Automatic Image Ortho-Rectification Strategy using Deep-Learning-based Image Matching Algorithm

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Image ortho-rectification is an essential process to remove geometry deformation and enable the overlay of satellite imagery correctly onto the location of an existing map. Generally, a rational function model (RFM) with 80 rational polynomial coefficients (RPCs) is employed to describe the relationship between image and object coordinate space. However, the coefficients provided by vendors are derived from ephemeris data and lack consideration for ground information, thereby implying systematic biases. To address this issue, RPC is essential to recalculate by incorporating the information from ground control points to obtain ortho-rectification results with research-level accuracy. The GCPs acquisition is a time-consuming and labor-intensive task, and the quality of GCPs also influences the quality of the orthorectified images. To expedite the process, the prevailing approaches employ image matching with an ortho-rectified reference, enabling the extraction of a large number of control points simultaneously. Besides, the rapid advancements in electronic technology have significantly improved hardware capabilities, enabling efficient processing of extensive computational tasks associated with deep learning. Consequently, deep learning has gained considerable popularity, and deep learning-based image matching techniques have garnered significant attention and have shown great potential in recent years. This paper proposed an automatic ortho-rectification process using deep-learning-based image matching. This image matching model utilized a self-supervised feature extraction model, which significantly improves the robustness, quantity, and spatial uniformity of the extraction of the matching pairs. Then a feature matching model considering self-attentional and cross-attentional is adopted for image matching. Consequently, the high-quality GCPs are utilized to refine the RPCs and improved the stability and accuracy of the ortho-rectification results. However, RFM comprises third-degree polynomials and might exhibit limitations in describing intricate geometric deformation in specific scenarios. To overcome this constraint, the least squares collocation (LSC) is adopted as an auxiliary technique to accurately describe fine-scale geometric deformation, thereby enhancing the precision of ortho-rectification results. Two distinct datasets are employed to evaluate the performance of the automatic ortho-rectification process. The first dataset comprises 2-meter resolution cloudy images obtained from the FORMOSAT-5 satellite and 1.5-meter resolution SPOT-6/7 imagery as reference. Different times and regions in Taiwan are selected to evaluate the stability of the automatic ortho-rectification process. The second dataset consists of FORMOSAT-2 and FORMOSAT-5 satellite images with homogeneous regions, including areas such as deserts or snow-covered lands, characterized by rapid changes and presenting challenges in obtaining an adequate number of ground control points for accurate ortho-rectification using 10-m resolution Sentinel imagery as reference. The experimental results demonstrate that the deep learning-based matching method outperforms traditional techniques, particularly for imagery with large cloud cover and homogeneous regions. The deep learning approach enables the extraction of a larger number of image matching points with a more uniform spatial distribution, leading to improved stability and accuracy in the ortho-rectification results. Quantitative evaluation indicates that the orthorectified results of FORMOSAT-5 satellite imagery are improved and have a mean squared error around a subpixel to 2 pixels in maximum.

Keywords: satellite image orthorectification, deep learning, feature-based image matching