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Single tree remote sensing, STRS using airborne images and LiDAR data

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Learning goals (gaining understanding in)

- STRS: history, potential and limitations, outlook

- Principles of 3D reconstruction using images and LiDAR: vocabulary, methods, automation possibilities, differences between sensors, pros and cons, confines of, cost-issues.

→ Combination of sensors for enhanced object (tree) detection and reconstruction: when appropriate?

- Radiometric issues in LiDAR and aerial images: do we make full use of the data? Deriving reflectance from DN-values?

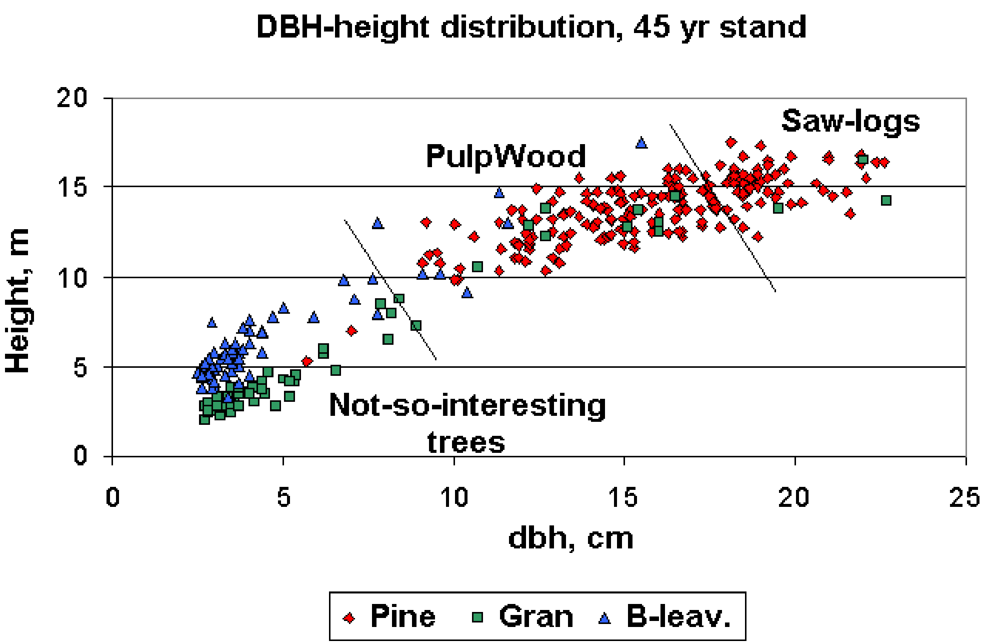
Program 08:00-16:00

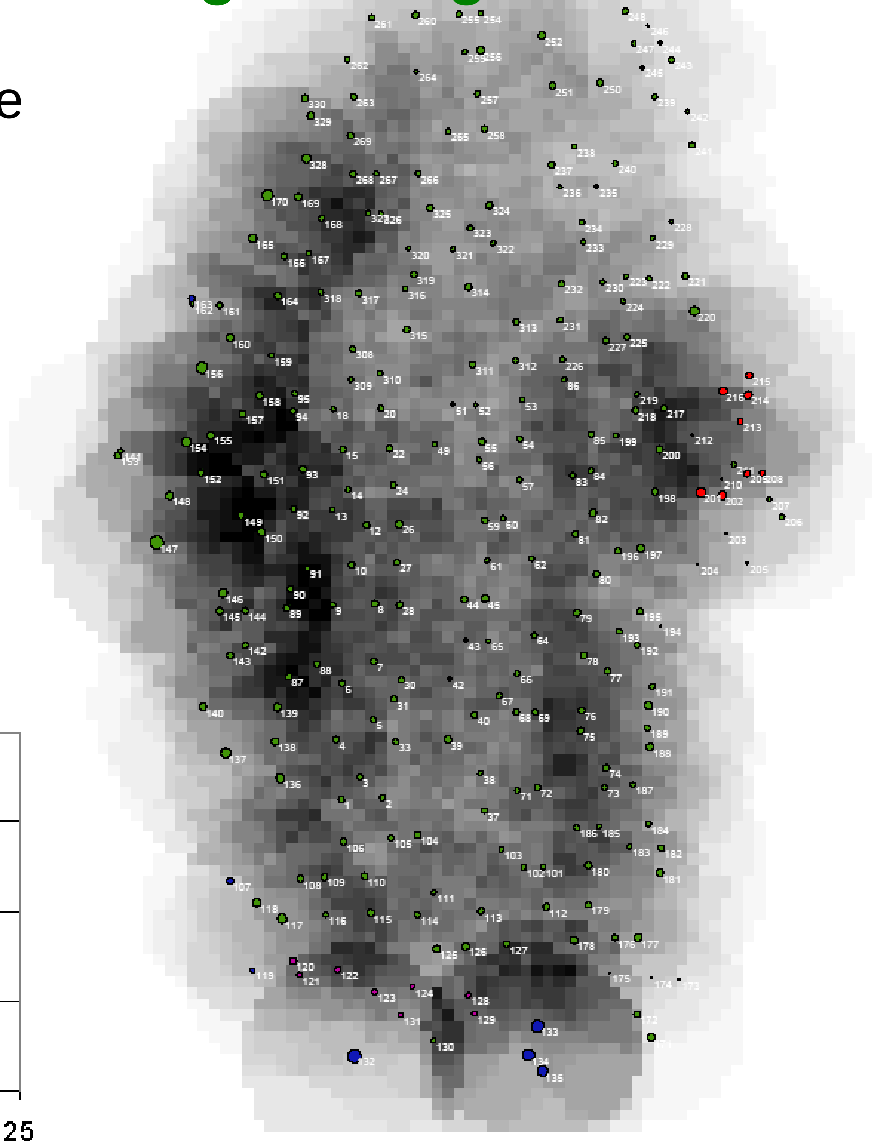
Lecture 1	Single Tree Remote Sensing – in optical images and LiDAR
Lecture 2	Sensor models and 3D detection and reconstruction – Pulsed LiDAR and aerial cameras - geometry
LAB 1	Learning about the geometric properties of images and LiDAR (KUVAMITT VB/C++ program)
Lunch	
Lecture 3	Radiometric properties of images and LiDAR
LAB 2	Semiautomatic STRS, collecting radiometric features for trees; Tree species classification in with LiDAR

AIRBORNE Single tree remote sensing - Background

Forest - a finite set of trees or an infinite set of samples of density fluxes inside an ill-defined area-delineation?

Forest inventory – tedious and expenive work balancing between costs, sampling, measurement and model errors.





Airborne Single tree remote sensing - Background

Driving forces
Continuous cost-efficiency demands
Advances in RS-technology

Basic hypothesis
Use of individual trees is made possible the technical advances affecting also the costs. A higher precision is assumed with single trees in comparison to grid/segment delineations.

What **direct and indirect measurements** are possible?

{XYZ, Sp, Height, Crown dimensions}
{Leaf area, foliage mass}
$\Rightarrow$ indirect step
{stem diameter, volume, increment, health,..}

Airborne Single tree remote sensing - Background

Photogrammetric interpretion since ~1950s

- In stereo, analogue

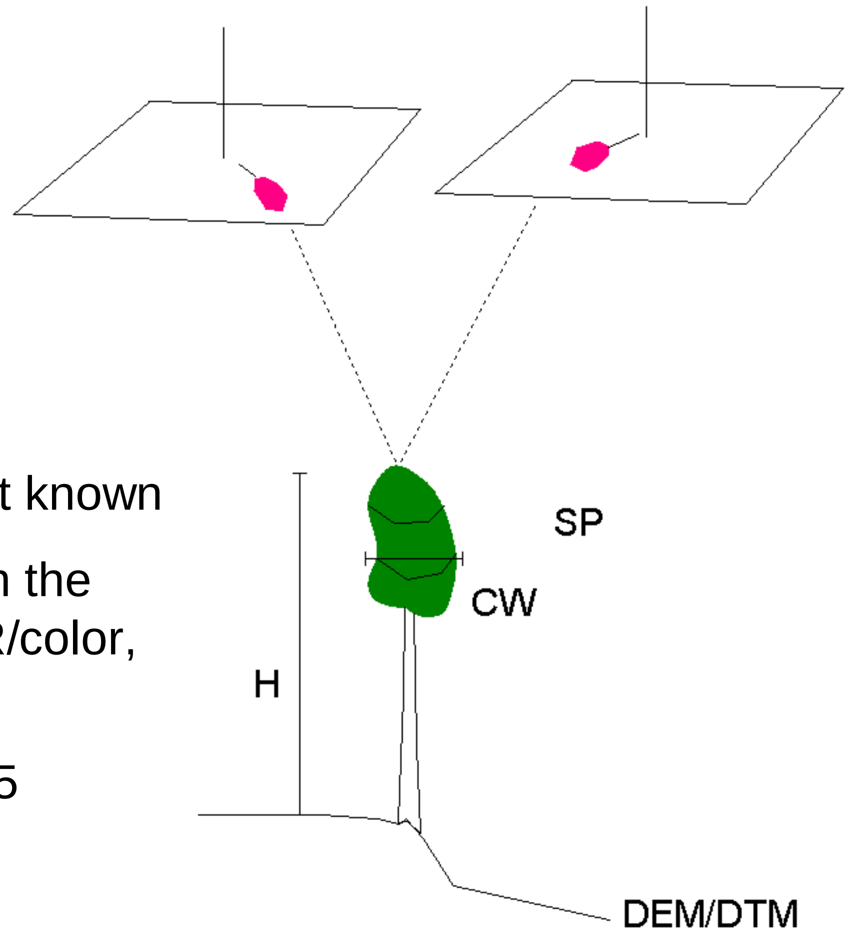
- Monoscopic

- Crown diameter x DBH (Ilvessalo 1950)

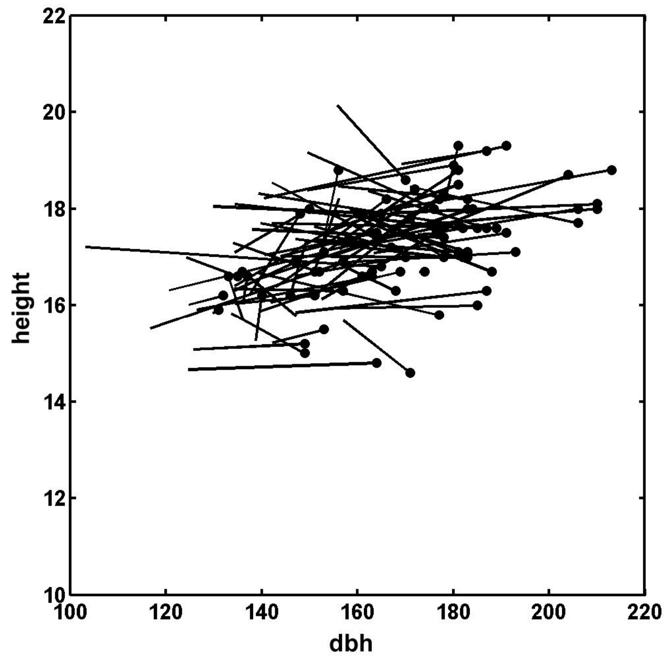
- Tree height problematic because of
  - ground occluded in images
  - true scale and orientation of the images not known

- Species interpretation – experience gained in the effecs of image scale (resolution), use of CIR/color, phenology

- Ample research, SWE, CAN, USA 1960-1985 e.g. Talts 1977 in Sweden



Airborne Single tree remote sensing - Background



STRS - accuracy achievable?

- Consider direct measurement errors
- Indirect measurement errors (model)

dbh = f(sp, cw, cl, h) + ε

Sp – species-spesific allometric relationships
cw – maximal cw correlates with dbh (linear)
cl – lenght of the living crown, correlates with stem form?
h – height correlates with volume

-Parametric models have a noise level of ~ 10%

- Non-parametric estimation methods (k##N) might be more accurate in producing extreme values correctly

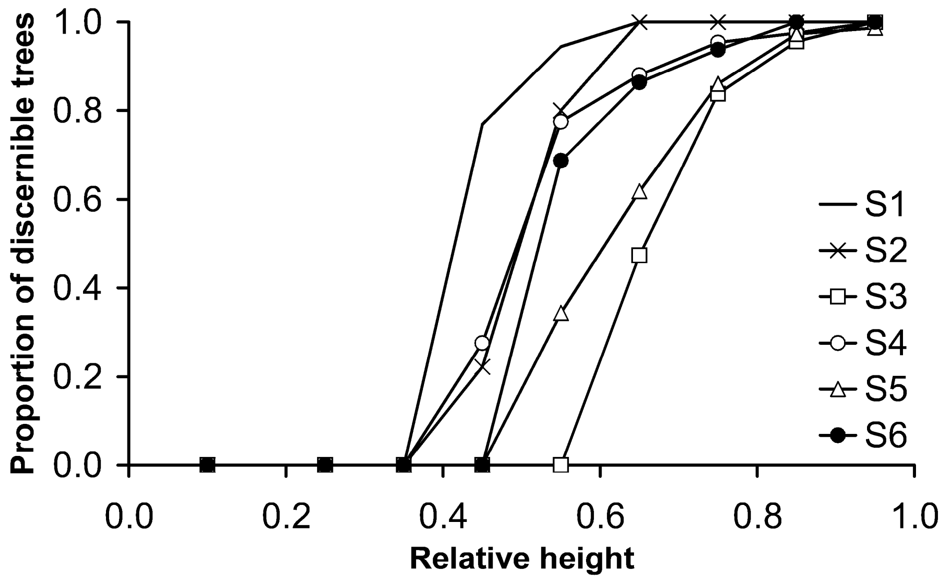
- Allometry is influenced by stand level effects

Airborne Single tree remote sensing - Background

STRS - accuracy achievable?

It seems that STRS estimates (of volume and dbh) are prone to noise and bias, which is caused by the fact that the effects of stand history are not measurable.

Noise is at best ~10%, and allometric bias at stand level ±0-10%, roughly.



Ilkka Korpela 2004

The probability for detection is affected by the relative height.

P(Occlusion) ~ f(viewing angle, relative height)

P(Shading) ~ f(sun angle, relative height)

Airborne Single tree remote sensing - Background

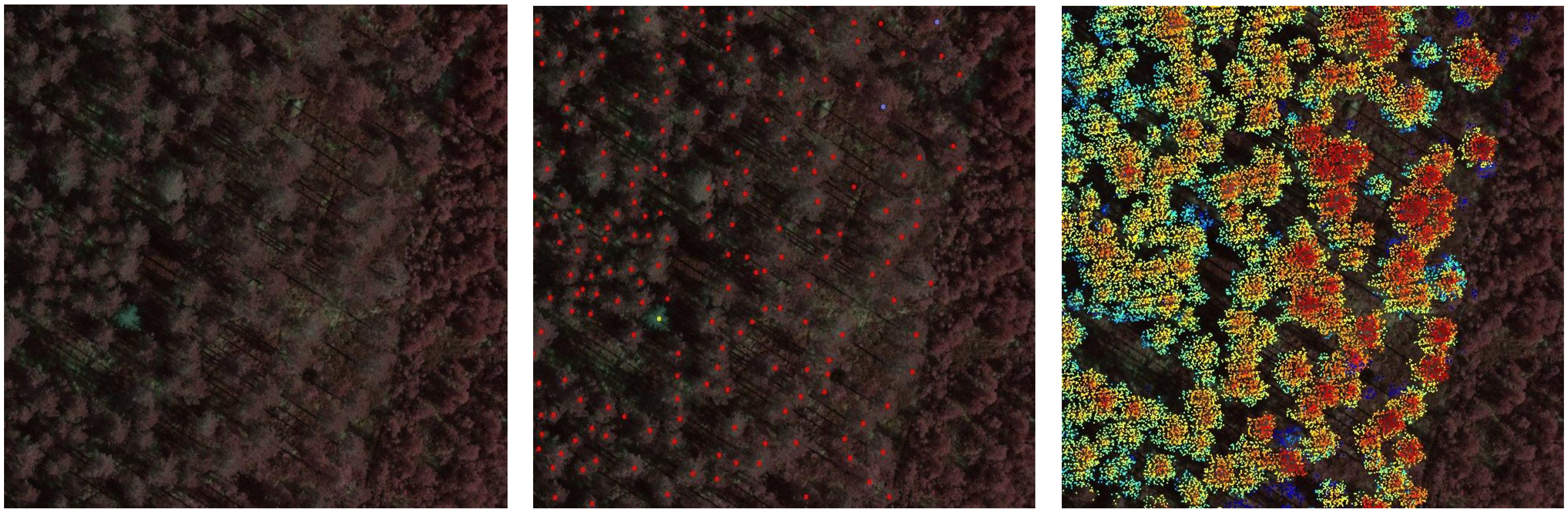
STRS - accuracy achievable?

Noise is at best ~10%, and allometric bias at stand level ±0-10%, roughly..

Non-seen trees consitute 0-100% of stems, 0-10% of volume depending on the vertical canopy structure, density of the stand.

How small trees are detectable?

- Key factor is contrast between the crown and its background, usually bright against dark, but sometimes there’s hardly any contrast.



Airborne Single tree remote sensing - Background

How small trees are detectable?

Tree crowns ~ 0 – 8 m in width → several pixels per crown

Height measurement accuracy ~ f(image scale, intersecting ray geometry, orientation accuracy, point measurement accuracy) → prerefably several images viewing the trees from different directions, high-resolution to allow measurement of small trees.

Measurent accuracy of SP

Radiometric and geometric reasoning

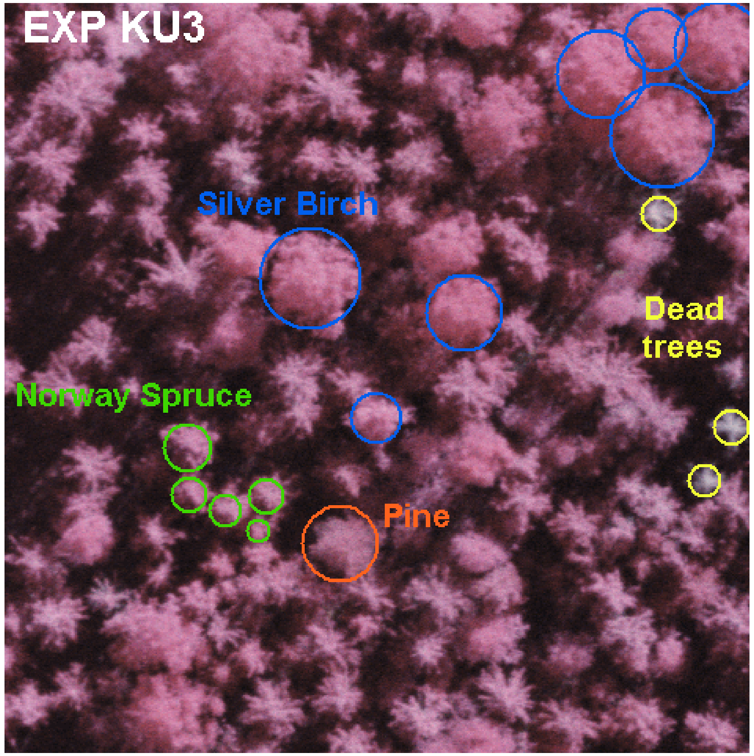
Sensor properties

Effects of age, health, background

BRDF

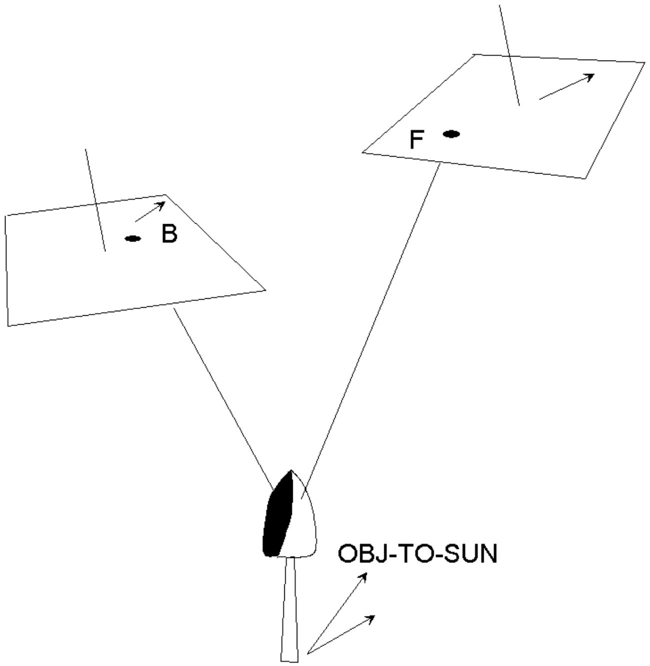
Atmosphere

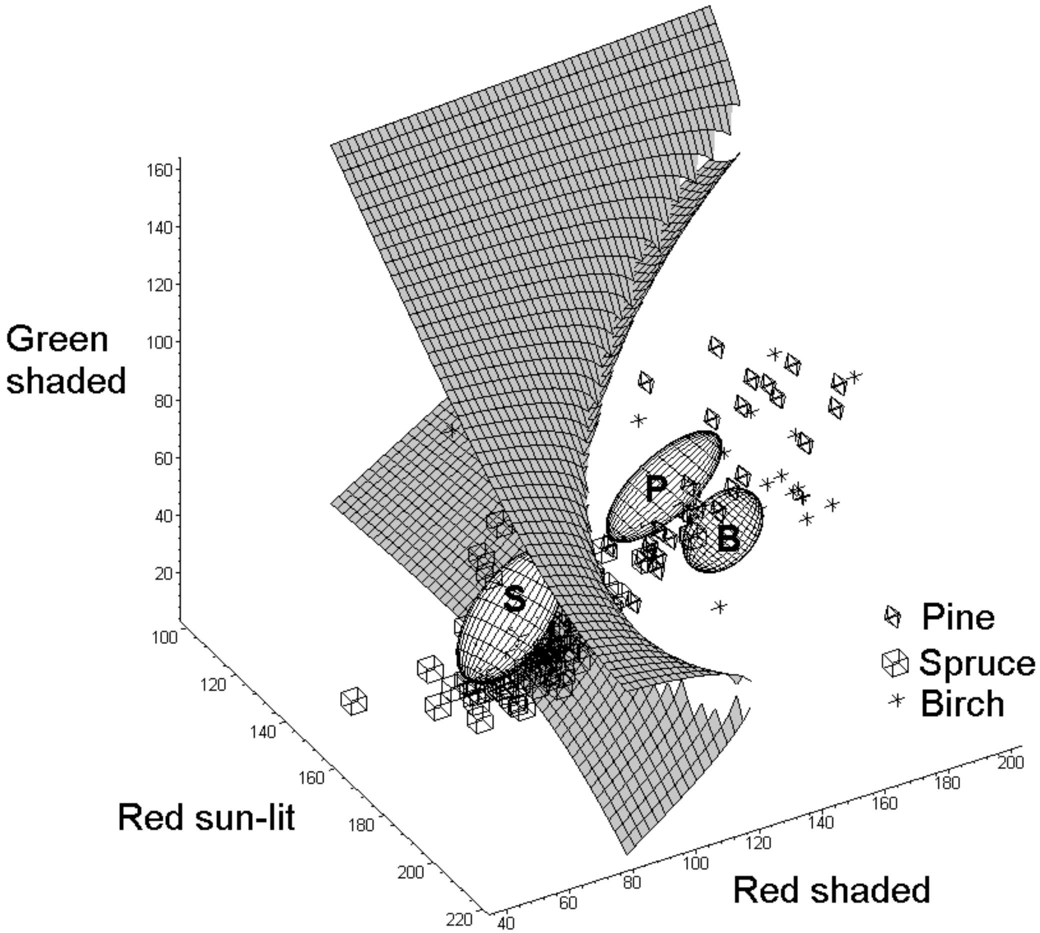
Scale



Airborne Single tree remote sensing - Background

Measurent accuracy of SP



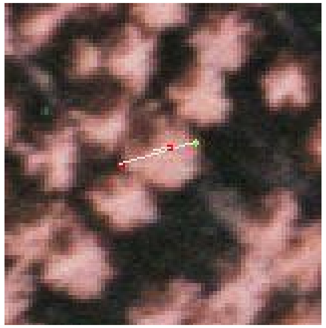


Quest for invariant features

In Finland, we strive for 95% classification accuracy

Airborne Single tree remote sensing - Background

Measurent accuracy of cw, cl



- Cw is usually underestimated
- Bias increases for oblique views
- cl cannot be measured in images

→ NEAR-NADIR views are excellent for cw, but 3D reconstruction calls for oblique views

STRS (in images) SUMMARIZED

Measurement errors, easily biased measurements
Allometric modeling errors
At single tree RMSE of 12-15% for dbh (with height)
At stand level underestimation of treecount, volume, bias in dbh-distributions due to allometric stand-effects
+ tree positions for dominant-intermediate trees

Airborne Single tree remote sensing - Background

A bit of History

First ideas in the 1930s
Canadians active in the 1960s
Sweden, Norway in 1970s and 1980s

Manual measurements were expensive
Orientation of the images very expensive (GCPs)
Only stereo
Machnery were very expensive (analytical plotters etc.) and for experts only

In 1990s digital revolution and lots of research in monoscopic interpretation of aerial images.

Airborne Single tree remote sensing - Background

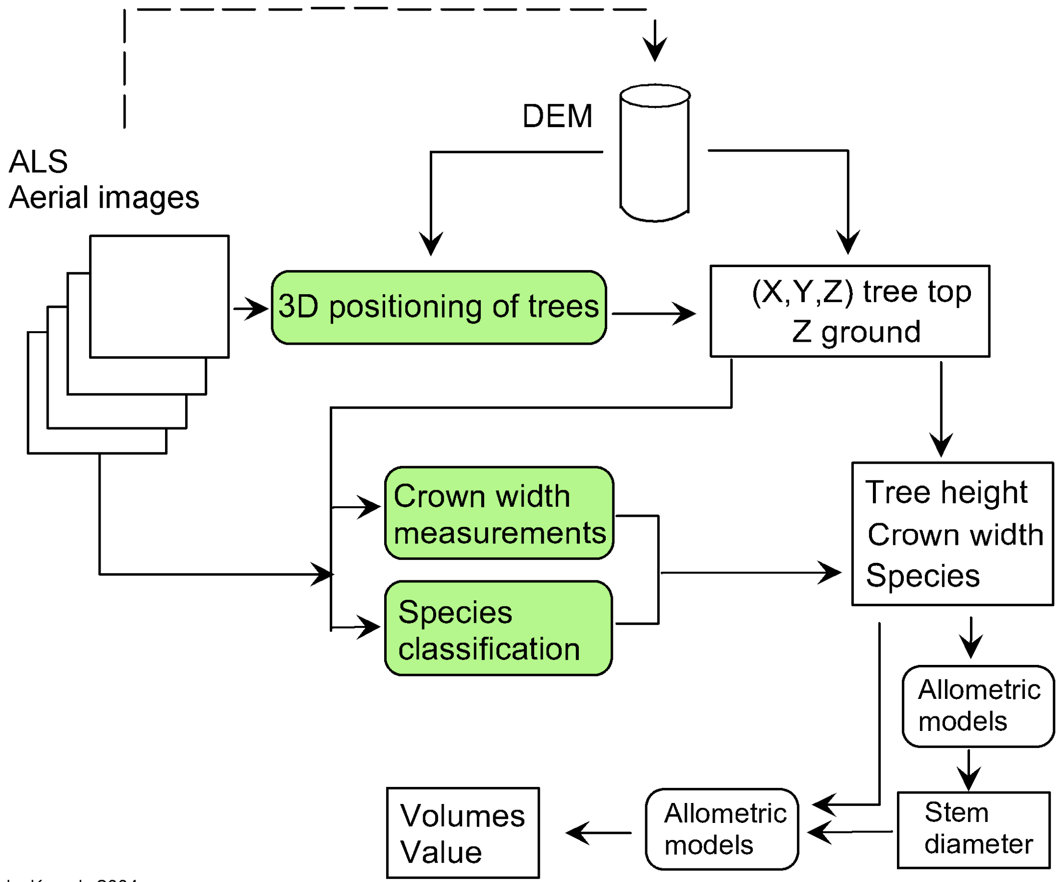
Pioneers in optical / numerical / photogrammetric STRS

1989-1991 Axel Pinz (AT)
1990- Pasi Kiema, Risto Suvanto & Hannu Salmenperä (FIN)
1990- Donald Leckie, Francois Gougeon, Richard Pollock (CAN)
1995- Kim Dralle, Morten Larsen, Mats Rudemo (DK)
Kenneth Olofsson (SWE), Thomas Brandtberg (SWE)
Nicholas Coops (AUS), Pouliot, King, Juho Pitkänen (FIN), Mike Wulder (CAN),

3D
1999- Mads-Jeppe Tarp-Johanssen (DK), Ilkka Korpela (FIN)
2000- Peng Gong & Greg Biging (USA)

3D Canopy modelling (photogrammetric DSMs / CHMs)
1995- Carson, Miller & Walker (1996), Adler & Koch (1999), Halbritter (2000)

Airborne Single tree remote sensing - Background



Ilkka Korpela 2004

STRS-SYSTEM

Input: images, LiDAR, knowledge, user-intervention

Output: STRS variables

Sub-tasks:

- detection
- measurements
- model chain

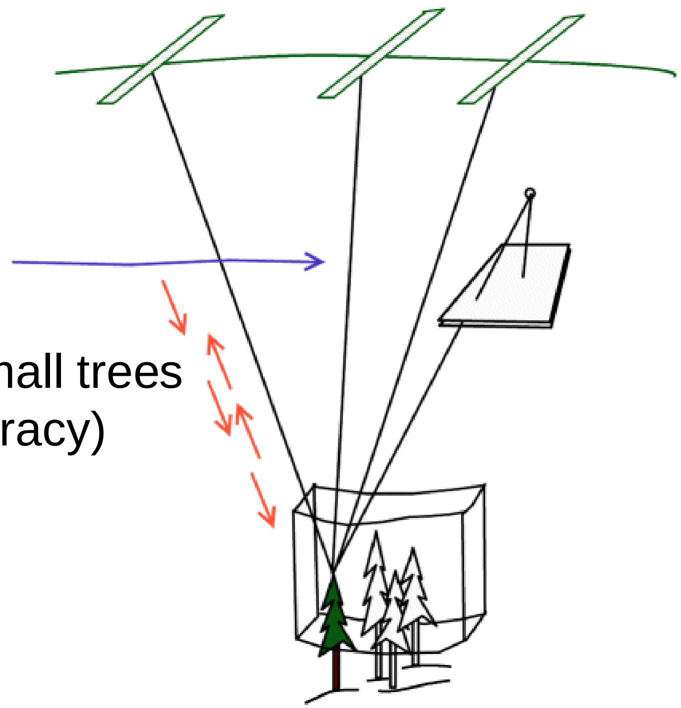
Airborne Single tree remote sensing – with LIDAR

In about 2004 came LiDAR with 1-3 p/m² @ < 5 €/ha

+++ LiDAR solved the problems in terrain elevation!!
++ Even sparse LiDAR helps in image-based 3D reconstruction!
+ LiDAR intensity orthogonal to image DN-values?
++ Bacscatter reflectance is free from BDRF
+ 4-6 times more flying hours

+/- Near-nadir data avoids occlusions, no shading

- Very dense LiDAR can be expensive,
- XY-offsets between strips may distort detection of small trees
- Very high flying heights cannot be used (attitude acuracy)



Airborne Single tree remote sensing – with LIDAR

Examples of co-use of aerial images and LIDAR

Korpela (2007) : use sparse LiDAR to delineate the volume of photo-visible treetops – concentrate image matching efforts there – better solutions; tree heights from LiDAR DEM

Korpela et al. (2007): Use high-resolution images for treetop detection, but the semi-sparse LiDAR points for modeling the crown shape.

Olofsson/Persson/Holmgren in Sweden: Detect trees in LiDAR point cloud; use images to collect features for SP-detection by mapping the crown segments to the images.

Others too., I believe Barbara Koch’s group is active; Eetu Puttonen at FGI (Prof. Hyyppä).

Airborne Single tree remote sensing – CO-USE SUMMARY

Co-use of aerial images and LIDAR

Combine them for the most effective solution of the sub-tasks of the STRS system

Use the ”orthogonal features” in both

Use them to their full potential.