

A convergent image configuration for DEM extraction that minimises the systematic effects caused by an inaccurate lens model

R. Wackrow^{a, *}, J.H. Chandler^a

^a Loughborough University, Department of Civil & Building Engineering, Leics. LE11 3TU Loughborough, UK - (r.wackrow, j.h.chandler)@lboro.ac.uk

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EXTENDED ABSTRACT:

Introduction

It is known that uncertain internal geometry of consumer grade digital cameras limits the accuracy of data that can be extracted. The uncertainties can be resolved by calibration and the potential of these sensors to maintain their internal geometry over time was assessed in Wackrow et al. (2007). However, residual systematic error surfaces, discernable in digital elevation models (DEMs), were identified in Chandler et al. (2005), Chandler et al. (2007) and Wackrow et al. (2007). These are caused by slightly inaccurate estimated lens distortion parameters and a theoretical proof was given in Fryer and Mitchell (1987).

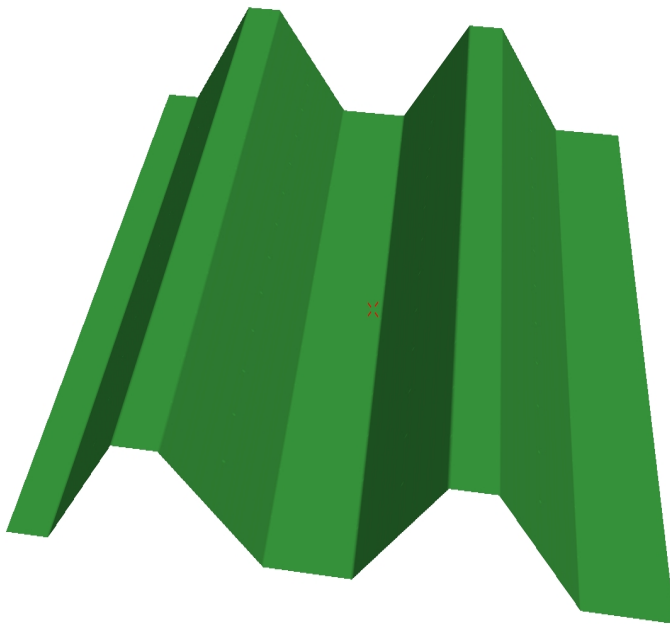


Fig. 1. Rendered Block model of the test field

Practical work

Research conducted at Loughborough University introduced the use of simulated data to ascertain the effect of changing lens distortion parameters on extracted DEMs and also to establish a methodology to minimise their effect. Hundreds of XYZ coordinates representing a non planar virtual 3D test field were generated. Figure 1 illustrates the geometry of this test field, created using the surface generation tool of the Erdas Image 8.7 software, at 1mm resolution. The XYZ coordinates were used to compute perfect photo coordinates using simulation (Fryer et al., 1994). The interior orientation included: focal length, principal point offset and one parameter ($k1$) to model radial lens distortion. The exterior orientation described a stereo image pair configuration which represents the photogrammetric normal case typically used in routine photogrammetry. The camera base was parallel to the object plane and the optical axes of the camera intersected the object plane orthogonally. The camera-to-object distance was set to 2.5m and a base to distance ratio of 1:7 was used. Each image covered the entire test field. An external self-calibrating bundle adjustment GAP (Chandler and Clarke, 1992) was then used to compute object coordinates for each of the photo coordinates in

which the parameters for the exterior orientation were re-estimated. The interior orientation parameters were controlled directly. The parameter $k1$ of the interior orientation was changed to +20%, whilst all other inner orientation parameters remained unmodified. The computed object coordinates represent the impact of the changed $k1$ parameter and the 3D surfacing tool of the Erdas Imagine 8.7 software was employed to create a DEM at 3mm resolution. This DEM was compared with the Truth DEM by interpolation and subtraction. The derived DEM of difference is presented in Fig 2. Areas with elevations less than -5mm are illustrated by solid red colour, solid green regions indicate height differences greater than +5mm and white areas represent regions of no elevation difference between the Truth DEM and the DEM in which the lens model was deliberately changed. Therefore, deviations must be attributable to the known inaccuracy of the lens model.

* Corresponding author

Different image configurations were tested, including simulation for a convergent stereo image configuration. The key characteristic of this convergency was that optical camera axes intersected the object plane at the same point and was achieved by modifying the exterior orientation parameters. The interior orientation in which $k1$ was changed to +20% used in the simulation process for the photogrammetric normal case, was also employed for the convergent image configuration. A DEM of difference was extracted and presented in Fig 3. By comparing both DEMs of difference, it is notable that the systematic error surface attributed to the inaccurate lens model was almost eradicated when a convergent image configuration has been used. It should be noticed that the elevation differences in Fig 3 were rescaled to $\pm 1\text{mm}$ in contrast to the DEM of difference for the normal case (Fig 2). This clearly indicates the potential of a convergent image configuration to minimise the “domes” arising from an inaccurate lens model, in DEMs.

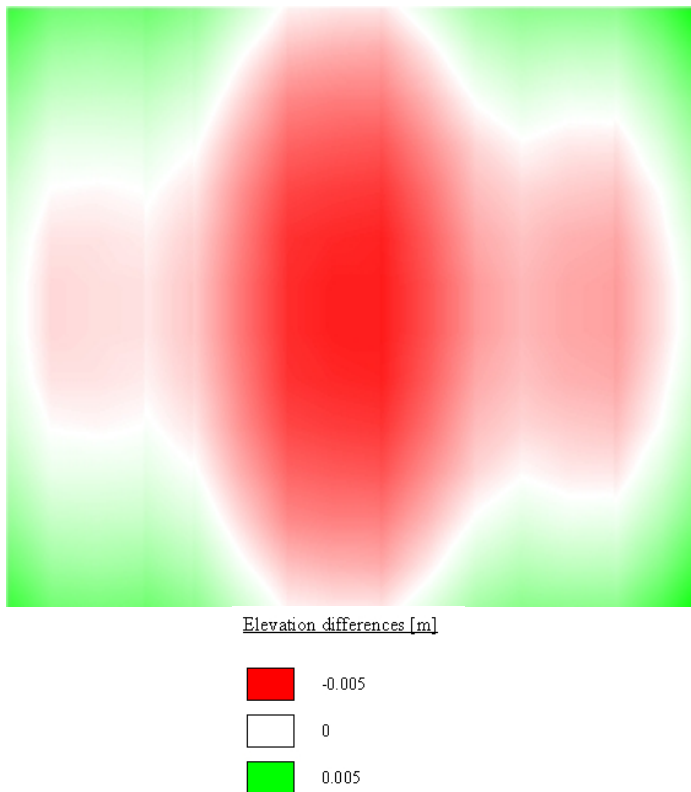


Fig. 2. Elevation differences, $k1$ changed by +20% (photogrammetric normal case)

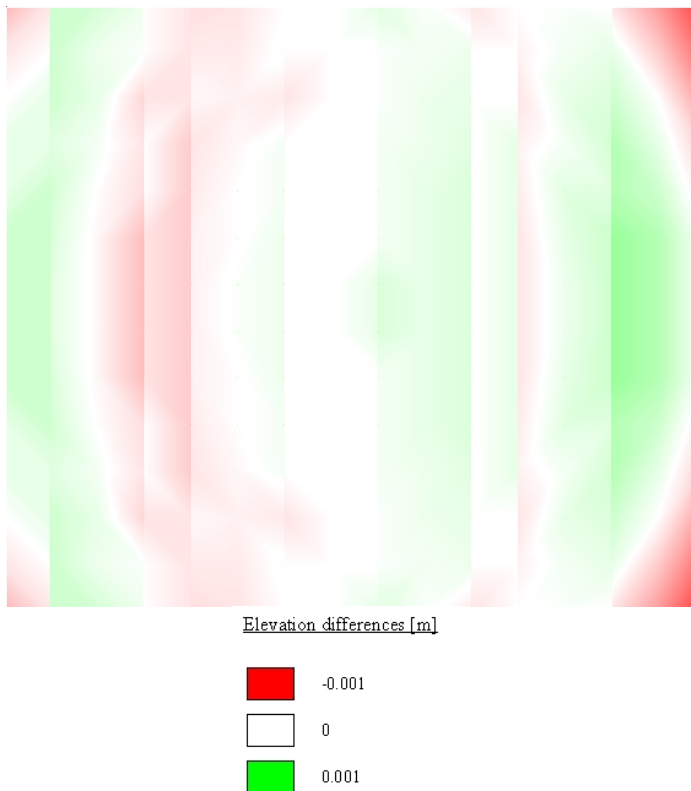


Fig. 3. Elevation differences, $k1$ changed by +20% (convergent case)

Practical tests

A Nikon D80 digital camera was used to demonstrate the potential of the convergent image configuration in practise. The camera was purchased for a research project, conducted at Loughborough University, to develop new approaches to estimating flood flows via surface videography and 2D & 3D modelling. The Nikon D80 is a non-metric camera and has to be calibrated for accurate data extraction. The calibration process included six frames of a test field (used for stability analyses of the Nikon Coolpix 5400 digital cameras (Wackrow et al., 2007)) in which two frames describe the photogrammetric normal case. Two additional frames representing the convergent image configuration were also captured. A DEM representing the whole of the physical structure of the test field was created at 1mm resolution to represent the “Truth”. The Leica Geosystems LPS 8.7 software was used to measure the control points manually, before 100 tie points were added automatically. The interior orientation parameters were estimated by using an independent self-calibrating bundle adjustment. DEMs were extracted at 3mm resolution for the normal and convergent camera configuration and compared with the “Truth DEM” by interpolation and subtraction. DEMs of difference and computed statistical quantities clearly confirm that a convergent image configuration eradicates the systematic error surfaces, caused by inaccurate lens distortion parameters. A full description of the results of the simulation and further practical tests (using the Nikon D80 digital camera) will be presented in a full journal paper to be submitted to The Photogrammetric Record.

Conclusion

The work presented this extended abstract identified the potential of a convergent image configuration to eradicate systematic error surfaces in extracted DEMs, caused by inaccurate lens distortion parameters. The result is significant as it can improve the accuracy of many routine measurement tasks and will further increase the use of cheap digital sensors for spatial measurement. Further experimental work is being conducted to demonstrate the practicability of this methodology for a variety of applications.

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