Derivation of Structural Forest Parameters from the Fusion of Airborne Hyperspectral and Laser Scanning Data

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Airborne Laser Scanning
• Active Remote Sensing technique that measures three-dimensional structure

Source: Hug et al. 2004

Imaging Spectroscopy
• Also known as Hyperspectral Remote Sensing
• A full reflectance spectrum is measured in each pixel of the image
• Passive technique that measures the surface

Source: Hug et al. 2004
Areas of study

- Idarwald forest near Morbach
- Pfälzerwald forest near Kaiserslautern
- Managed forests
- Dominant tree species:
  - Norway Spruce
  - Douglas Fir
  - Beech
  - Oak

![Map showing locations of Morbach/Idarwald Forest and Merzalben/Pfälzer Wald Forest](image)
## Datasets

<table>
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<th>Idarwald</th>
<th>Pfälzerwald</th>
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| **Imaging Spectroscopy Data**  
(125 bands, 420-2450 nm, 5m GSD) | HyMap: 2003               | HyMap: 2009               |
| **Waveform Laserscanning Data** | Riegl LiteMapper 5600: 2005 | Optech ALTM 3100: 2009    |

**Riegl LiteMapper 5600**

**Hyvista HyMap Hyperspectral Mapper**
Combination of image and ALS data

One way of combining passive image data and ALS data is to project the image data on a Lidar-generated height model.
Another possibility is to add LiDAR-derived products like tree height or crown base height or percentile height bands.

But we wanted to use the full waveform data, not just a collection of bands.
The LiDAR sensors record the full waveforms of the echoes: We get a vertical intensity profile for each laser pulse.

→ Full waveform, small footprint airborne Laser scanning data
From Waveforms to Voxels

All waves that converge on a small area. Mean waveforms in different stand types
From Waveforms to Voxels

A mesh of Voxels atop each HyMap pixel was defined.

Each Voxel is $5 \text{ m} \times 5 \text{ m} \times 0.5 \text{ m}$

The Voxels get filled with the mean Lidar Intensity
Idarwald Forest

122 Hymap bands combined with 76 fullwave LiDAR bands.

Combined spectra show reflectance properties and stand structure.

Forest stands with nearly identical reflectance spectra can be discriminated (b-d and c-e).
**Pfälzerwald Forest:**
125 HyMap bands combined with 40 LiDAR waveform bands
(1 m vertical resolution)
Applications: Classification

A better discrimination between similar classes (coniferous trees):
- 4 age classes of Norway spruce
- 2 age classes of Douglas fir

See also Buddenbaum, Schlerf & Hill, IJRS 26, 2005.
Applications: ALS-based estimation of forest structure

- We can estimate tree height, crown closure and stem density using single-pulse Lidar.
- Other structure parameters like crown base height and number of crown layers benefit from full waveform data.
Applications: Vertical Slices through ALS data
Applications: Horizontal Slices through ALS data

- Ground
- 10 m above ground
- 20 m above ground
- 30 m above ground
- 38 m above ground
Applications: Percentile Images

90th percentile  
20th percentile

Lidar percentiles have been used for the estimation of biomass, timber volume etc.
Conclusions

- Combining IS and ALS data (passive and active remote sensing) increases the dimensionality without adding much redundancy.

- Vertical intensity profiles from several small-footprint waveforms correspond to large-footprint waveforms of the pixel size.

- Valuable as
  - classification input
  - detailed description of the stand
  - physically-based derivation of structural parameters like crown base height and crown length.

- Single waveform profiles are rather noisy, composite waveforms show the vertical crown extent well.
Further Reading


Thanks for your Attention

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If you are interested in Hyperspectral remote sensing, visit the 9th EARSel SIG Imaging Spectroscopy workshop 14-16 April 2015, Luxembourg http://www.earsel2015.com/

Reference:

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