Alignment of Vertical DiAerences in LiDAR Data from Multiple Airborne Surveys Using Last-Return Point Matching

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***Abstract*—Airborne LiDAR data acquired during multiple flight campaigns often exhibit small systematic vertical differences that adversely affect the quality of subsequent processing and spatial analyses. This paper presents an automated methodology for the vertical alignment of overlapping LiDAR datasets based on the use of Last Return points as reference data, without the need for terrain classification or the creation of a digital terrain model. The proposed methodology was implemented in Python and experimentally verified using airborne laser scanning data. The experimental results demonstrated reliable determination of the global vertical shift and improved geometric consistency of the point clouds while maintaining high computational efficiency. The proposed solution represents a robust and easily implementable approach to the automated vertical alignment of multi-temporal LiDAR datasets and is suitable for processing large datasets used in technical infrastructure monitoring and other geoinformation applications.**

***Keywords*—LiDAR, LAS, vertical registration, KD-Tree, geospatial data processing, Python**

I. Introduction

Airborne laser scanning (LiDAR) is one of the most important technologies for acquiring accurate three-dimensional spatial data. Thanks to its high point density, centimetre-level measurement accuracy, and ability to capture spatial objects with high geometric fidelity, it is widely used for creating digital terrain models (DTMs), digital surface models (DSMs), forest mapping, technical infrastructure monitoring, flood-risk modelling, power-line inspection, and the creation of digital twins [1], [2]. As the scale of LiDAR projects increases, so do the requirements for ensuring uniform geometric quality of data acquired during multiple independent airborne surveys.

Large-scale LiDAR campaigns are generally carried out through multiple flight missions performed at different times and under different operating conditions. Despite the use of the same coordinate system and standard georeferencing procedures, small systematic vertical differences often occur between individual datasets due to inaccuracies in GNSS/INS navigation, sensor calibration, flight trajectory, or subsequent data processing [2], [3]. Although their magnitude is usually only a few centimetres, in overlap areas they can cause point-cloud deformations, reduce the accuracy of digital models, and adversely affect the results of subsequent spatial analyses [3]. An example of a systematic vertical mismatch in the overlap area of three independent LiDAR records is shown in Fig. 1. The visible elevation mismatch illustrates the type of problem that must be eliminated before further data processing. These inaccuracies are particularly significant in multi-temporal analyses, change monitoring, and applications requiring high vertical accuracy.

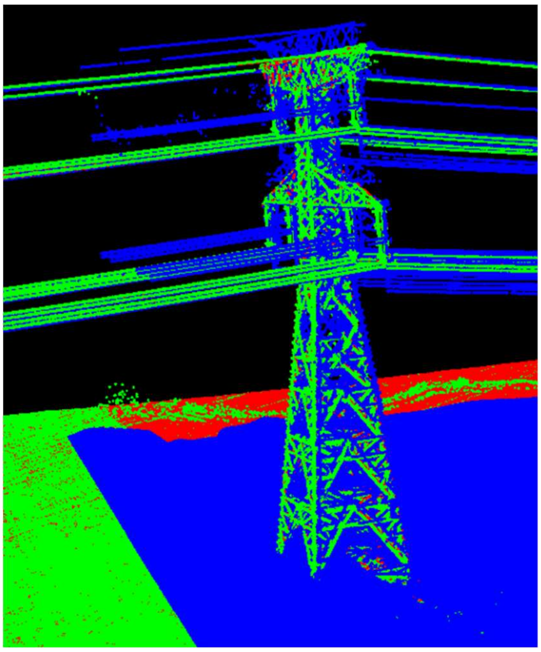

Fig. 1. Example of a vertical mismatch when merging point clouds from multiple flights

A wide range of commercial and academic solutions address LiDAR data registration. The most common approaches use algorithms based on the Iterative Closest Point (ICP) principle, classified ground points, or digital terrain models created by interpolating the point cloud [4], [5]. These methods are implemented, for example, in TerraScan, CloudCompare, and LAStools and provide satisfactory results in many applications [6]. However, their accuracy strongly depends on the quality of point classification, terrain characteristics, point-cloud density, and correct input-