3D Modeling using DMC Data Input

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ABSTRACT

In the surrounding of the "arcForest" product - a digital sensor based forestry inventory and modelling system DMC-data will be used for the data mining.
The collected images will be implemented in a complete workflow of basic photogrammetric work, remote sensing and mathematical models.
Raw-data points will be created by the "Image Station Automatic elevation" procedure from Z/I. Depending from the radiometric resolution, the use of different channels, and landscapes, up to 5 million raw elevation points per image can be found. These raw data points are then used for generating different datasets, descriptions, of surfaces and terrain models and 3D-interesting facts of forests and landscapes in different scales of viewing.
The procedure for this generation uses the standardized products from Z/I and adds additional tools for the quality checking of calculated raw points and later processing.
Canopy structures can excellently be analyzed. The description of the horizontal and vertical structure of the trees offers in combination with the multi-channel data new possibilities in forestry inventory and modelling.
The comparison with other, specifically airborne, inventory methods in forests shows the advantage of using optical sensors and the necessary future trend of a highly efficient workflow in combination with different sensors.

1. arcForest IN GENERAL

The system arcForest, provides the following: Modelling of forest all aspects with a high accuracy, reduction of inventory costs, the fast availability of data and the results in a GIS-based application. These are realized with DMC-Technology from Z/I Imaging.
arcForest is the first system with a complete workflow from photogrammetric data mining to forestall modelling with a focus on high efficiency and flexibility for the use in different regions. The system is modular build and therefore can be integrated in existing business applications and delivered data for forestry, timber and paper industries, conservation departments and other intelligent business applications. The worldwide first DMC – Digital Mapping Camera - in combination with new applications and a high speed photogrammetric and remote sensing workflow are the basis for answering long-term questions of the economy of timber production, resource and disaster management, conservations, environmental protection, land use, and so on.
With the concept and product arcForest is a provided system, which on the basis of most diverged geographically oriented data, which is united, processed and analyzed in a GIS-supported modelling system, enabling long-term prognoses regarding the development and endangerment of forests, wood and plant reservoirs e.g. in the form of economical characteristic numbers, probabilities of disaster and action options.
The use of most recent technology in data mining enables the use of arcForest above all also in large, closed and to the greatest possible extent unexplored forest areas. As the most important technical innovation within this range the latest developed DMC from Z/I Imaging needs to be specified, which provides fast availability of information through the digital concept. Image data as well as the individual sensor channels (panchromatic, red, green, blue and NIR) bring up within a few hours or days after the flight service high and low-resolution raw data for an automatic determination of numerous parameters like e.g. humidity, tree and plant species and height information. In this way large areas can homogeneously be analyzed with reasonable costs and this data serves as a base for spacious models.

Required input information for the modelling system are the orthophotos and the 3D-DTM-points, either as a regular grid or scattered height points, both received from the ImageStation photogrammetric process. Out of this data for each forest stand the height points will be analyzed and differentiated into tree crown or ground points and gaps in the forest stands considered. The ground points deliver surface information like relief, aspect, slope and slope lengths. The combination of ground and tree crown point datasets as well as forest stand and tree/plant species data, outputs tree heights, height layers and stands roughness. Out of this information and the canopy density, received from the classification process in ERDAS, it is possible to determine the forest stands in a very specific and accurate way. Using the tree height data, segmentation of the orthophotos and the geometric analysis of a canopy, a single tree-list will be created.
The arcForest data model is the principal item of the entire system. It contains the models as well as the technique for their control and the data input or data output. It uses the possibilities of MSSQL or Oracle for redundant management of the data, the extended possibilities of a spatial database for versioned management of vector -, raster and DTM data as well as the safety mechanisms of the SQL Server. The data model is modular developed and is not dependent on a specific GIS system, in which the data can be viewed or updated.

2. MATERIAL AND METHODS

Most of the analysis based on DMC-test flights in September 2002, December 2002 and some data of Z/I internal test flights 2003. The data from September 2002 contains the whole island of Usedom (Germany) in a flight height of 3.800 ft and areas nearby Pasewalk (Mecklenburg-Vorpommern) in different lower heights. The data is compared with terrestrial forestry measurements with a Blume-Leiss system and a LEHDA from Jenoptik and data of the commercial forestriall inventory.

3. RESULTS

3.1. Collection of data from the DMC-Sensor

Beginning with the mission planning with an overlap of 60% in line and 30% on side the basis for the calculation of stabile elevations points is grounded. All proceeded flights take place in the time of well-developed leaves using Applanix. Following parameters of the DMC flight have in the given priority an influence to the number of later founded points and their quality.

1. The effective radiometric bandwidth of the Foresthill areas on the recorded images depend from the integration time and the shutter of the sensors.
2. The homogeneous daylight in the time of taking exposures.
3. The flight height, flights lower than 3.500 ft reduce the number of founding ground points in the forests.
4. The light intensity in time of taking exposures.

After the DMC-flight operations, standardized postprocessing and triangulation of the images the Z/I program ISAE will be used for the calculation of the elevation points. Depending from the structures of forests in average, following numbers of raw elevation points will be detected:

Pine forest adult (more than 70 years old)	80.000 points/ha
Pine forest juvenile (less than 5m height)	170.000 points/ha
Red Beech adult (more the 120 years old)	120.000 points/ha
Mixed Forest adult (Pine, Beech, other deciduous trees)	135.000 points/ha

Additionally the number of points was dependant from the quality parameters of the ISAE. The mean absolute accuracy of elevations in comparisons to terrestrial measured control points is 26cm.

3.2. Qualifying procedure of the elevation date

In the next step all founded points are imported to a database system and two types of errors are located. The mistakes of the calculation of the elevation on the frame of models (this error can be found on 46% of all models) and the errors of elevation points inside the models (depending from the type of the forests less than 1 %). For this procedure statistical outliers tests are be used.
After reduction of errors of the RAW-elevation data, the points were differenced with the help of the orthophoto PAN and a self-made procedures. The point set was shared in the top points of the trees, the different canopy levels and founded ground points inside the forest. These points will later be handle in separate datasets. Depending from the canopy closer, the percentage of ground points inside the forests was between 0.3 and 7.2% of all founded elevation points. Half starting from the center of the image to the frame reduces the percentage.

3.3. Calculation of different Surface and Terrain Models

With the different datasets the surface model for the forest can be calculated. In all scopes the data of aspect, slope and slope length are calculated. The grid width of the calculation gives the scales of the final datasets for the arcForest-Modelling system. With a Grid width of 10 meters a macro-surface is estimated. This data is used for instance for general storm models.
The grid width of 2m give the meso-scale data used for instance for the verification of detection of forest stands and the grid width of 0.5m give details of the canopy structure, for instance as the basis of the rawness and calculations of the internal stability of the forests.
From the sum of "non-forest" elevation points around the forests and the gaps and the founded ground points inside the forests, are combined and two scales of terrain models are calculated.
For the calculation of the surfaces and the terrains, the ERDAS-Software-package was used.

3.4. Usage of the Elevation data in Foresthill descriptions

Additionally to the terrain and surface models the data of the elevation points are used for detection e.g. following forestrical datasets.

1. The average height of the tree species in a forest stand.
2. The height of individual trees.
3. The size of the canopy of individual trees (one of a set of characteristics).
4. The Rawness of the canopy.

The accuracy of the founded heights of individual trees was on average 32% worse than ground based points, absolutely less the 50 cm. It is dependant from the age of the trees and the size of the canopy. In comparison to the height measurements with terrestrial equipment the differences in old trees are extremely higher than in trees smaller than 20 m. The difference was in well visible trees (terrestrial measurements from three standing points less than 1m, the reason might be the mistakes of the optical terrestrial measurements.
In an additional step all points are noted with the distance to the nadir-zone and shared into four classes. For the nadir-near class members the data is used together with radiometric data for the description of the horizontal structure of individual trees and the model of the typical tree of the species / age group in the forest stand. The data of the two outer nadir groups are used for the description of the vertical structure of the trees. These possibilities are dependant from the canopy

closer, acceptable results are calculable with a closer of less than 0.8. A description of the complete typical tree is now available.
The data can be use for the analysis of the tree and the prognosis of timber mass and other Foresthill parameters. Together with the individual tree list the data can be used for 3D-Visualisation of the forests and the use of this data for instance in timber harvesting systems.

4. PROBLEMS AND COMPARISON OF DMC-BASED DATA AND OTHER SENSOR SYSTEMS

The usage of the DMC for data mining gives the possibility to also collect elevation data by a standardized photogrammetrical workflow. The data is solidly dependant from the forest stands and the application parameters of the DMC-camera.
Comparing with film based and scanned images the 12bit-radiometric resolution and the possibilities of large integration times opens possibilities to also find elevation points in the shadows of the trees and smaller gaps. The number of points is absolutely dependant from the canopy closure and the lighting conditions on the day of taking the images.
With the Images using the ISAE-algorithm from Z/I it is possible, to detect for more then 90% of all individual trees the canopy top with a better quality than terrestrial measurement on large trees. This offers a cheaper method for collecting inventory data, the usage of interactive 3D-Plotters for instance in ArcGIS give additional possibilities for acceptance of the DMC-based data.
Comparing with laser scanning the elevation data from the DMC are not regular, the top of the canopy can with the optical detection from the DMC-images be better detected, but the penetration of the canopy is smaller. So its only in combination with the orthophoto-data possible to analyze the canopy structure in detail. The number of founded ground points is in comparable forest stands smaller. The postprocessing and analysis of the data is easier with the DMC-data, especially in view of the usage of the multi-sensor data and the possible object orientated analyzing methods. The technical combination of both concepts would be desirable but it is in the moment from commercial view not thinkable.
The comparison with the ADS40, the other available commercial digital camera system shows the same problems. The accuracy of optical-based elevation points is smaller; the application frame for the camera (more than 2000m flight height) limits the usage of the height measurements in forestry applications. Additionally the problems with the different channels and at the same time the calculation of a RGB and CIR-image reduce this practicability.

5. FUTURE DEVELOPMENTS

With the first DMC-cameras on the market a lot of data will be produced. This data must show the possible usage of the DMC in different surroundings (flight heights, weather conditions, forest structures etc.) for forestry inventory. For forests in middle Europe a usage was shown and the implementation of the camera in existing workflows and new applications of forestry inventory was realized. The mean topic of the next time must be the organization of an effective workflow of data processing and the consolidation of the applications with statistical data. The future combination of different methods, for instance laser scanning and DMC-flight is a proper possibility to stabilize these methods.

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