UAV monitoring of a large-scale environmental project

A sand dune remobilisation and rejuvenation project, believed to be the largest of its kind in the UK, has been undertaken by Natural Resources Wales (NRW). Alan Roberts compares the use of UAV, LiDAR and terrestrial Laser Scanning surveying techniques for monitoring sediment movement

The project commenced in January 2015 and involved the removal of large quantities of sand, vegetation and organic material via a series of cut 'notches' to the west facing front end of well-established, over-vegetated aeolian (wind-shaped) sand dunes at a site near Newborough in south-west Anglesey.

The primary works involved the mechanical excavation of material from strategic positions along the dune front. This would enhance the movement of sand from the beach area, through the main dune wall, and into the dune slacks to the rear of the system. It was anticipated that this would encourage the reinvigoration of species normally found in a mobile dune ecosystem. The surveyed project area (Fig.1) forms part of a larger dune system and conifer forest.

Collaborative effort

This described survey forms part SEACAMS, a five-year initiative, part-funded through the European Regional Development Fund (ERDF), and involving a partnership between Bangor and Swansea universities and Anglesey-based DTM Technologies Ltd. Its goal is to develop the marine and coastal sector economy in Wales through collaborative R&D projects.

In furtherance of this work, project lead Bangor University and DTM Technologies investigated various techniques for capturing high resolution, high accuracy, topographic data. SEACAMS researchers conducted a series of repeat surveys using a terrestrial laser scanner (TLS) at Newborough Warren, the site of the dune remobilisation project undertaken by NRW.

Fig.1: Location of the survey area

Survey and ground control

A total of 32 ground-based targets (Fig.2) were laid out over a survey area of approximately 56 hectares, the targets measuring $30cm^2$ with a well-defined centre point for capture in the aerial imagery. While targets are normally laid out within a specified, highly structured grid, the undulating and overgrown nature of the ground made this impracticable. Each point was surveyed using both a networked RTK, and a Leica base station and rover.

Fig.2: Ground Control Points

The SEACAMS team used the Leica Scan Station C10 HDS laser scanner which uses pulses of laser light to develop a 3D digital model of the surrounding environment. 50,000 pulses per second are emitted and reflected off nearby surfaces by the scanner to build the model, first as a point cloud and then, by combining data derived from different positions, shadowed areas can be filled in and a full 3D representation of the environment generated.

Each TLS survey at Newborough Warren used approximately 10 scanning stations and the acquisition of around 50 million points. By positioning the data using differential GPS control points, comparisons of topographic differences can be made between TLS surveys and data from other sources such as aerial LiDAR and UAV photogrammetry.

Taking to the air

The aerial images for the photogrammetry process were captured by CAA-certified DTM Technologies using a small UAV (drone). A total of 363 images at a resolution of 4000 x 3000 pixels were captured from an altitude of 60 metres, each image having a 65% overlap.

The survey was flown manually in as close to a 'lawnmower' pattern as possible (Fig.3), with data post-processed using off-the-shelf software. The output was a high resolution point cloud, with a point density of 41 points/m², an orthomosaic image with a resolution of 3cms/pixel, and a digital surface model with a sample spacing of 15cms. The data acquisition process, including both terrestrial and UAV surveys, took approximately five hours, with data processing taking a further 12. All exported

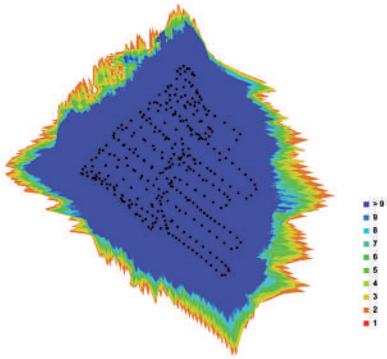

Fig.3: Image overlap and camera location

files were geo-referenced to British Grid OSGB36.

A total of three surveys were conducted in this manner, the first before any remobilisation-associated work was undertaken, the second a month later, and the third approximately a year later. All data was provided to the NRW team for more detailed analysis and a comparison of topographic and habitat change that had taken place between surveys.

Excellent results

The aerial surveys worked well and can be deemed as excellent for this type of project, due in part due to the economic benefits, a decrease in survey time, and the fact that the photogrammetric process produces both Digital Surface Models as well as high resolution orthomosaics.

This combination allows topographical analysis to be conducted as well as a visual inspection/analysis of plant growth, habitat change, sand movement and, even to a degree, moisture content. Regular surveys coupled with rapid turnaround in terms of output mean the data sets will prove invaluable in projects of this nature demonstrating how the terrain surface and material composition will vary over time.

Fig.4 shows a comparison of all survey methods (left) as well as a transect through an area of the two largest notches (right). The solid green represents the terrestrial LIDAR scan, the purple dotted line the UAV survey, and the red dotted line the airborne 1m LIDAR data set (taken before any work was carried out). The vertical red lines, A, B and C are points where elevation measurements on the survey data were taken to demonstrate the relative heights of each survey.

Conclusions

The primary differences between the terrestrial LiDAR and the UAV aerial survey are within 5cms to 25cms depending on the degree and adequacy of ground cover. There are advantages for both processes: an aerial survey can cover a much larger area in a shorter time frame, but it averages the terrain with the vegetation, providing only a surface model.

Further processing is possible to remove the vegetation but this can be time-consuming. Automated processing techniques are available but not as reliable as LIDAR, where 'intensity' strength of return can be used to classify the points and correctly differentiate between vegetation and ground.

Terrestrial LiDAR will usually have a much higher point density than can be achieved via an aerial survey but, being terrestrial, the angle of return is much steeper and can cause shadowing. However, this can be mitigated in many cases by increasing the number of scan locations. Terrestrial LiDAR is capable of producing a coloured point cloud, but this can easily double the time required to undertake each scan. In conclusion, by comparing all three surveying techniques, the outputs clearly demonstrate what is possible. Each method has its pros and cons ... all of which need to be weighed against the desired requirements/outputs, area to be surveyed, timeframe and overall budget.

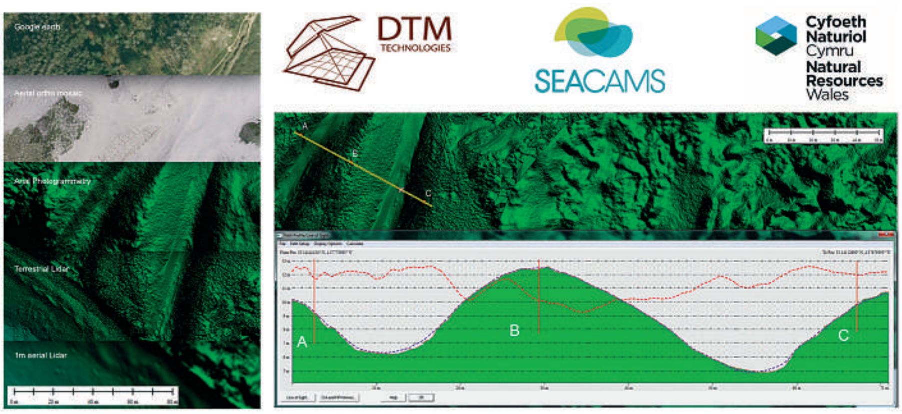

Fig. 4

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Point A	Elevation	Point B	Elevation	Point C	Elevation
1m LIDAR	11.649m	1m LIDAR	10.151m	1m LIDAR	11.96m
Terrestrial LIDAR	8.908m	Terrestrial LIDAR	12.448m	Terrestrial LIDAR	9.765m
Photogrammetric survey	9.085	Photogrammetric survey	12.486m	Photogrammetric survey	9.601m

The above table shows three points measured from the processed terrain models. It shows an average difference in elevation of 12cm between the terrestrial LIDAR and the aerial photogrammetric survey. The distance between point A and point C is 63 metres.