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Research paper

Whitebox GAT: A case study in geomorphometric analysis

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A R T I C L E I N F O

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A B S T R A C T

This paper describes an open-source geographical information system (GIS) called Whitebox Geospatial Analysis Tools (Whitebox GAT). Whitebox GAT was designed to provide a platform for the rapid development and testing of experimental geospatial analysis methods, supported by its extensible design, integrated facilities for custom plug-in tool authoring, and its novel open-access design philosophy. One of the unique characteristics of Whitebox GAT is the ease with which users can inspect and modify the algorithms for individual geoprocessing tools. The open-access software model that Whitebox GAT adopts is designed to lessen the barriers that are often imposed on end-users when attempting to gain deeper understanding of how a specific function operates. While Whitebox GAT has an extensive range of GIS and remote sensing analytical capabilities, making it broadly suited for advanced scientific research applications in the Earth Sciences, this paper focusses on the software's application in the field of geomorphometry. An airborne LiDAR data set for a small headwater catchment of the Missisquoi River in northern Vermont, USA, was filtered to identify ground-points and then interpolated into a 2.0 m resolution bare-Earth DEM. The DEM was processed to remove spurious off-ground objects (mainly buildings), to reduce surface roughness under heavy forest cover, and to hydrologically pre-condition the DEM. These data were then used to extract salient hydrological structures, i.e. the stream network and their associated sub-basins.

1. Introduction

Geomorphometry is the field of study concerned with the representation and quantitative analysis of topography (Pike et al., 2009). The discipline focuses on extracting information from digital elevation models (DEMs) to better understand landscape processes (Wilson and Gallant, 2000). As a sub-discipline of geomatics, geomorphometry draws upon the methods and theories of geographical information science, spatial analysis, geocomputation, and remote sensing. Over the past few decades, improved terrain modeling technologies and processing techniques have underpinned many advancements in soils and vegetation mapping, flood forecasting, hydrological modeling, sediment transport modeling, slope stability analysis, geological resources inventorying, and numerous other environmental applications (Moore et al., 1991; Zhou et al., 2008). Although specialized software has been developed for terrain modeling and analysis, such as Landserf (Wood, 2008), many of the analysis methods of geomorphometry are so central to applications in the Earth Sciences that they have been widely integrated in GIS. For example, DEM based surface flow-path modeling is essential for the parameterization of many hydrological models (Peckham, 2008) and most modern GIS have the ability for performing some of these types of analyses, such as watershed mapping and the calculation of upslope contributing areas.

Like many of the sub-disciplines of geomatics, geomorphometry is a highly active field of scholarly research and publication, as existing analysis techniques are tested and novel techniques are continually developed for improved land surface characterization, processing of new topographic data sources, and the expansion of geomorphometric methods to new application areas. The objective of this paper is to describe the Whitebox GAT software. The software was designed to provide a platform for the rapid development and testing of experimental geospatial analysis methods, supported by extensive facilities for data handling and visualization. This paper describes the conceptual basis and design of the Whitebox GAT software and demonstrates its application in the area of geomorphometry. A case study is used to illustrate the capabilities of Whitebox GAT, focusing on the geomorphometric analysis of a LiDAR data set of the Mill Brook Catchment, Vermont USA.

2. The Whitebox GAT project history and goals

The Whitebox GAT project began in 2009 through the development efforts of researchers at the University of Guelph, Canada.

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The project was conceived as a replacement for the Terrain Analysis System (Lindsay, 2008, 2005), a freeware software package with an emphasis on analysis of digital elevation data. Whitebox GAT was intended to have a broader focus than its predecessor, positioning it as a desktop GIS and remote sensing software package for general applications of geospatial analysis and data visualization. The project also adopted the open-source GNU General Public License (GPL).

Two main goals have guided the development of the software. First, Whitebox GAT is intended to provide an environment for advanced geospatial data analysis with applications in both environmental research and the geomatics industry more broadly. Whitebox GAT was envisioned from the outset as providing an ideal platform for experimenting with novel geospatial analysis methods. Equally important is the project's goal of providing a tool that can be used for geomatics-based education. These competing goals have necessitated a design that balances advanced functionality, and the complexity that is often inherent therein, with a user-centric emphasis on ease of use. Based on the author's experience communicating with users directly and through the software's email listserv, Whitebox users span the entire spectrum of experience from the students of introductory level GIS and remote sensing courses to researchers and GIS analysts that use the software for advanced data analysis. Many of the characteristics of the software have arisen out of the need to balance these main design goals. For example, the project's stated open-access software philosophy, described below, contributes to Whitebox GAT's goal of serving as a tool for geomatics education and enhances its utility for experimental geospatial analysis methods development.

3. Software characteristics

3.1. Software design and user interface

Whitebox GAT is developed using a combination of programming languages targeting the Java runtime environment (JRE) including Java, Groovy, Jython (the Python implementation for Java), and Javascript. The software is cross-platform, targeting all major operating systems that offer a JRE. While many of the plug-in tools used for data analysis have been developed using the supported scripting languages of Groovy, Python, and Javascript, the core components of Whitebox GAT, including the user interface, are developed using the Java programming language.

The Whitebox GAT user interface consists of a menu, a tool bar, a side panel for accessing and manipulating tools and data layers, and a central area where data layers are visualized (Fig. 1). Users can add and manipulate cartographic elements such as map areas, insets, scale bars, legends, and north arrows. Elements can be selected, resized, repositioned, grouped, and aligned in a manner that is similar to the content layout managing method used in most drawing packages. Volunteers from the user community have translated large portions of the user interface to 11 languages, which may somewhat reflect Whitebox GAT's global usage patterns. A survey of usage showed that Whitebox GAT was downloaded 14,932 times since January 1, 2014, with a recent download rate averaging 840 per month. Downloads of the software originated from 150 countries worldwide with the top ten countries, accounting for nearly 59% of the downloads, including the United States, Canada, Italy, the United Kingdom, India, Germany, Australia, Spain, France, and Brazil.

Whitebox tools are listed within a toolbox tree-view structure located in the *Tools* tab of the side pane (Fig. 1), a design that allows for easy integration of new plug-in tools and toolboxes. Tools can also be accessed through a search and a listing of recent and

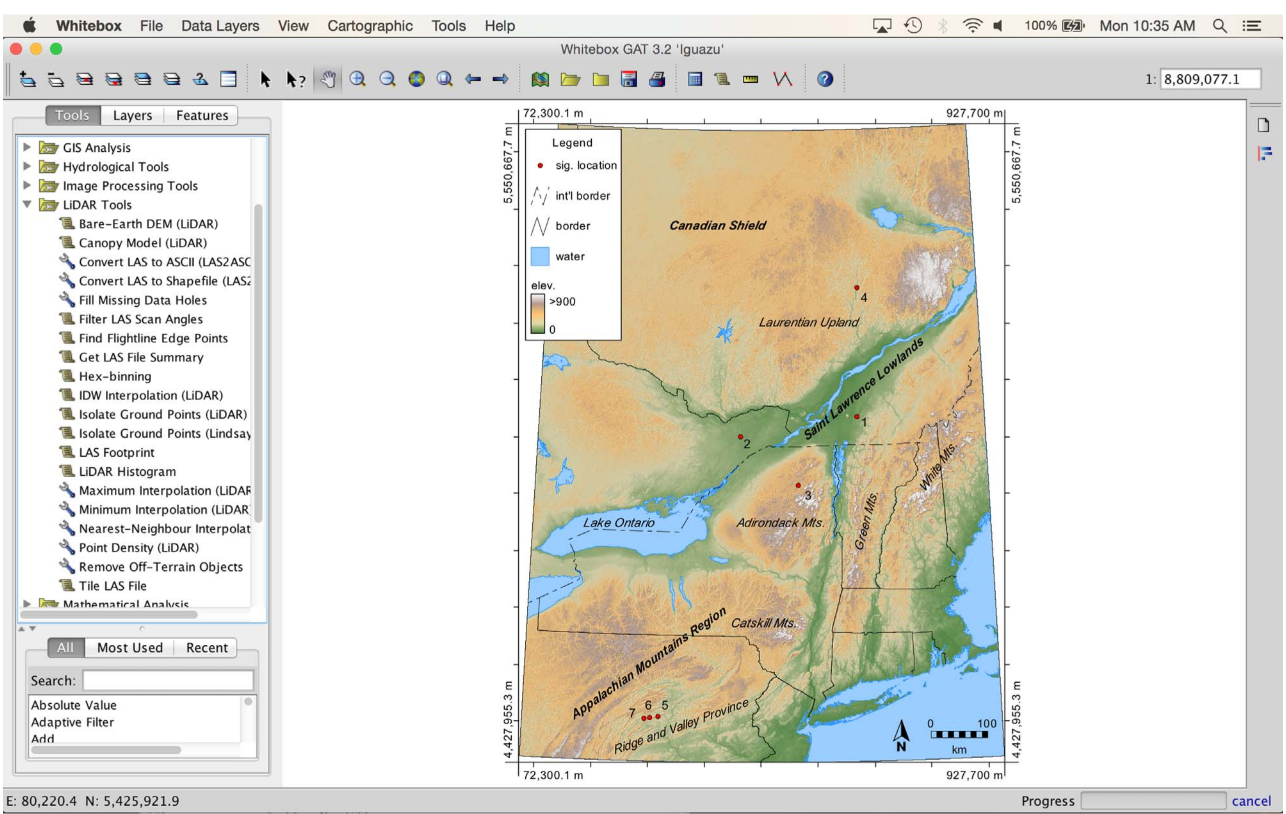

Fig. 1. The Whitebox GAT user interface showing the toolbox and a cartographic example.