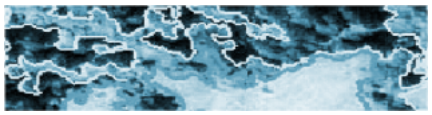
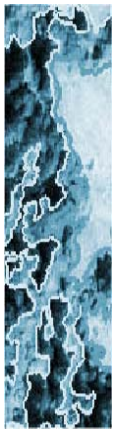
UNIVERSITÄT SALZBURG

Stand Montafon Forstfonds



Transferability of a Tree-Crown Delineation Approach Using Region-specific Segmentation



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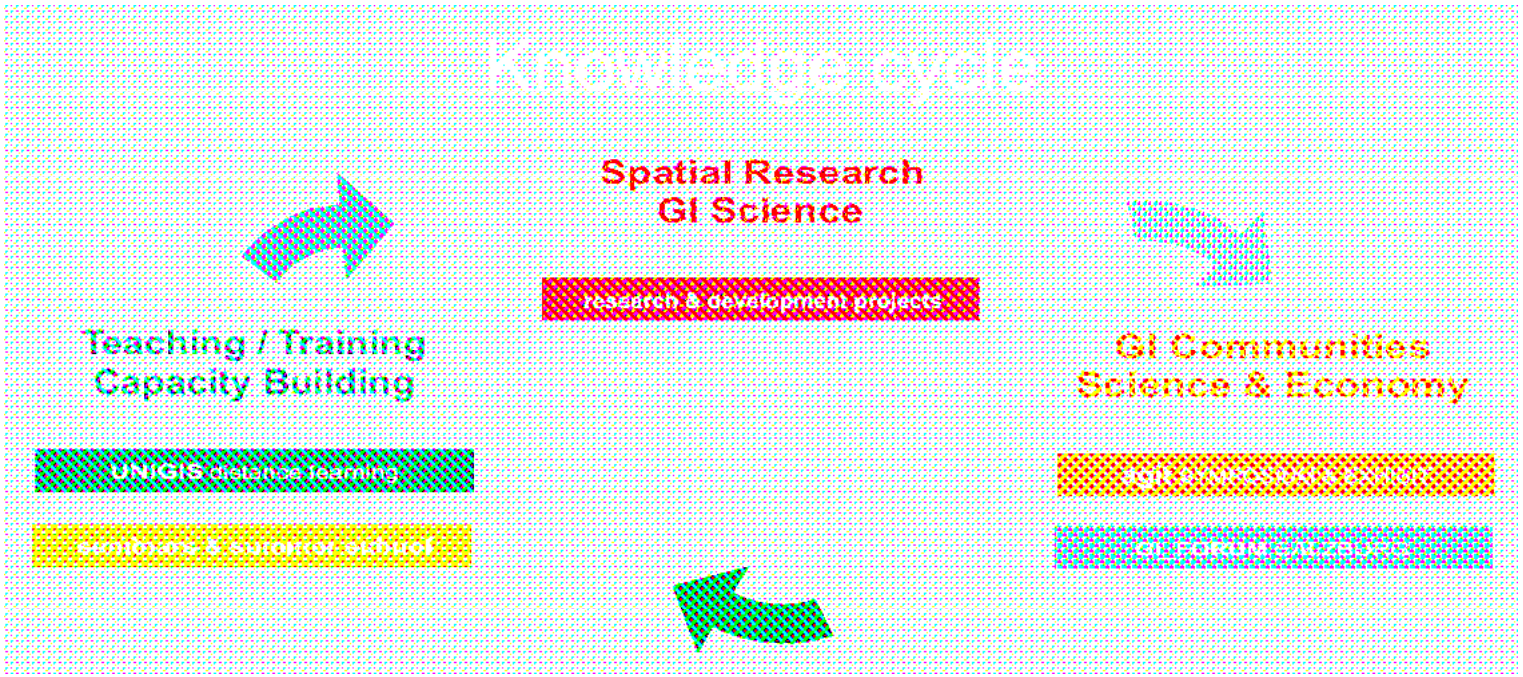
Centre for Geoinformatics, Salzburg University;
Stand Montafon Forstfonds, Austria

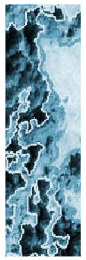
XIII SBSR - Simpósio Brasileiro de Sensoriamento Remoto - 2007

Florianópolis, April 23, 2007

Z GIS

- **The Centre for Geoinformatics**
  - Interdisciplinary **research centre** at Paris-Lodron University Salzburg
  - 30 staff members (1/3 non-academic)
  - Since 1985, formally established as 'centre' in 2004





Motivation

- **Forests in Austria / Europe: multifaceted and multifunctional meaning in small scale**
  - Economical and ecological factors interlinked
    - AT: 46% of entire area (84000 km²) covered by forest
    - 83% highly managed
    - Clear-cuts prohibited by law (> 3ha)
    - Timber production and harvesting in balance according to the principle of 'sustainability'
    - Climate control, green lungs
    - Habitat function
    - Social welfare

Multifunctionality of Forests

- **Forests in Austria / Europe: multifaceted and multifunctional meaning in small scale**
  - Specific function in mountainous areas: Protection forest
    - 29 % in Austria
    - Preserving settlements and stabilising slopes in hazard-prone areas
    - Characteristic mix of standing and dead wood (‘habitat wood’)

Multifunctionality of Forests

Protection Forest

Photographs: from Maier et al., 2006

Motivation

- **Measuring forest structure is essential to assessing protection functions of forests in hazard-prone areas exposed to**
  - **Rock-fall**

[Photo: B. Maier]

Motivation

- **Measuring forest structure is essential to assessing protection functions of forests in hazard-prone areas exposed to**
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  - **Avalanches**

[Photo: B. Maier]

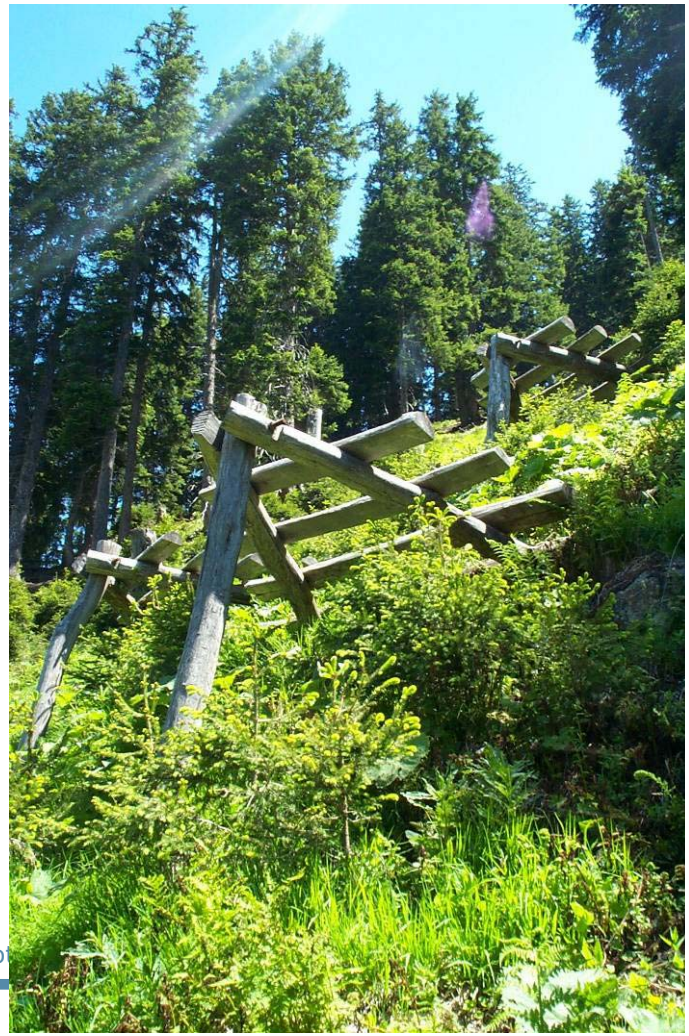
Motivation

- **Measuring forest structure is essential to assessing protection functions of forests in hazard-prone areas exposed to**
  - **Rock-fall**
  - **Avalanches**
  - **Mudflows**
  - **Landslides**

[Photo: B. Maier]

Motivation

- **Measuring forest structure is essential to assessing protection functions of forests in hazard-prone areas exposed to**
  - **Rock-fall**
  - **Avalanches**
  - **Mudflows**
  - **Landslides**
  - **and similar events**



[Photo: B. Maier]

Approach

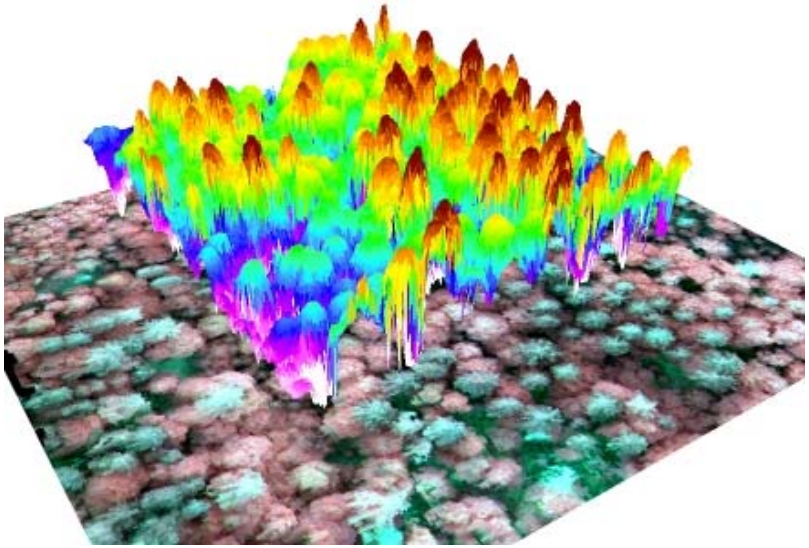
Integration of multispectral optical data and airborne laser scanning (ALS) data for (semi-) automatic object-based

- single tree detection
- tree crown delineation

using region based segmentation

- **➔ basis for forest structure assessment as a crucial indicator of forest integrity**
- **➔ enables forest managers and natural risk engineers to evaluate whether a forest can fulfil its protective function or not.**

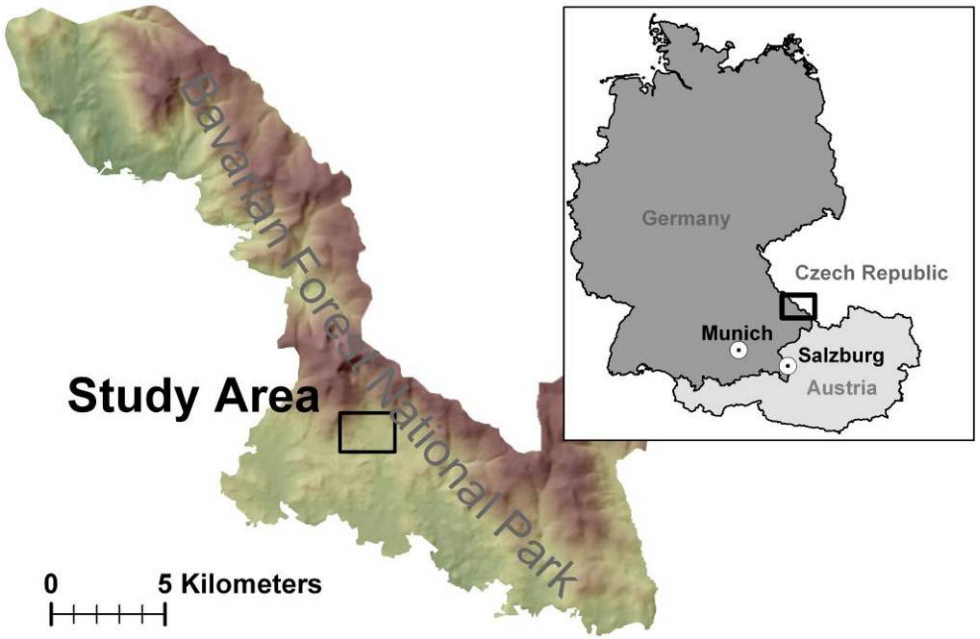
[Traditional methods for assessing forest structure like field inventories and aerial photo interpretation are intrinsically limited in providing spatially continuous information over a large area.]



Approach

- **Originally developed for a study site in the National Park Bavarian Forest**
  - **Hilly area**
  - **National Park no protection forest needed/necessary**
  - **Near natural forest, no harvesting allowed**

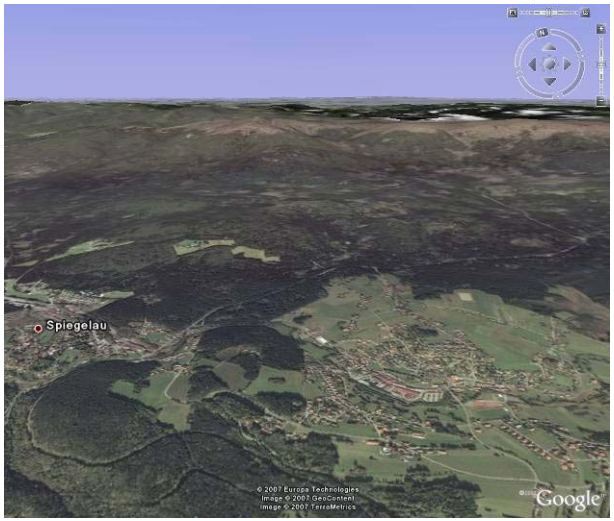
  BUT:
  - **A lot of high-quality remotely sensed data available (test site for the evaluation of remote sensing based methods for the identification of forest structures)**



Transfer of the approach

Transfer of the approach:

- **Hilly to mountainous areas**
- **Higher to lower density ALS data (10 pts/sqm ➔ 0.9 pts/ sqm) which influences quality of derived nCM**
- **Different optical data sets (line scanner camera RGB + NIR (1 m GSD) ➔ FCIR (0.25 GSD))**



[Source: Google Earth]

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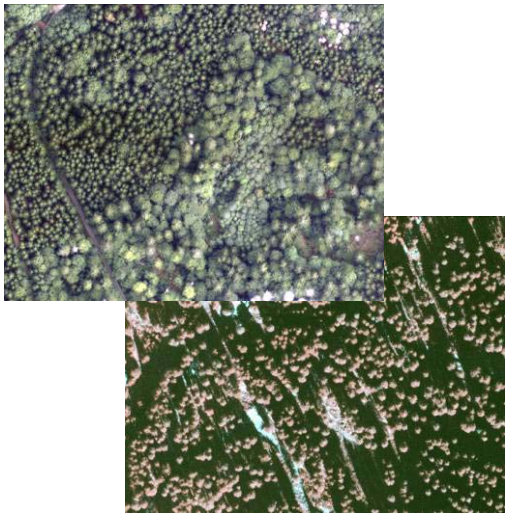
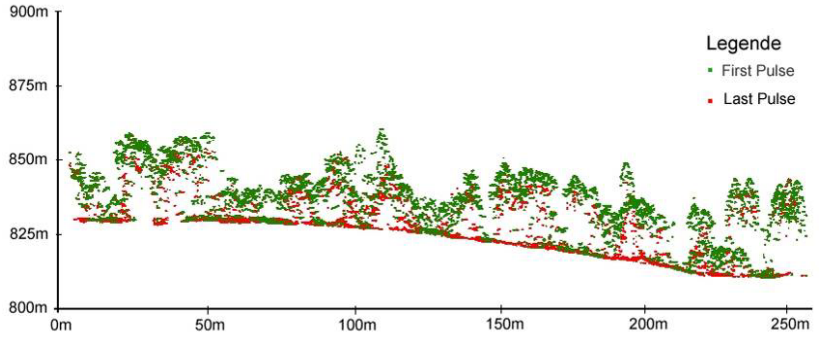
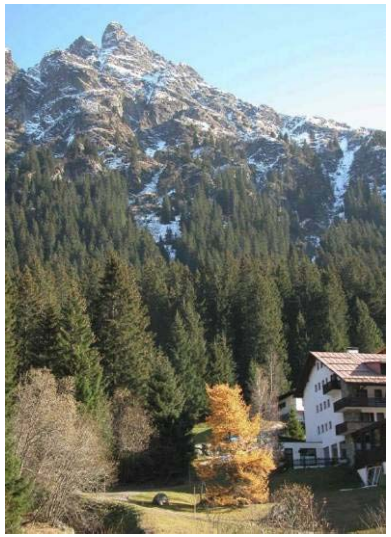
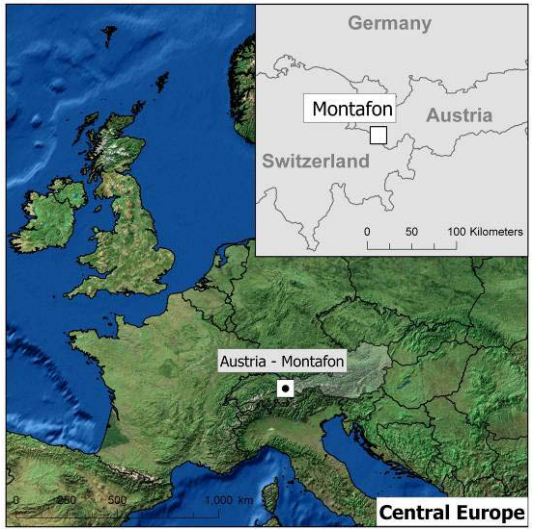


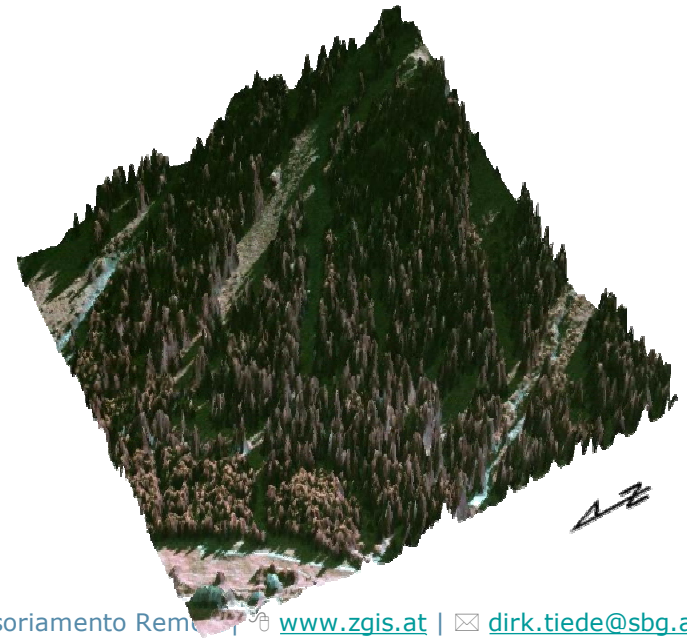


Study Area

- Located in the Montafon area in Western Austria in the federal state of Vorarlberg
- West-facing slope, directly above the tourist centre of Gargellen and ranges from 1,400 to 1,800 meters a.s.l; inclination between 25 and 40 degree; 22 ha in size.
- Forests coverage on this slope prevents hotels and houses from damages due to rock-fall or avalanches.





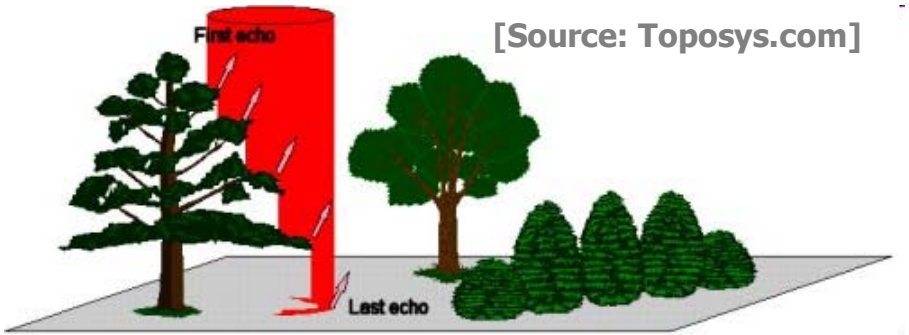


Study Area & Data

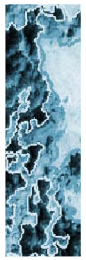
Data

- ALS data acquired in 2002 by TopScan (Muenster, Germany); first and last returns were collected.
  - **Point density of 0.9 points per sqm and a footprint of approximately 30 cm**
- First and last return laser raw data were processed at TU Vienna. Both a digital terrain model (DTM) and a digital surface model (DSM) with 1 m resolution were interpolated

- FCIR aerial photos (2001) recorded independently with a ground sample distance (GSD) of 0.25 m
- Terrestrial mapped structure types and visual interpretation were used for validation purposes.



[Source: Toposys.com]



Study Area & Data

- Normalised crown model (nCM) with 1 m resolution was calculated ➔ serves as basis for the single tree-crown delineation

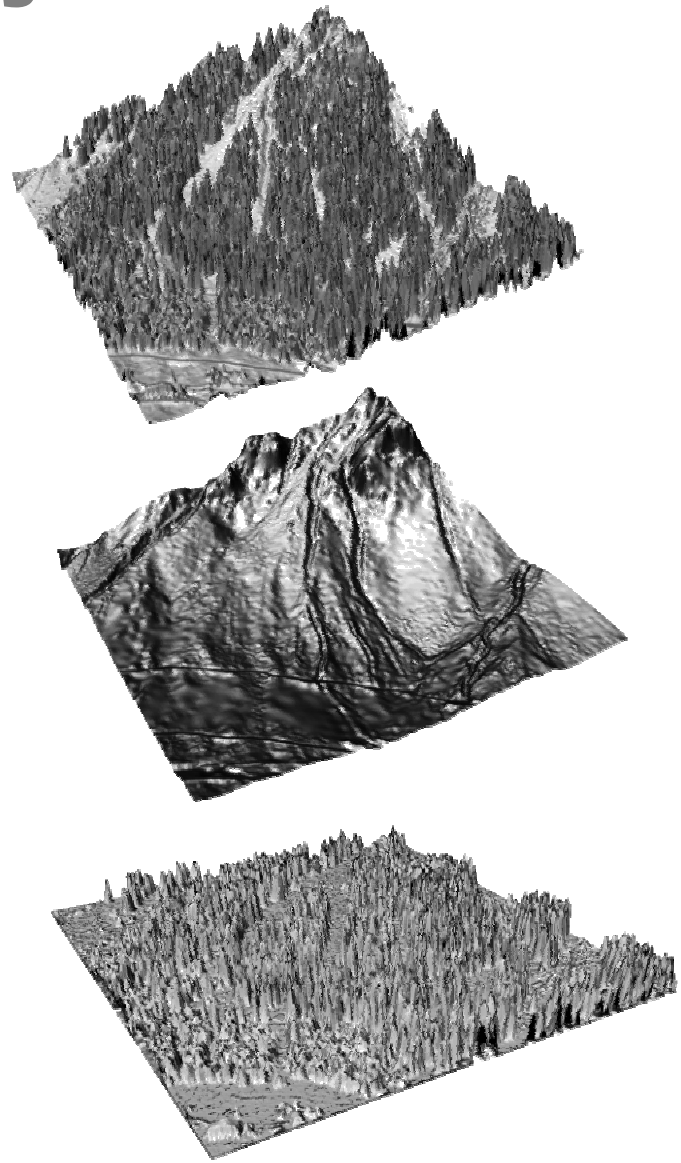
DSM

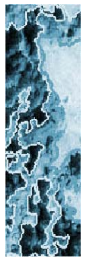
-

DTM

=

nCM





Methodology

- **Region-specific segmentation means utilising a-priori knowledge of the respective scale domain of the envisaged target features**

- **In other words:**
  - Profound forest characteristics (e.g. spacious vs. non-spacious forest) control the application of an optimised rule set for tree crown delineation.

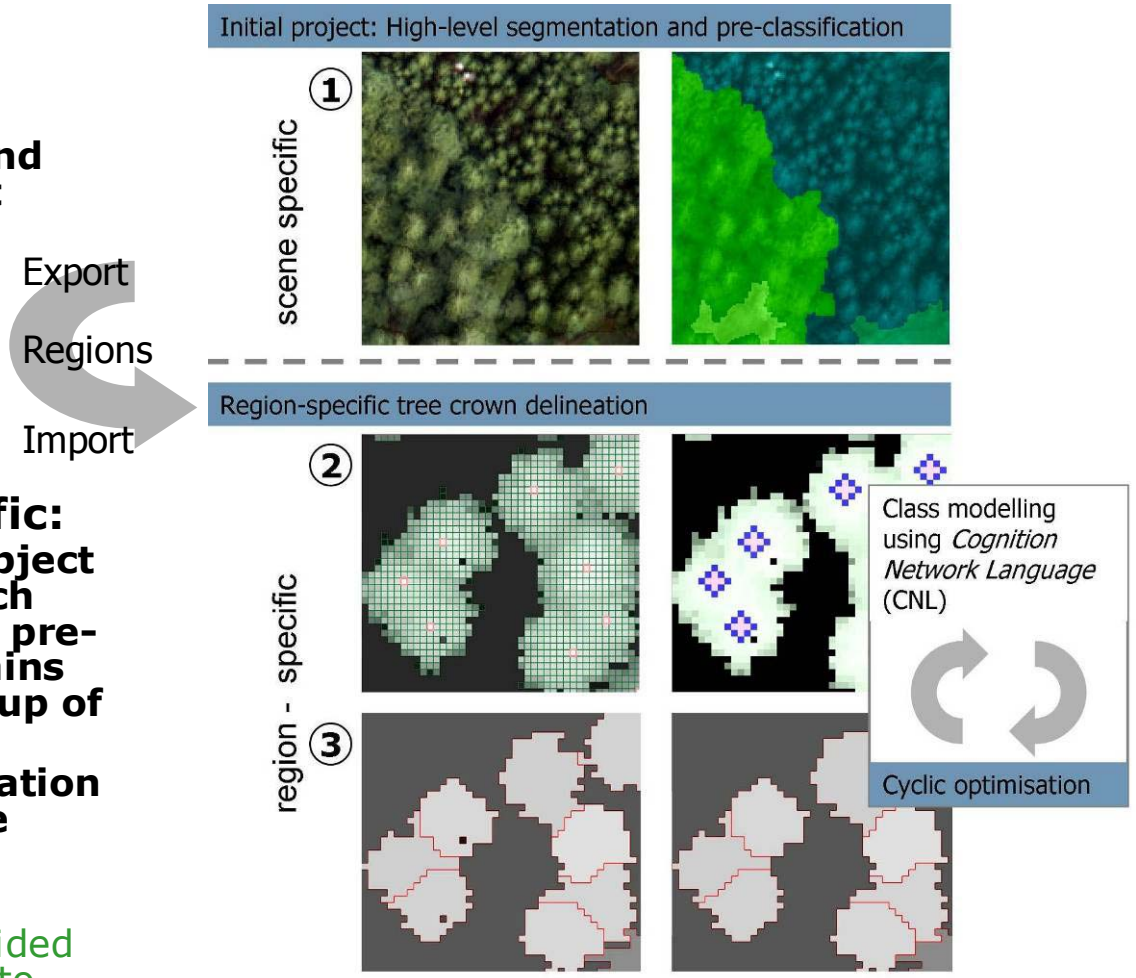
- **Rule set design was realised using Cognition Network Language (CNL) of Definiens Developer software.**

Workflow

- **Scene specific:**
  - **High-level segmentation and pre- classification of forest types**

- **Region (Forest type) specific:**
  - **Scalable segmentation / object build-up algorithms for each forest type: Break down of pre-classified forest type domains to small objects and build-up of region-specific objects**
  - **Cleaning and final classification of the extracted single tree crowns**

- ➔ Original workflow had to be divided into two different project settings to overcome resampling problems



High-level sgmentation and pre-classification

High-level segmentation:

- region-based, local mutual best fitting approach (Baatz and Schäpe 2001)
- In the segmentation process only FCIR data whereas in the pre-classification process both data sets (spectral and height values) were deployed.

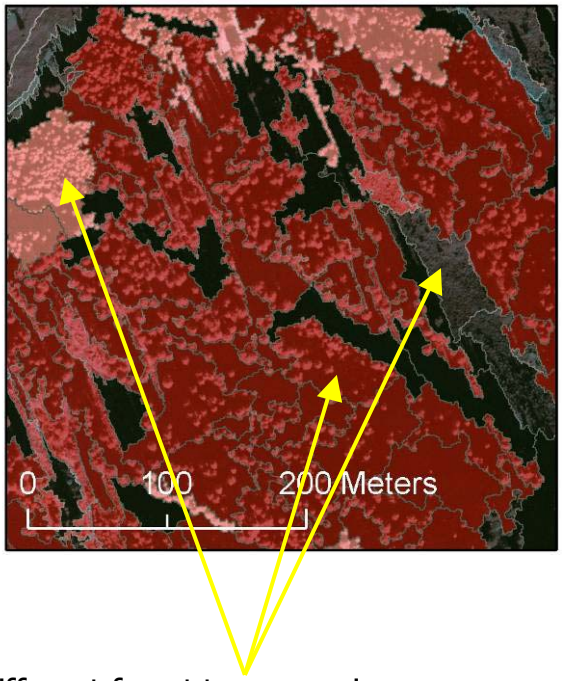
Pre-classification:

(due to NDVI values and the standard deviation of the nCM as an indicator of the forest structure) :

- coniferous spacious (old / young)
- coniferous non-spacious (old / young)
- Additional classes: non-vegetated area (roads, larger clearance areas etc.)

  ➔ used as a mask to follow analysis steps

- **Results were exported to a vector file (Shapefile) and re-imported into the second project setting preserving all relevant information regarding the forest types.**



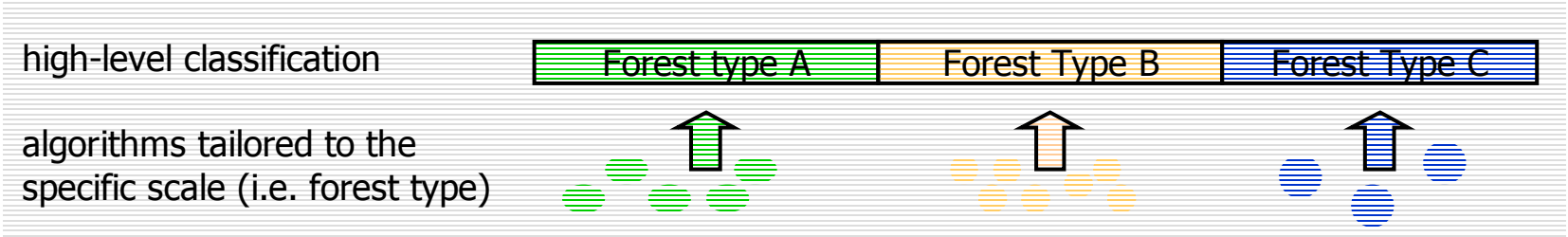
Different forest types require different single tree delineation algorithms

Region specific tree crown delineation

Problem:

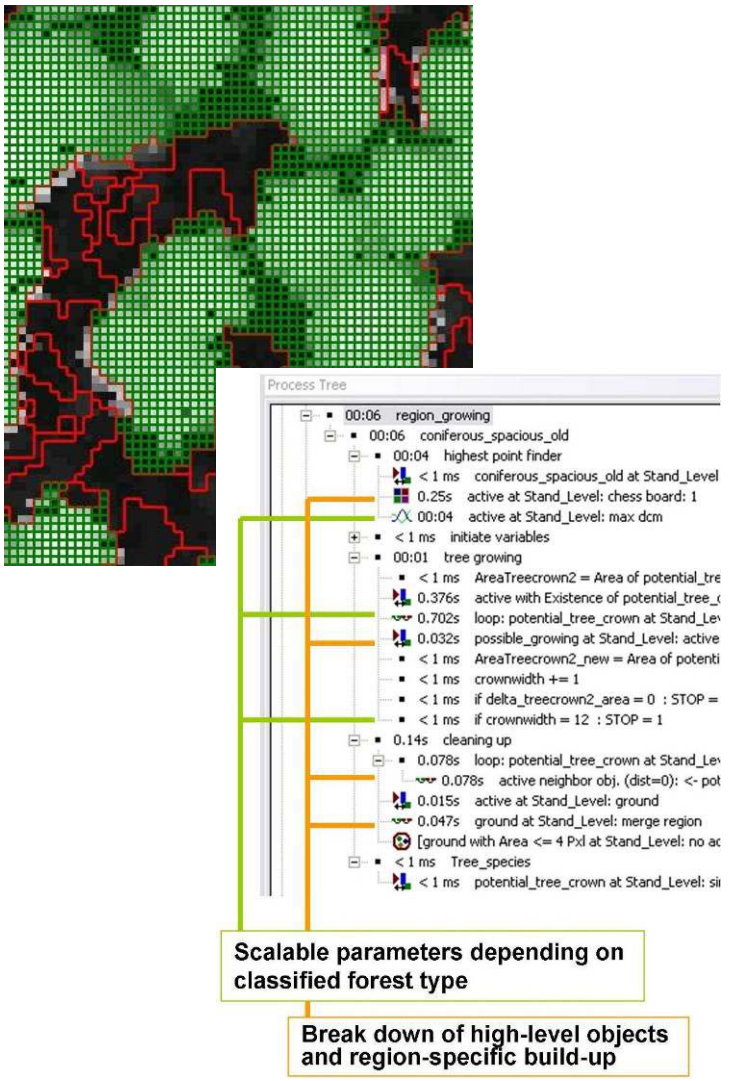
In case of single tree crown delineation, segmentation algorithms based on homogeneity (like the algorithm used for the high-level segmentation) are not suitable for addressing complex, inhomogeneous canopy representations in VHSR data

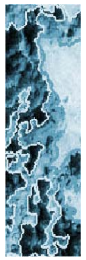
- **➔ Scalable segmentation / object build-up algorithms were developed which can be adapted to the very situation and applied within regions or domains.**
- **➔ Pre-classified forest types served as spatial constraints for building a region-specific two-level hierarchy, inside which the scalable algorithms were embedded and optimized multi-scale segmentation was accomplished.**
- **➔ Parameters of the algorithms are directly influenced by the high-level classification (a-priori information)**



Region specific tree crown delineation

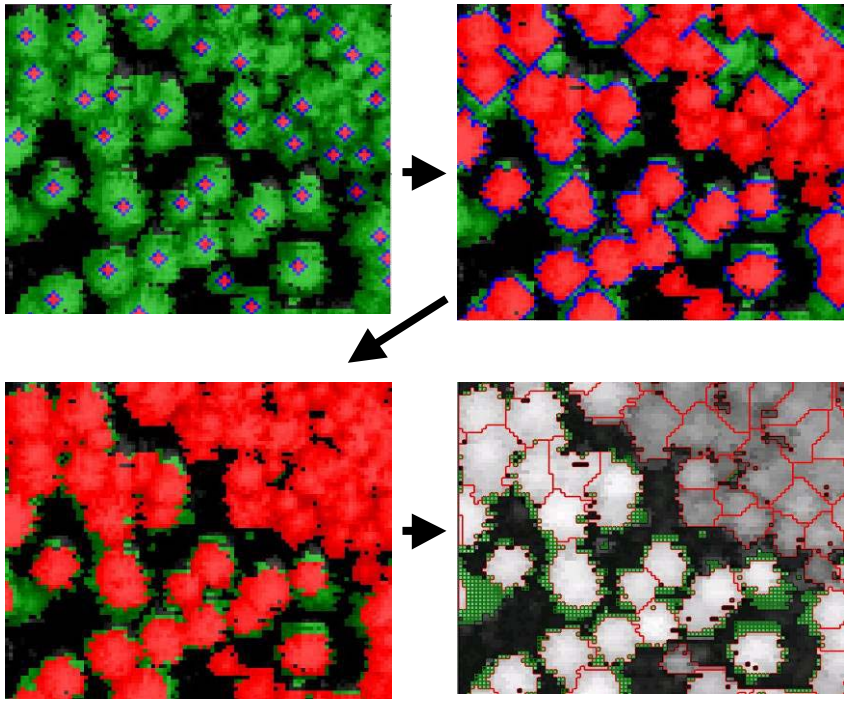
- **Realised by developing a rule-set using Cognition Network Language (CNL) for the Definiens Developer Environment:**
  - Sort of a modular programming language allowing typical programming tasks like branching, looping and variable definition
  - Enables addressing single image objects and supports manipulating / supervising the process of building scaled objects in a region-specific manner
- **One core element: possibility to break down the regions to pixel sized objects that still reside in the super object boundary that represents the very forest type.**





Region specific tree crown delineation

- **Region-specific tree crown delineation using nCM data only → FCIR not used to avoid forced resampling**
- **Modelling of single tree crown objects was carried out in an iterative optimisation process**
- **→ Regions are broken down to pixel sized objects in order to build up new supervised objects (here: tree crowns). This build-up process starts from local maxima derived from nCM**
- **Information about different forest types, which controls the parameterization for each region-specific algorithm, is included by integrating the vector file of phase 1 in the segmentation**

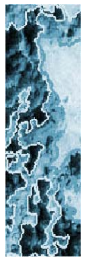


Region specific tree crown delineation

Parameterisation includes:

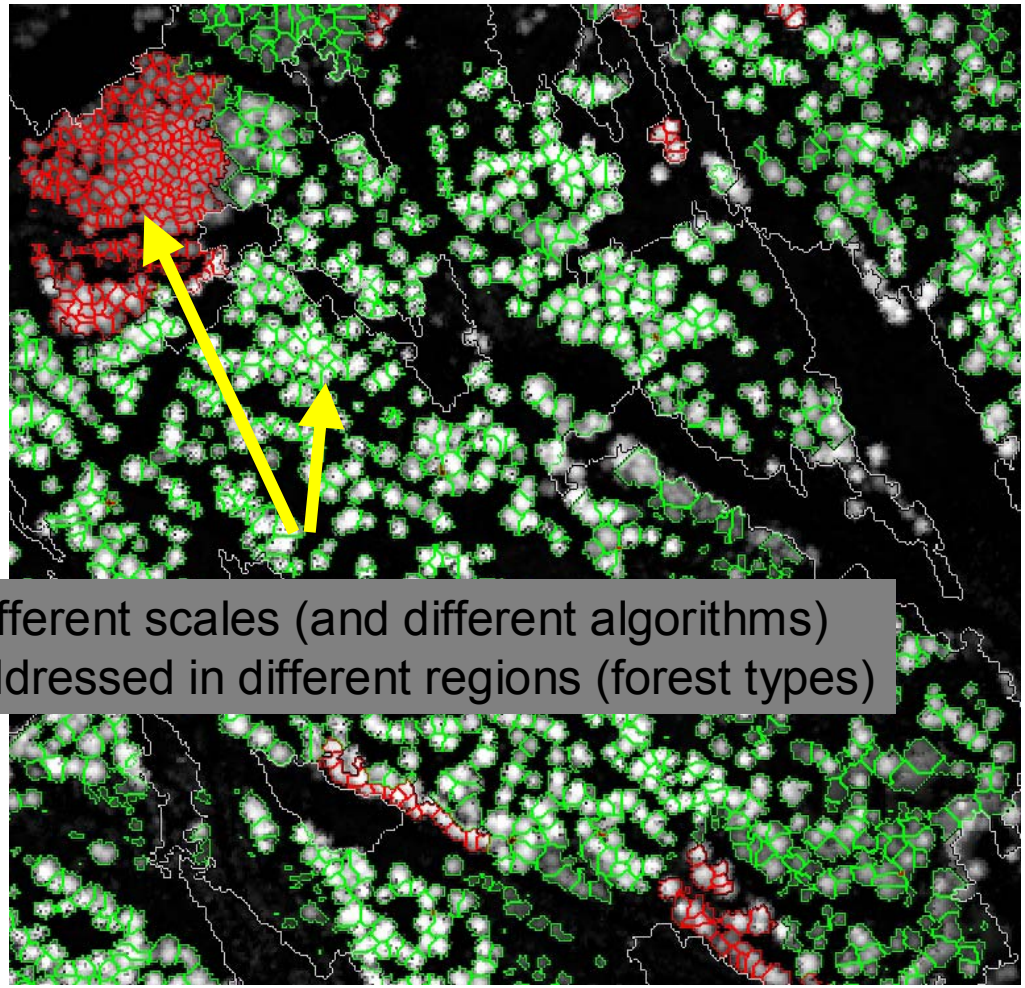
- **(1) search radius for the local maximum method is depending on the assigned forest type: taller, spacious trees require a bigger search radius to minimizing false positives, whereas dense coniferous stands require smaller search radii for detecting even closer standing tree tops.**
- **(2) Stopping criterion for the region-growing process - Neighbouring objects are only taken into account, if height difference not exceeds a defined limit.**
- **(3) Crown width limit prevents uncontrolled growing as a result of falsely identified tree tops.**

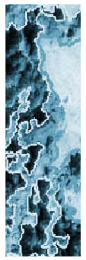
Parameter	Finer scale – smaller trees	Coarser scale –larger trees
Local maximum search radius	- to detect even tree tops in closed stands	+ to avoid false positives
Sensitivity of the stopping criterion value due to underlying nCM data	+ for small coniferous trees	- for large coniferous trees
Crown width limit in segmentation process	- for small coniferous trees	+ for large coniferous trees



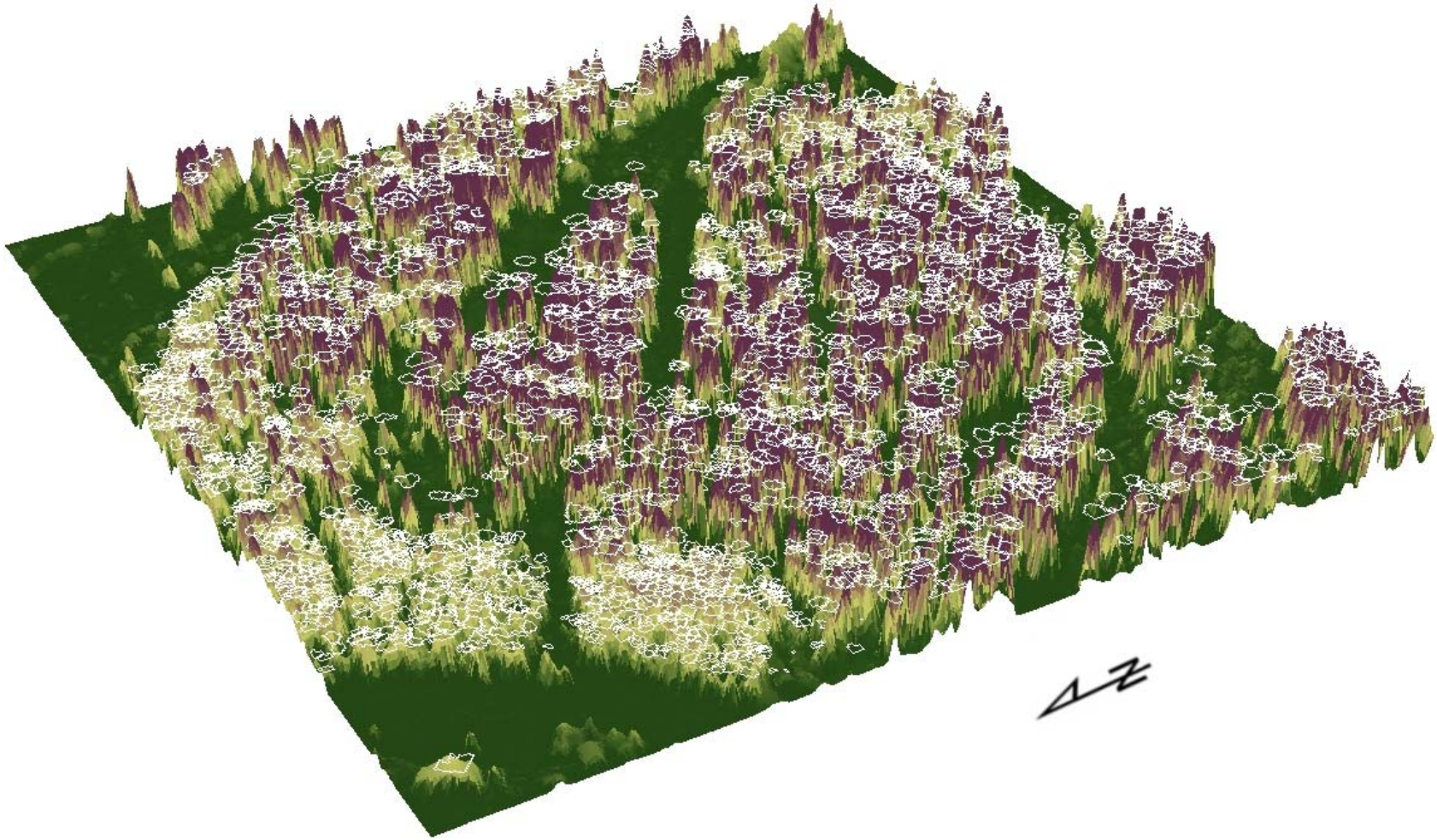
Results

- **2,344 single trees taller than 5 m were detected**
- **For most of them a tree crown could be delineated, even in the dense pole forest**
- **A few local maxima were detected without a following delineation of a tree crown.**
  - ➔ small trees or dead trees, where the given point density of the ALS data fails to represent the whole tree crown in the interpolated nCM



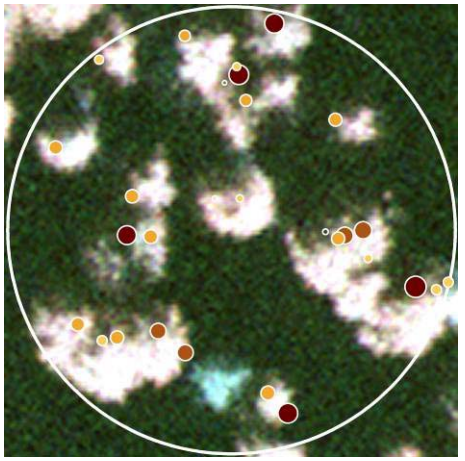


Results



Accuracy Assessment

- **Accuracy assessment was performed using:**
  (1) ground truth information of a reference sample and
  (2) visually delineations, because single tree ground truth information was not available for the entire area.



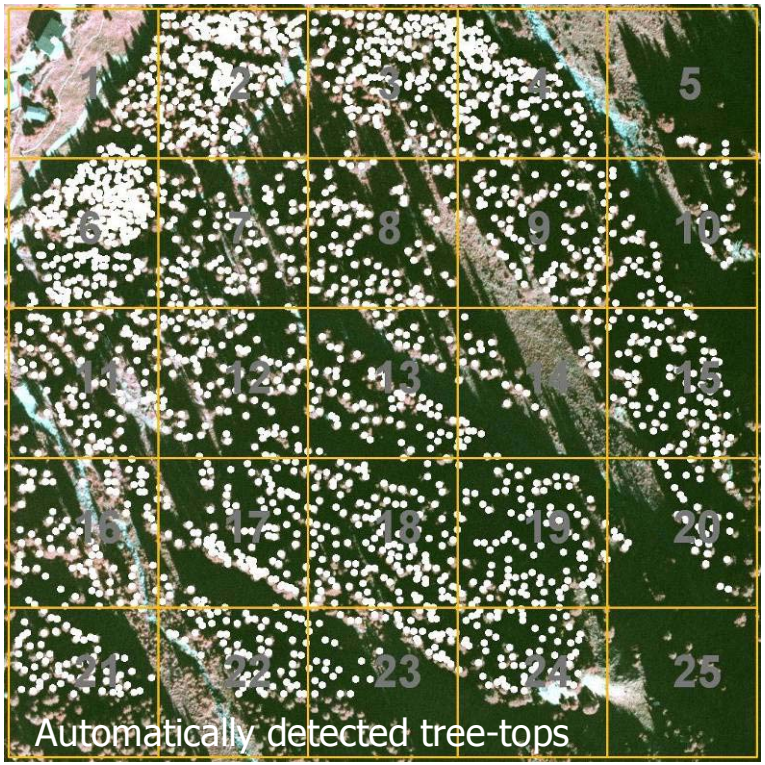
- **Comparing the results with the ground truth control sample revealed that dominant trees were detected correctly**

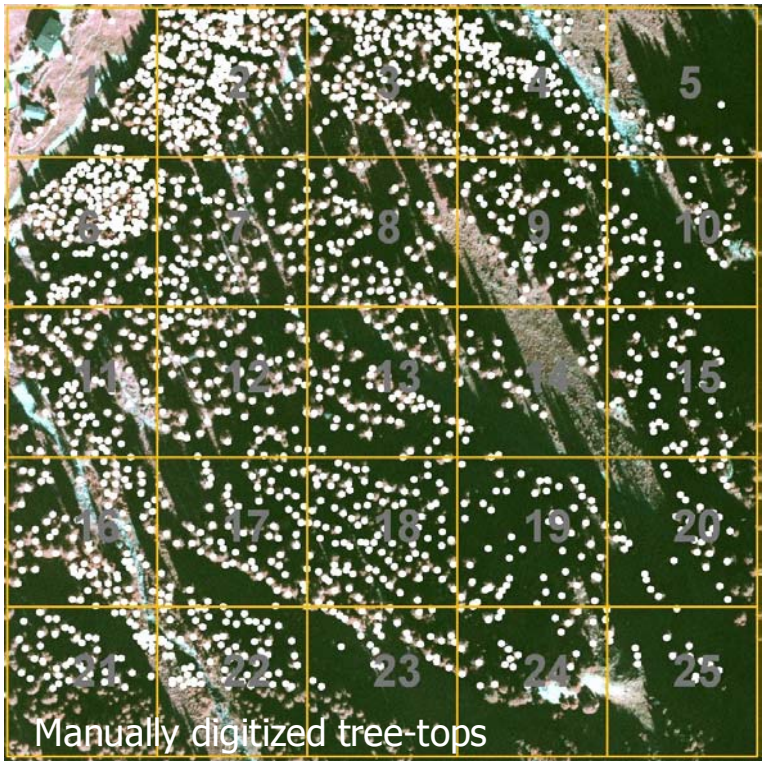
- **➔ trees with a BHD above 25 cm were properly delineated**

- **➔ Smaller trees clustered or grouped with larger trees and double crowns could not be detected; distinct local maximum was not detectable in the nCM data ➔ general problem when assessing forest structure by means of remote sensing.**

- **Obviously: positions of detected tree tops and surveyed trees on the ground are not the same ➔ inclined tree growth in such a mountainous area.**

Accuracy Assessment





- **Visual accuracy assessment was done by on-screen digitizing of tree tops using FCIR and nCM data.**
- **➔accomplished by an external expert for reasons of objectivity and independence**
- **To obtain spatially explicit results the machine-detected tree-tops and the digitized ones were disaggregated to regular 100 x 100 m raster cells**

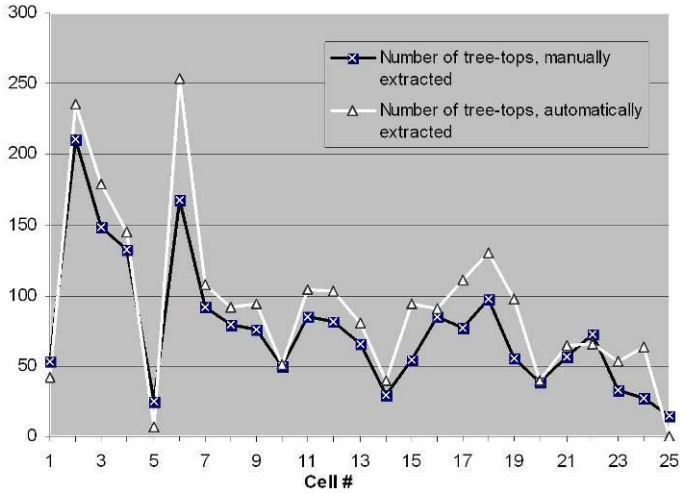
Accuracy Assessment

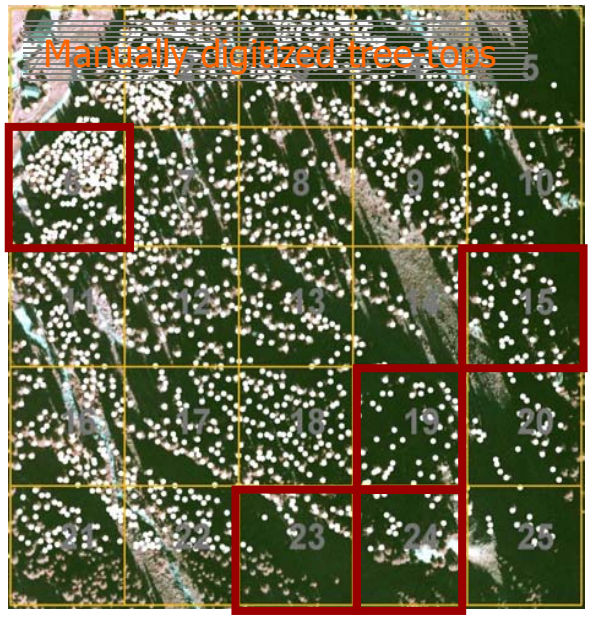
- **High congruence (correlation coefficient: 0.95) between the two techniques**
- **Percent of automatically classified dominant trees (point in polygon analysis) ~90 %**

- **Automatically detected tree-tops overestimated by 23 % in average as compared to manual detection (false positives)**

➔Reasons:

- Shady condition of the aerial photographs hampers visual detectability. Highest overestimated areas (cells: 15, 19, 23, 24) are located in the steepest and most shady south-eastern part of the study site.
- Dense spruce pole forest (cell: 6)



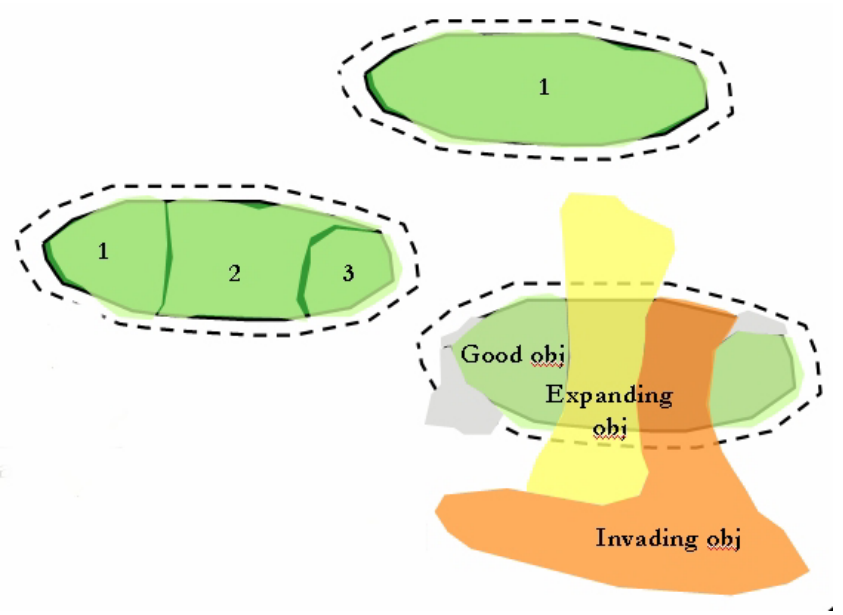


Accuracy Assessment

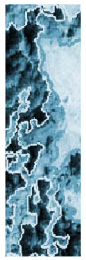
- In a stricter methodological sense, assessing the accuracy of polygonal features through point locations as mere proxies may be considered inadequate to the object-based approach

- ➔ evaluation of the delineated tree-crowns as such, has not been performed as yet.

- Generally stated: when dealing with spatial objects the geometrical accuracy of an object boundary needs to be assessed as well, beyond assessing locational and thematic agreement.
- To accomplish this in an automated, yet methodologically sound and inter-objective manner is a pertaining challenge for ongoing studies.



[Lang et al.; in press]

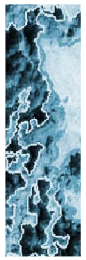


Conclusions

Conclusion I (transferability):

- Problems of transferability:
  - Resample problem of different data sets (software problem) – could be solved through workflow adaptation
  - Some tree crowns are not perfectly represented in the nCM derived from ALS data with a point density of 0.9 sqm ➔ only affected a small amount of trees

- Positive:
  - Algorithms work with only minor adaptations on completely different data sets and area
  - For protection forest monitoring ALS data with 0.9 pts/ sqm and the use of FCIR orhtophotos seems to be sufficient ➔ saves time and money



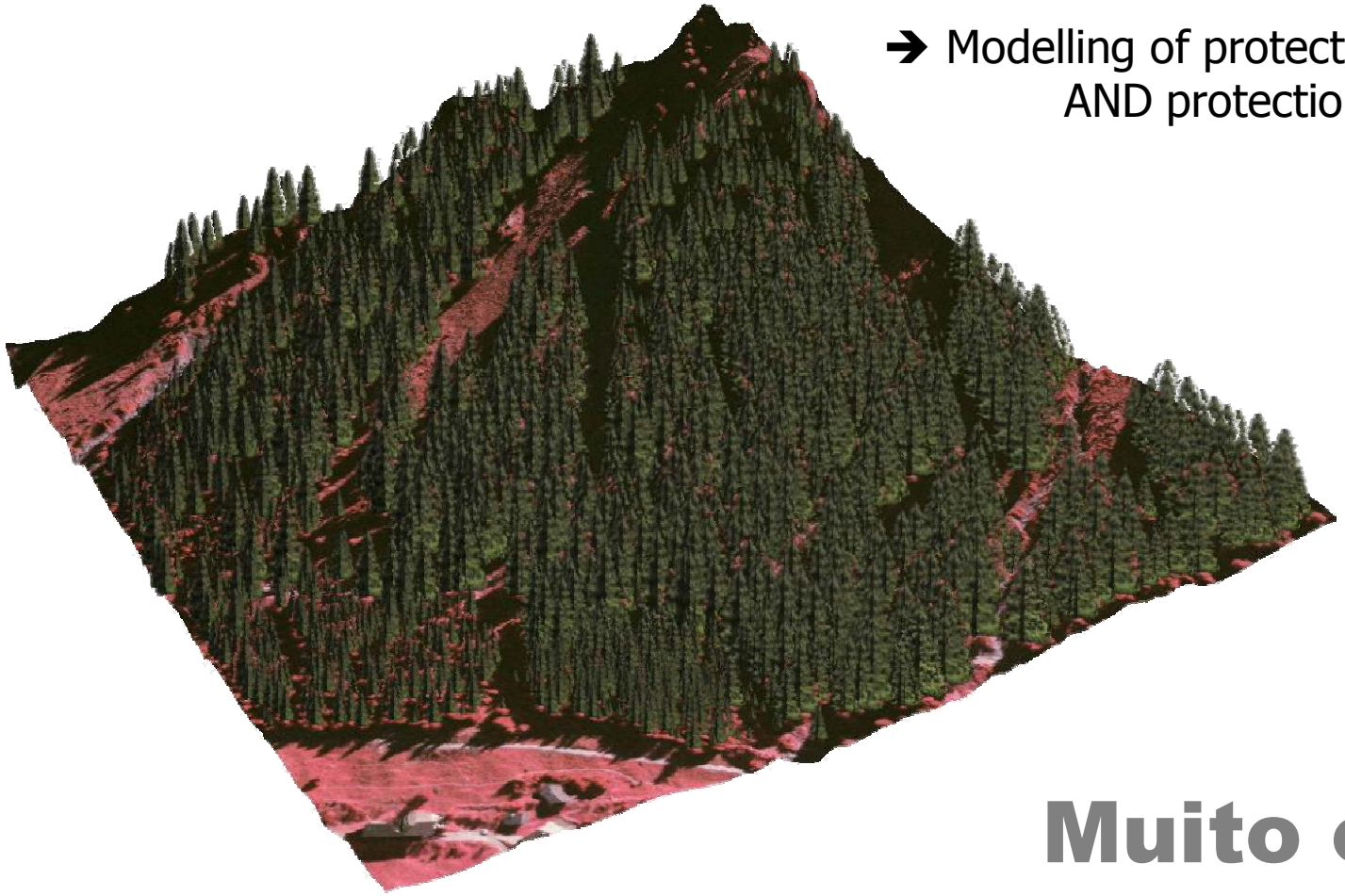
Conclusions

Conclusion II (generally):

- Could be a step towards operability by controlling linked algorithms through an initial high-level segmentation and classification.

[Quality of the high-level segmentation and classification of regions in the first step plays an important role concerning the effectiveness of the region-specific single tree algorithms]

- ➔ Idea of an algorithm library for scale-specific target features, different scenes or different data sets.
- ➔ High-level classification would determine which features may be expected within the specific region. This again would be used to apply the best fitting algorithms in terms of data sets and occurring features.



➔ Modelling of protection forest
AND protection function

Muito obrigado!

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ZGIS