FOREST MAPPING USING 3D DSM DATA FROM SPOT HRS AND Z/I DMC CALIBRATED USING ALS DATA

Jörgen Wallerman, Johan E.S. Fransson, Jonas Bohlin, and Håkan Olsson

Swedish University of Agricultural Sciences,
Department of Forest Resource Management,
SE-901 83 Umeå, Sweden
Jorgen.Wallerman@srh.slu.se, Johan.Fransson@srh.slu.se

1. INTRODUCTION

Recently, the Swedish national land survey started production of a new and highly accurate digital terrain model (DEM) of Sweden. It will be produced using airborne laser scanning (ALS) between year 2010 and 2013 to provide nation-wide cover. The new DEM can possibly form the future basis for low-cost vegetation height data acquisition using digital surface models (DSM) acquired using photogrammetric processing of optical multi-view image data, such as acquired by the High Resolution Stereoscopic (HRS) sensor onboard SPOT-5, and images produced by airborne digital photogrammetric cameras (e.g. the Z/I DMC (www.intergraph.com) and LEICA (www.leica-geosystems.com) systems). In Sweden, the national land survey utilizes the Z/I DMC to repeatedly map the country at a nominal rate of 1/3rd of the area annually. Using photogrammetric modeling and automatic image matching of such multi-view optical data, DSM data of the vegetation canopy height (above mean sea level) can be produced [1, 2, 3]. Then, given the ground level (DEM), the vegetation canopy height above ground may be assessed. Such data are in practice today only available using specially ordered ALS missions at a high cost. Clearly, there is a new and possibly powerful potential to enhance forest vegetation mapping applications in Sweden, such as the nation-wide forest map *k*NN Sweden (skogskarta.slu.se) as well as data capture for forest management.

The HRS sensor is one of several satellite sensors designed to acquire global 3D information of the earth's surface by matching imagery acquired in different view angles along the track. In the case of HRS, there are two sensors, looking 20º both forward and aft. The imaging swath width is 120 km × 600 km, and the spatial resolution, is 5 m × 10 m, along and across track, respectively. Studies investigating the vertical accuracy of DSMs processed from SPOT HRS images acquired over bare ground, report accuracies in the order of 4-6 m [4, 5, 6, 7, 8]. Presence of forest is identified as an important source of increased errors [e.g. 6, 7, 8]. In fact, in forested areas the HRS DSM is a mix of a DEM representing the ground and a DSM of the forest canopy height, since the HRS stereo models capture the height of the first visible surface from above. This is commonly viewed as a problem which degrades the quality of the product. To decrease the impact of forest, methods such as spatial filtering [7] to smooth the differences between open and forested areas has been proposed. On the other hand, several studies [6, 7] point out that there is inherent information regarding the tree height in the SPOT-HRS DSM which can be assessed using accurate information of the ground elevation such as a DEM acquired by ALS. These studies showed the height bias of the SPOT-HRS DSM in forest to correspond to approximately 50% of the tree height. This information may prove to be very valuable as a complement to the spectral data provided by the SPOT-HRG sensor. SPOT-HRG image data has been thoroughly investigated for the purpose of mapping boreal forest (see [8]). Mapping accuracy is commonly similar to an R2 of 0.44 (SE = 50%) [9] for maps of stand mean forest stem volume. Extending such mapping models by incorporating tree height information derived from the SPOT-HRS DSM and an existing accurate DEM may very well improve the performance significantly. Unfortunately, the current commercial generation of DSMs from SPOT-HRS data is not optimized to generate vegetation height information; vegetation is considered rather as a source of error. Various steps are taken to reduce the influence of existing tree cover in order to produce as accurate terrain height models as possible for creation of the SPOT-DSM. Clearly, there are expected benefits of a new surface generation method optimized to extract vegetation height information from SPOT-HRS data, and especially in combination with an existing highly accurate ALS derived DEM.

The photogrammetric camera Z/I DMC simultaneously registers images in four wavelength bands, including infrared, and high-resolution pancromatic images. In Sweden, the standard aerial photography is carried out using the Z/I DMC at a flying altitude of 4800 m, producing multispectral and pancromatic images with 2.0 m and 0.5 m pixel size, respectively. The available research show this data to be efficient for tree species discrimination, classification accuracy in the order of 85% has been reported [10,11], although the full potential of Z/I DMC data for automatic mapping of Swedish forest has not been investigated. For this purpose, photogrammetric processing may provide very valuable data of the forest canopy height, given the multi-view angle characteristics of the data [2, 3]. This is the case for a recent pilot study of DSM data generated by the Rapid 3D Mapper (www.c3technologies.com) high-resolution airborne optical camera system (600 m flying altitude and 0.1 m × 0.1 m pixel size), which reports preliminary results of mapping accuracy in the order of 4.7% RMSE, 11% RMSE, and 18% RMSE, of mean tree height, mean tree diameter and mean stem volume, respectively [12].

This project aims to investigate the potential to enhance the accuracy of commonly applied large-scale forest mapping based on optical image data, using additional data of vegetation height above ground assessed by SPOT HRS and Z/I DMC in combination with DEM data acquired by ALS. Here, spectral models predicting standing stock of forest stem volume, mean tree diameter and mean tree height will provide the base-line for the research.

2. STUDY AREA

The project is carried out using data from the 70 km^2 large Krycklan test site locateded in the north of Sweden (64º14' N, 19º50' E). It is the forested watershed of the Krycklan stream, which is managed and owned by both Swedish forest companies and private owners. The prevailing tree species is Norway spruce (Picea abies) and Scots pine (Pinus sylvestris), but some deciduous tree species, e.g. birch (Betula pubescens), are also present. Topography is hilly with several gorges and the ground elevation ranges between 125 and 350 m above sea level. Field inventory was carried out at the Krycklan test site 2007 and 2008, and in total 419 circular field plots of 10 m radius have been measured. Using a subset of these plots, the average states of the forest in 31 stands are objectively estimated with high accuracy. At each plot, stem diameter in breast-height are measured for all trees and the height is determined for a sub-sample of threes. Plot positions were established using post-processed differential GPS measurements of each plot centre. The Krycklan watershed was scanned by airborne laser in 2006 (sparse intensity) and in 2008 (dense). The latter was performed on the 5:th and 6:th of August 2008 with the TopEye Mark II LRF system (S/N 425) mounted on a helicopter, at a flight altitude of 500 m above ground level, resulting in approximately 5 emitted pulses/m^2. At the area, the commercial SPOT HRS DSM is available, as well as a DSM of 1 m × 1 m pixel size processed using the MatchT software and the standard aerial photos acquired by Z/I DMC at 4800 m flying altitude in year 2009.

3. METHODS

Statistical analyses will be performed using a regression framework, continuing the spectral models derived in previous research [8]. Based on these, the improvements of adding information of tree canopy height from DSMs acquired by SPOT HRS and Z/I DMC for estimation of volume of standing stock (m^3/ha), mean tree diameter (mm) and mean tree height (m), will be addressed in detail. Key issues will be the relationship between accuracy and the influence of spatial scale on the resulting estimates and comparison of the results derived when using the optically acquired DSMs to estimates based on ALS derived canopy height. The DSM generated from SPOT-HRS has been shown to contain errors of varying degree, in the form of bias as well as erroneous representations of aspect and slope (e.g. [4, 5]). Thus, direct utilization of this data may not prove efficient. Here, the aim is to utilize the combination of an ALS DEM and field plot data to calibrate the SPOT DSM into a DSM of the tree canopy height, in order to assess the inherent vegetation height information. The ALS DEM provides accurate height of the ground level, and normalization of the SPOT DSM to this base-level is expected to be an important first step. Then, the field-plot measurements provide accurate information of the true tree canopy height above ground, enabling establishment of a calibration function from normalized SPOT DSM height to tree canopy height.

4. REFERENCES

[4] S. Airault, P. Gigord, L. Cunin, E. Breton, A. Bouillon, R. Gachet, and M. Bernard, "Reference3D location performance review and prospects", In: Proceedings of the ISPRS Workshop "High Resolution Mapping from Space", Hannover, Germany, 6-8 October, 2003.

[3] E. Baltsavias, A. Gruen, H. Eisenbeiss, L. Zhang, and L.T. Waser, "High-quality image matching and automated generation of 3D tree models", *International Journal of Remote Sensing*, 29:1243-1259, 2008.

[5] A. Bouillon, M. Bernard, P. Gigord, A. Orsoni, V. Rudowski, A. Baudoin, "SPOT 5 HRS geometric performances: Using block adjustment as a key issue to improve quality of DEM generation", *ISPRS Journal of Photogrammetry & Remote Sensing*, 60:134–146, 2006.

[1] B. Hallert, *Fotogrammetri*, Norstedt & Söner, Stockholm, 1964.

[2] M. Hirschmugl, *Derivation of forest parameters from UltracamD data*, Ph.D. Thesis, Graz University of Technology, Graz, Austria, 2008.

[10] J. Holmgren, Å. Persson, and U. Söderman, ”Species identification of individual trees by combining high resolution LiDAR data with multi-spectral images”, *International Journal of Remote Sensing*, 29:1537-1552, 2008.

[9] J. Hyyppä, H. Hyyppä, M. Inkinen, M. Engdahl, S. Linko, and Y.H. Zhu, “Accuracy comparison of various remote sensing data sources in the retrieval of forest stand attributes”, *Forest Ecology and Management*, 128:109-120, 2000.

[8] D.A. Lutz, R.A. Washington-Allen, and H.H. Shugart, “Remote sensing of boreal forest biophysical and inventory parameters: a review”, *Canadian Journal of Remote Sensing*, 34:286-313, 2008.

[11] K. Olofsson, J. Wallerman, J. Holmgren, and H. Olsson, “Tree species discrimination using Z/I DMC imagery and template matching of single trees”, *Scandinavian Journal of Forest Research*, 21:106-110, 2006.

[6] P. Reinartz, R. Müller, D. Hoja, M. Lehner, and M. Schroeder, “Comparison and fusion of DEM derived from SPOT-5 HRS and SRTM data and estimation of forest heights”, In: EARSeL Symposium, Porto, Portugal, 6.-11. June 2005.

[7] P. Reinartz, R. Müller, M. Lehner, and M. Schroeder, “Accuracy analysis for DSM and orthoimages derived from SPOT HRS stereo data using direct georeferencing”, *ISPRS Journal of Photogrammetry & Remote Sensing*, 60:160–169, 2006.

[8] T. Toutin, “Generation of DSMs from SPOT-5 in-track HRS and across-track HRG stereo data using spatiotriangulation and autocalibration”, *ISPRS Journal of Photogrammetry & Remote Sensing*, 60:170–181, 2006.

[12] J. Wallerman, K. Lundberg, and J. Bohlin, ”Forest data capture using optical 3d digital surface models from the C3 Technologies system”. In: Proceedings of the Digital mapping, from elevation to information, ASPRS/MAPPS 2009 Conference, San Antonio, Texas, November 16 to 19, 2009.