EduServ 19th
Distance e-Learning Courses
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Recent LiDAR technologies

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Target audience: Staff of national mapping agencies, public authorities, private companies, and PhD students with interest in small and large scale airborne laser scanning

Preconditions: Familiarity with the basic concepts of Airborne Laser Scanning

Maximum number of participants: 40

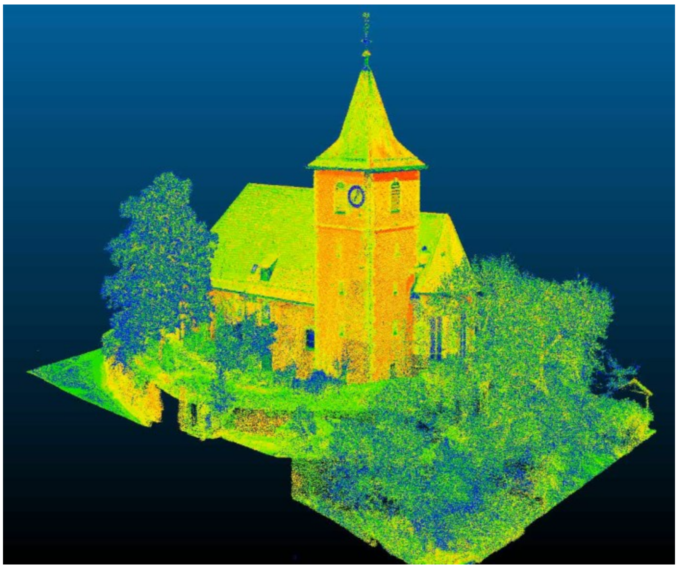
Course objectives: The recent decade has brought tremendous progress in Airborne Laser Scanning (ALS), the state-of-the technique for 3D mapping of topography and shallow water bathymetry. The pulse repetition rates increased from the kHz to MHz level and, together with the introduction of single photon sensitive receiver arrays, this boosted both the achievable point density and area coverage performance. LiDAR point cloud classification further profited from multi-spectral laser scanning using infrared and green wavelengths and from concurrent capturing of image and scan provided by modern hybrid sensor systems. Green lasers are used for measuring underwater topography, also referred to as bathymetry, laser bathymetry. Airborne Laser Bathymetry is no longer restricted to charting shallow coastal areas only but evolved to a powerful tool for high resolution mapping of the entire littoral area, referred to as topo-bathymetric LiDAR. Finally, sensor miniaturization and progress in aviation technology has opened new close-range airborne applications due to integration of lightweight LiDAR sensors on Unmanned Aerial Vehicles. All these topics are covered in the EuroSDR distance course “Recent LiDAR technologies”.

In this course, the participants will refresh the basics of ALS, will learn details about the above mentioned technologies in theory, and will also process provided sample data in hands-on sessions. For the theory part of the course, respective papers, text book excerpts, and slides will be provided along with short pre-recorded videos. The scientific laser scanning software OPALS is the basis for practical data processing. The participants obtain a temporal personal scientific license in advance, so that they can already familiarize themselves with the software before the actual start of the course. The examination consists of multiple choice tests (theory) and short technical reports (exercises).The course is divided into the following six modules.

Topics tackled: The course tackles the recent progress in Airborne Laser Scanning (ALS), the state-of-the technique for 3D mapping of topography and shallow water bathymetry, including the following topics:

- Point density and spatial resolution: Higher scan rates in the MHz range increase the point density, which leads to an increased spatial resolution if, in addition, the laser footprint sizes match the point-to-point distance.

- Full waveform analysis: State-of-the art FWF processing techniques enable higher measurement precision and better target characterization.
- Multispectral Laserscanning: Scanners using laser wavelengths facilitate point classification by exploiting the radiometric content of the captured data.
- Hybrid sensors: Scanners and cameras mounted on the same platform enable joint data orientation and processing of laser scans and image blocks.
- Single Photon LiDAR: These new mapping sensors provide a higher area coverage performance at the prize of lower accuracy and higher outlier rate requiring robust point cloud filtering techniques.
- Topo-bathymetric LiDAR: Beyond charting shallow coastal areas, laser bathymetry evolved to a powerful tool for high resolution mapping of the entire littoral area.
- UAV-LiDAR: Sensor miniaturization and progress in aviation technology has opened new close-range airborne applications due to integration of lightweight LiDAR sensors on Unmanned Aerial Vehicles.



Module 1: ALS basics

This introductory module refreshes the basic concepts of ALS (ranging, scanning, georeferencing, sensor calibration, flight planning). Furthermore, basic point cloud processing techniques (principle component analysis, grid interpolation, ground filtering, etc.) are recaptured. As modern laser sensors provide additional attributes per point along with the x-y-z coordinates (intensity, scan angle, echo width, reflectance, etc.), this module also discusses point attribute handling strategies for the use in specific processing tasks. The practical part of this module comprises an entire quality assessment of a concrete flight block with data from a state-of-the-art laser scanner including DEM interpolation and visualization, point density analysis, and evaluation of strip height differences.

Module 2: Multi-spectral LiDAR

Multi-spectral data facilitate the interpretation and classification of objects on the Earth's surface. While the use of multi-spectral image data are widespread, it constitutes a rather new development in ALS enabling full 3D analysis of backscattering characteristics on a single point basis. The module concentrates on radiometric calibration of ALS point clouds in general and multi-spectral ALS point clouds in particular. In the exercises, the participants will implement a workflow to generate a false-color 3D point cloud of a laser scanner featuring three channels (wavelength λ=532/1064/1550nm). For each band the relative reflectance will be calculated based on the raw amplitude values considering the laser range and the incidence angle between the laser beam axis and the surface normal direction.

Module 3: Hybrid sensor systems

Most of the current laser sensors also operate a high-quality RGB(I)-camera along with the LiDAR unit. This opens the possibility of data fusion of passive image data and active scan data. In particular, the concurrently captured image data can be used for colorization of the 3D laser point cloud. Proper co-registration of the different sensors is a precondition for this task. This module therefore focusses on a comprehensive orientation of simultaneously acquired LiDAR point clouds and aerial images in a hybrid strip adjustment approach. This will be explained in theory and also carried out in a practical example using a dataset from a sensor featuring two laser channels and a 100MPix RGB camera. The final result is a feature-rich laser point cloud containing RGB color information.

Module 4: Single Photon LiDAR

While state-of-the-art full waveform ALS sets a high standard with respect to point cloud accuracy and reliability, the introduction of single photon sensitive laser scanners has increased the achievable point density and areal coverage performance at the prize of a higher outlier rate. This module explains the basics of single photon sensitive sensors operating in the so-called Geiger-mode and discusses the pros and cons of this technology. The practical part concentrates on filtering of clutter points stemming from spontaneous false triggerings of the single photon sensitive sensor. A high amount of clutter points is a characteristic property of single photon LiDAR datasets, and the separation of noise and usable points is a crucial task.

Module 5: Topo-bathymetric LiDAR

Since the early days of measuring submerged topography of clear coastal waters based on Airborne Laser Bathymetry (ALB), the technology using green water-penetrable laser light has evolved dramatically in the recent years. The datasets of modern topo-bathymetric LiDAR sensors provide a seamless transition from the dry land via the water surface to the under-water bottom of both coastal and inland water bodies. A basic limitation of this optical method for capturing hydrography is water clarity. This module provides the theoretical background for processing laser bathymetry data. This includes methods to model the water surface, which is the basis for refraction correction of the raw laser signals. In the exercises, a multi-temporal laser bathymetry dataset of a pre-alpine gravel bed river serves as the basis for change detection and quantification of side erosion rates.

Module 6: UAV LiDAR

ALS based on manned platforms (aircraft, helicopters, etc.) is a mature data capturing technique and is widely used as the basis for the acquisition of country-wide digital elevation data with point densities approximately ranging from 1-20 points/m^2. The ongoing miniaturization of both sensors and platforms has enabled the integration of survey-grade LiDAR sensors on Unmanned Aerial Vehicles (UAV). This applies to both multi-copters and fixed-wing UAVs. The module provides an overview of existing UAV scanners and platforms and discusses the implications for data processing when dealing with ultra-high resolution 3D UAV LiDAR point clouds featuring point densities of hundreds of points per m^2 and a size of the laser footprint of less than 5 cm. In the practical examples, UAV LiDAR point clouds will be used to estimate tree diameters and to reconstruct buildings in LoD3.