AIRBORNE AND MOBILE LASER SCANNING IN MEASUREMENTS OF SEA CLIFFS ON THE SOUTHERN BALTIC

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ABSTRACT
Measurements of sea cliffs performed using periodic surveying based on laser scanning is currently one of the fastest and most accurate solutions. Supported with the technology of satellite measurements using GNSS (Global Navigation Satellite System) positioning and photographic measurements with the use of aerial vehicle, they enable an effective monitoring of the sea cliffs affected by the erosion. In case of the coast of southern Baltic, there are also the cliffs with a low angle of inclination and terraces; additionally there is a restriction concerning an access to the cliff from the shore side because of the narrow or non-existent lane of the beach. Hence there is a need for synergy of mobile measurements (Maritime Laser Scanning, MarLS) with airborne measurements.

Keywords: Maritime Laser Scanning, Airborne Laser Scanning, boat scanning, sea cliffs.

INTRODUCTION
Monitoring of sea cliffs is an important issue because of public safety and the ability to assess the progress of sea erosion. This type measurements bring the difficulties associated with an access to the surface of the cliff due to the slopes inclination, narrow beach lane or even unavailable seashore. In addition to environmental and geological aspects, cliffs should be monitored because of the buildings and engineering structures located on a cliff and its vicinity. Current measuring technologies focus on the use of GNSS positioning (Global Navigation Satellite System), measurement using TotalStation and methods of digital photogrammetry and laser scanning, including combining TLS (Terrestrial Laser Scanning) with ALS (Airborne Laser Scanning) [1-3,5-7,8-9,11-15].

The article presents the results of experimental works carried out on the southern coast of the Baltic Sea. Due to the construction of the cliffs i.e. simultaneous presence of
horizontal and vertical surfaces as well as the local presence of vegetation, the combination of ALS and MLS (Mobile Laser Scanning) technologies – more specifically – MarLS (Maritime Laser Scanning) – was used. The experiment was aimed at determining the suitability of the use of fusion of measurement sensors for monitoring sea cliffs by defining their characteristic features e.g. length of the abrasive disc.

**EXPERIMENT REALIZATION**

Test measurements were performed on a section of the southern coast of the Baltic Sea, limited on the west by the Jastrzębia Góra village and on the eastern side – by seaport in Władysławowo. The field works were made during the summer 2014. There have been also analysed the availability of GNSS satellites and the planned availability of ASG-EUPOS network station in order to ensure the availability and reliability of positioning, especially for MarLS measurements within the port in Władysławowo.

Data were recorded by the hybrid scanner of VZ-400 Rieglo Laser Measurement Systems GmbH, located on the hydrographic cutter "Tucana", belonging to the Maritime Office in Gdynia. The measurement was additionally enriched with air scanning, carried out using VQ-580 laser scanner of the same company, but located in one of the boxes of Auto-Gyro Callidus gyroplane. This solution allowed to enhance MarLS with points on the ground registered by ALS, which were not seen from the sea. Taking into account the previous experience [8], it was refused to collect data using TLS method (Terrestrial Laser Scanning) where the scanner would be placed on the abrasive board. This solution would limit the registration of the upper layers of the cliff and it would be time-consuming.

Mobile and air scanner base their operation on the trajectory. It is referred to as the path of the object motion in a function of time and it is the starting material for the integrated system of IMU / GNSS (Inerial Measurement Unit / Navigate Global Satellite System).

**IMU** – the device which determines the speed and orientation of the measuring instrument. Thanks to the use of gyroscopes, the accelerometer determines the rotation angles: roll (transverse swinging), pitch (longitudinal swinging) and yaw (angle, corresponding to the device descent of the course). In order to appropriately take into account the corrections during post-processing, it is required to know (e.g. from the manufacturer’s documentation) the spatial shift between the origin of the scanner SOCS (Scanner Own Coordinate System) and the mid-point of the IMU.

The GNSS receiver determines the coordinates and time of the device and then, the these data are transmitted to the scanner (using the RS232 interface, additionally aided by the time synchronization signal). Any information coming from the GNSS receiver is assigned to the XYZ point information obtained by the scanner. They are important for the correct execution of coordinate transformations registered by the scanner into the coordinates recorded by the GNSS receiver. In order to transform the coordinates correctly, it is required to measure the distance between the point 0.0 of the receiver (the phase centre) and point 0.0 of the scanner (the origin of the scanner).

Each measured point is strictly defined in time, on the basis of the data from IMU / GNSS, giving clear and accurate information on laser beam emission. During the collection of spatial data, the device operator has the ability to change settings,
parameters and to monitor the angular values presented by the integrated IMU / GNSS system.

**DESIGN AND ACQUISITION OF FLIGHT DATA**

Prior to designing the raid it is required to decide on the minimum density (number) of points per 1 square meter. Fig. 1 shows the frequency and height, planned to obtain the proper, predetermined density of points.

**Figure 1. Scope of measurement and density of points, according to the Riegl specifications [10].**

Due to the fact that the ALS acquisition was made from a height of 550 m and with the speed of 100 km / hr (54 kn), the used frequency of 300 KHz and 380 KHz is able to ensure an appropriate density of points. These are not the only available frequencies. Another important issue that was taken into account when designing the raid was the MTA zone (Multiple Time Around), in which the measurement was carried out. MTA zone is referred to as the so-called “echo issue”. This is about the scanner previous pulse echo reaching the scanner and leading to the ambiguity. In this case, the region of the graph in Fig. 1 is divided into four zones. In zone 1 (MTA 1) the pulse is received without registering the preceding echoes. However, when the scanner registers a single, ambiguous echo returning to the scanner, the raid must take place in the second zone. The MTA 3 has already two ambiguous echoes.

When analysing the cover and terrain shape, it was established that the optimum density of points on 1 square meter should be 8. According to Fig. 1 it was established that the most appropriate choice of flight altitude and frequency of the measurement would be
550 m at a frequency of 300 KHz. It was also agreed that the raid will take place in one MTA zone - the second one. This reduces the problem of ambiguity of signal return, as mentioned above. In addition, the width of the block of LiDAR data has been determined as 630 m.

Figure 2. Raid plan in IGI Plan software.

Figure 3. Panel of RiAcquire ALS software during the collection of information.

After determining the raid parameters and indicating the development area (record in .kml file), it was prepared the raid plan in WGS84 system (World Geodetic System 1984), dedicated to the IGI plan software (Fig. 2), which was implemented in gyro scanning system, where the system responsible for display of raid range (data acquisition) and monitoring of movement towards it is CCNS 5 system from IGI. Program used for the data collection is RiAcquire ALS (Fig. 3).
DATA PLANNING AND DATA ACQUISITION MarLS

Description of the measurement and data development was presented in [4,8]. The specificity of scanning from the sea requires attention to the lack of the possibility to use DMI (Distance Measurement Instrument) according to the rules applicable in the MLS, and ease of exceeding the maximum distance from which it is possible to register points on the shore.

After initialization of IMU / GNSS parameters and scanner and after the approval of its relevant configuration, data logging was started. Despite good geometrical conditions of GNSS satellites, there have been errors of yaw angle measurement (angle, corresponding to the descent of the course unit; rotation around the vertical axis) due to the uncertainty of its determination (the measurement does not use pair or triplet of GNSS receivers to determine the tilt and direction change to obtain complete information about the boundary accuracies and difficulties in data geometrisation in MarLS technology). The stability of this can be achieved only through dynamic alignment, i.e. alternating acceleration and deceleration and sudden changes in direction of movement before scanning. While this is relatively simple in traffic conditions for MLS, it was difficult to achieve in case of KH "Tucana".

To obtain data, the system of LV POS and RiAcquire program, supplied by Riegl GmbH, were used. Fig. 4 shows a screenshot showing the work of the scanner in the RiAcquire MLS.

![Figure 4. Preview of the scanner operation in MLS RiAcquire in MarLS mode.](image)

Working on a similar basis as RiAcquire ALS, this program provides the operator a preview of data recording by the scanner. GNSS parameters quality and scanning control is signalled by a green or red indicator (when scanning from the sea, the lack of mentioned yaw angle stability was indicated by red indicator).

EXPERIMENT RESULTS

For the estimation of VQ-580i (ALS) scanner trajectory the Aerooffice program was used. RiProcess program was used for the scans adjustment. Applanix PosPac MMS program was used for the adjustment of VZ-400 (MarLS) scanner trajectory.
Figure 5. Values of raid trajectory deviation for ALS.

Figure 6. The filtered cloud of points from the combination of ALS and MarLS.

Figure 7. Cliff model in the form of a Digital Terrain Model (DTM).

Figure 7: Example of a section through a cliff in the coordinate system of PL-2000 standard.

Recognizing that the data from these two systems (mobile and air) are reliable (do not have an extreme error) it is possible to determine the nationality of points to scan (ALS /
Photogrammetry and Remote Sensing

MarLS). Data was exported in format of .las to Riscan Pro program which performed the analysis of the suitability of mobile and air scanning to the monitoring of marine cliffs. The achieved models have been verified through the field inspection.

CONCLUSIONS

When determining the characteristic values of land located on the cliffs and in their vicinity (the size of a cliff, the length of the coastline, the volume of soil mass) and creating sections in anywhere, it is possible to do this with an accuracy of approx. 20 cm (the result obtained on the basis of measurements results alignment). The development of the model did not use control objects (objects with known coordinates designated by traditional surveying methods) to obtain information about the possibility to use only ALS in conjunction with MLS (MarLS).

The combination of laser scanning performed from air and from water seems to be a good alternative to other methods of cliffs measurement. In case of monitoring cliffs, there is additionally a need of the reference measurement, which is compared to data obtained in other measurement campaigns, e.g. after the storm. The obtained differences in size, volume or height of the object being monitored determine its shifts and changes. Currently, data from the ALS measurements are available for most areas in Poland, and the inclusion of MarLS allows for the measurement of cliffs and embankments inaccessible in the technology MLS / TLS realized from the beach (sea shore).

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REFERENCES


