The Transition to High Resolution Digital Surface Models: Improvements in Visibility Analysis Performance

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1. Introduction

The field of digital terrain modelling has witnessed a "revolution" in recent years with the development and availability of high-resolution remotely-sensed datasets (e.g. radar and lidar). These data are often sourced from primary acquisition techniques, and will contain additional surface information such as buildings, vegetation and roads. This has led to advances in "digital surface modelling" applications, such as radiocommunications planning and intervisibility analysis, while more realistic visualisations and fly-by animations are now possible. At the same time, a large research community has developed in order to remove or filter surface features from such datasets for applications such as hydrological modelling, where the true shape of the underlying terrain surface is more important than the features on it (e.g. Sithole & Vosselman, 2004; Maas et al., 2003).

The transition from digital terrain modelling to digital surface modelling brings with it a need for better data models, algorithms, and understanding of the nature and errors in such data. In some cases, there is a need to re-appraise traditional GIS algorithms to take account of the use of digital surface models (DSMs) instead of digital terrain models (DTMs). For example, for viewshed analysis there is an understandable belief that a DSM will be more accurate than a DTM for "built-up" terrain, as the buildings and vegetation will be integrated with the terrain model. However, this is not always the case, as the observer or target location may end up on top of a building or on top of the vegetation canopy, rather than at ground level. In most cases, additional information is required to determine the nature of each location in the DSM. Without this knowledge, spatial analysis such as visibility analysis will continue to be problematical and error-prone. In addition, our algorithms have to adapt to be able to handle and process such additional information.

Furthermore, remotely-sensed DSMs exhibit a lot of "noise" in the surface model, rather than distinct or uniform representations of features (e.g. a building will rarely appear as a regular block with sharp edges and a constantly sloping roof). While this is not a requirement for all applications, except perhaps large-scale visualisations, it is useful in reminding us of the accuracy of our datasets. A "noisy" building can demonstrate the sensitivity of some forms of spatial analysis, such as intervisibility analysis, where a very small error in elevation can produce a completely wrong analsis/result. Noise in data sets such as DSMs will hopefully lead us to re-consider our approaches to some spatial analyses. In particular, for visibility analysis, it is perhaps more pertinent to re-consider the more widespread adoption of probability models in our GIS (e.g. Fisher, 1995).

This paper presents some of these considerations for the transition from digital terrain modelling to digital surface modelling and the implications and needs for GIS users. These arguments are discussed in the context of our experiences in revisiting the problem of visibility analysis applied to a variety of different DTMs and DSMs for an area of South Wales. In addition, the relative accuracy of each model is evaluated with a detailed field survey to verify each line-of-sight.

2. Methodology

With the development of many new DSM products, there is a requirement to evaluate and compare products with respect to performance or other criteria. This can be done at a number of different levels, including scale, accuracy, application accuracy, level of visualisation/realism, computational overheads, storage costs, and financial cost. For this research, it was decided that DTMs and DSMs would be compared with respect to the accuracy of intervisibility analyses. This is a good example, as visibility/viewshed analysis is one of the most popular uses of DTMs and DSMs, but very little verification work as to the accuracy of results is undertaken. Maloy & Dean (2001) demonstrate that the accuracy of viewsheds can vary widely, and that on average, commonly used elevation data and analysis techniques produce predicted viewsheds of only mediocre accuracy. Kidner et al. (2001) demonstrate that the results of DSM visibility analysis can improve by 44% compared to bare-Earth DTMs (i.e. the DSM was 93% correct for 365 line-of-sight calculations as opposed to 48% correct for a DTM). However, very little verification work has been undertaken to date, and very little at large scales. This study attempted to redress this shortcoming by evaluating visibility across a wide range of surface scales, and determining the relative merits (and increase in performance) of incorporating the surface features into the DSMs.

Eight DTMs/DSMs were used/produced for this study, based on a 6 x 4 km area of South Wales centred around the campus of the University of Glamorgan. The terrain can be best described as a series of hills and valleys, with the valleys being quite well developed (buildings, woodland and other vegetation). A selection of these are illustrated below in Figure 1.

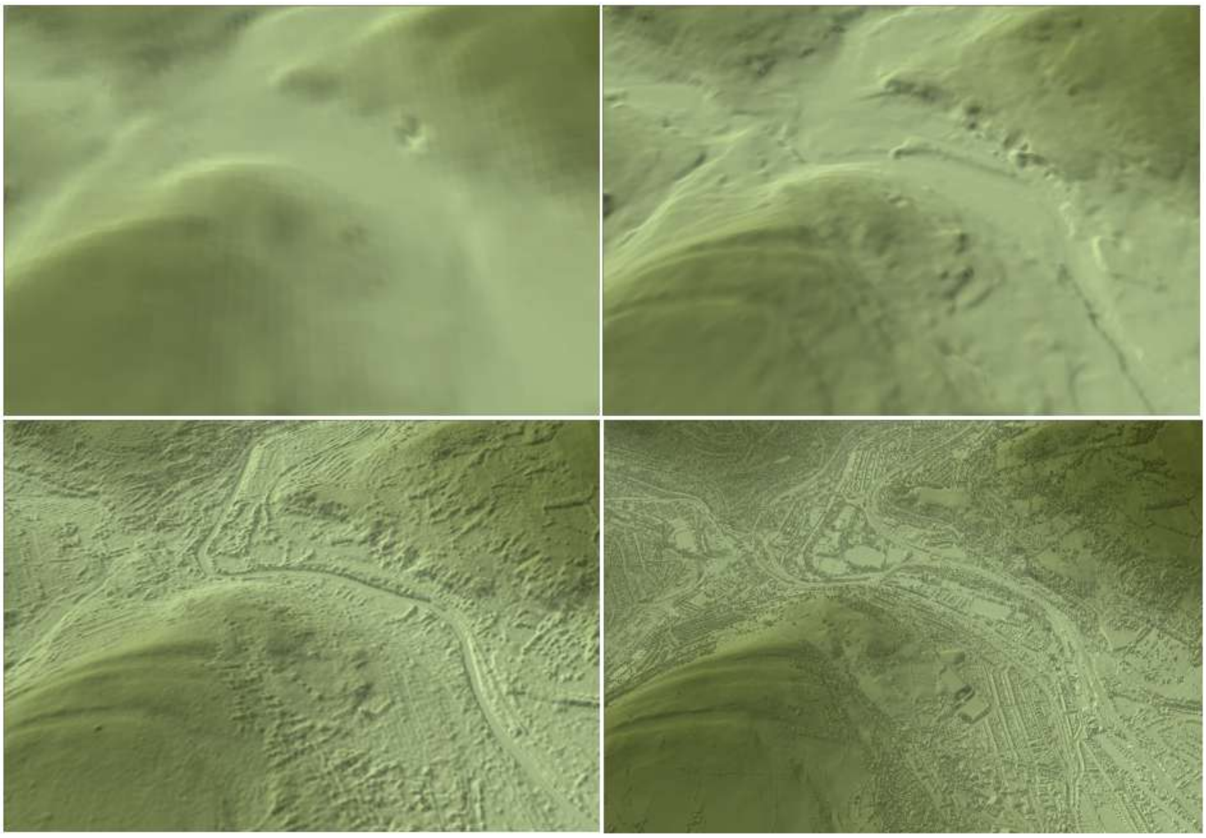

Figure 1 – Four of the DTM/DSMs used for the study area of South Wales (University of Glamorgan Campus is in the foreground). Top Left: O.S. 50m Landform Panorama, Top Right: O.S. 10m Landform Profile, Bottom Left: NextMap 5m DSM, Bottom Right: InfoTerra 1m DSM.

The full set of models evaluated included:

- O.S. Landform Panorama DTM (50m resolution)
- Landmap Interferometric DSM (25m resolution)
- Landform Profile DTM (10m resolution)
- Nextmap Britain Interferometric DTM (5m resolution)
- Nextmap Britain Interferometric DSM (5m resolution)
- Infoterra LiDAR DTM (1m resolution)
- Infoterra LiDAR DSM (1m resolution) (Last Pulse Return)
- Infoterra LiDAR DSM (1m resolution) (First Pulse Return)

These datasets will be described in more detail in the full paper. Figure 2 illustrates the surface cross-section derived from each model for a small profile across the University grounds. This clearly illustrates the differences in elevation between models, and not just due to the presence of surface features.

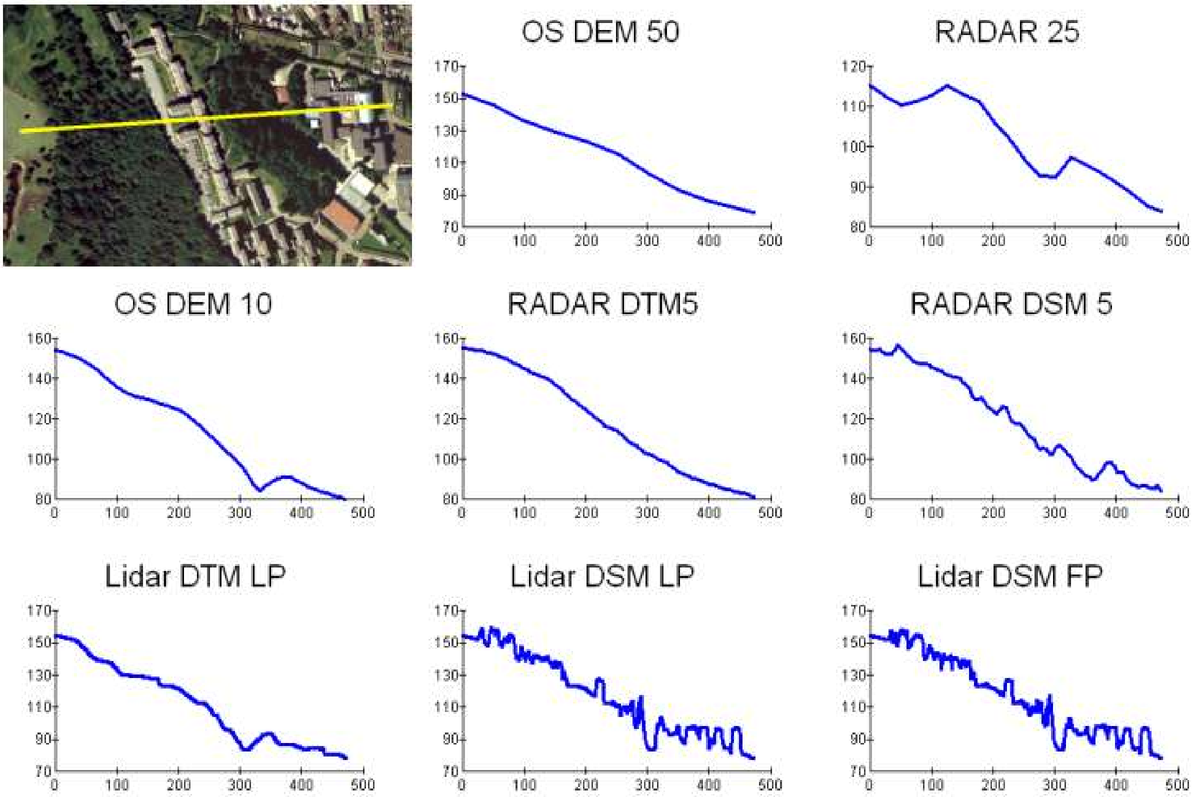

Figure 2 – Surface cross-sections through the eight DTMs/DSMs used in this study for a small profiles across the University of Glamorgan campus.

Viewsheds were generated for each model for three local communications masts (Figure 3) in the study area to identify areas of discrepancy. These areas were then selected for further fieldwork verification, i.e. identifying hundreds of individual observer locations for line-of-sight (LOS) analysis to the masts. As part of this field study, these locations were then surveyed using Kinematic GPS and the visibility to the masts recorded. The LOS results were then calculated for each of the DTM/DSMs.

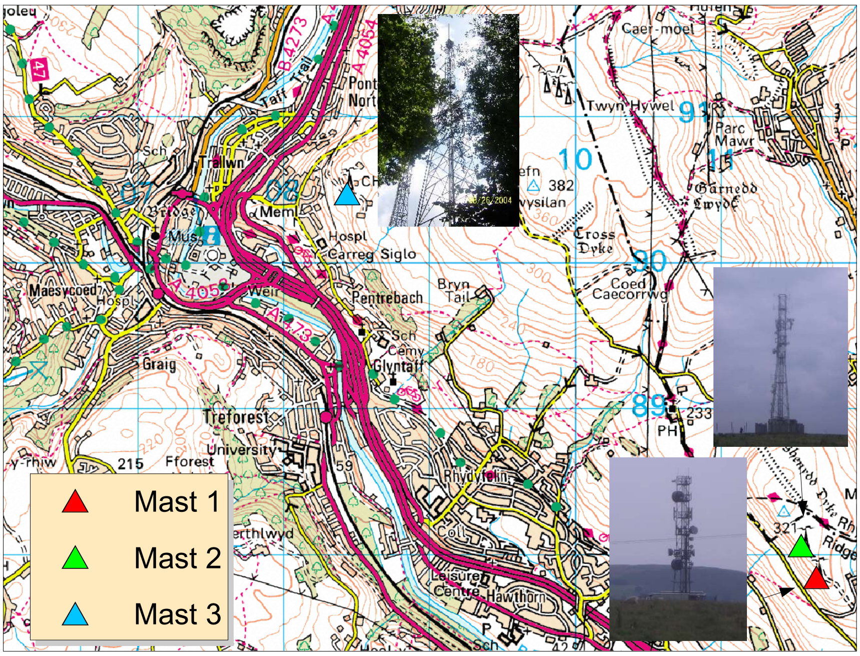

Figure 3 – 6x4 km study area and the three masts used in the viewshed and LOS verification analysis.

In general, the results were very good for the DTMs, and far better than expected (with respect to Kidner et al.'s 2001 study). This is probably due to the nature of the terrain and the target locations of the masts. The accuracy of the models varied from 64% for the O.S. 50m Landform Panorama DTM to 88.5% for the Infoterra 1m LiDAR (first pulse return) DSM. The full results and an analysis of them will be presented in the full paper. However, the results were very sensitive to the accurate positioning of the observer (hence the need for kinematic GPS), as very small lateral movements can have a large impact on the results of the LOS (e.g. see Figure 4).

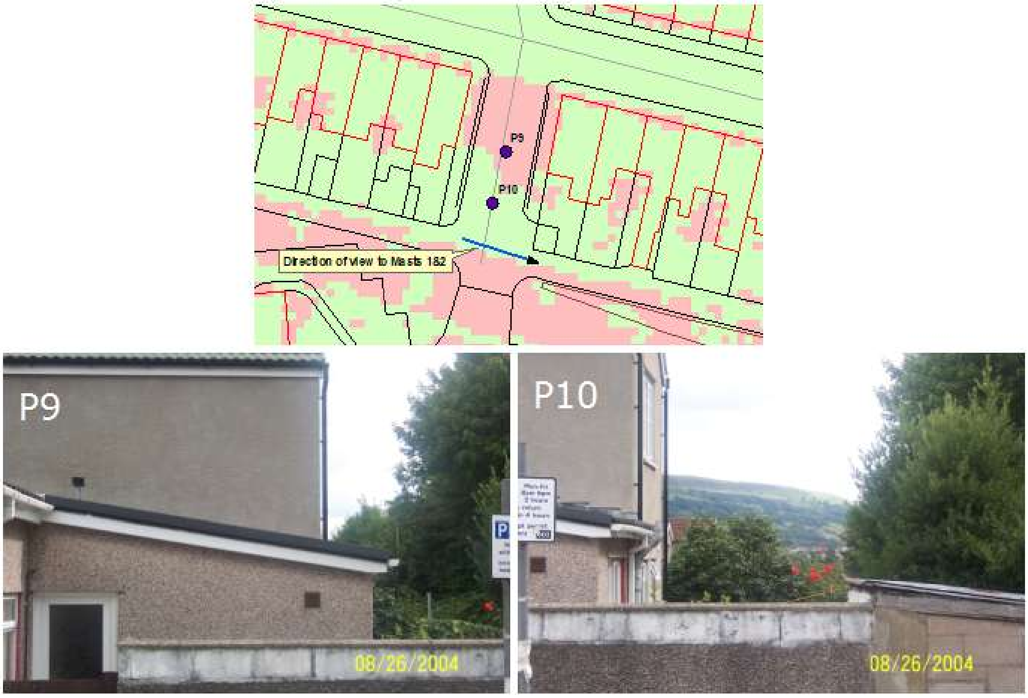

Figure 4 – Illustration of the difference in LOS for a very small lateral movement of the observer (from P9 to P10) due to the relative position of a building in the foreground. The top figure illustrates this on the map together with the viewshed results.

In order to compensate for this, the sensitivity of each observer location is analysed with respect to surface features in the vicinity. A Monte Carlo simulation is set up by applying a small offset (e.g. 50 cms) to each of the x,y,z coordinates of the observer. This can determine profiles where a wrong result may be returned due to very local noise in the DSM. Similarly, further probabilistic simulations can be applied to all points in the cross-section (Fisher, 1995). These issues will be described in more detail in the full paper.

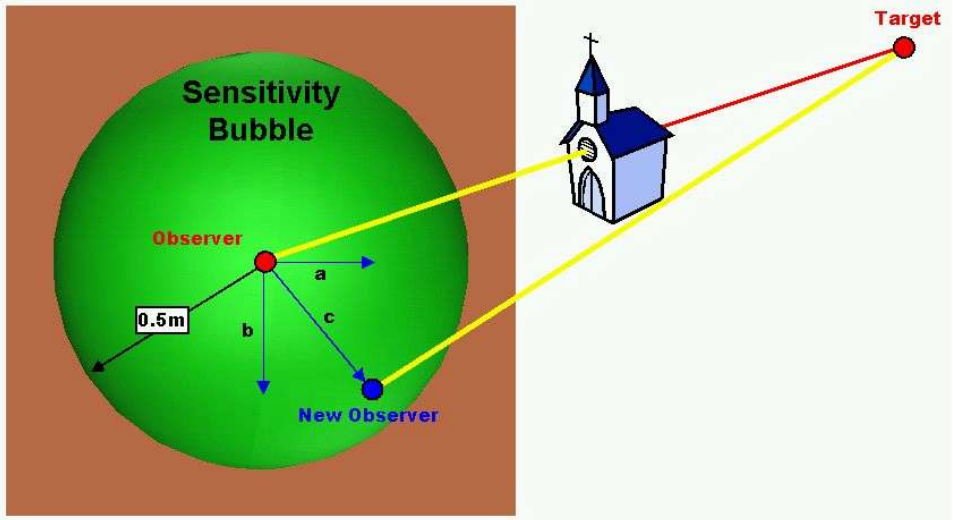

Figure 5 – Concept of the Sensitivity Bubble to analyse the stability of the observer location for LOS analysis.

3. References

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4. Acknowledgements

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