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Persistent Vegetation error in Aerial LiDAR DSMs: Impact on spatial models of inundation risk.

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1. Introduction

1.1 Light Detection and Ranging (LiDAR)

LiDAR derived Digital Elevation data are used widely in the Geosciences to model topographically dependent environmental processes. Common applications include modelling coastal inundation vulnerability (Gornitz et al. 2002, Leatherman et al. 2003, Webster et al. 2004) assessment of coastal erosion risk (Woolard & Colby, 2002, Brown et al., 2006) and managing river flood risk (Gomes-Pereira & Wicherson, 1999; Brasington et al. 2000; Cobby et al., 2001).

All of these applications require base data that represent the ground surface accurately. LiDAR data do generally provide the highest accuracies relative to other Digital Elevation Model (DEM) acquisition techniques. However, the manner in which LiDAR data are acquired can make it exceptionally difficult to define ground level in areas where ground vegetation prevents laser penetration to the ground surface (ASPRS, 2004). Critically, these conditions often predominate in coastal areas and can seriously affect the reliability of coastal inundation prediction models. This question is sometimes not full recognised by data users. This paper highlights the degree to which vegetation-derived DSM can affect the spatial prediction of coastal inundation risk.

1.2 Removal of vegetation during DSM generation

The classification of first and last pulse laser returns provides a mechanism by which objects close to a LiDAR sensor can be segregated from objects that are more distant from it. This typically corresponds to the segregation of laser-translucent objects that protrude from the surface (trees for example) and the ground surface itself (Lim et al., 2003, Hall et al., 2005; Webster, 2006). The method is particularly effective when laser penetration of vegetation cover is achievable, but it does require the ground surface to be identifiable across a reasonable proportion of the area surveyed. This tends to limit its applicability to relatively sparsely vegetated areas, where laser penetration to the ground surface is viable across a reasonable proportion of the area surveyed.

The advent of LiDAR waveform scanners provides a more refined method for the segregation of laser-translucent objects and the ground surface (Nayegandhi et al., 2006, Wagner et al., 2008). However, this method also relies on laser penetration to the ground surface. The identification of a reasonable number (and geographical spread) of ground surface laser return points is often difficult in naturally vegetated areas, and may be totally impossible where dense ground vegetation cover occurs. This issue is quite common in natural coastal environments, and is often overlooked when LiDAR DSM data are used to model the spatial extent of risk from coastal inundation. This oversight is easy to understand, due t the manner in which DSM elevation error is commonly reported.

1.3 Residual vegetation error in DSM datasets

Typical error ranges quoted by LiDAR data providers fall within the general magnitude range of ±0.2m. However, the manner in which LiDAR accuracy standards are framed (FGDC, 1998, ASPRS, 2004, Höhle & Potuckova, 2006) means that quoted elevation errors for natural areas are more likely to be classified relative to ‘compiled to meet’ accuracy statements (ASPRS, 2004) rather than by direct ground validation. Therefore, elevation errors in densely vegetated natural or cropland areas will typically be larger than quoted DSM elevation error for an entire DSM dataset. Vegetation-derived elevation errors of the order of 1m have been noted in a number of studies (Paine et al., 2005, Rosso et al., 2006, Coveney et al. 2006). Errors of this magnitude are sufficient to adversely affect the spatial prediction of short-term flood risk, and maximum sea-level rise risk over the next 100 years. The extent to which LiDAR accuracy statements may understate elevation errors in natural areas is often not considered by end users.

1.4 Principal objectives of this paper

The presentation accompanying this abstract will focus on two principal issues. The problem of persistent vegetation error in LiDAR DSM data will be elucidated, and the magnitude of this error will be quantified across a range land-cover types using three separate LiDAR DSM data sources captured in three overlapping survey areas.

2. Approach

2.1 Selection of datasets

LiDAR DSM data are used by three separate agencies in Ireland, namely; the national mapping agency, the Office of Public Works, and the INFOMAR (Integrated Mapping for the Sustainable Development of Ireland’s Marine Resources) project. The national mapping agency coverage is growing, the OPW coverage is limited to river course and limited coastal areas, and the INFOMAR data is a bathymetric LiDAR dataset (with a relatively substantial onshore component). Three overlap areas are used to evaluate DSM error across a range of natural and manmade land cover types (table X.X) and to consider the implications of these errors on the reliability for the spatial prediction of coastal inundation risk. Elevation errors are highlighted by external validation with high-accuracy Global Positioning System (GPS) survey data.

2.2 External validation data source

Dual frequency (DF) GPS survey is capable of exceptionally high accuracies, and is used widely as a source of external validation data for the assessment of DEM (REFS) and DSM error (REFS). Elevation errors within DF GPS data are corrected using one of two methods. Realtime Kinematic (RTK) GPS achieves accuracies in the region of 2-4cm for elevation measurements (Pitri, 2007; Ahn et al., 2006; Grejner-Brzezinska, 2005; Mitasova et al., 2004). Even higher accuracies can be achieved with dual-frequency GPS by applying corrections from a local GPS reference station using post-processing (Featherstone & Stewart, 2001).

GPS data are captured within a range of broadly representative natural, semi-natural and human-constructed land cover classes (table X.X) using a Trimble R8 DF GPS receiver. Validation data are captured using RTK survey (for densely vegetated areas) and using limited FastStatic survey (for paved and thinly vegetated areas). Five land cover types are evaluated (table X.X).

Generic class	Land cover type
Natural	Open terrain (sand, rock, soil, ploughed fields, lawns, golf courses).
Natural	Brush lands and low trees.
Natural / semi-natural	Tall weeds and crops.
Semi-natural	Forested areas fully covered by trees.
Anthropogenic	Urban areas with dense man-made structures.

Table X. Land-cover classes evaluated (source ASPRS, 2004).

2.3 External validation approach

External validation is carried out using ArcGIS Geostatistical Analyst. The test land cover types are segregated prior to validation to avoid using a single global kriging model for all land cover types. The external validation process applied involves the following steps for each land cover type:

- Isolation of the spatially autocorrelated trends (Universal kriging)
- Fitting a suitable semi-variogram model for each individual land cover type
- Cross-validation of the optimised interpolations (to isolate interpolation error)
- External validation using DF GPS data captured with the chosen land cover types

3. Preliminary results

Initial tests of the methods outlined here revealed elevation errors of up to 1m in open coastal terrain

2. Equations, Figures and Tables

Equations should be centred on the page and numbered consecutively in the right-hand margin as (1), (2), etc. They should be referred to in the text as, for example, equation 1.

Table 1. Venues of Geocomputation conferences 1996-2000.

Figure 1. The logo of the University of New South Wales.

3. References and Citations

IN text citations using Harvard system (Authority 1973, Learned and Expert 1982), although the work by Fudgit et al. (1997) is an exception.

The reference list should be formatted as in this example, using 10pt font and 1cm hanging paragraphs for each reference.

4. File format

Abstracts should be submitted as files compatible with Microsoft Word (e.g. Word document, Rich Text format) or Acrobat (pdf). Files larger than 1MB should be sent as zipped archives. Abstracts should be submitted as email attachments and sent to: geocomputation@unsw.edu.au (note that there is a 10MB attachment limit on this server). The email should contain the following contact information for the corresponding author: name, institution, postal address, telephone number, email address.

5. Deadline

The submission deadline is **30th of June 2009**. Authors will be notified whether they have been accepted for paper presentation or poster presentation by the end of August 2009. Those accepted as poster presentations may be given the opportunity, at a later date, of presenting in a paper should some presenters withdraw.

Any questions regarding the submission and publication process should be addressed to **geocomputation@unsw.edu.au**.

6. Acknowledgements

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7. References

Authority F, 1973, Stating the obvious: an interdisciplinary approach. *Journal of Entirely Predictable Results*, 63(2):1037-1068.

Fudgit B, Publish HWP and Writer AB, 1997, *Looming deadlines and how to deal with them*. Partridge & Co, Norwich, UK.

Learned C and Expert M, 1982, Reworking previous publications for fun and profit. In: Doctor K and Professor B (eds), *Proceedings of the 2nd International Conference on Something You Thought Was Relevant But Isn't Really*, Los Angeles, USA, 120-149.