these issues and future versions of TerraEx may provide more choices. For now TerraEx should be used as any other search engine, the results should be taken as suggestions and examined by an analyst for utility.

Acknowledgements

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