UAS based laser scanning for forest inventory and precision farming

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1. Introduction

Airborne Laser Scanning (ALS) has proven a convincing method in vegetation mapping and habitat monitoring over the last decade. As a complimentary approach to photogrammetric techniques laser scanning enables the penetration of several layers of vegetation resulting in high resolution and high precision 3D data.

In this presentation we will focus on the potentials of laser scanning for two major issues of natural resource management, namely precision agriculture and forest inventory.

Up to now remote sensing by commercial civil unmanned aerial systems (UAS) has mainly relied on photogrammetry techniques, making use of small and lightweight consumer-grade digital cameras to account for payload limitations. The new *RIEGL* VUX-1, is the first laser scanner of survey-grade measurement quality specifically developed for use on UAS. The new instrument and the employed *RIEGL* technology are presented. Two applications in vegetation and habitat monitoring are discussed and sample datasets are analysed with respect to precision, quality and content.

2. *RIEGL* VUX-1 Instrument presentation

The small and lightweight laser scanner *RIEGL* VUX-1 has been designed in order to meet with the requirements of UAS. Limitations in size and weight as well as several mounting options for a variety of different types of UAS and their flight characteristics have been considered throughout the development of the instrument.

The *RIEGL* VUX-1 performs a profile scan covering almost 360 degrees, which seems quite uncommon for a LIDAR instrument to be used on an airborne platform at a first glance. This large field of view (FoV) is explained by the typical scanning scenarios for which UAS are meant: areas difficult to access by conventionally piloted aircraft, such as narrow valleys or complexly structured environments. Furthermore, considering the flight path of UAS, the large FoV guarantees a gapless observation of fine structures such as power lines even upon sudden swiveling movements of the aircraft.

The scanning mechanism is based on a fast rotating mirror, which provides fully linear, unidirectional and parallel scan lines, resulting for straight flight paths in an excellent regular point pattern on the surveyed objects.

Figure 1: *RIEGL* VUX-1

eye safety class	Laser Class 1
max. range @ target reflectivity 60 %	920 m
max. range @ target reflectivity 20 %	550 m
minimum range	5 m
accuracy / precision	10 mm
laser pulse repetition rate (PRR) @ 300° FOV	up to 550 kHz
max. effective measurement rate	up to 500.000 meas. / sec
field of view (FOV)	up to 330°
max. operating flight altitude AGL	350 m / 1.150 ft

Figure 2: *RIEGL* VUX-1 instrument specifications

The *RIEGL* VUX-1 features a variety of different interfaces for utmost flexibility and simplicity in system integration. Besides mandatory interfaces for smooth integration with external IMU/GNSS systems for position and attitude determination the instrument provides interfaces for commanding through a UAS on-board control unit, as well as an interface for remote control via a digital radio link of limited bandwidth. With the availability of a radio down-link it is possible to transmit the IMU/GNSS position and attitude measurements as well as the scan data to a ground station PC or laptop. By geo-referencing the scan data in real-time viable information on the coverage and point density, data quality and system status are available for the operator. The raw scan data as well as raw IMU/GNSS data are stored on an internal solid state disk of the laser scanner, available for data processing after the flight.

The *RIEGL* VUX-1 offers all the well-established state-of-the-art features developed for the *RIEGL* V-Line scanners: echo digitization, online waveform processing, multi-target capability, calibrated amplitude, calibrated reflectance, pulse shape information of echo signal on all measurements, variable measurement speed, multiple-time-around capability.

3. Advantages of Laser Scanning in Vegetation Monitoring

By contrast to photogrammetry, which is limited to determining digital surface models (DSM), the technique of laser scanning enables to capture data suitable for the generation of DSM and digital terrain models (DTM). Advanced processing algorithms account for a full exploitation of the information contained in scan data. A typical target situation is measuring areas covered by vegetation. The laser beam may be scattered multiple times, from the tree canopy through layers of branches and low vegetation, until the last echo results from the ground surface. Several target echoes resulting from a single laser pulse emission are obtained by echo digitization and subsequently resolved by online waveform processing, resulting in measurement ranges, echo amplitudes, calibrated target reflectance and pulse shape information.

Laser scan data provide viable information on the condition and status of agricultural and forestry areas. It enables the analysis of factors indicating seasonal growth of vegetation and the detection of significant changes or even deterioration of land. Estimates of bio-mass volume, determination of different habitats, forest inventory and tree growth assessment, detection of deadwood and rolled-lumber are only a few applications where laser scanning is a frequently used technique.

While ALS can be considered an undisputed method in vegetation monitoring nowadays, the new generation of remotely piloted aircraft opens up yet new aspects of surveying. UAS are to be employed for economic reasons as in repeated survey missions, or for reasons of personal safety in otherwise difficult to access areas.

4. Example applications

4.1 Precision farming

Crop growth and health is closely monitored in precision farming in order to minimize the use of fertilizers or insecticides. Airborne laser scanning data enable to observe plant growth while at the same time displaying changes in ground surface, or to detect areas of hail damage. The repetitive task of airborne sensing missions by manned aircraft is a cost-intensive factor. Therefore, UAS could be a cost-effective solution for carrying out these survey missions at much shorter intervals while still at a lower cost in the near future.
We will present a time-series of scans captured over an agricultural field. The data enables the analysis of growth rates and the detection of areas, where the development of agricultural crops differs. It is to be investigated if from such repetitive surveys the relative reflectance attribute may serve to assess the crop’s ripeness or the area’s humidity

4.2 Forest inventory

Because of their potential in providing digital terrain models, detection of deadwood, biomass and underwood estimation, and canopy change monitoring, airborne laser scanning data have proven significantly relevant for the forest industry. Yet in difficult-to-approach areas or narrow valleys where it would be dangerous or impossible to employ conventional aircraft, UAS come into play. The large FoV of the *RIEGL* VUX-1 provides a comprehensive scan of such environments.

We will present a scan data set captured in a narrow valley with dense vegetation.

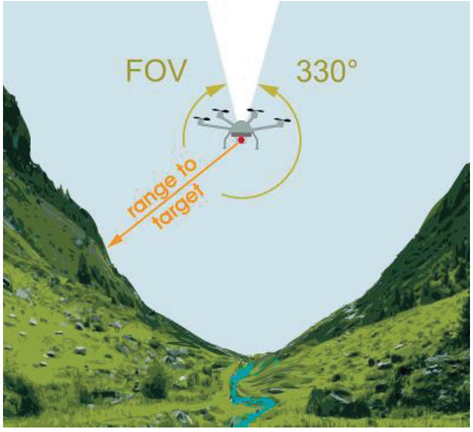

Figure 3: *RIEGL* VUX-1 Field of View

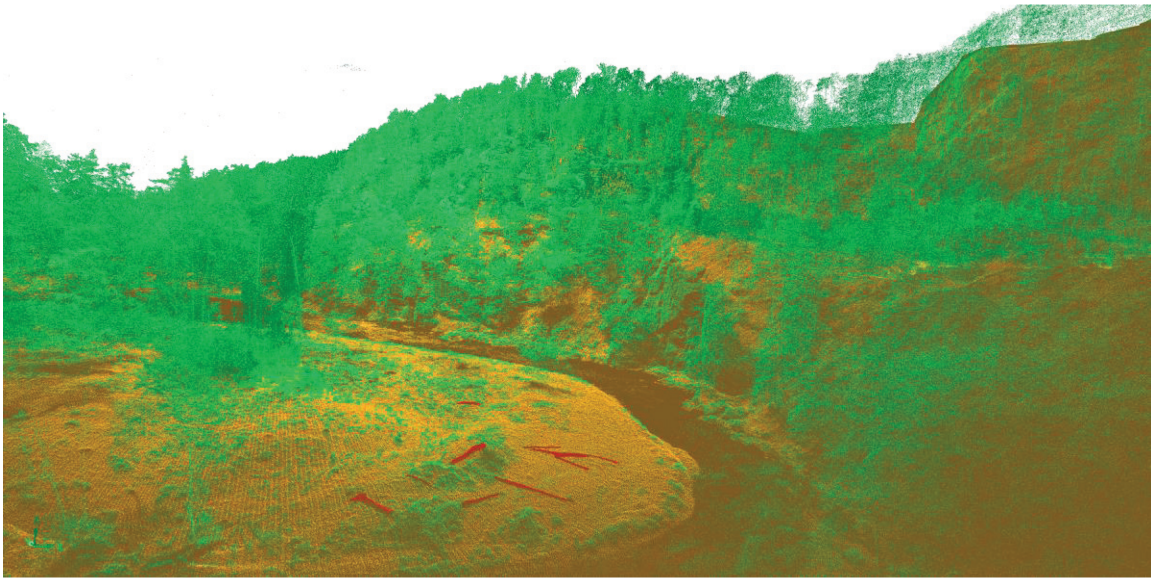

Figure 4: *RIEGL* VUX-1 scan data pointcloud.

Scanning has been performed from a manned helicopter, flying at 60m altitude AGL and at 40 kn speed. Scanning at 550 kHz PRR, the point density is 130 points per square meter. Color encoding corresponds to target classification (ground, vegetation). In the foreground, deadwood is highlighted in red.

For monitoring tree growth, points classified as vegetation are used to estimate the relative canopy height and enable the comparison of different height models collected over a certain period of time. In conjunction with imagery captured simultaneously with the scan data it is possible to identify individual tree species for completing forest inventory maps.

For planning cleanup efforts, fallen trees can be identified as linear structures in the point cloud classified as low vegetation. The analysis of the DTM, which is an inherent product of laser scan data, enables mapping of roads and trenches as well as geomorphologic studies of slope instability and erosion.

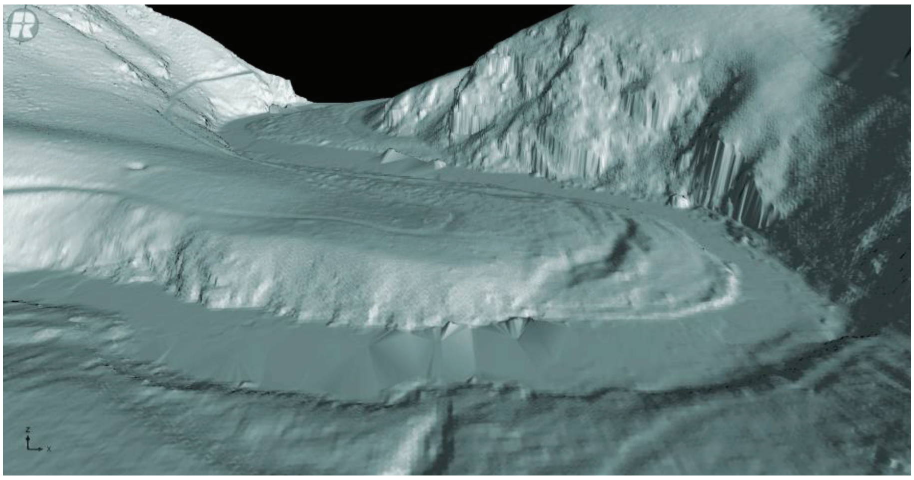

Figure 5: DTM calculated from the *RIEGL* VUX-1 scan data

References

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