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ABSTRACT OF THE DISSERTATION

„Orientation of multitemporal aerial imagery using computer vision techniques”

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Archival aerial images represent a unique source of spatial data, enabling retrospective analyses of changes in both natural and anthropogenic environments. Their informational value – encompassing both quantitative and qualitative aspects – makes them an invaluable material in studies, such as geoinformation, urbanisation history, cultural heritage preservation, and legal analyses concerning property boundaries. However, the effective use of such data requires precise spatial orientation, which in the case of archival materials poses numerous challenges, ranging from the lack of metadata and poor radiometric and geometric quality to substantial changes in land cover.

Classical orientation methods based on aerial triangulation and photogrammetric control networks often prove insufficient or impossible to apply, particularly for images acquired before the year 2000, for which no information about exterior orientation parameters is available. In response to these challenges, the rapid development of computer vision and Structure-from-Motion (SfM) techniques presents new possibilities for the automatic processing of archival aerial imagery, eliminating the need for classical approaches that rely on manual measurement of ground control points.

A review of methods and algorithms for orienting archival aerial images was conducted. The key issue in such orientation lies in the automatic identification of tie points between images within a single block and across image blocks acquired at different times. In the experimental phase, three main approaches to determining points used in the orientation of multitemporal image series were tested, along with their corresponding algorithms. The first approach, Detect-then-Describe, separates the detection and description stages used for keypoint determination, on the basis of which common tie points are determined. The second, Detect-and-Describe, integrates both processes within a single model. The third, Describe-then-Detect, reverses the traditional order by performing description before detection.

This study aims to develop and validate a methodology for sequential orientation of archival aerial images using computer vision algorithms, enabling accurate georeferencing in the absence of a photogrammetric control network. The proposed approach relies on overlapping image blocks from different epochs, allowing for effective spatial orientation transfer from images with known orientation parameters to archival images with unknown parameters. The research demonstrated that this methodology remains effective even when there are significant

temporal gaps between datasets, as well as variations in spatial resolution and radiometric quality.

A series of research questions were formulated to assess the effectiveness and accuracy of the proposed methodology for orienting archival aerial images. First, the influence of spatial resolution and radiometric quality of images from different epochs on the efficiency of tie-point detection was analysed. Next, the performance of various feature detection and matching algorithms was evaluated in terms of their ability to achieve the highest accuracy in photogrammetric block reconstruction. The final aspect concerned identifying the most effective strategies for sequential orientation transfer between image blocks acquired at significantly different times.

The conducted experiments utilised aerial data acquired across several decades, from 1976 to 1986, 1994, 2014, and 2022, covering a temporal span of approximately 40 years. The employed images varied in spatial resolution, radiometric quality, and acquisition parameters. The methodology comprised a two-stage sequential orientation process for aerial image blocks. In the first stage, image orientation parameters were determined for each block within a local coordinate system, followed by the generation of true orthophotos and Digital Surface Models (DSMs). In the second stage, using the previously described algorithms, the x and y coordinates of tie points between orthophotos from different periods were automatically identified, with corresponding elevation (z) values derived from the generated DSMs. The resulting set of three-dimensional tie points (x, y, z) was used to compute the spatial transformation parameters between corresponding temporal blocks. The experiment assessed the time required to obtain tie points, their accuracy, number and spatial distribution, as well as the accuracy of spatial transformation between oriented blocks.

As part of this research, a novel methodology for sequential orientation of archival aerial image blocks was proposed, based on a modified Structure-from-Motion approach. This method involves the chronological transfer of orientation between temporal blocks, from the most recent to the oldest, using a previously oriented reference block with known exterior orientation parameters. Such an approach is particularly relevant in cases of significant temporal gaps between images, where direct matching of the newest and oldest data is infeasible due to the lack of common ground features, often resulting from extensive urban development.

Experimental results demonstrated that the proposed methods enable effective image matching and orientation even under conditions of significant land cover change, particularly in highly urbanised areas. The proposed methodology proved effective for georeferencing archival aerial images in situations where traditional methods are ineffective. The results confirm the research thesis that the application of computer vision methods enables reliable automatic reconstruction of the orientation of archival aerial images acquired over long temporal intervals (up to 40 years), achieving accuracy comparable to image resolution (ground pixel size), and in some cases, even sub-pixel precision.



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