COASTAL APPLICATIONS OF LIDAR IN CATALONIA

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KEY WORDS: laserscanning, DTM, coast

ABSTRACT

The Institut Cartografic de Catalunya has completed in 2008 the first airborne laser scanning coverage of the Catalan coast with a point density of 0.4 points/m^2. It is planned to repeat the survey of the coast every year. For some areas older data is also available. With the new lidar equipment, it is possible to complete the coast survey, around 450 km, in only 4 flight sessions. Examples are given of the application of these data to beach change evaluation and detection of buildings in protected areas. Beach change evaluation includes measurement of sand volume change, shoreline displacement and change of the beach surface.

INTRODUCTION

Coastal areas concentrate most of the population and the economical activities in our region. Tourism is one important economic activity on this area but many other industries concentrate in our coasts. These areas are affected every year by storms whose effects range from sand displacements to damages to properties or even lost of human lives. Defences have been installed in many beaches to protect the sand but the net effect of the natural transport on most of the beaches is shoreline erosion, probably due to a widespread reduction of the sediments supply from the rivers because of the urbanization of many areas in the river basins, presence of dams and river channelling.

Tourists want to find beaches in good conditions for the bath and the authorities expend a lot of money to regenerate beaches after the storms. In Catalonia the rate of tourists per km of beach is the highest in Spain reaching 21,464 tourists/km in 2006, (Ministerio de Medio Ambiente, 2007). Coastal erosion and the probable rise of the sea level due to global warming threaten the coast, being the delta of the Ebre River the most vulnerable area in our region. Other threatens that could affect us are storm surges and tsunamis. Lidar can provide a fast response after major events.

Systematic monitoring is required to quantify the evolution of the coast. In the USA, the USGS, NASA and NOAA are collaborating to monitoring the coast with lidar since 1995. Lidar has many advantages over photogrammetry in these areas. It is an active sensor that can be operated day and night and the low texture of sand does not reduce lidar accuracy. The presence of water difficults photogrammetry because it is not possible to measure stereo points on the sea surface and stereo models with large areas covered by water can present deformations due to bad distributions of tie and control points. Lidar is very fast and allows getting models of a region shortly after the flight, showing an almost instantaneous “picture” of the situation each time it is flown. As it is cheaper, surveys maybe repeated periodically. The Spanish Environment Ministry (MINISTERIO DE MEDIO AMBIENTE, 2008) recommends repeating surveys 4 times a year in beaches not in equilibrium and every one or two years after when they are in equilibrium but the most common survey technique is still photogrammetry.

There are two kinds of lidar systems useful in coastal areas: topographic lidar and bathimetric lidar (Ruiz, 2008). In topographic lidar systems near infrared lasers are employed and light of this frequency doesn’t penetrate water. Bathimetric lidars employ a green laser, which in clear waters can reach up to 50 m depth. Current bathimetric systems combine both sensors and can survey simultaneously the surface above and below the sea.

Law 22/1988 on the coastline defines the land-sea public scope. According to this law, the strip of land that has ever been reached by the sea is public domain and the public administrations must recover the ownership and adapt land uses to a “more natural” state. The European Community has given some guidelines on coastlines and sea environment policy. Coastal resources must be handled according to an integrated coastal zone management (ICZM) and decisions must be taken based on true data and information. Lidar data is one of the data sources on which authorities can rely to take informed decisions.

DATA

The Catalan coast was flown in 3 flight sessions during 2008, from October 16 to

November 3, with a topographic lidar Leica ALS50-II. There were 65 strips in total. Flight parameters are shown in Figure 1.

FOV º	56
Scan rate (Hz)	22
PRF (Hz)	88000 MPiA
Above Ground Level (m)	2250
Speed (knots)	140-165
Strip width (m)	2393
Average point density (m^{-2})	0.37
Nadir point density (m^{-2})	0.25
Footprint diameter(m)	0.58
Precision in height (cm)	15
Precision in plan (cm)	32

Figure 1. Lidar flight parameters

The calculated laser points are affected by height offsets because of GPS errors, which are corrected in a strip adjustment that is standard at the ICC (Kornus et al. 2004). As control information served 22 transversal lidar strips, which have already been adjusted in an earlier project as well as 13 control areas, each comprising approximately 40 control points observed with differential GPS at an accuracy of a few centimetres.

As result of the adjustment, height offsets for each flight line are estimated as unknowns from three different groups of observations:

- Height differences between crossing flight lines
- Height differences between flight lines and control areas/control flight lines
- Heights of the control areas/control flight lines

For the first group at each crossing area of two intersecting flight lines a ground DTM is computed with a regular grid from the laser points for each strip. The height differences between corresponding grid points are statistically analyzed, outliers are eliminated and the mean height difference observation is calculated. The a priori weight of the observation is defined as a function of the calculated standard deviation. In case of control areas in the second observation group also a ground DTM is generated and the mean difference between the heights of all control points and the respective interpolated DTM heights is computed.

Altogether, 235 observations were used to estimate the height offsets of the 65 project flight lines. The statistics of the estimated residuals are listed in S'ha produït un error: No s'ha trobat la font de referència. The last column refers to the check information (4 control areas and 12 control flight lines) and gives an idea of the achieved accuracy after the height correction, which is approximately 3 cm.

Observation Group	1+2	3 (control)	3 (check)
Number	201	18	16
Sigma [cm]	1.5	1.9	3.1
Max.[cm]	7.4	4.0	3.9
Min.[cm]	-6.8	-3.4	-5.5

Figure 2. Statistics of estimated residuals.

The statistics of the estimated height corrections in Figure 3 show that the height offsets caused by GPS errors vary from day to day, but can also vary significantly during a single flight session as happened on the 2nd day. If not corrected they would produce systematic height shifts in the final DTM in the order of 1-3 decimeters, far beyond the lidar point accuracy.

	Day 1	Day 2	Day 3	Day 4	Σ
Number of flight lines	7	22	23	13	65
Mean [cm]	8.5	15.6	0.4	-2.2	5.9
Sigma [cm]	2.2	5.2	2.8	2.3	8.4
Max.[cm]	11.1	24.8	4.3	1.3	24.8
Min.[cm]	5.0	5.2	-5.6	-6.0	-6.0

Figure 3. Statistics of estimated height corrections

APPLICATIONS

This accurate data has many applications. Some of them are the following:

- Detailed digital terrain modelling of floodplains for mapping and risk analysis.
- Change monitoring: Volume computation of sand movements and shoreline change
- Detection of buildings in protected areas.
- Cataloguing of coastal defences and man-made structures.
- Dunes and beach morphological classification
- Development and emergency planning
- 3D models for landscape analysis, environmental impact, wind propagation, etc.

Floodplain areas require increased accuracy for contouring and are easily surveyed with lidar. Delta de l'Ebre was firstly flown in 2004 with an Optech 3025. Flooding risk models and maps are currently being elaborated from these data. In (Ruiz & Kornus, 2002 and Ojeda et at. 2004) one example of change monitoring was shown. On that year, a storm removed a lot of sand from the emerged part of the beaches in Barcelona. They were surveyed shortly after the storm and, later, after the artificial regeneration of the beach and volumes of displaced sand and changes in beach surface were computed.

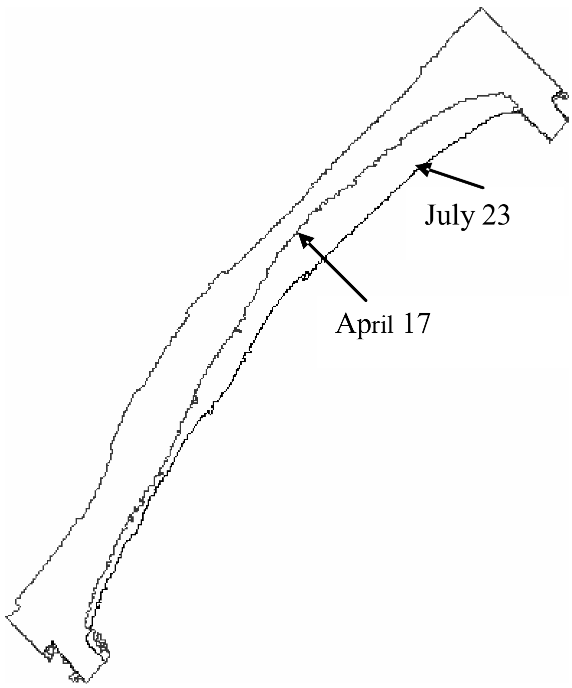

Figure 4: Difference between DTM from 2 epochs, Bogatell beach, Barcelona.

Between December 26 and 29, 2008 a strong storm with winds from the East produced damages on the beaches and harbours of Costa Brava. Buoys measured waves of almost 9 m in front of Roses Bay. Blanes and Palamós harbours resulted damaged. The coast from Barcelona to Lloret de Mar was surveyed again on January 17 and 28, 2009 with lidar and digital aerial photography taken with a DMC camera. The change evaluation is currently being done.

Detection of buildings is a standard tool in lidar points' classification software. Once the ground model has been edited by an expert operator, it is possible to classify points higher than the ground as vegetation and, between them, to choose automatically those that could belong to a building roof and so detect those buildings lying inside a protected area. The main difficulty to perform this detection is that ground classification must be very accurate and badly classified cliffs can be misclassified as buildings.

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