LIDAR

Exploiting the Versatility
of a measurement principle
in Photogrammetry

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Photogrammetry and cameras

- TU Wien, 200th anniversary
  November 6, 1815: k. k. polytechnisches Institut in Wien

- Theodor Scheimpflug, 1865-1911: 150th anniversary

Images: TU Wien, Bundesamt für Eich- und Vermessungswesen
Cameras and Laser Scanners

- Measurement of angles/directions
- Measurements in focal plane simultaneous
- 3D point reconstruction: 2(+) exposures, sun light = 3(+) rays
- Measurement of angles/directions and range
- Sequential measurements
- 3D point reconstruction: 1(+) scan = 1(+) vector

Other differences and convergence
- Size of aperture & resolution limit
- Sampling (under-, contiguous, over-sampling)
- Push broom cameras and flash lidar sensors
- Exterior and interior orientation of sensor system
- Bundle of vectors
- Area-wise sampling of surfaces
- Accuracy and resolution proportional to depth

Laser scanning is the polar photogrammetry...
... beyond rays vs. vectors

- **Laser Range Finder** → **Light Detection and Ranging**
- **Lidar principle**
  - emission of a laser pulse and
  - time resolved detection and analysis of its echo to infer properties of the reflecting objects (targets, reflectors, ...)

\[
P_{D,i}(t) \approx \frac{d_{D}^{2}}{4\pi R_{i}^{4} \beta E} \int_{R_{i} - \delta}^{R_{i} + \delta} P_{E} \left(t - \frac{2R}{v_{g}}\right) \sigma_{i}(R) dR
\]

**The Versatility of Lidar**

- Wavelength of the emitted pulse
  - Lidar bathymetry
  - Case study on river dynamic morphology
- Full waveform recording
  - Waveform analysis and radiometric calibration
  - Case study on bi-temporal classification of grass-land
- Single photon counting
  - Towards Lidar from space
- Platform developments
  - Case study on measurement of vegetation parameters
- Additionally exploited in (e.g.) atmospheric remote sensing:
  - frequency shift of the backscatter, polarization, ...
Reflectance and LiDAR wavelength

Bathymetric Lidar

Challenges to Understanding
- Backscatter from water surface, relation of water properties, effect on echo time lag and shape

Challenges in Processing
- Identification of water surface echoes
- Modeling of water surface for application of Snell’s law
- Classification of echoes Foreland, vegetation, river bottom, water column reflectors, etc.
- Suitable modeling for specific application
Lidar and water surface

- Difference to topographic Lidar shape of emitted pulse typical example

- Case study on river bank

Processing and modeling of bathymetric point clouds
River morphodynamics: Feb 2014 – October 2014

### Effect of annual flood event

- **Erosion:** 4887 m³
- **Deposition:** 5358 m³
- **Total:** 511 m³

**Bank erosion**

### Effect of 30-years flood event

- **Erosion:** 9050 m³
- **Deposition:** 11580 m³
- **Total:** 2530 m³

**Gravel bar dislocation**

**New meander shortcut channel**

**Woody debris**

**Massive bedload transport and bank erosion**

April 2013 - February 2014

February 2014 - October 2014
Waveform analysis and exploitation

- Amplitude of emitted pulse and backscattered echoes are sampled $\Delta t = 0.5 \text{ ns} - 2 \text{ ns}$
- Waveform recording allows radiometric calibration
  Measurement at sensor $\rightarrow$ reflection properties of objects
- Established (e.g.) to strongly support differentiation between low vegetation and ground/solid objects (terrain in forest, deadwood, ...)

Waveform: exploitation of radiometric and geometric measurements

Study on the classification of grass land
- 10 classes, including fringe, abandoned, meadow-like, lowland hay meadow, dry meadow

Exploitation of
- waveform shape
- radiometric measurement
- geometric properties
- geometric texture
- difference between temporal development of vegetation March – July
Waveform: exploitation of radiometric and geometric measurements

Classification
- Decision trees
- Machine learning based on ground reference data
- Determine class and probability (on pixel basis)

Most important bands according to classifier
- Leaf off echo width, difference between leaf on/leaf off reflectance, leaf off nDSM height

Results
- Classification accuracy ~70% equivalent with competing methods, i.e. hyperspectral imaging

Zlinszky et al., Remote Sensing, 2014
Detection: Single Photon Counting

Large “flying” heights, lidar on space-borne platforms
- Strong signals required for weak return signals
- Therefore, single photon detection


Single Photon Counting / Simulation

Simulated return of 5m footprint, SPC

Simulated SPC Signal for a 5m Footprint (from stack; n = 195)
UAV as platform for Lidar

Modeling of tree diameter from UAV Lidar

Relative reflectance

Mandlburger et al., GfK, 2015

Data provided by Riegl
Take home message

- Lidar provides more than (multiple) ranges along the direction of imaging rays
- Additional observations (echo width, reflectance, ...) for land cover classification / object detection
- Wavelength choice adapted to studied phenomenon or process e.g. water will become importance for classification (multi wavelength case)
- SPC (and also beam deflection) studied by space agencies for global lidar coverage
- Correct interpretation of point clouds requires knowledge about footprint size
- Very high resolution dynamic lidar point cloud acquisition will require refined models of strip adjustment

Literature

Comparison of point clouds

(a) ALB  
(b) ALS  
(c) ULS

Mandlburger et al., SPIE, 2015.
keine zeitabhängige Korrektur der Trajektorie

zeitabhängige Korrektur mit $\Delta t = 60\,\text{s}$

zeitabhängige Korrektur mit $\Delta t = 30\,\text{s}$

Histogramm mask. Streifendiff.:

median = 1.7 cm
sigma.mad = 10.9 cm

median = 0.1 cm
sigma.mad = 2.6 cm

median = 0.0 cm
sigma.mad = 2.2 cm

Bedingungen: C1-, C2-, C3-Stetigkeit, 1. und 2. Abl. = 0 zu Start- und Endzeit
FWF-Signale rückfalten zur Objektcharakterisierung
Pixel, Bewegungsrichtung, Trajektorie, Segmente in Raum und Zeit

Baummodelle aus TLS Punktewolken im Wald (für RT)
Punktwolken: Review (paper) und Prozessierung (software)

Liegendes Totholz aus FWF Airborne Laserscanning

(a) LiDAR data
(b) Dense matching

Liegendes Totholz aus FWF Airborne Laserscanning
Fringe (e.g. Urtica), abandoned (e.g. woody encroachment), meadow like (e.g. timber storage and traffic), lowland hay meadow, dry meadow