3-D urban modelling using airborne oblique and vertical imagery

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Abstract:

Often the existing methods of texturing 3-D urban models use conventional vertical imagery and libraries of generic textures. These may be sufficient for some applications of 3-D models like training simulation, gaming, and telecommunication planning, but in engineering and cultural heritage documentation there is a need for photo-realistic modelling for maximum levels of detail and geometrical accuracy. Photorealism and high levels of detail can be achieved through using terrestrial imagery but it is very time-consuming process particularly in large modelling projects. It is possible to improve efficiency by image capture from a moving ground based vehicle but this requires an extra process in the work flow if the initial modelling has been undertaken by aerial photogrammetric processes.

Pictometry vertical and oblique images are an established technique for visual inspection of the landscape as they provide good viewing directions and high levels of detail of not just the roof tops but also many facades of the buildings. The more conventional method of collecting aerial images with for example UltraCamD, can also provide excellent views of roof tops and some of the building faces when located away from the nadir on the images. Combining the imagery provides an opportunity to maximise the capture of 3D urban models from aerial imagery.

This paper will present the experiences from the research undertaken to date at the IESSG to explore the use of the Pictometry images and the UltraCamD images for 3D urban modelling. Nottingham is the study area for this research.

The extraction of 3D geometry for buildings in the study area has been performed using both vertical Pictometry imagery and UltraCamD imagery. The high metric qualities of the polygons extracted from the UltraCamD images can be used as a bench mark (BM) to check the accuracy of polygons obtained from Pictometry.

Planimetric and height comparisons of the extracted features from Pictometry system with the BM results have been performed. The results show that the Pictometry imagery produced good results especially in plan taking into consideration the differences in the GSD, and the two camera systems.

The results of automatically texturing the models have shown that using the vertical blocks of UltraCamD or Pictometry produces very good roof textures but limited in producing high quality on the facades. The use of oblique Pictometry images in texturing can produce very good facades but in some instances not such good quality roof textures. The successful combining of vertical and oblique Pictometry images provides an excellent opportunity to produce an efficient method of high quality urban model texturing.

The results do lead to investigations in to combining the aerial images with terrestrial images to further improve the quality of models particularly at the ground level. This is important as people normally view the urban environment from the pavement.

1. INTRODUCTION

1.1 Background

There is an increasing demand from a growing range of applications, for 3D computer 'digital' models of our environment. Dependent on the application defines the level of detail required in the 3D model. This is comparable to the traditional concept of the scale of mapping required to ensure fitness-for-purpose. In many applications there is no need for a geometrically correct 3D model of an environment as there is only a need to view an area of interest to support a decision making process. This has major financial benefits as the creating of 3D models is a costly process. However, a geometrically accurate 3D landscape model may be necessary in some cases particularly where for example; there is a need for the integration with engineering design information and for cultural heritage documentation (Smith et al, 2008). Photorealism and high levels of detail can be achieved through

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using terrestrial imagery but it is very time-consuming process particularly in large modelling projects. It is possible to improve efficiency by image capture from a moving vehicle (mobile mapping) but this requires an extra process in the work flow if the initial modelling has been undertaken by aerial photogrammetric processes.

To enable visualization, particularly in urban areas with deep building canyons, the most appropriate viewing angle is often from the air looking obliquely at the ground and facades of the surrounding buildings. Pictometry vertical and oblique images are an established technique for visual inspection of the landscape as they provide a good view and high level of detail of not just the roof tops but also many facades of the buildings (Pictometry, 2008). The more conventional method of collecting aerial images with for example the UltraCamD, can also provide excellent views of roof tops and some of the building faces when located away from the nadir on the images. Combining the imagery provides an opportunity to maximise and optimise the capture of 3D urban models from aerial imagery.

1.2 Aims and objectives

The aim of this paper is to present results of investigating the geometric potential of using the Pictometry images for 3D modelling and texturing. This will be done through exploring the following objectives:

a. Assessment of 3D geometry of all buildings extracted using both photogrammetric systems: Pictometry and UltraCamD.
b. Investigation into the quality of texturing the 3D models using vertical, oblique and combined blocks of both camera systems.

1.3 Methodology

The methodology is based on the following stages:

1. Creation of a test site with available:
   a. ground control and check points;
   b. Pictometry images;
   c. UltraCamD imagery.
2. Extraction of 3D geometry using semi-automatic techniques (manual roof measurement and automatic extrusion to the ground defined by a manual point measurement) with both image types. The Leica stereo analyst software is used unless otherwise stated.
3. Texturing of the 3D geometry from Pictometry and UltraCamD images was performed using automatic techniques in Leica Texel Mapper.
4. Comparison between the models from the two camera systems.

2. TEST SITE AND DATA

2.1 Test site

The IESSG has coverage of The University of Nottingham Campus with both Pictometry and the UltraCamD images and therefore forms an ideal test site for the research described. Ground control has already been established for the UltraCamD images and will form the basic control for the Pictometry images. By combining the two image sets together it is possible to assess the value of using the larger format UltraCamD images with the oblique images for 3D building model texturing. In addition, a small area in the city centre of Nottingham will be used.

2.2 Imagery

The available data consists of a block of 86 UltraCamD images with a focal length of nominally 100mm, a pixel size of 0.009mm flown at a height of approximately 500m to give a GSD of approximately 6cm, with 60% forward overlap and 30% lateral overlap. High quality in-flight GPS and IMU data was available. The Pictometry digital images cover approximately a 2 km^2 region of The University of Nottingham main campus and about 0.5 km^2 in the city centre area. The GSD for the oblique imagery is approximately 11 - 15cm with the flying height between approximately 975m and 1038m. The GSD for the vertical imagery is approximately 10 - 14cm. The pixel size is 0.009mm with a nominal focal length for the vertical camera of 65mm and the oblique cameras of 85mm. The forward overlap for the vertical images varies from 38% to 46% and the side lap from 25% to 36%. The forward overlap of the oblique imagery is approximately from 21% to 47% and side lap 23% to 45%. In-flight GPS and rotation information was available but the quality is not fully known.

3. TRIALS, RESULTS AND ANALYSIS

3.1 Geometric consideration of the Pictometry system

The Pictometry images are provided with in-flight information so that potentially, efficient photogrammetric processing can take place. The quality of the direct measurement of the position and orientation of the images will have a direct influence on the quality of the 'mapping'; the 3D point coordination. There are a number of issues to be considered related to the use of this imagery for mapping purposes, issues such as; camera geometry and calibration, aerial triangulation quality with and without the directly measured parameters, and choice of images for feature extraction and mapping. Several photogrammetric blocks have been created using the available GCP's and, independent check control points (CCP's); these include for the Pictometry vertical and oblique images and the UltraCamD images. The results of AT using LPS and Orima have shown that high quality image measurements and fit on the ground control points have been achieved for all the image blocks. The quality is also further improved by the oblique images which provide strong intersection angles at the measured points (Hamruni et al, 2008).

3.2 Modelling results

Building modelling using aerial photos requires different processes which can be summarised as following:

a. Extraction of 3D geometry of buildings using the roof outlines.
b. Extrusion of the digitised polygons of each building as a whole.
c. Texturing the 3D models using different techniques.

3.2.1 Extraction of 3D geometry

Extraction of 3D geometry for buildings in the study area has been performed using both vertical Pictometry imagery and UltraCamD imagery. These include 3D building models extracted from vertical Pictometry images and from UltraCamD images for the University campus, and 3D building models extracted from vertical Pictometry images for Nottingham city centre. Extraction of 3D geometry from the oblique images was not always possible because some roof outlines cannot be seen due to the tilt of the oblique images, figure 1.

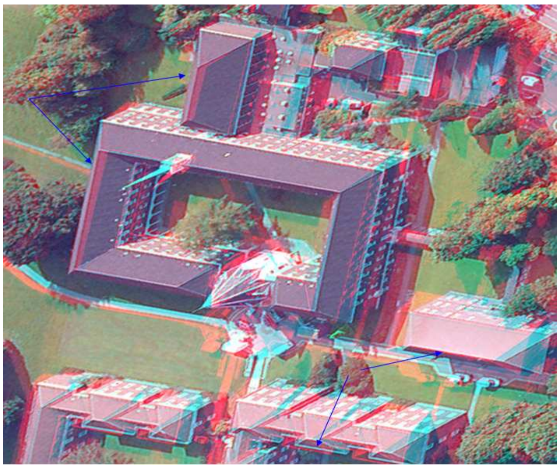

Figure 1. Some blind (dead ground) roof outlines in Pictometry oblique images (please wear anaglyph glasses)

All GCPs and CCPs have been measured on stereopairs using the vertical Pictometry block, oblique Pictometry block, and UltraCamD block. The results have been compared to the benchmark values (GPS coordinates) to check the performance of each set of images from stereo model measurement.

Block		Vertical Pictometry	Oblique Pictometry	UltraCamD
Min.	X(m)	-0.180	-0.179	-0.129
	Y(m)	-0.280	-0.177	-0.056
	Z(m)	-0.260	-0.272	-0.099
Max.	X(m)	0.110	0.174	0.092
	Y(m)	0.200	0.396	0.066
	Z(m)	0.120	0.127	0.103
St.dev.	X(m)	0.060	0.093	0.036
	Y(m)	0.100	0.126	0.029
	Z(m)	0.090	0.086	0.042

Table 1. Results of comparing stereopair observed photogrammetric coordinates to 37 ground measured check points

Table 1 shows that the standard deviation of the difference between ground 'check' coordinates and stereopair measured coordinates from the UltraCamD block and the Pictometry blocks. The UltraCamD results show they are better than the Pictometry by a factor of 2 in X and Z components and factor of 3 in Y component.

3.2.1.1 Accuracy of 3D extracted features

The 3D building polygons extracted from Pictometry imagery will be compared to the benchmark (BM) polygons (extracted from UltraCamD). Figures 2 and 3 typically show the plan and height differences of the features extracted from Pictometry images. Notice some systematic differences occurring. Table 2 shows a summary of the results achieved from comparing 977 points on 99 buildings in plan (X and Y components). It also shows the results of comparing 762 points on 100 buildings in height (Z component). From the results in Table 2, the GSD and the flying height between the two camera systems must be taken into consideration see section 2.2.

The Pictometry imagery has produced good results especially in X and Y taking into consideration the differences in resolution.

Component	X	Y	Avg. Z
Min.	-0.960	-0.800	-2.380
Max.	0.582	0.590	2.300
St.dev.	0.286	0.187	0.952

Table 2. Results of comparing 3D polygons extracted from Pictometry and UltraCamD

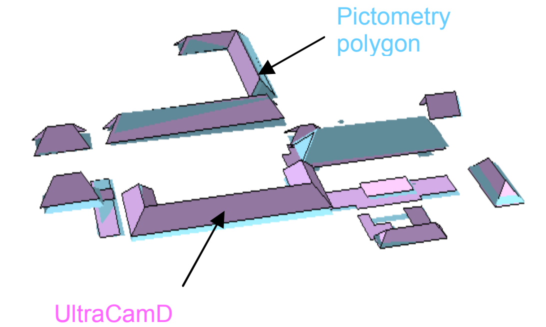

Figure 2. Buildings' roofs with some vertical exaggeration to show the height differences created by the two camera systems

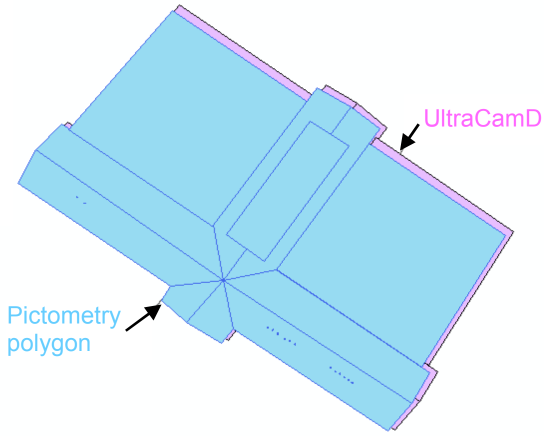

Figure 3. Two roof outlines superimposed over each other to be used for Planimetric comparison

3.2.2 Texturing results

Adding texture to the building models created is important since it makes 3D models more realistic. In texturing, colour images are mapped onto a 3D geometric surface. Knowing the parameters of the interior and exterior orientation of the images in the coordinate system of the geometric model, the corresponding image coordinates are calculated for each vertex of a triangle mesh representing the 3D surface. Then colour RGB values within the projected triangle are attached to the surface.

Texturing of the 3D polygons was performed using the vertical Pictometry block, oblique Pictometry block, UltraCamD block, a combined (vertical and oblique) Pictometry block, and combined UltraCamD and Pictometry block. The visual inspection of the textured models show that using either vertical Pictometry block or UltraCamD block has given very good roof structure but when it comes to façade texturing the quality was not as good as roofs quality, figure 4.

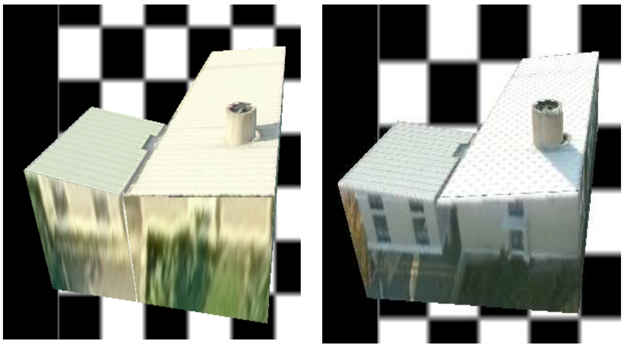

Figure 4. 3D building models textured using: left, vertical Pictometry block and right, UltraCamD block

When only the block of oblique images was used for texturing the 3D models, the façade texturing was of very good quality but the texturing quality of some buildings' roofs was reduced compared with the vertical images, figure 5.

Figure 5. 3D building models textured using Pictometry oblique images block

High quality images from the UltraCamD system have been used for texturing to compare with Pictometry images. Again, the roof texturing was of high quality while the facades quality is not so high, figure 6.

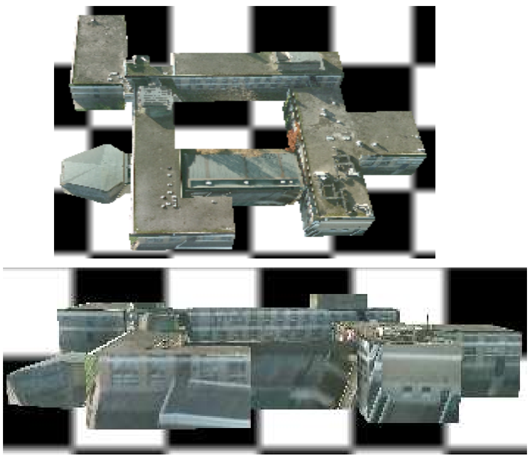

Figure 6. 3D building models textured using UltraCamD block showing the roof textures significantly better than the facades

Combining both vertical and oblique images gives the benefit of good quality textures for both the roofs and facades, figure 7.

Figure 7. 3D building models textured using Pictometry combined block, very good texturing quality of roofs and facades

The overall quality of the Pictometry images is characterized in some instances by the presence of haze which affects the texture mapping quality; figure 8 shows textured facades which are affected by the haze in the images used for texturing.

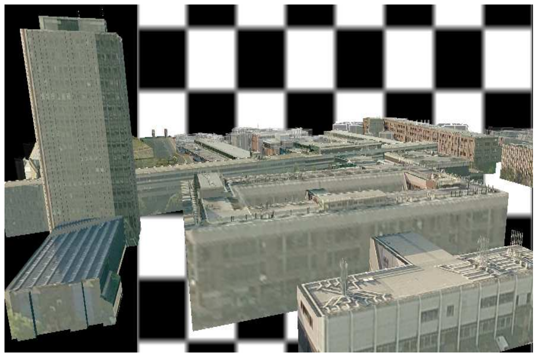

Figure 8. Texturing quality is affected by haze in some images

Figure 9 shows the effect of area that cannot be seen from the aerial images due to shadow or perspective view often called 'dead ground'. Figure 9 also shows a building with internal quadrangles which are very challenging to texture from airborne images.

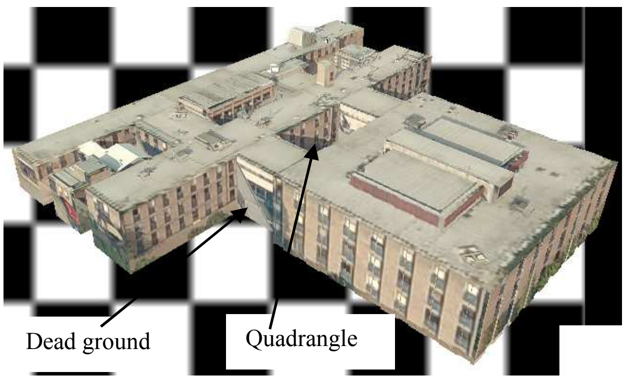

Figure 9. Texturing quality is affected by dead ground in images

Occlusions can occur often due to vegetation or dynamic objects (e.g. moving people or vehicles). Modelling these objects and the buildings behind correctly is often complex or time-consuming.

Figure 10 shows the effect of vegetation cover on the building facades. This can only really be overcome by the use of terrestrial images behind the vegetation or using patches of the visible façade to paste over the obscured surface.

Figure 10. Texturing quality is affected by vegetation close to the building facades

A section of Nottingham City Centre is shown as a 3D model in figure 11 which has been produced from the vertical and oblique Pictometry images. High quality 3D urban models can be produced of the geometry, roof textures and upper building textures. Figure 11 shows some of the issues presented above in the context of the urban environment. Difficulties of presenting good quality models for ground level viewing is challenging for aerial imagery. Unfortunately often the ground level view is very important for many urban model applications. If high quality street level viewing is required, then aerial imagery may need to be complemented with appropriate terrestrial images to produce the final result.

4. CONCLUSION

The results of 3D modelling show that using only vertical Pictometry images or only UltraCamD images has produced high quality roof textures but have limited value for high quality façade textures. Oblique Pictometry images can be used successfully for texturing the facades of 3D models when the vertical images are less successful. However, in some buildings the oblique images have difficulty to produce good textures.

The successful combining of vertical and oblique Pictometry imagery provides an excellent opportunity to produce an efficient method of high quality urban modelling. The combined block of both types of images has automatically produced very good quality roofs and facades textures.

The quality of texturing 3D building facades will further be improved in terms of level of detail and accuracy by including terrestrial images in the texturing process.

5. References and/or Selected Bibliography

Hamruni, A., Smith M., Jamieson, A., 2008, Investigation into the geometry of Pictometry imagery. RSPSoc annual conference, 15-17 September, 2008, Falmouth, UK

Pictometry, 2009. http://www.pictometry.com/
Accessed 03/03/09

Smith M., Kokkas, N., Hamruni, A., Critchley, D., Jamieson, A., 2008, Investigation into the orientation of oblique and vertical digital images. EuroCow08 conference. 30 January-01 February 2008, Barcelona, Spain

5.1 Acknowledgements

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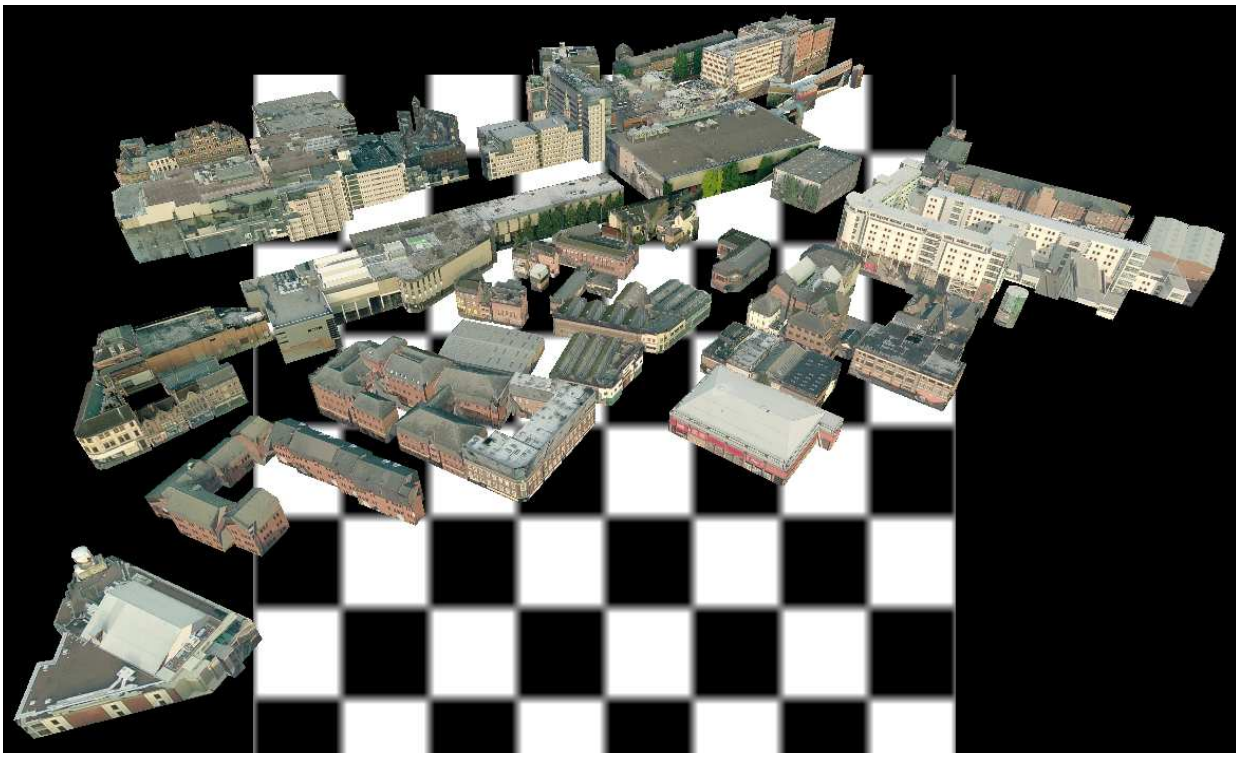

Figure 11 A collection buildings in Nottingham City Centre textured using the combined block of (vertical and oblique) Pictometry images