COMBINATION OF TERRESTRIAL LASER SCANNING WITH HIGH RESOLUTION PANORAMIC IMAGES FOR INVESTIGATIONS IN FOREST APLLICATIONS AND TREE SPECIES RECOGNITION

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ABSTRACT:

The management and planning of forests presumes the availability of up-to-date information on their current state. The relevant parameters like tree species, diameter of the bowl in defined heights, tree heights and positions are usually represented by a forest inventory. In order to allow the collection of these inventory parameters, an approach aiming on the integration of a terrestrial laser scanner and a high resolution panoramic camera has been developed. The integration of these sensors provides geometric information from distance measurement and high resolution radiometric information from the panoramic images. In order to enable a combined evaluation, in the first processing step a coregistration of both data sets is required. Afterwards geometric quantities like position and diameter of trees can be derived from the LIDAR data, whereas texture parameters as derived from the high resolution panoramic imagery can be applied for tree species recognition.

1. INTRODUCTION

The development of tools allowing for an automatic collection of information required to build up conventional forest inventories is one of the main objectives of the NATSCAN project. Within this project, which provided the framework for the approaches presented in this paper, forest inventory parameters of interest are tree species, tree height, diameter at breast height (DBH) or crown projection area. Additionally, information about the numbers and types of wood quality features and the length of the branch free bowl have to be provide, since these parameters determine the value of the timber products. By the development of tools for automatic data collection, traditional manual approaches can be replaced and thus the individual influence of human measurement can be eliminated. Within the NATSCAN project the automatic feature collection is aspired by the application of LIDAR measurements from airborne and terrestrial platforms, respectively (Friedlaender & Koch 2000) (Thies et al 2003).

This paper describes an approach aiming on the further improvement of the LIDAR based data collection from a terrestrial platform by the application of a panoramic camera. This camera additionally captures high resolution colour images, which can be used as a complementary source of information and thus support the analysis of the range images from LIDAR measurement. In the following section the sensor system, i.e. the terrestrial laser scanner and the panoramic camera is described. The coregistration of the collected data sets, which is a prerequisite for further processing is presented in section 3. Finally, approaches aiming on the collection of the required inventory parameters based on a combined data interpretation are discussed in section 4.

2. DATA COLLECTION

Within the project, the IMAGER 5003 system from Zoller+Fröhlich was used for the collection of the terrestrial laser scanning data. This sensor utilizes phase difference measurements to capture the required distance information, which limits the maximum range of the system to 53.5 m. The main advantages of the system are the high speed of data collection and the large field of view, which allows the realization of 360° horizontal and 310° vertical turns during measurements. For the IMAGER 5003, the divergence of the laser beam of 0.3 mrad results in a spot size of the laser footprint of 1.9 cm at a distance of 50 m.

Figure 1: Range image captured from LIDAR scanner.

Figure 2: Reflectivity image captured from LIDAR scanner.

Figure 1 presents the range image of the test area close to the city of Freiburg, which was collected by the LIDAR sensor. In this example, the pixel coordinates of the image are defined by the horizontal and vertical direction of the laser beam, respec-

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tively. The size of the image is 5000 pixels in height and 8400 pixels in width.
Figure 2 depicts a reflectance image of the same measurement. This image can be additionally captured based on the intensity measurement of the respective laser footprints. The spectral information as provided from this reflectivity image is limited to the wavelength of the laser beam, which is in the near infrared spectrum. The spacing is exactly the same for range and intensity image, since they relate to the same point measurements. Thus, the main advantage of the intensity measurement is the exact coregistration of both data sets. This is demonstrated exemplarily in Figure 3, which shows a 3D view of a tree trunk generated from the range and reflectance image as provided from the laser scanner.

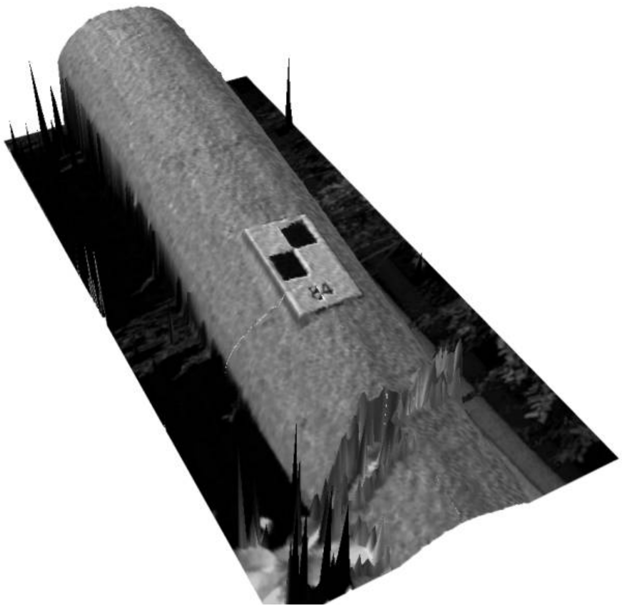

Figure 3: 3D view of tree surface, texture from reflectivity image of LIDAR measurement.

One general problem of LIDAR measurements is the limited spatial resolution if compared to digital images of good quality. This resolution is sufficient for the collection of geometric parameters like tree position or diameter at breast height. Nevertheless, the discrimination of different tree types, which i.e. requires an analysis of the tree bark's structure, is only feasible if an increased spatial resolution is available. Thus, for our investigations, a panoramic camera is additionally applied in order to collect high resolution colour imagery.

Figure 4: EYSCAN camera.

Figure 4 depicts the panoramic camera EYESCAN, which was used in our project. The camera was developed by the KST GmbH in a co-operation with the German Aerospace Centre (DLR). Image collection is realised with a CCD line, which is mounted parallel to the rotation axis of a turntable (Scheibe et al 2001). Thus, the height of the panoramic image is determined by the number of detector elements of the CCD line, resulting in an image height of 10.200 pixels. A 360° turn of the camera, which is performed to collect a full panorama, results in an image width of 43868 columns. Since the CCD is a RGB triplet, true colour images are captured. The spectral resolution of each channel is 14 bit, the focal length of the camera is 60 mm and the pixel size is 7 μm. This for example results in a sampling distance of 6mm at a distance of 50 m for the collected imagery.

3. DATA COREGISTRATION

As a first processing step, range data and high resolution panoramic imagery have to be coregistrated to allow for the subsequent combined processing of both data sets. This coregistration can for example be achieved similar to a standard ortho image generation by mapping the panoramic image to the surface from the LIDAR measurement. In order to perform this process, information on the full geometric model of the camera, which is for example described by (Schneider & Maas 2003) is required. In addition to the interior orientation, the exterior orientation of the camera has to be determined i.e. by a spatial resection based on control point measurements.
In our configuration both data sets were collected from the same position. Additional, since laser scanner and panoramic camera are based on rotating devices, both data sets can be represented in a cylindrical coordinate systems. For these reasons, the coregistration process could be simplified considerably by mapping the panoramic image to the range and reflectivity images from LIDAR measurement using a 2nd order polynomial.

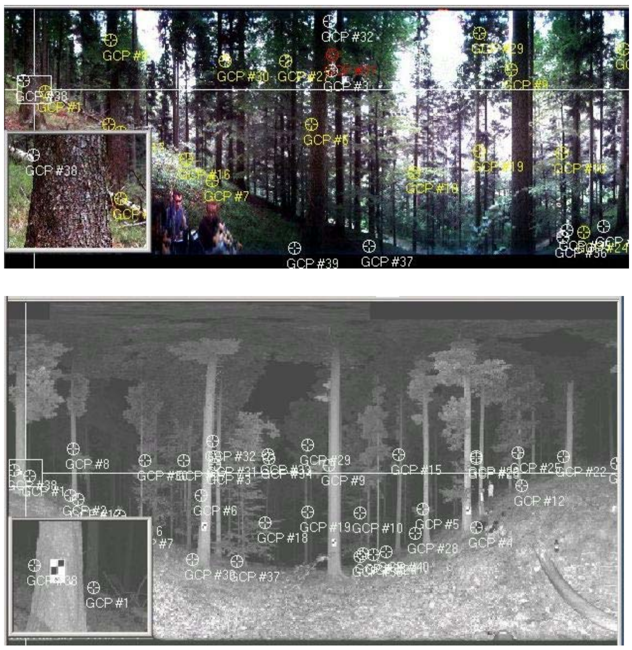

Figure 5: Measurement of corresponding points in panoramic (top) and reflectance image (bottom).

The parameters of this polynomial can be determined easily from corresponding points in the respective data sets. As it is depicted in Figure 5, for point measurement the reflectivity image of the LIDAR data was applied. By these means, the manual identification of corresponding points could be simplified since the reflectance data is more similar to the panoramic image than the corresponding range measurements. Still, point measurement in a forest environment is relatively difficult. Problems can for example occur due to wind movement of the tree branches. For our data sets additional problems resulted from the relatively large period of time between the collection of panoramic image and LIDAR data. These problems resulted in remaining differences (RMSE) between the corresponding points after mapping in the order of 10 pixel.

Figure 6: 3D view of tree surface, texture from high resolution panoramic image.

Nevertheless, for our applications these differences were acceptable, as it is exemplarily demonstrated in Figure 6. The 3D view of this tree trunk was already presented in Figure 3. Whereas in this figure the reflectance image of the laser scanner is used for texture mapping, in Figure 6 the high resolution colour image is used for the same purpose. Since the panoramic image was collected at a different epoch, the signalised point, which is depicted in Figure 3 is no longer available.
In addition to a potential increase of the mapping accuracy by a more rigorous transformation using the full geometric model of the camera, the availability of a fully integrated system would optimise the process of data coregistration. If an exact calibration of the differences in position and orientation between laser scanner and panoramic camera is available, tie point measurement is no longer required. Thus a much simpler and faster data collection would be feasible.

4. DATA INTERPRETATION

After the coregistration of the range data and the high resolution panoramic image, a combined evaluation can be performed in order to collect the required forest inventory parameters. In this context, the LIDAR measurement is very well suited for the collection of geometric properties like the automatic localization of trees and the computation of tree diameters. This can for example be realized by the application of a Hough-Transform, which detects circular structures in the 3D point clouds derived from range measurement (Simonse et al 2003).

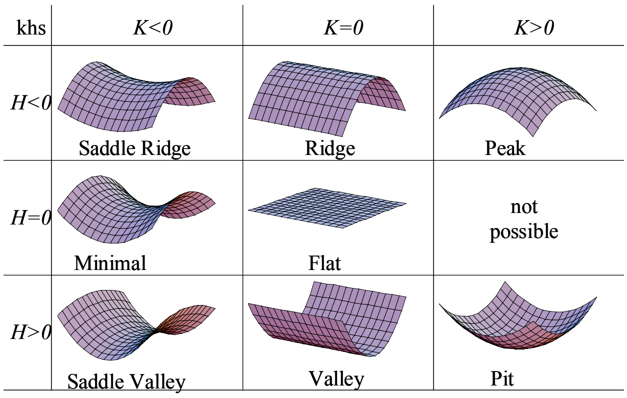

Figure 7: Fundamental surface types by mean and Gaussian curvature signs.

A similar type of information can be extracted from range image analysis by the application of a curvature based segmentation. Figure 7 depicts the different surface types, which can be derived from range data based on the sign of the mean and Gaussian curvature (Besl 1988). By these means, the respective surface type can be calculated for each pixel of the range image and thus corresponding pixels can be combined to regions. Figure 8 gives an example of this surface type analysis, which was used to classify cylindrical objects in order to localize tree trunks.

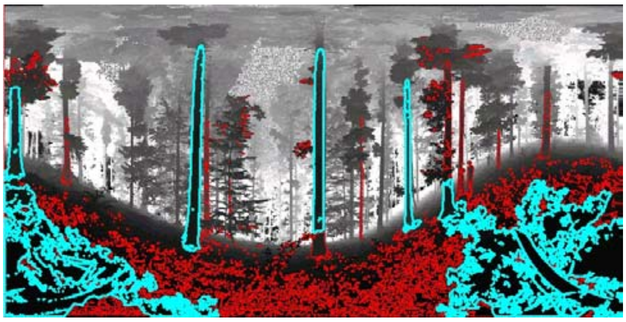

Figure 8: Result of curvature based segmentation.

Complementary to the analysis of the range data for the collection of geometric features, the high resolution panoramic images can be applied for a texture based classification. By these means, the structure of the respective tree bark is analysed in order to discriminate between different types of trees in a subsequent step.

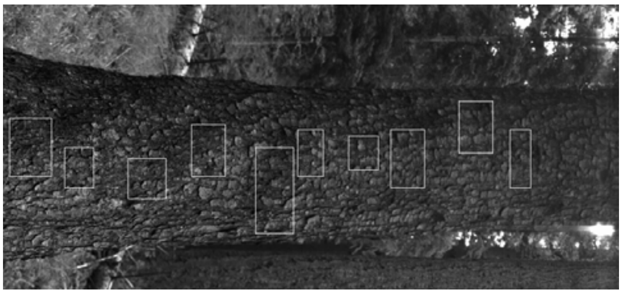

Figure 9: Different samples of a tree used for calculation of texture measurement.

In order to demonstrate the potential of the available data for this purpose, different image samples of tree bark were collected at various positions for a number of trees. An example for these samples at a single tree is given in Figure 9.

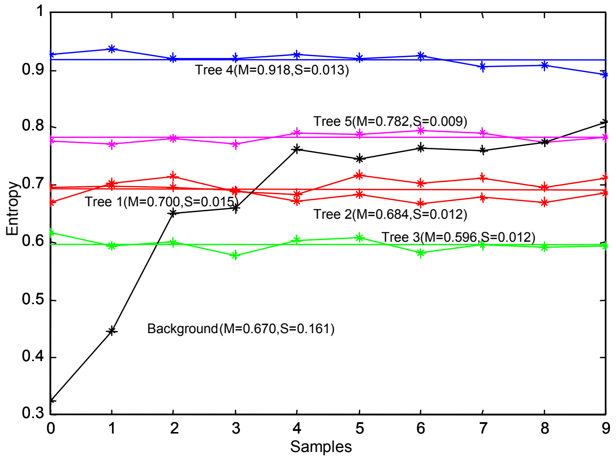

Figure 10: Calculated texture parameters for different types of trees.

For the available samples, texture parameters can be calculated based on the computation of fuzzy entropy (Kundu & Pal 1990). The result of this process is given in
Figure 10. Since the computed parameters are similar within a single tree, but dissimilar between different trees, a discrimination of different tree types based on fuzzy classification seems to be possible. Nevertheless, additional investigations for a larger number of data sets still have to be performed.

5. CONCLUSION

Within the paper, the combined evaluation of high resolution colour imagery from a panoramic camera and LIDAR data from a terrestrial laser scanner was described. Data collection based on these types of sensors has already been demonstrated for applications like virtual city modelling or heritage documentation. In contrast, the presented application on the automated collection of tree parameters required for forest inventories is a novel approach and thus demonstrates the potential of this type of integrated sensor configuration also for natural environments.

6. ACKNOWLEDGEMENT

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