Title:
Automatic Extraction and Placement of Building Point Vector Data from Aerial Imagery for the 1: 25 000 Topographic Map Production using U-Net

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Information about you (and your team): Military-educated geodetic engineer and researcher with expertise in remote sensing, digital image processing, GIS, and cartography. Passionate about combining teaching and research in both military and civilian sectors, with a keen interest in the emerging field of Geo AI, leveraging artificial intelligence techniques to revolutionize geographic data analysis and decision-making processes.

Area of interest

The problem addressed in the paper is the cumbersome and error-prone process of manually extracting and positioning building footprints for topographic map production. Traditional methods involve manual digitization of building footprints from aerial imagery, which is time-consuming, labor-intensive, and susceptible to human error. This challenge is particularly critical for the production of digital topographic maps at the Military Geographical Institute, which requires precise and up-to-date spatial data for various applications, including urban planning, navigation, and military operations.

The importance of solving this problem is underscored by the growing demand for accurate and current topographic information in response to rapid urbanization and infrastructure development. As cities expand and landscapes change, maintaining accurate topographic maps becomes increasingly difficult with traditional methods. Automated extraction techniques can significantly enhance the efficiency and accuracy of this process, ensuring that maps reflect the latest geographic information.

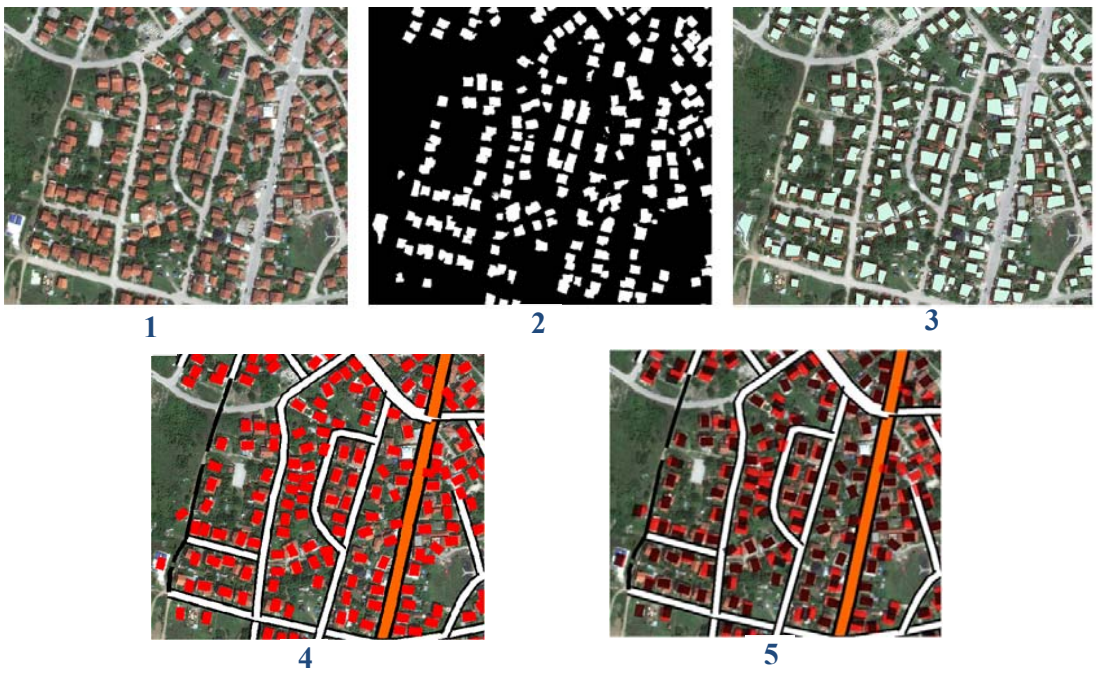
The current relevance of this topic is heightened by advancements in remote sensing technology and the availability of high-resolution aerial and satellite imagery. Moreover, the integration of deep learning algorithms, such as U-Net convolutional neural networks, into cartographic workflows represents a significant innovation. These technologies enable the automated extraction of building footprints, reducing the need for manual intervention and allowing for more timely updates to topographic maps.

Consequently, this automated approach addresses a critical need for accurate, up-to-date geospatial information in a rapidly changing world.

Approach to the problem

The methodology employed in the study involves using a U-Net convolutional neural network for the automatic extraction of building footprints from high-resolution orthophotos. The process begins with applying the U-Net model, implemented in Python, to a 30 cm resolution satellite image (Figure 1, view 1). The U-Net model, trained on the open INRIA dataset, performs binary segmentation to produce an object prediction mask that identifies building rooftops (Figure 1, view 2). Once the prediction mask is generated, vector processing is performed to convert the mask into generalized polygons with assigned rotation data (Figure 1, view 3). These polygons are further processed to create point vectors representing building locations (Figure 1, view 4). The methodology involves using ArcGIS Model Builder and Python for additional calculations to ensure that the generated point vector data adheres to strict cartographic rules. These rules include maintaining a minimal distance between buildings and ensuring an appropriate distance from graphic road markers. To enhance the aesthetic presentation of the final map, the algorithm rotates objects in the road environment in the same direction. This step ensures a more visually coherent and accurate representation of the buildings on the topographic map (Figure 1, view 5). In Figure 1 - view 5, the final topographic data are shown in transparent black, while the initial data are shown in red. The methodology was tested over the urban area of Vranje, resulting in a highly accurate and efficient extraction of building footprints.

Figure 1. Building data extraction steps overview



By automating the extraction and positioning process, this methodology addresses the identified problem of manual digitization's time-consuming and error-prone nature. The automated approach significantly reduces the need for manual intervention, thus saving time and resources while ensuring high accuracy and compliance with cartographic standards. This methodology can be adapted for use on topographic maps of various scales, making it a versatile solution for modern cartographic needs.

Results, conclusions and next steps

The study successfully applied the U-Net convolutional neural network to automatically extract and position building footprints from high-resolution aerial imagery for the production of a 1:25 000 scale topographic map. The methodology was tested over the urban area of Vranje, Serbia, and demonstrated high accuracy and efficiency in generating building footprints. The results showed that the U-Net model could produce accurate object prediction masks, which were then effectively vectorized and processed to create point vectors representing building locations. These vectors were positioned according to strict cartographic rules, ensuring the final topographic data met the required standards. The process included initial data generalization, rotation of vector points based on the orientation angle of the polygons, and adherence to minimal distance requirements between buildings and from road markers.

One of the significant findings of the study was that the automated methodology required minimal manipulation and correction of the obtained data, resulting in substantial time and resource savings. The automated approach also simplified the overall process of topographic map creation, enhancing the efficiency and accuracy of the final product.

In conclusion, the study demonstrated that the integration of deep learning algorithms, specifically U-Net, into the cartographic workflow, offers a viable solution to the challenges of manual building footprint extraction. The automated methodology not only improves the accuracy and efficiency of topographic map production but also ensures that the maps meet modern cartographic standards. This approach can be adapted for various scales and regions, making it a valuable tool for contemporary cartography.

References

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