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Multitemporal 3D data capturing and GIS analysis of fluvial processes and geomorphological changes with terrestrial laser scanning

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LiDAR is a state of the art method for directly capturing 3D geodata. A laser beam is emitted in a known direction. The time of flight of the laser pulse is recorded and transformed into the distance between sensor and scanned object. The result of the scanning process is a 3D laser point cloud densely covering the surveyed area. LiDAR is used in a vast variety of research fields. In this study, the focus is on the application of terrestrial laser scanning (TLS), the static and ground-based LiDAR operation, in a multitemporal analysis of fluvial geomorphology.

Within the framework of two study projects in 2011/2012, two TLS surveys were carried out. The surveys covered a gravel bar of about 150 m $\times$ 25 m size in a side branch of the Neckar River near Heidelberg (49°28'36"N, 8°34'32"E) located in a nature reserve with natural river characteristics. The first survey was performed in November 2011, the second in June 2012. Due to seasonally changing water levels, the gravel bar was flooded and the morphology changed. For the field campaigns, a Riegl VZ-400 was available. Height control points and tie points for registration and georeferencing were obtained with a total station and GPS equipment. The first survey was done from 6 scan positions (77 million points) and the second from 5 positions (89 million points). The point spacing for each single scan was set to 3 mm at 10 m distance. Co-registration of the individual campaigns was done via an Iterative Closest Point algorithm. Thereafter, co-registration and fine georeferencing of both epochs was performed using manually selected tie points and least-squares adjustment. After filtering of vegetation in the 3D point cloud in the software OPALS, a digital terrain model (DTM) with 0.25 m by 0.25 m cell size was generated for each epoch. A difference raster model of the two DTMs for assessing the changes was derived excluding water surface areas using the signal amplitude recorded for each echo. From the mean difference in z-values (-0.14 m) a net erosion of about 660 m^3 was estimated. The difference model further indicates the spatial distribution, magnitude and patterns of morphological processes.

The study exhibits a great potential of high resolution 3D TLS data for research in fluvial geomorphology. In particular, the full access to 3D point cloud data, processing and analysis is to be emphasized also for geomorphological studies because e.g. fine georeferencing, 3D surface classification (e.g. vegetation and water) and DTM generation require the point cloud and are the basis for accurate change detection and quantification. Future research will focus on the integration of TLS full-waveform and radiometric information for improving surface classification and thus morphological change analysis.