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The Fierce Rise of Airborne Lidar

A View on Status, Developments and Trends

LOW-COST VS. HIGH-END SYSTEMS FOR AUTOMATED 3D DATA ACQUISITION

SENSOR TECHNOLOGY EVOLVING IN MANY DIRECTIONS

CAPTURING, MODELLING AND BUILDING THE REALITY

INTERVIEW PAGE 12
Capturing, Modelling and Building the Reality
Interview with Aidan Mercer, Bentley Systems

FEATURE PAGE 16
The Fierce Rise of Airborne Lidar
A View on Status, Developments and Trends

FEATURE PAGE 21
Protecting Location Privacy Brings Opportunities to the Geosector
Winner of Pan-American Thesis Contest

FEATURE PAGE 24
Low-cost vs. High-end Systems for Automated 3D Data Acquisition
Modelling an Early Mediaeval Ring Fort in Germany

FEATURE PAGE 29
An Open Platform for Documenting Property Rights
Cadasta Foundation

REPORT PAGE 31
National Mapping as a Service
Ordnance Survey Ireland Shows New Perspectives, Part 2

REPORT PAGE 34
Russian Focus on the World
Racurs Conference

COMPANY'S VIEW PAGE 36
Aerial Survey Innovators
Aerometrex Group

News & Opinion	page
Editorial	5
Insider's View	6
News	7
5 Questions	10

Organisations	
FIG	38
GSDI	38
IAG	39
ICA	40
ISPRS	40

Other	
Advertisers index	3
Agenda	42

This issue is focused on laser scanning, both airborne and terrestrial. The first commercial airborne Lidar systems appeared on the market in the mid-1990s. Since then this active remote-sensing technology has evolved rapidly. An article on this subject from page 12 onwards provides an overview of the main technological advances of today's operational systems. (Image courtesy: Nova Scotia Community College).

ADVERTISERS INDEX

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MODELLING AN EARLY MEDIAEVAL RING FORT IN GERMANY

Low-cost versus High-end **Systems for Automated 3D Data Acquisition**

Topographic mapping is a standard surveying task and the instrument of choice used to be a total station. The use of terrestrial laser scanning has become popular over the past decade or more, but today there is a much wider choice of methods for the acquisition of a digital surface model (DSM). For the 3D recording of an early mediaeval ring fort, the authors investigated the use of three modern systems: a portable (kinematic) laser scanning system, a static terrestrial laser scanning system (TLS) and a photogrammetric unmanned aerial system (UAS). The systems were compared to each other based on the following criteria: efficiency and performance in the field, degree of automation for data processing, and accuracy achieved in relation to the system costs.

▲ *Figure 1, Aerial view of the ring fort of Lembecksburg, Germany, captured by a Sony Nex-5 camera on a hexacopter.*

THE EARLY MEDIAEVAL RING FORT OF LEMBECKSBURG

The Lembecksburg ring fort is located on the North Sea island of Föhr (Figure 1), 1km north of the village of Borgsum. This circular earthwork was built on top of a geest, or slightly raised landform, next to the Föhrer Marsh. The outer diameter is 140m and the inner diameter is approximately 90m. The height is 10m above the outer ground, while on the inside the ground is only 3 to 4m below the wall top (Figure 1). In earlier times there was a ditch around the outside of the wall. This is difficult to identify today, although it is slightly visible in the east. Until the 19th century there was a tideway from the north of the wall to the Wadden Sea, which was presumably navigable for most of its length. The first construction of the wall dates back to the 8th century – the time of the Vikings – but traces of the Roman Empire (ceramics) have also been found at the archaeological site. Today the complete ring fort as well as the surrounding area is grass-covered.

Data Acquisition Methods and Systems Used

All data was collected by geomatics students from HafenCity University (HCU) in Hamburg,

▲ *Figure 2, Scanning while walking using the kinematic laser scanning system from the company p3d systems.*

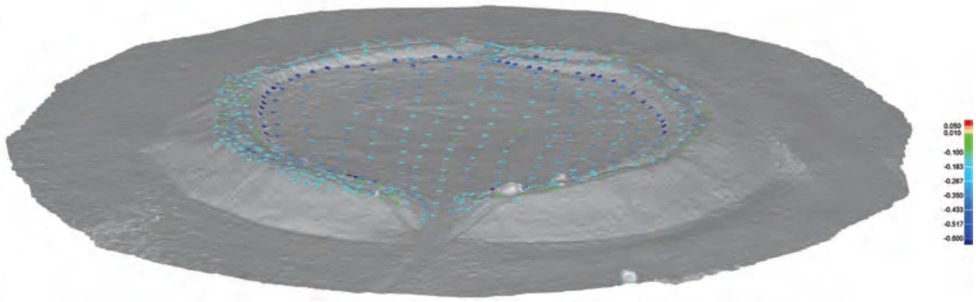
▲ *Figure 3, The flight was controlled manually due to the strong gusting wind.*

Germany, during a three-day measurement campaign. The reference data was surveyed using a Leica TCRA 1201 total station. A total of 550 topographic points were recorded covering the wall and the centre of the ring fort. For the static TLS data, the Zoller + Fröhlich IMAGER 5010 laser scanner was used. From 42 stations, an amount of about 12 million points per scan was acquired, which corresponds to a total number of approximately 504 million points and a scanning time of about 12 hours. For the registration of the scans at least five black and white targets per scan were used, which were determined by total station in a local coordinate system. The kinematic laser scanning was carried out with the ProScan system, provided and operated by the company p3d systems GmbH from Hamburg. This system is equipped with a TLS – in this case the IMAGER 5010 from HCU – plus a GNSS antenna and a high-precision inertial measurement unit from iMAR Navigation GmbH. Additionally, a GNSS reference station was needed for the system positioning, which was installed in the field close to the ring fort. To carry the 18kg system in object space, the sensor components were mounted on a special carrier known as a steadicam (camera stabiliser mount) used in the film industry (Figure 2). During walking the operator is able to control the system using a tablet PC. In total, four tracks were scanned in two hours by three operators, covering a length of 1,143m and an amount of 154 million points. For UAS photogrammetry a hexacopter Sky Hero Spy 750, equipped with a gimbal-mounted digital camera (Sony NEX-5, 16mm focal length, 14 megapixels), was used. 186 images were taken during an eight-minute flight, which was controlled manually rather than in automatic flight mode due to the strong gusting wind (Figure 3). For georeferencing of the image block, five targets for XYZ control points were distributed around the object and determined by total station.

DATA PROCESSING

The collected data was processed in such a way that similar and comparable datasets were obtained for each sensor. For the georeferencing of the point clouds, however, different processing procedures were implemented. For the p3d systems data the trajectories were calculated in the PCloud software in order to generate one point cloud for each track. The GNSS signal from the reference station was used to transform the data directly into UTM XY coordinates, while the height was adjusted by a constant shift. The positioning accuracy of the tracks was approximately 2 to 3cm. The static laser scans were georeferenced using the scanned targets; each station was registered using the target coordinates from total station measurements with a mean deviation of 2.4mm. The UAS image data was triangulated in Agisoft PhotoScan using five control points in a bundle adjustment for the determination of the image orientation and camera calibration parameters. The residuals of the control points after adjustment were less than one centimetre. The three different point clouds from kinematic TLS, static TLS and UAS photogrammetry were sampled down to 15cm point spacing. For the comparison, the ring fort itself plus an area of 40m around the ring fort was investigated. Each data volume was thus reduced to 1.2 million points. Finally, from each of the three point clouds, two datasets were derived for each sensor system. For the first, the point cloud was meshed in Geomagic with the 15cm point spacing, and for the second dataset a regular grid with 20cm point spacing was derived by filtering, where the lowest point was kept for each cell. In illustration, Figure 4 shows the

▲ *Figure 4, The mesh from the UAS data, filtered to a 20cm grid cell using the lowest point.*



▲ *Figure 5, Spatial distribution of the reference points from total station including colour-coded differences with the test system.*

▶

System	SC [EUR]	deviations of dataset 1 [m] (15cm point spacing)			deviations of dataset 2 [m] (lowest point in 20cm cell)			time [h]
		Ø	MIN.	MAX.	Ø	MIN.	MAX.	
TLS	50,000	-0.28	-0.87	0.02	-0.22	-0.87	0.09	25
p3d	150,000	-0.26	-0.79	-0.03	-0.19	-0.90	0.06	5
UAV	5,000	-0.27	-1.21	0.01	-0.25	-0.99	0.03	5
SC = System Costs, Time = Amount of time for data acquisition and processing								

▲ *Table 1, System costs, height differences compared with the reference dataset and amount of time involved in the three different measurement systems.*

mesh from the UAS data, which was filtered to a 20cm grid using only the lowest point.

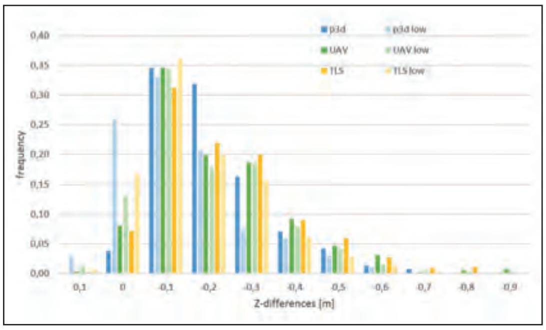
COMPARISON OF DERIVED DATA

To obtain information about the accuracy of the DSM generated, the different models were compared to the reference data of the total station (Figure 5). Due to the long grass on the ground, which was estimated to be up to 40cm in height, significant differences are visible in all DSMs; none of the three tested methods is dominant. Assessing the meshed models without filtering achieved the following results:

The proportion of points having a maximum deviation of 20cm is 39% for the static TLS with IMAGER 5010, 43% for the UAS photogrammetry and 38% for the kinematic TLS from p3d systems. In comparison with the results for the filtered data, the proportion of points with max. 20cm deviation is higher for all methods, but not to a similar degree. The p3d systems dataset has improved significantly to 63%, the IMAGER 5010 dataset is now at 53%, while the UAS dataset shows a slight rise to 49% (Figure 6). Here it is clearly apparent that dense image matching is not able to generate 'real' ground points in the case of low vegetation such as grass or meadows. Nevertheless, the laser scanners have also problems with the grass height; on the one hand they deliver better results close to the scanning stations, but on the other hand points with increasing distance to the scanner station have similar deviations as the UAS data due to the scanner's angle of incidence. Table 1 summarises the deviations in height against the reference dataset, including the amount of time spent on data acquisition and processing in relation to system costs.

CONCLUSIONS

The authors investigated three different systems and methods for DSM generation and compared the achieved datasets against a reference dataset. Due to the long grass and vegetation, the mean deviations in height against the reference dataset were up to 30cm. Additional filtering of the datasets slightly improved the results, but could not eliminate the differences. Overall, the p3d systems dataset was evaluated to be the best one, followed by static laser scanning and UAS photogrammetry. Taking into account the time spent on data acquisition and processing, with a workload of five hours the kinematic TLS and the UAS photogrammetry are much more efficient methods than the static TLS which has a workload of 25 hours. It has to be assumed that in the case of less vegetation the UAS-generated data could obtain a similar quality in comparison to the kinematic TLS. Due to the low system costs, UASs are an alternative solution to static and mobile laser scanning. However, the slightly better results in this investigation were achieved by a high-end system costing approximately EUR 150,000, which might be an exclusion criterion for many applications. ◀



▲ *Figure 6, Frequency distribution of Z differences between reference (total station points) and two different DSM datasets, each derived from three different sensor systems.*

FURTHER READING

Kersten, Th., Lindstaedt, M., Mechelke, K., Omelanowsky, D., Prenting, J., 2016. Low-Cost vs. High-End Systeme im Vergleich – 3D-Aufnahme der Ringwallanlage Lembecksburg auf der Nordseeinsel Föhr (in German). *Photogrammetrie, Laserscanning, Optische 3D-Messtechnik – Beiträge der Oldenburger 3D-Tage 2016,* Th. Luhmann/Ch. Schumacher (Hrsg.), Wichmann, VDE Verlag GmbH, Berlin und Offenbach, pp. 150-161

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