DIGITAL TERRAIN MODELS FROM AIRBORNE LASER SCANNER DATA - A GRID BASED APPROACH

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ABSTRACT:

Since Airborne laser scanning sensors are operational and the data capture, including the calculation of the exterior orientation by using GPS and INS, has reached a high level of automation, the focus has turned on the development of algorithms to extract information from the 3D point cloud. The main tasks are the derivation of terrain information, forest parameters or the extraction of buildings. Since terrain information also affects the calculation of forest parameters and gives an input to building extraction, many different approaches were developed in the past years to derive highly accurate digital terrain models. Most of these approaches, like mathematical morphology, weight iteration or triangulation, work with the 3D data points itself. This paper presents an approach that is based on the rasterization of data points which allows the usage of fast digital image processing methods for the calculation of DTM's. The algorithm consists of a hierarchical approach in combination with a weighing function for the detection of raster elements that contain no ground data. The weighing function considers the terrain shape as well as the distribution of the data points within a raster element.

1. Introduction

In the past years airborne laser scanning has become a reliable technique for a data capture of the earth surface. It supplements the assortment of sensors to obtain topographical information. Using a laser scanner for data acquisition will yield to a 3D point cloud that consists of quasi randomly distributed points. These points define the spot were the emitted laser pulses got remitted and stopped the runtime measurement of the signal. The exterior orientation can be accomplished by GPS and INS (Lohr, 1999). Besides erroneous points the 3D point cloud defines a digital surface model (DSM) which requires a task driven filtering to extract information. The main tasks are the derivation of digital terrain models (DTM), forest parameters (Schardt et al, 2000) and the extraction and reconstruction of buildings (Axelson, 1999; Maas and Vosselman, 1999).
Since terrain information also affects the calculation of forest parameters and gives an input to building extraction, many different approaches were developed in the past years to derive highly accurate digital terrain models.

2. DTM generation

For the generation of DTM's a separation between ground points and non ground points is required. Most of the developed algorithms work on the raw data points itself. Examples are the usage of mathematical morphology (Vosselmann, 2000), adaptive tin models (Axelson, 2000) or a weight iteration (Pfeifer und Briese, 2001). The method developed at Joanneum Research (Wimmer et al, 2000; Ziegler et al, 2001) presents an approach that is based on the gridding of data points which allows the usage of fast digital image processing methods for the calculation of DTM's from airborne laser scanner data.

3. DTM generation – a grid based approach

To enable a processing with regularly distributed data requires a gridding of the randomly distributed raw data points. Each raster element contains numerous raw data points depending on its size. Since each raster element can only be represented by one height value, it takes some considerations to define this height correctly.

4. From vector data to raster data

If the centre of each raster element refers to the terrain height at this point, the height value of the lowest raw data point within the raster element is not a good representation. In steep terrain this point would be located somewhere at the edge of the raster element and cause a significant height deviation from the terrain at the centre. To find a representative value of the terrain height the gradient information is used to define the perpendicular of the terrain. According to this axes the lowest data point will be taken and a height adaptation, based on the gradient information, applied. The adaptation is necessary

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to obtain a correct height that refers to the centre of the raster element.

5. The algorithm

The algorithm combines a hierarchical approach with the usage of a weighing function for the detection of non terrain raster elements (figure 1).

In a first step raster elements with a resolution of 9 meter are used which enables the algorithm to interpolate a DTM in regions with large buildings or dense vegetation. To find a representative height value for each raster element, the gradient information of a filtered 9m DTM gets calculated. This rough 9 meter DTM simply uses the lowest data point height from 99 % of all data points within a raster element, by this way the algorithm can overcome the influence of erroneous data. The gradient information for each raster element can now be used to find the real quasi lowest data point according to the perpendicular of the terrain. To exclude regions that strongly deviate from the terrain model of the first approach a maximum allowed height deviation is defined. If such raster elements are detected, they will be replaced by the height values of the DTM-first approach. This helps to accelerate the further calculations.

In a second step all non terrain elements need to be detected and removed. Here a laplacian of gauss (log) operation helps to detect such elements. The resulting DTM with a 9 meter resolution serves now as a base for the calculations with a resolution of 3 meters.
The gradient information of the resampled 9m DTM enables the algorithm now to calculate a representative height value for the 3m raster elements. Due to thresholding the raster elements with height values from heigh buildings or trees are cut out and replaced by the values from the resampled 9m DTM.

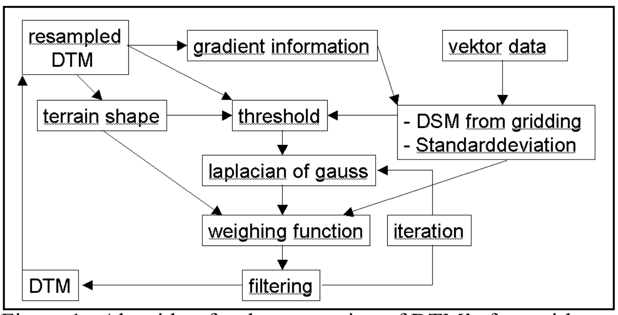

Figure 1. Algorithm for the generation of DTM's from airborne laser scanner data

The remaining raster elements that contain no terrain points are again detected by laplacian of gauss. At a resolution of 3m and beneath this operation lets edges of the terrain occur as elements that don't contain terrain points. Therefore a weight function that considers the standard deviation of the data points within each element and the terrain shape needs to be applied on the output data of the log operation.

After a removal of the remaining non terrain elements the resampled 3m DTM serves now as a base for the calculation of the DTM with 1m resolution. All the operations mentioned before are used again to derive the final DTM. Higher resolutions like 0.33m and 0.11m are also possible if required but a resolution of 1m is most common.

6. Examples

At two sites a geodetic network was first created by the use of GPS and a total station. Tachymeter measurements with the total station defined several dense point clouds which served as reference to verify the results of the DTM's from laser scanner data. In both sites no manual corrections to the DTM have been applied.

6.1 Test site Hohentauern

This site is located in the north part of the austrian Province Styria. At this alpine test site 3500 points have been measured. For the calculation of this DTM only first pulse data was available (figure 2.).

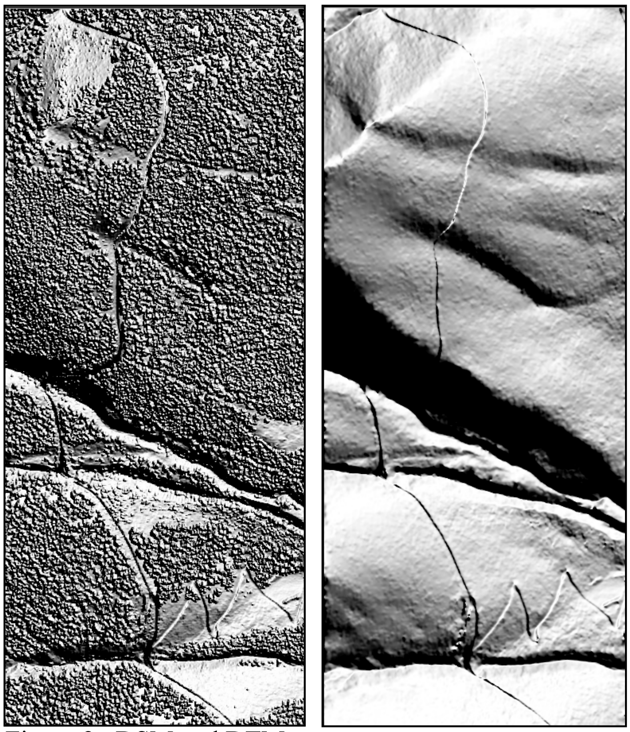
Figure 2. DSM and DTM

The average penetration rate of the laser pulses in forest areas only reached a level of 25 %. This fact has an impact on the results of the verification (table 1). All plots are located at dense forest areas where only few information on the terrain is available.

test site	HT-21	HT-22	HT-3	HAT-4
mean[m]	-0,051	-0,060	0,020	0,110
stdev[m]	0,460	0,195	0,294	0,324

Table 1. Verification results at test site Hohentauern

6.2 Test site Monte do Prado

This Portuguese site has an area of 60 km² and is covered with dense eucalyptus plantations. The scanning mission was flown by TOPOSYS at a height of 800m which yielded to a 3D point cloud of 5 Gigabyte last pulse data. The derivation of the DTM (figure 3) with 1m resolution, calculated by the algorithm described above, took about 6 hours.

test site	600 points
mean[m]	0,11
stdev[m]	0,20

Table 2. Verification results at test site Monte do Prado

A tiling of the area as a preprocessing step was not required. The verification of the results (table 2) show better results then the test site Hohentauern which can be explained by the missing last pulse data at the test site Hohentauern and its steep terrain.

A visual interpretation of the DTM showed some remaining vegetation at creeks in narrow valleys and also some remaining small low buildings. In both cases the weighing function scaled down the output data of laplacian of gauss which resulted in a classification of the elements as terrain. This was caused firstly, by a low standard deviation of the data points within each raster element at the dense vegetation and secondly by the location of the non terrain elements. Since the terrain shape is defined by the second derivative of the DTM it causes the weighing function to be more permissive in areas with a higher curvature.

7. .Conclusion

In this paper we presented a grid based approach for the generation of DTM's from airborne laser scanner data. The regular distributed data allows the usage of fast digital image processing techniques and yields to a reduced amount of data that needs to be handled. Consequently a tailing for the processing of large terrain models is not require. The laplacian of gauss operator in combination with the weight function enables the algorithm to detect and remove raster elements that do not contain any ground points, all other raster elements stay unchanged. To verify the quality of the final DTM's,

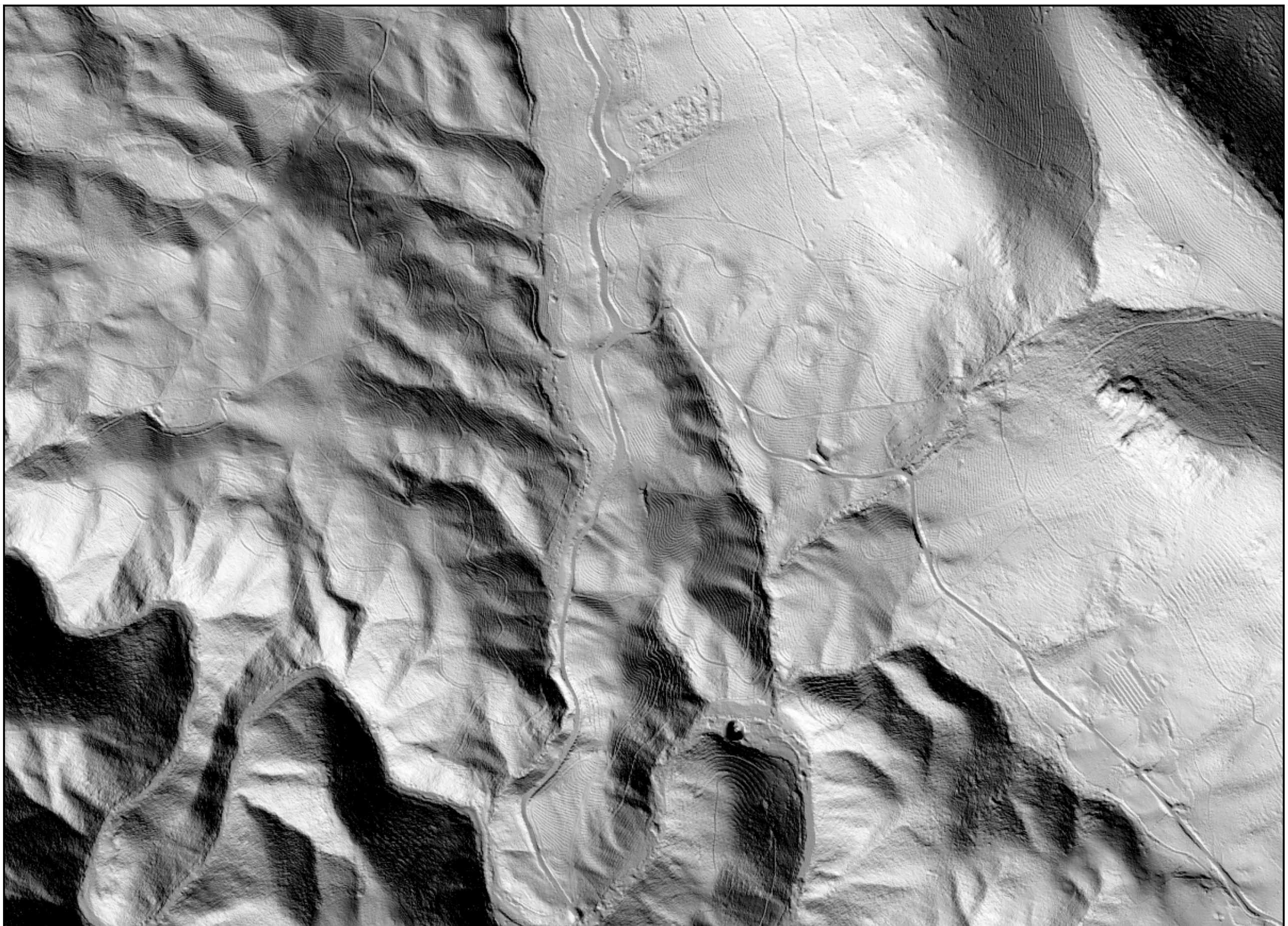

Figure 3. Part of the DTM of test site Monte do Prado

several thousand terrain points from dense tachymeter measurements have been used. The results show that a high accuracy of the DTM's can be achieved.
The removal of some affects at terrain edges, where the correct detection of raster elements that contain no terrain data sometimes failed, will be a task for further investigations.

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