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Laser scanned point clouds to support autonomous vehicles

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Abstract

Autonomous vehicles are considered as the next major milestone in the history of transportation. Current vehicles are widely equipped with satellite-based positioning units and further sensors: cameras, laser scanner, and radar-based sensors. These new technologies are capable of not only detecting other vehicles, pedestrians or road obstacles, but of collecting information about the vehicles' neighborhood. If the vehicle positioning is to be extended by additional environmental information provided by these modern sensors, the available map database has to be prepared to be able to receive such data. Therefore map databases have to be extended to 3D and the map content must be improved. Such advanced 3D maps enable to receive, manage and integrate all data collected by the vehicles. These maps can support autonomous vehicle control, since such vehicles must continuously survey their close- and mid-range environment; not only other road users but also the partly changing road environment. The terrestrial and mobile laser scanners are excellent instruments to capture 3D data about roads and their environment. One big problem with the laser scanning is that it results huge point clouds with high geometric resolution, but – since it captures everything within its range - without any prior selection between more and less important details. Recording the measured points requires high storage capacity. The primary goal of the processing procedure is to extract the relevant content and transform it to useful and storage-optimized format. The paper discusses a workflow for basic laser scanned road data processing and demonstrates several use cases in storage and visualization.

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Keywords: autonomous vehicles; laser scanning; voxel model; 3D map; environment mapping

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1. Introduction and literature review

Future autonomous vehicles do not require any human interaction during the trip. To achieve this goal, the development has to solve some problems, like controlling the vehicles' behavior, determining its position and attitude all the time or continuously sensing the environment. The environmental sensing and the positioning require redundant sensors, which can obtain measurements with high accuracy and reliability. Because the fully automated vehicle control cannot ignore simultaneous positioning techniques, therefore the GNSS (Global Navigation Satellite System) and IMU (Inertial Measurement Unit) based "traditional" methods must be extended by new solutions. These can be based on environmental sensing, like scanning by cameras and laser scanners (LIDARs). The camera and LIDAR measurements have to be compared to a 3D environmental representation, i.e. to the map. The newly defined map stores information on the road surface, the road furniture, the surrounding buildings and all potentially useful spatial objects.

The storage of the spatial point measurements or the point clouds has mature concepts. [Meagher 1982] has described an excellent methodology about geometric modeling with the help of octrees for convex and concave objects, with or without holes, disjoint parts or free-form surfaces. [Elseberg et al. 2013] demonstrate an efficient octree storage technique within a 3D modeling pipeline and give a comparison to k-d tree storage. As an application example, plane extraction is presented. [Wang et al. 2015] create voxel model from LIDAR point clouds and focus on managing overlapping point clouds. Their algorithm has been demonstrated on mobile and airborne laser scanned data sets. The scientific research is still active on octree cell addressing: [Payeur 2016] presents a paper on quadtree and octree data storage, cell addressing methods and neighborhood identification.

The goal of our research is generally twofold: (1) how to make a map in this sense by the currently available measurement technologies and (2) how to represent the information on this map.

Because one of the most efficient mass data collection technique is laser scanning, an experiment based on terrestrial and mobile laser scanning was conducted. To prove the capability of laser scanning, an urban test site was chosen, where the road/street environment has great variability and several potential problems could occur.

Further efforts focused on the storage of the environmental objects, captured as point clouds but prepared for positioning purposes. The basic idea was to transfer the point clouds into voxel models, where these models can efficiently represent the environment with the required resolution and accuracy.

2. Terrestrial and mobile laser scanning – general introduction and field test

Terrestrial laser scanning (TLS) is a technology, where a laser scanner is mounted on a tripod and the neighborhood is scanned by laser beams. The instrument emits a laser pulse, measures its travel time to and back from an object, while the orientation angles are taken as constant. The raw measurement therefore consists of spatial angles and a distance, so the 3D coordinates in the instrument's own coordinate system can be obtained. With adequate further measurements with GNSS receivers, the point cloud can be transformed into any other reference systems (e.g. WGS-84). The result is a universal point cloud – containing millions of points about the walls, trees, pavements, traffic signs etc.

The measurement methodology enables to set some parameters, e.g. point density or whether to take images from the stations (which enables coloring the points). Because the measurement range of the instrument is limited, many stations are required to cover large areas.

Mobile mapping, especially based on mobile laser scanning (MLS) is a technology, where the instruments are mounted on a moving platform, e.g. on a car or truck. The mobile systems scan the environment generally by two tilted laser profile scanners and capture images by several cameras. The GNSS/IMU/odometry based positioning component of the mobile system determines the actual position and orientation of the platform during the mapping procedure, so the result is a colored, georeferenced point cloud – containing billions of points.

The test site for the research was chosen in Budapest, where both terrestrial laser scanning and mobile mapping data were available. Figure 1 shows the two sections of the Piarista and Váci streets, which were captured by a Faro Focus 3D 120S terrestrial laser scanner and by a Riegl VMX-450 mobile mapping system.