International Cartographic Association
Association Cartographique Internationale

Automated detection of terrain depressions in spatial data using a contour tree-based approach

Vojtěch Müller, Tomáš Bayer *

[a] *Czech Technical University in Prague, Dpt. of Geomatics, vojtech.muller@fsv.cvut.cz, tomas.bayer@fsv.cvut.cz*

* Corresponding author

Keywords: point cloud, depressions, analysis, contours, root tree, digital terrain model

Abstract:

The detection and analysis of terrain depressions are fundamental to the interpretation of geospatial data, with applications spanning a wide range of disciplines, including hydrology, geomorphology, environmental modelling, and archaeology. In addition to these domains, the identification and generalization of such landforms is also critical in cartography, particularly for automated map production, terrain visualization, and the derivation of thematic layers from digital elevation data. Terrain depressions, including natural features such as sinkholes, closed basins, and erosion forms, as well as anthropogenic structures, are significant components of landscape structure that affect both analytical interpretation and cartographic representation.

This presentation introduces a novel approach for detecting terrain depressions in both raster and vector terrain data. The proposed method constructs a dense contour model from elevation data, organizing contours into a contour tree that describes their hierarchical and spatial connections. The contour tree enables efficient analysis while preserving key attributes for each contour, such as elevation, enclosure, and geometric properties.

To enhance the thematic relevance and accuracy of detected features, the method incorporates multiple filtering procedures. Shape-based filtering is employed to exclude artefacts resulting from noise, interpolation errors, or data resolution limitations, and constitutes a key advantage of the approach. This filtering enables the selective extraction of terrain depressions with specific morphological characteristics, reflecting the distinct geometric properties of various feature types. Consequently, the method can target particular landform categories while suppressing others, depending on the intended application.

Additional filtering is applied to remove features situated near linear anthropogenic structures, such as roads, railways, or artificial embankments, which could otherwise result in false detections. These refinements improve the suitability for cartographic applications, where clarity, interpretability, and semantic accuracy of map content are essential.

The algorithm was implemented in Python and evaluated using digital terrain model tiles from the Czech Office for Surveying, Mapping, and Cadastre. Results demonstrate that the method detects terrain depressions of diverse shapes and sizes across various landscape types and data formats. A key feature is the ability to control detection through input parameters, allowing users to filter and extract only features that meet specific geometric or morphological criteria. This flexibility supports applications requiring targeted landform identification.

Abstracts of the International Cartographic Association, 12, 98, 2026
European Cartographic Conference – EuroCarto 2026, 8–11 September 2026, Brno, Czech Republic.
https://doi.org/10.5194/ica-abs-12-98-2026

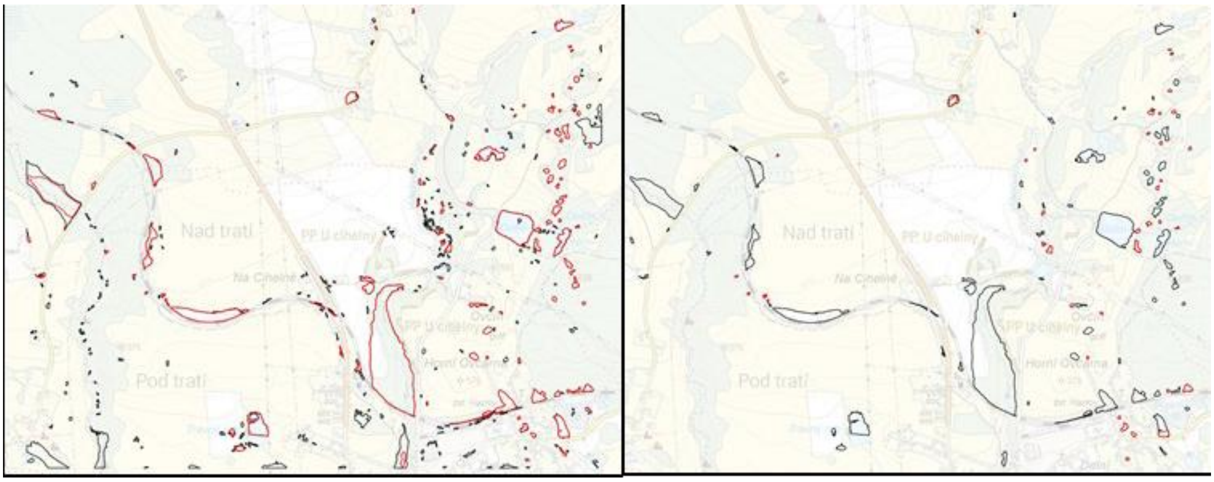

Figure 1. Comparison of terrain depression detection methods. (Left, black: ArcGIS Pro raster-based detection; left, red and right, black: presented method; right, red: presented method with filtration)

The method is computationally efficient, utilizing a tree structure to represent contour relationships. This structure enables rapid traversal and evaluation during detection. Generating the dense contour model from input data is the most computationally intensive step, whereas processing within the contour tree remains efficient.

Overall, the approach enables rapid and efficient detection of terrain depressions, as well as flexible identification of features. By integrating a contour-based representation, tree structure, and parameter-driven filtering, the method extracts features with diverse shapes, sizes, and morphologies. This capability makes it suitable for applications that require selective and scalable detection of specific landform types.

References

Bo, Yo; Tao, Zhang; Kexun, Zheng; Shuanguing, Zao; Xiao, Han et al. (2023): Enclosed Karst Depression Identification and Analysis for the Pumped Storage Power Station Reservoir Construction Using DEM. Geofluids, Vol. 2023.

Meneses, Meneses a Diego, Martin (2023): Hydrologically significant surface depressions on grassy land surfaces, solar photovoltaic farms, and porous parking lots: identification and quantification using terrestrial laser scanning point cloud and triangulated irregular network. New Brunswick, New Jersey: School of Graduate Studies Rutgers, The State University of New Jersey.

Kweon, So a Kanade, Takeo (1994): Extracting Topographic Terrain Features from Elevation Maps. CVGIP: Image Understanding, Vol. 59(2), s. 171-182.

Abstracts of the International Cartographic Association, 12, 98, 2026
European Cartographic Conference – EuroCarto 2026, 8–11 September 2026, Brno, Czech Republic.
https://doi.org/10.5194/ica-abs-12-98-2026