Author: **Magdalena Pilarska-Mazurek**

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Airborne Laser Scanning technology is widely used in photogrammetry and remote sensing. By measuring the scan angle and distance, three-dimensional information about objects and the ground is obtained. Data from airborne laser scanning are used primarily as a source of height information, including the digital terrain model and digital surface model generation, as well as 3D models of buildings.

In addition to the X, Y, Z coordinates of the points during data acquisition, the intensity of the signal returning to the scanner is also recorded. Intensity is an attribute that describes the power with which the laser beam has reflected from a given object. The intensity value varies depending on the reflectance properties of the object, i.e. colour, texture, material, as well as the incidence angle of the beam on the object. These properties lead to the use of intensity in object classification processes, such as land cover classification and tree species classification. Importantly, the use of intensity has gained popularity with the appearance of multispectral scanners. These scanners simultaneously acquire data in more than one spectral range. Currently, there are multispectral scanners on the market that operate in two (λ=532 nm, λ=1064 nm) or three (λ=532 nm, λ=1064 nm, λ=1550 nm) wavelengths.

Furthermore, intensity may take different values for the same objects located in the ends and in the middle of the strips. To compensate for these differences, a correction of the intensity values must be performed. The correction is based on compensating the effects of various factors on the recorded intensity values. These factors can include: incidence angle, scanning angle, range, as well as the effect of the apparatus (scanner) and the atmosphere in which the beam is scattered.

These methods of correction, calibration and normalisation are described quite comprehensively in the literature, and the influence of these factors is already largely resolved. In these methods, however, it is usually assumed that all returns in a cloud are treated as single returns, or only the correction of the first return of a given beam is mentioned. Meanwhile, it is known that a laser beam when encountering vegetation, particularly trees, is able to penetrate the vegetation. As a result, for one laser beam, several returns may be registered, which may be on the crown of the tree, in the lower parts of the trees, as well as on the ground. Furthermore, with each subsequent return, the power of the laser beam is lost. This means that the intensity of a ground return, which is e.g. the third return of a given beam, has a lower power than the intensity of a single return at the same place. This phenomenon can be a problem when classifying and interpreting land cover under trees, especially in urban areas. To obtain correct intensity values for objects under trees, a correction is necessary.

The aim of the dissertation is to present the author's methodology for intensity correction of multiple returns. The work consists of an introductory part, which is a review of the literature on the idea of airborne laser

scanning, as well as the directions of development of this technology. In the following part, the problems of obtaining and interpreting the intensity of the returning signal are discussed. The different notions by which the intensity of returns is determined are highlighted and the current applications of the signal intensity are cited. The dissertation presents the problem of returning signal intensity correction, showing factors affecting its values, as well as currently applied intensity correction methods. In the next part of the thesis, the author's proposal of intensity correction of multiple returns is presented. The methodology is described in detail, reference fields designed within the research are shown as well as the results of the applied correction methods. At the end of the experimental part, an evaluation of the applied correction methods is made and conclusions are presented. The correction methods were applied to correct the intensity of multiple returns recorded on the ground.

The following multiple return intensity correction methods were analysed in this thesis: methods based on transmittance, a method using Beer-Lambert's law, and a method taking into account the sum of the intensities of all returns of a given beam.

The dissertation data from the Riegl VQ-1560i-DW multispectral scanner were used. These data were acquired for two areas: Dobrocin Forest District and Warsaw. Such areas, differing in coverage, were selected for the experiments so that the applicability of the methodology under different conditions could be assessed. For both areas data from two dates were available: leaf-on and leaf-off season. A more detailed evaluation of the methodology was carried out for data acquired for Warsaw, as mainly in urban areas the correction of intensity of multiple returns can be applied. The evaluation of the correction methods was performed on the basis of intensity images recorded on the ground before and after correction. In addition, for both areas analysed in the thesis, a detailed statistical analysis was carried out to determine which method gives results most similar to the values of single returns in the selected area. It was expected that after applying the correction, the intensity values of multiple returns would be more similar to the intensity values of single returns.

The thesis shows that it is possible to effectively correct the intensity of a signal for multiple returns, and that this correction improves the interpretation of the land cover under trees. Furthermore, it is shown that different correction methods should be used depending on the spectral channel in which the data are recorded and the time of the data acquisition.

PRZEWODNICZĄCY
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dr hab. inż. Konrad Lewczuk, prof. uczelni