The Journal of Open Source Software

lidar: A Python package for delineating nested surface depressions from digital elevation data

Qiusheng Wu[1]

1 Department of Geography, University of Tennessee, Knoxville, TN 37996, United States

DOI: 10.21105/joss.02965

Software

- Review
- Repository
- Archive

Editor: Katy Barnhart

Reviewers:

- @laijingtao
- @cheginit
- @amanaster2

Submitted: 08 December 2020
Published: 02 March 2021

Summary

lidar is a Python package for delineating the nested hierarchy of surface depressions in digital elevation models (DEMs). In traditional hydrological modeling, surface depressions in a DEM are commonly treated as artifacts and thus filled and removed to create a depressionless DEM, which can then be used to generate continuous stream networks. In reality, however, surface depressions in DEMs are commonly a combination of spurious and actual terrain features (Lindsay & Creed, 2006). Fine-resolution DEMs derived from Light Detection and Ranging (LiDAR) data can capture and represent actual surface depressions, especially in glaciated (Wu & Lane, 2016) and karst landscapes (Wu et al., 2016). During the past decades, various algorithms have been developed to identify and delineate surface depressions, such as depression filling (Wang & Liu, 2006), depression breaching (Lindsay & Dhun, 2015), hybrid breaching-filling (Lindsay, 2016), and contour tree method (Wu et al., 2015). More recently, a level-set method based on graph theory was proposed to delineate the nested hierarchy of surface depressions (Wu et al., 2019). The **lidar** Python package implements the level-set method and makes it possible for delineating the nested hierarchy of surface depressions as well as elevated terrain features. It also provides an interactive Graphical User Interface (GUI) that allows users to run the program with minimal coding.

Statement of Need

The **lidar** package is intended for scientists and researchers who would like to integrate surface depressions into hydrological modeling. It can also facilitate the identification and delineation of depressional features, such as sinkholes, detention basins, and prairie potholes. The detailed topological and geometric properties of surface depressions can be useful for terrain analysis and hydrological modeling, including the size, volume, mean depth, maximum depth, lowest elevation, spill elevation, perimeter, major axis length, minor axis length, elongatedness.

State of the Field

Currently, there are a few open-source Python packages that can perform depression filling on digital elevation data, such as RichDEM (Barnes, 2018) and whitebox, the Python frontend for WhiteboxTools (Lindsay, 2018). However, there are no Python packages offering tools for delineating the nested hierarchy of surface depressions and catchments as well as simulating inundation dynamics. The **lidar** Python package is intended for filling this gap.

lidar Functionality

The key functionality of the **lidar** package is organized into several modules:

- filtering: Smoothing DEMs using mean, median, and Gaussian filters.
- filling: Delineating surface depressions from DEMs using the traditional depression filling method.
- slicing: Delineating the nested hierarchy of surface depressions using the level-set method; computing topological and geometric properties of depressions; and exporting depression properties as a CSV file.
- mounts: Delineating the nested hierarchy of elevated features (i.e., mounts) using the level-set method; computing topological and geometric properties of mounts; and exporting mount properties as a CSV file.
- toolbox: An ArcGIS toolbox for delineating the nested hierarchy of surface depressions and simulating inundation dynamics.

lidar Tutorials

The **lidar** Python package has a C library dependency called GDAL, which can be challenging for some users to install on their computer. Alternatively, users can try out the **lidar** package using just a browser without having to install anything on their computer.

- Try it out with Binder: https://gishub.org/lidar-binder
- Try it out with Google Colab: https://gishub.org/lidar-colab
- Help documentation: https://lidar.gishub.org

The **lidar** package also provides an ArcGIS toolbox for delineating the nested hierarchy of surface depressions and catchments as well as simulating inundation dynamics. Video tutorials for using the toolbox are available at https://lidar.gishub.org/get-started/#arcgis-toolbox.

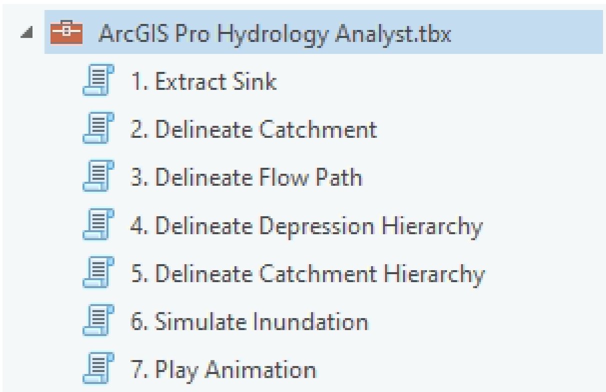

Figure 1: The ArcGIS toolbox for the lidar Python package

Acknowledgments

The author would like to thank the open-source community, especially the developers of numpy (Harris et al., 2020), scipy (Virtanen et al., 2020), scikit-image (Walt et al., 2014), matplotlib (Hunter, 2007), and richDEM (Barnes, 2018). These open-source packages empower the **lidar** Python package.

References

Barnes, R. (2018). RichDEM: High-performance terrain analysis. *PeerJ Preprints*, *e27099v1*. https://doi.org/10.7287/peerj.preprints.27099v1

Harris, C. R., Millman, K. J., Walt, S. J. van der, Gommers, R., Virtanen, P., Cournapeau, D., Wieser, E., Taylor, J., Berg, S., Smith, N. J., Kern, R., Picus, M., Hoyer, S., Kerkwijk, M. H. van, Brett, M., Haldane, A., Del Río, J. F., Wiebe, M., Peterson, P., … Oliphant, T. E. (2020). Array programming with NumPy. *Nature*, *585*(7825), 357–362. https://doi.org/10.1038/s41586-020-2649-2

Hunter, J. D. (2007). Matplotlib: A 2D Graphics Environment. *Computing in Science & Engineering*, *9*(3), 90–95. https://doi.org/10.1109/MCSE.2007.55

Lindsay, J. B. (2016). Efficient hybrid breaching-filling sink removal methods for flow path enforcement in digital elevation models. *Hydrological Processes*, *30*(6), 846–857. https://doi.org/10.1002/hyp.10648

Lindsay, J. B. (2018). *WhiteboxTools User Manual*. GitHub.com. https://jblindsay.github.io/wbt_book

Lindsay, J. B., & Creed, I. F. (2006). Distinguishing actual and artefact depressions in digital elevation data. *Computers & Geosciences*, *32*(8), 1192–1204. https://doi.org/10.1016/j.cageo.2005.11.002

Lindsay, J. B., & Dhun, K. (2015). Modelling surface drainage patterns in altered landscapes using LiDAR. *International Journal of Geographical Information Science*, *29*(3), 397–411. https://doi.org/10.1080/13658816.2014.975715

Virtanen, P., Gommers, R., Oliphant, T. E., Haberland, M., Reddy, T., Cournapeau, D., Burovski, E., Peterson, P., Weckesser, W., Bright, J., Walt, S. J. van der, Brett, M., Wilson, J., Millman, K. J., Mayorov, N., Nelson, A. R. J., Jones, E., Kern, R., Larson, E., … SciPy 1.0 Contributors. (2020). SciPy 1.0: fundamental algorithms for scientific computing in Python. *Nature Methods*, *17*(3), 261–272. https://doi.org/10.1038/s41592-019-0686-2

Walt, S. van der, Schönberger, J. L., Nunez-Iglesias, J., Boulogne, F., Warner, J. D., Yager, N., Gouillart, E., Yu, T., & scikit-image contributors. (2014). scikit-image: image processing in Python. *PeerJ*, *2*, e453. https://doi.org/10.7717/peerj.453

Wang, L., & Liu, H. (2006). An efficient method for identifying and filling surface depressions in digital elevation models for hydrologic analysis and modelling. *International Journal of Geographical Information Science*, *20*(2), 193–213. https://doi.org/10.1080/13658810500433453

Wu, Q., Deng, C., & Chen, Z. (2016). Automated delineation of karst sinkholes from LiDAR-derived digital elevation models. *Geomorphology*, *266*(Supplement C), 1–10. https://doi.org/10.1016/j.geomorph.2016.05.006

Wu, Q., & Lane, C. R. (2016). Delineation and Quantification of Wetland Depressions in the Prairie Pothole Region of North Dakota. *Wetlands*, *36*(2), 215–227. https://doi.org/10.1007/s13157-015-0731-6

Wu, Q., Lane, C. R., Wang, L., Vanderhoof, M. K., Christensen, J. R., & Liu, H. (2019). Efficient delineation of nested depression hierarchy in digital elevation models for hydrological analysis using the level-set method. *Journal of the American Water Resources Association*, *55*(2), 354–368. https://doi.org/10.1111/1752-1688.12689

Wu, Q., Liu, H., Wang, S., Yu, B., Beck, R., & Hinkel, K. (2015). A localized contour tree method for deriving geometric and topological properties of complex surface depressions based on high-resolution topographical data. *International Journal of Geographical Information Science*, *29*(12), 2041–2060. https://doi.org/10.1080/13658816.2015.1038719