Counting Trees by Airborne Measurement

GIS and Image Processing Explore Timber Resources

Germany has the largest resources of timber in the European Union, more than Scandinavia. As during the last decades the consumption of timber has decreased, the growth was not harvested. Thus, at many places forest management often only insufficiently know how much harvestable timber is situated in their woods. Currently, increasing energy costs have made timber more interesting. As a renewable primary product, timber is more in demand as a fuel, and during last years its prices have gone up. Thus, in the foresting industry an atmosphere of departure has arisen: Again, timber economically has got interesting.

By Lutz Kreutzer

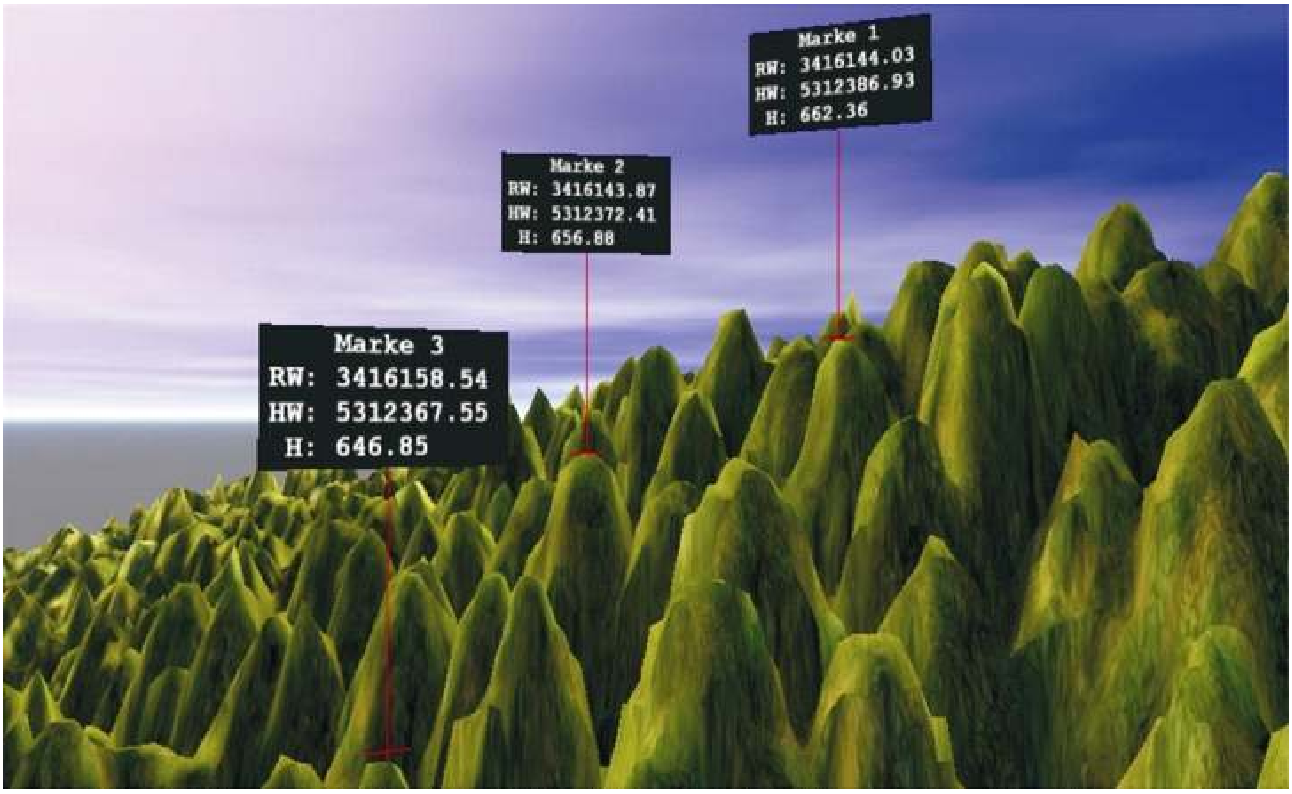

Fig. 1: Digital surface model (DSM); flags show digital information about the measured 3D points

Especially, electric utilities begin to be interested in the resources of the German woods. However, to investigate these by conventional mapping methods would be to staff- and time-consuming. That means: to expensive.

During the last years, a research team at the Department of Remote Sensing and Landscape Information Systems, University of Freiburg, Germany, around Prof. Dr. Barbara Koch has developed a system to exactly evaluate the tree population by airborne laser scan data and using image processing algorithms in an exiting way. Now, the system is ready for market and will be realized by the Steinbeis Transferzentrum Felis.

Fig. 2: Digital terrain model (DTM) with clearly visible forest trails.

TreesVis

One important target was to create a planning visualization tool for potential interested parties as forest managements and increasingly electric utilities. After discussions with employees from these institutions it was clear that they were looking for fast, reliable, and easy-to-use software. Results should be available without long runtime.

The Felis team had access to the data of airborne laser scan of TopoSys GmbH and the geodesic survey of the state of Baden-Württemberg. These data were explored within 2002 to 2004. Because these data cover a relative large area of woodlands, they are predestined to be used for an area-wide analysis.

Models from Laser Data

During aerial survey, 100,000 laser impulses a second are sent out. The laser light is emitted coniform with beam spread of 0.1 mrad. Thus, a laser impulse send out from a 1.000 metres altitude originates a footprint diameter of one meter on the ground. From every impulse the first pulse and the last pulse are simultaneously detected. During the aerial passing of a forest area, some signals are stopped by a tree's crown, some penetrate a tree's branches to the ground. Hence, by the detection of first and last pulse the crowns' surface as well as the forest's surface is scanned. During survey, the data are scaled with a GPS and an initializing system and thus are stored geo-referenced.

By the amount of the impulse rate, the density of data is high enough to generate highly accurate models. On the one hand a digital surface model (DSM, fig.1) can be constructed, on the other hand a digital terrain model (DTM, fig.2). The DSM characterizes the surface of the trees' crowns, the DTM reproduces the earth's surface.

The Lidar system measures the delay of the emitted and reflected laser pulses which can be converted into altitudes. Every altitude can be translated into a grey value. The thereby generated

16 bit grey value patterns are stored as a geo referenced tif-file. Caused by the different delays, one grey value image for the DSM and one for the DTM can be created. The resolution of these models depends on the distance of the laser spots on the surfaces. Under the present term, one pixel represents an area of 0.25 up to 1 square meter.

An adjusted model of the trees' height can be generated by the subtraction of both models (DSM minus DTM). In principle, the result grey value accords the delay difference of the laser pulses at one point. Thus, every grey value corresponds with a tree's height at its specific point.

Image Processing

Grey value patterns are predestined for digital image processing. The Freiburg University group developed their image processing routines based on the standard software library Halcon from

Maxima & Pouring

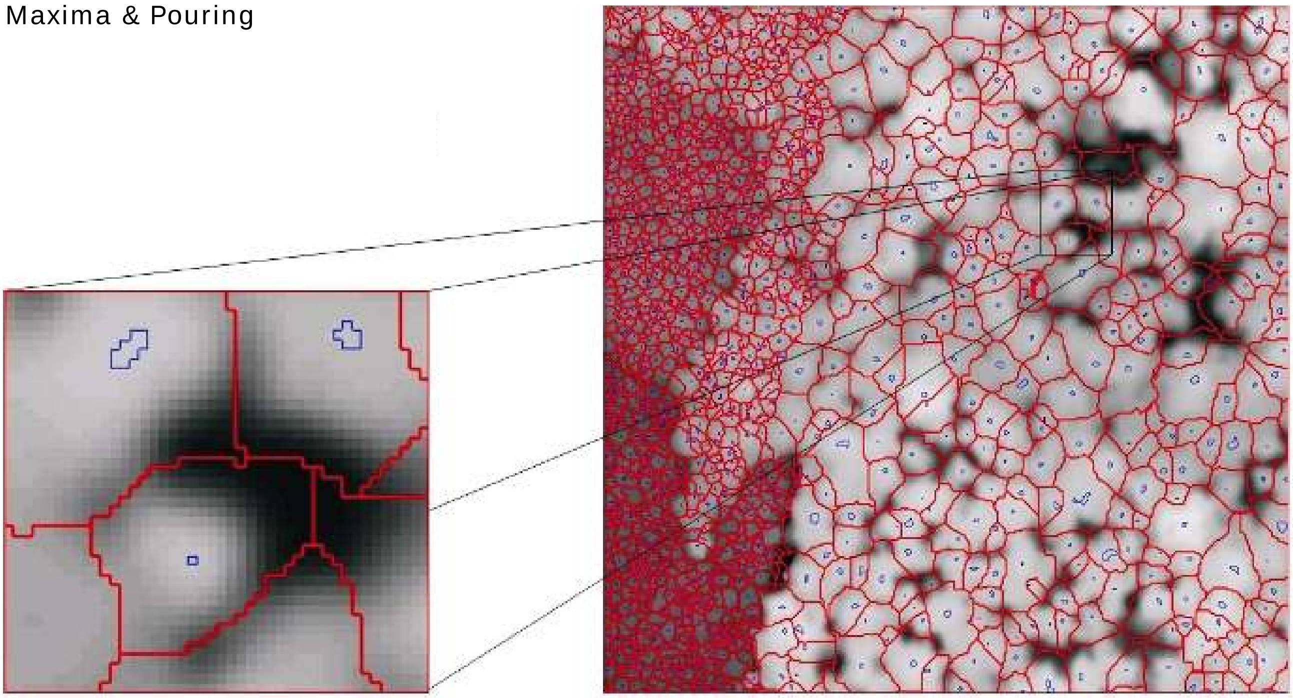

Fig. 3: Halcon based pouring algorithm show maxima and grey value valleys (dark). The maxima (blue polygons) indicate trees' crowns.

MVTec. The specific was the possibility to combine Halcon operators and own algorithms. For that purpose, Halcon's integrated development environment HDevelop was used.

In principle, the researchers separate the types of tree population (older population and younger population). Older trees are higher and show more a coarse surface as closer young populations. Thus, to effect a good result each population type has to be processed in an own way. After the differentiation of younger and older tree areas, the raw topography of the older trees must be smoothed during preprocessing with a Gaussian filter.

The actual image processing is done with a pouring algorithm under Halcon (fig.3). With this algorithm, grey value valleys will be determined. It works like a watershed algorithm, but with an inverse effect. This pouring algorithm calculates until all valleys between the trees' crowns are found. Thus, crown areas can be isolated. Thereby, a line is drawn along the deepest points which

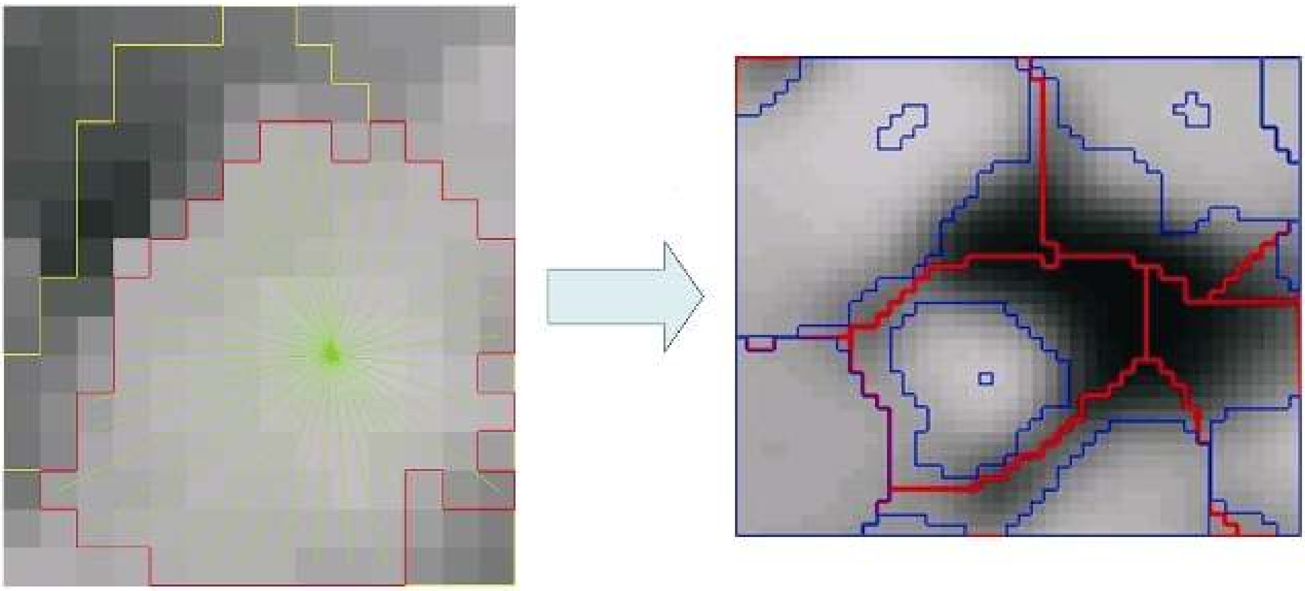

Fig. 4: To calculate the crown's boundary, an expansion similar to running raindrops is done. The resulting model is very close the natural situation.

not must accord to the boundary of the crowns. These so isolated areas can also contain surfaces which outreach the crowns if there is empty space between neighboured crowns, caused by planting gaps. To cover the actual crown boundary, an expansion is done from the maximum down to the valley-bottoms like raindrops running downhill in all possible directions (fig.4).
This algorithm detects along the calculated lines the difference of height in several steps. If this difference is negative or undercuts a variable but specific value, the measure point is assigned as one point of the crowns boundary. After some further adaptations as border and minimal distance adjustments, the crown model is very close to the natural conditions.

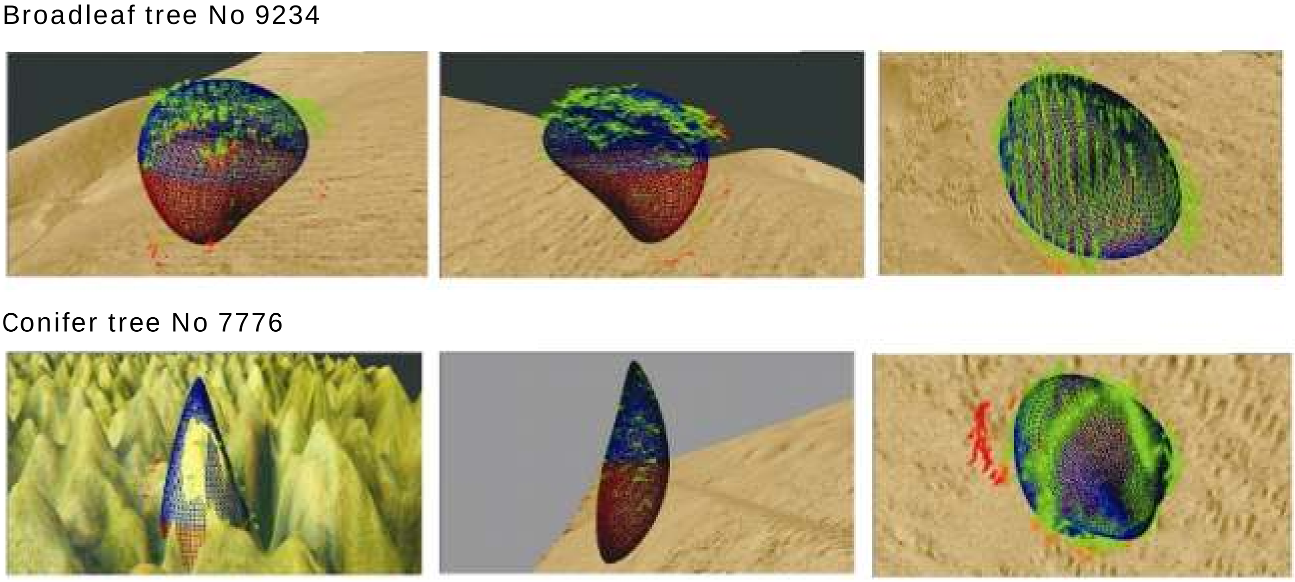

Fig.5: of a broad-leafed and of a coniferous tree.

By these evaluations, the crowns of older tree populations can be extracted out of a grey value pattern in a highly satisfying way. From the number of the crowns in combination with the heights of the trees (known from the laser data), the reserve of timber volume can be sufficiently estimated.

Broad-leafed or Coniferous Trees?

It is important to know for the timber industry if the explored area houses broad-leafed or coniferous trees. To answer this question, the ratio of light crown height to light crown area is computed (fig.5). For coniferous trees, this value normally is higher as for broad-leafed trees. Unfortunately, this matter only applies to older broad-leafed trees, because younger ones have a similar topography as conifers. Thus, this method is only applicable to forest areas which are known as old grown.

A further certain method to differ broad-leafed and coniferous trees is the analysis of winter explored laser data because conifers reflect the last pulse much more in opposite to a winter broad-leafed tree without leafs. In this case, the laser pulse penetrates the wood much more down to the bottom surface. Also this question can be answered very successful with Halcon's operators.

Interface to ArcGIS

All results can be read out of the TreesVis system in shape or grid format and adopted to a GIS. Thus, a direct link-up to ArcGIS and an accordant further processing is possible.

Contact:

Dr. Lutz Kreutzer
Manager PR & Marketing
MVTec Software GmbH
Neherstr.1
81675 München, Germany
Tel. +49 (0)89 457695-0
Fax +49 (0)89 457695-55
www.mvtec.com
press@mvtec.com