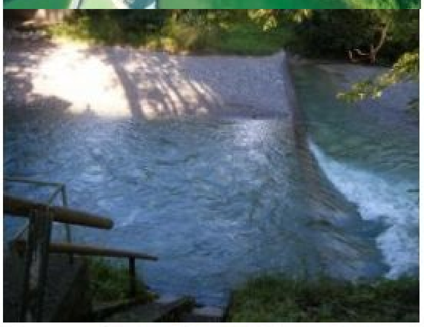
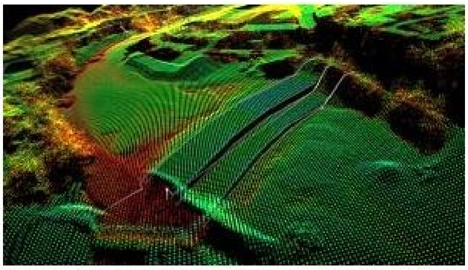
HYDROMAPPING - HIGH RESOLUTION SHALLOW WATER MAPPING FROM AN AIRBORNE PLATFORM

Riverbed Surveying





In order to meet the requirements of the European Water Framework Directive (EU-WFD), authorities face the problem of performing area-wide surveys of all kinds of inland waters repeatedly. Especially for mid-sized and small rivers, a traditional survey approach imposes almost insurmountable logistical efforts and costs. Employing the new airborne hydrographic laser scanner RIEGL VQ-820-G, potential large-scale surveying of a river system is exemplarily demonstrated on the river Loisach in southern Germany, carried out by the company AirborneHydroMapping (AHM) and the University of Innsbruck.

By Martin Pfennigbauer, RIEGL, and Frank Steinbacher, University of Innsbruck, Austria.

In co-operation with the Bavarian Water Authority (Wasserwirtschaftsamt Weilheim) a pilot project was initiated by the Unit of Hydraulic Engineering at the University of Innsbruck (Austria) and RIEGL Laser Measurement Systems. In order to assess the possibilities of a new Lidar measurement system with high spatial resolution and high measurement rate, Lidar data have been acquired on about 70km of riverbed and foreland for the river Loisach. The captured data was compared against cross-section surveys obtained by classical means. The aim of the project was to derive data supporting the monitoring and managing of inland water bodies as required by the EU-WFD. The reason for chosing the Loisach as pilot area was based on its complex and rapidly changing river structure ranging from a steep-sloping mountain river over segments within cities heavily intruded by manmade structures to a wide estuary into lake Kochel (Figure 1).

Classic survey procedures by boat or by wading are extremely time-consuming and expensive, especially for deep sections of the river or inaccessible areas. Therefore, the typical density of actual survey data is in the range of one profile every 200m at best which has to be put in contrast with more than 10 points per square metre achieved by hydrographic airborne laser scanning.

The RIEGL hydrographic airborne laser scanner VQ-820-G enables the surveying of shallow water, terrain, manmade structures and vegetation at a new level of spatial resolution due to its high measurement rate of up to 250kHz and low beam divergence of 1mrad. It consists of a compact and lightweight scan head and a laser source housed in a 19" case (Figure 2). The scan mechanism is based on a rotating multi-facet mirror with the centre of the scan line tilted by about 20 degrees with respect to the nominal nadir direction. The measurement rate in combination with a small beam divergence (footprint size of about 50cm at nominal operating altitude) and the short laser pulse provide the spatial resolution required for shallow water surveying.

The instrument performs echo digitisation and online waveform processing. Refraction is taken into account during post-processing of the data. After georeferencing the acquired point clouds, the water surface is determined and targets below the water surface are shifted to the correct position according to refraction (beam bending and waveform compression).

Data Acquisition / Pilot Projects

A survey of the river Loisach was performed in July 2011 and took two days in total. The pilot project was performed in the course of a large-scale surveying campaign carried out from June to October 2011 also including the river Isar and parts of the coastline of Lake Ammersee in Bavaria. In addition to the laser data, high resolution aerial images (~5 cm/pixel) were taken to provide an optical reference, offering a wide range of possibilities for subsequent research, monitoring and management. The field of view of the aerial camera covered slightly more than the swath width of the laser scanner.

The data acquisition of the analysed area was performed by helicopter and included two flight strips. One conducted from an altitude of about 500m with a pulse repetition rate of 138kHz and maximum laser pulse energy, the other in opposite direction at about 200m above ground with a pulse repetition rate of 250kHz at reduced laser pulse energy, maintaining eye-safety even for the aided eye.

Lidar Performance for Hydrographic and Topographic Needs

The system offers the possibility to perform hydrographic and topographic cross-surveys at a high level of resolution and accuracy. Water surface and waterbed are captured at the same wavelength. Especially in shallow and clear water areas the water surface echoes might be sparse and further data processing needed to extract the water plane for refraction correction. By choosing days with suitable water quality, satisfactory penetration down to the river bed was achieved throughout the project. While depths of up to 4m were reached it was even more important to assess the performance in complex situations, i.e. with boulders in the river or splitting of the river into several shallow arms. The resulting point density ranged from 10 to 25 points per square metre.

Data Processing

The requirements of data evaluation for ecologic, hydraulic, and water-related topics were investigated within a joint research project of the Unit of Hydraulic Engineering of the University of Innsbruck and RIEGL. This led to software developments based on the analysis and visualisation software (VisHydro) utilising high-performance HDF5 data files to handle spatial datasets (website 1). Monitoring tasks as imposed by the EU-WFD require a coupled analysis of all datasets related to rivers, standing waters or coastal shallow-water areas. This provides a more comprehensive understanding of the actual condition and thus allows the identification of changes required for our water bodies. In order to facilitate these analyses the Lidar data should be combined with data acquired by topographic scanner systems, RGB images and hyperspectral images.

Data processing also comprised the generation of different derivatives of the raw point cloud and RGB images as coloured point cloud-, mesh- and GIS-datasets. Data from terrestrial surveys was used to calibrate the processed point cloud. The resolution of numerical meshes depends on the requirements of the related application like monitoring sediment transport, hydro-dynamic numeric modelling or habitat modelling. While in the past gross estimates had to be used for building the meshes due to the lack of underwater information, we now even face the problem of decimating the high-resolution information by filtering. It is one of the fields of research at the Unit of Hydraulic Engineering of the University of Innsbruck to find filter algorithms which not only observe the numerical and performance limitations of existing models but at the same time provide improvements on the quality and usability of the results. The data-processing strategy is motivated by the demand of end users to have a new data basis to extract basic information on a daily basis without being forced to handle large point cloud datasets.

Ground-truth Comparison

The accuracy of the system was evaluated by comparing the laser scan data with 70 ground-surveyed reference cross-sections of the river (Figure 3) also comprising the water level. The system's error range is in the range of +/- 5-10cm, similar to conventional topographic airborne scanners. In contrast to traditionally waded terrestrial cross sections at a resolution of typically 200m, small-scale channel bed or bank structure changes can be captured by the new high-resolution survey method (Figure 4, 5, and 6). The reduction of absolute point accuracy compared to terrestrially gained measurements is more than compensated by the overall accuracy arising from spatial point information – information bringing up a three-dimensional thinking of under water conditions and enabling successful and efficient monitoring for our water bodies.

Data Density and Filtering

Novel algorithms are needed for point cloud classification of vegetation, topography under vegetation or under the water surface and vegetation in the water. Due to the high resolution of the scanner it is possible to deliver DEMs with a cell size smaller than 0.2m even for single flight strips (Figure 7). Being able to identify all structures relevant to the flow and habitat units from a single fly-by is an amazing progress. For comparison, to fulfil the requirements of habitat modelling a two-day ground survey would merely cover an area of less than 200m in length and by no means capture the complex structures of channels, pools and the relevant vegetation.

Building Derivatives

With the new airborne hydromapping Lidar sensor it is possible for the first time to describe higher order hydrographic features and their spatial relationship. Information on hydraulic or ecologic underwater features as derivatives of distance, slope, curvature, area, or volume can be gained. Evaluation of the data captured in the course of the pilot project as well as the development of corresponding tools to extract the information required to fulfil the EU-FWD is still in progress. A dataset of about 8km river length was chosen to pursue the steps from raw point information, data correction and calibration, filtering, linking the point cloud information to aerial image information, and building up a fine digital waterbed model (cell size ~10cm) for visual comparison and a coarse model (cell size ~1m) for hydraulic and habitat modelling purposes.

Conclusions

The demands established by the EU-WFD ask for a new technical approach with the possibility to acquire high-resolution survey information on the hydrographic, topographic and vegetation structures of our shallow-water bodies on a large-scale basis. Airborne hydromapping delivers for the first time the needed data basis to understand the complex interactions between hydromorphological, physico-chemical, biological and human-induced factors. An up-to-date, spatial, and integrative monitoring approach enabled by laser scan data and followed by analysis of the ecological impact meets the requirements to handle the present and future demands of our water bodies.

Acknowledgements

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Further Reading

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