Deep learning-based approach for landform classification from integrated data sources of digital elevation model and imagery

Sijin Li\textsuperscript{1,2,3}, Liyang Xiong\textsuperscript{1,2,3}, Guoan Tang\textsuperscript{1,2,3}, and Josef Strobl\textsuperscript{2,4}

\textsuperscript{1}Key Laboratory of Virtual Geographic Environment (Nanjing Normal University), Ministry of Education, Nanjing 210023, China
\textsuperscript{2}School of Geography, Nanjing Normal University, Nanjing 210023, China
\textsuperscript{3}Jiangsu Center for Collaborative Innovation in Geographical Information Resource Development and Application, Nanjing 210023, China
\textsuperscript{4}Department of Geoinformatics – Z_GIS, University of Salzburg, Salzburg 5020, Austria

Landform classification is one of the most important aspects in geomorphological research, dividing the Earth's surface into diverse geomorphological types. Thus, an accurate classification of landforms is a key procedure in describing the topographic characteristics of a given area and understanding their inner geomorphological formation processes. However, landform types are not always independent of one another due to the complexity and dynamics of interior and external forces. Furthermore, transitional landforms with gradually changing surface morphologies are widely distributed on the Earth’s surface. With this situation, classifying these complex and transitional landforms with traditional landform classification methods is hard. In this study, a deep learning (DL) algorithm was introduced, aiming at automatically classifying complex and transitional landforms. This algorithm was trained to learn and extract landform features from integrated data sources. These integrated data sources contain different combinations of imagery, digital elevation models (DEMs), and terrain derivatives. The Loess Plateau in China, which contains complex and transitional loess landforms, was selected as the study area for data training. In addition, two sample areas in the Loess Plateau with complex and transitional loess hill and ridge landforms were used to validate the classified landform types by using the proposed DL method. Meanwhile, a comparative analysis between the proposed DL and random forest (RF) methods was also conducted to investigate their capabilities in landform classification. The proposed DL approach can achieve the highest landform classification accuracy of 87% in the transitional area with data combination of DEMs and images. In addition, the proposed DL method can achieve a higher accuracy of landform classification with better defined landform boundaries compared to the RF method. The classified loess landforms indicate the different landform development stages in this area. Finally, the proposed DL method can be extended to other landform areas for classifying their complex and transitional landforms.