Summary Paper for Session: Data Capture, Processing, Integration and Application of High Resolution DEMs

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EXTENDED ABSTRACT

Originally when preparing this session our view of a high resolution DEM (Digital Elevation Model) was, DEMs with a spatial resolution of 10 metres or better and a vertical accuracy of tens of centimetres and based on dense measurements rather than interpolation from sparse contours or spot heights. This definition is particularly relevant for LiDAR derived DEMs that are rapidly being developed. However this definition needs to be broadened as the principle established by the papers presented in this session indicate that, a high resolution DEM is defined by the landscape process scale the researcher is interested in. If this scale can be matched by the DEM resolution and data capture technique then DEMs can be defined as high resolution.

This paper summarises the current status of data capture, processing, integration and application of high resolution digital elevation models from the papers presented in the MODSIM07 conference. Knowledge gaps and future research directions are identified.

1. INTRODUCTION

Recent developments in high resolution data capture techniques to create DEMs have occurred in recent years. This in part is due to the increasing availability of large storage devices and faster computing power. Recently radar and LiDAR (Light Detection and Ranging) data acquisition methods have become more widely available resulting in much wider availability of high resolution DEMs. We are now seeing a rapid expansion and use of this technology. The rapid growth of these high resolution DEMs has in part moved faster then researchers have had time to assess and utilise the data to its full extent. Many questions sit open in users minds such as: Do these radar and LiDAR data capture methods require specific pre-processing routines? Do I need accurate field data validation to determine the true quality of the data? Is it more appropriate in some cases to rely on DEMs that are derived through more traditional creation methods such as interpolation from contour data? This session aims to bring together users of high resolution DEMs to share our collective experiences on the application of approaches and uses of these data sets. We hope to fast track our understanding of the latest technologies for DEM creation and highlight the areas we need to focus our thoughts and attention when choosing to use a high resolution DEM. DEMs, as with any model are a compromise between reality and what's achievable with available technology. In other words what compromises we are willing to accept.

This session was broken into four main theme areas.

(1) Dem data preparation for radar and LiDAR DEMs.
(2) Handling of large DEM data sets.
(3) Resolution and accuracy.
(4) Terrain analysis applications with high resolution DEMs.

2. PAPER SUMMARIES BY THEME

2.1. Dem data preparation for radar and LiDAR DEMs.

Mandlburger and Briese (this session) used Airborne Laser Scanning (ALS) to define areas vulnerable to flood inundation showing a case study of the river Drau (Carinthia/Austria). Mandlburger and Briese states that the quality of the DEM and subsequent hydrological modelling depends on how well off-terrain points are eliminated from filtering processes. Mandlburger and Briese uses a technique of looking at the full backscatter waveform to derive physical characteristics like the echo width and backscatter cross section. This gives a more robust interpolation by allowing a reliable classification of the point cloud into ground and off ground points. As ALS data can't penetrate water it was also necessary to combine the ALS data with river bed data obtained from echo sounding and terrestrial survey. Mandlburger and Briese highlights the importance of ALS sensor calibration, fine adjustment of the ALS-strip data, proper fusion of the ALS and additional river bed field data as well as the elimination of random errors.

Pfennig and Wolf (this session) utilise the elevation data from Shuttle radar Topographic Mission (SRTM). The resolution of this data is 30 -90m. The intent of this study was to utilise the data to generate hydrological terrain characteristics to be used in water balance modelling. The authors point out that over 90% of the worlds' catchments are ungauged and therefore a data set such as the near global STRM makes this a high resolution DEM due to its coverage in areas where elevation data would otherwise not exist. To utilise this data for hydrological applications flow barriers such as sinks in the DEM have to be corrected for. Pfennig and Wolf found that the commonly utilised sink fill algorithms still created artificial flow barriers as the STRM3 data is often effected by back scatter as the large pixel size captures axillary information from surrounding hillsides, buildings etc. Further to this a small change in elevation offset can create a artificial depression or a "digital dam". To overcome these issues the authors have developed a Landscape based Sink Algorithm (LaSA) that uses relief characteristics to support the selection of an optimal solution for sink filling. It utilises a rule set which assesses the ratio between the depth and area of a sink. After correcting the STRM3 data with the LaSA, hydrological indexes derived from terrain data could be calculated allowing for the authors to create hydrological response units for catchment modelling.

2.2. Handling of large DEM data sets.

Mandlburger and Briese (this session) discusses that the DEM derived from the ALS technique generated large data sets. This data had to be simplified to allow it to be used with hydrological models. Mandlburger and Briese argues that currently available mesh generators in Computational Fluid Dynamic (CFD) models focus on the physical parameters of grid calculations like angle, aspect and expansion rations, but this ignores the detailed shape of the ALS DEM. Therefore a data reduction approach of the ALS data was taken using a TIN approach and mapping areas of more importance for the CFD model and removing redundant points in flat terrain. Further to this the preliminary TIN approximation has its cells aligned to the principle flow direction within the river bed improving river flow estimations in the CFD models.

Hartcher (this session) discusses how research strives to investigate landscapes at finer scales to improve the accuracy of derived parameters. Hartcher then explores what are the implications for acquiring, processing, and ultimately having to store these data sets and deal with issues of increased cost for acquisition, security, sensitivity, and availability. The paper provides an assessment of the most viable coupling of spatial resolution and coverage area, in light of determining an optimal combination.

2.3. Resolution and accuracy.

Kinsey-Henderson (this session) compares a 100m interpolated DEM from contour data, the 3-second (90m) shuttle radar (SRTM3) DEM and a 10m reference DEM developed from high resolution photogrammic autocorrelation techniques. Slope values were compared between the 100m interpolated DEM and the SRTM to the reference DEM. Results showed that for flat alluvial areas the STRM and interpolated DEM over estimates slopes. Both the SRTM and interpolated DEM preformed well in areas >5% slope. However STRM DEM was superior to the 100m interpolated DEM in the low relief terrain (characterised by sparse and convoluted contours).

Vaze and Teng (this session) assessed the effect of different resolution DEMs on the calculations of catchment areas for use in a hydrological models. By resampling the 1m resolution DEM to 1, 5, 10 and 25m they assessed the variation on the estimations of watershed boundaries and indicated that resampling the LiDAR DEMs up to 25m lead to less elevation structure losses when compared to a 25m DEM derived from contours. The authors conclude that if computation capabilities exist then a resample 25m LiDAR DEM is preferable to a contour derived DEM.

Vaze and Teng (this session) in their second paper also assessed the accuracy of a 1m LiDAR derived DEM. Results from a statistical analysis are undertaken to investigate the accuracy of the 1m LiDAR DEM by comparing the LiDAR elevations at more than 12000 points (in steep as well as flat areas) with on-ground field survey elevations. The field survey points used to quantify the accuracy of the LiDAR data have a vertical accuracy of 1mm. Both flat and relatively steep terrains were assessed and the largest discrepancies were in the steeper areas.

Many topographic parameter, can be calculated from DEMs. Xin (this session) looked at the widely used parameter of slope. Xin demonstrated how each point fluctuates and decreases with the decreasing of DEM resolution and the mean slope varies inversely and regularly with increasing DEM size. To control this effect Xin developed a slope downscaling model by introducing a slope decreasing velocity, which can show the effect of slope movement between two different resolutions.

Dowling *et al* (this session) developed a very high resolution digital elevation data set covering a $1m^2$ area, at 2.5cm resolution measured at varying intervals over a 20 year period to examine soil erosion and deposition. The results show that the erosion rates from high density $1m^2$ sampling compares reasonably with erosion rates measured at 30 star pickets spaced at 20m intervals. This result giving insight into the issue of scale and what resolution is necessary. The authors also highlighted that finer the DEM scale the more necessity it is to update DEMs more frequently.

2.4. Terrain analysis applications with high resolution DEMs.

Guoan *et al* (this session) uses DEM terrain pattern recognition to identify spatial distribution of terrain feature points. They utilised a 25m DEM derived from 1:50 0000 contour maps. Terrain morphology and landform classification are controlled by features like peak points, saddles ridges and the methodology presented aims to help classify these features. The study concluded that surface terrain feature points showed that horizontal and vertical distributions of peak points had close relationships with landforms.

Wilford *et al* (this session) also used a 25m DEM derived from contours to model the major landforms of a catchment. To enhance predictions of catchment weathering profiles radiometric remote sensing techniques were used to help determine mineralogy differences. The main finding of this study was that the 25m DEM was a suitable resolution when enhanced with other remote sensed imagery to achieve the outcomes of this soil regolith mapping project.

3. DISCUSSION/CONCLUSIONS

We are at an inconvenient stage in terrain analysis research where we can capture and store fine scaled DEMs but to a large degree we are only just beginning to work out how to process, transfer and manipulate these data sets. As a response this session has established the view point that a high resolution DEM is relative to the scale of the landscape process you are trying to represent, and to overcome data handling, storage, transferability issues, authors in this session simplified high resolution DEMs to give more representation in areas where the landscape processes are needed and remove data in areas of less relevance.

The challenge for researchers is to not be driven by technology of DEM data capture but to find a suitable resolution to answer the question being asked. This requires an assessment of the most viable coupling of spatial resolution and coverage area. In some cases the best technologies still cannot quite match our technical requirements, such as identifying floodplain channel networks.

Another consideration when selecting a DEM resolution is that we need to consider that as DEMs become finer and more detailed they will become more susceptible to becoming outdated in the vertical context.

Some future research questions that have arisen from this session are;

- We need to be careful that the algorithms we are developing for processing and manipulating DEMs will work for DEMs acquired by different techniques. The most common problem will be that algorithms developed to work with smooth interpolated DEMs may not work on the noisy DEMs resulting from some data capture techniques. We should not expect users to have to remove noise in order to apply routine algorithms.

- We need to develop a library of algorithm techniques to avoid duplication of effort as we now begin advancing our research direction towards using finer scaled DEMs. We should encourage use and refinement of good methods rather than the creation of a range of competing slightly different methods.

- What use can we make of the multiple returns acquired from data acquisition techniques such as LiDAR?

- What are the most efficient ways to utilise technology for data storage and handling. Are new DEM storage formats required in addition to fixed resolution grids?

- Can coupling of other data sources with DEMs increase the interpretability of data sets without necessarily needing to use finer scaled DEMs?

- Can we integrate DEMs at different resolutions to provide different but compatible elevation data for different purposes?

- Can we provide good advice on fitness-for-purpose of different DEMs? Can we provide tools for DEM quality assessment?

For MODSIM09 we would like to encourage participants of this session to consider these research questions and prepare papers that will progress our understand for data capture, processing, integration and application of high resolution DEMs.

4. ACKNOWLEDGMENTS

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