3D CITY MODELLING USING CONVENTIONAL SURVEYING METHODS – APPLICATIONS AND ADVANTAGES

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Abstract: *Three dimensional city models presents and animates all urban features such as buildings, roads, parks, street furniture etc on computer platform. A 3D model makes everybody to perceive real world easy. There are many applications such as urban planning, archaeology, virtual tourism, advertising, marketing, simulations, restoration etc. To achieve a 3D city model we can use different methods, all having pros and cons. In this paper we shall describe the creation of a 3D city model using conventional surveying methods and professional 3D modelling software.*

Keywords: *3D model,3D survey, N4ce Lite, SketchUp Pro*

1. Introduction

3D reconstruction is usually referred to as *modelling from reality* to distinguish it from computer-graphics creations produced by architects and 3D modellers for planning, games and movies.

The task of designing and executing a 3D modelling project requires clear understanding of the performance of existing equipment and methods. However, for digital 3D modelling techniques, there's historically no tradition of rigorous and systematic validation for the whole 3D modelling pipeline; the key performance criteria to be considered are: geometric fidelity, level of detail, model completeness and visual quality.

A 3D model can be presented different depending on final user requirements, so that can be:

- 3D Wireframe – is the easiest way of presenting a 3D building: it consists in lines and curves and shows only the edges in a transparent way, without texture and shading information; this technique is used mainly in CAD packages;
- Solid Model - surface models employ surfaces constructed across the wireframe to represent a "skin" that can be rendered;
- Texture or Photo Model – it is used for photorealistic visualization of the 3D models; texture mapping in its simplest form involves a single texture (image) being mapped onto the surface of a solid model.

The biggest advantage of the 3D model is its mobility and availability. Final product is a 3D city map, or part of it, that can be shown anytime and anywhere. 3D model allows people, who cannot or do not want to travel, to get to know the site/premises/entire area from their computer desks.

3D model is a valuable tool for:

✓ archaeological researches: investigate the topography, the visibility and the accessibility, monitoring the schedule of researches and discoveries;

- ✓ urban planning and architecture: elevations, engineering sections and visualisations can be extracted and generated using real survey data used to generate accurate 3D models;
- ✓ security and surveillance: it is much easier to detect and find black spots into a surveillance system using 3D models;
- ✓ virtual tourism: dynamic and static views can be created and serve as illustrations in publications or web sites; internet presentations and flythrough visualisations can be made and presented as well;
- ✓ advertising and marketing: everybody likes to promote their business using unusual means, so using visualisation impact is always a great method;
- ✓ operational planning for rescue services and transport management by setting up information systems based on 3D maps;
- ✓ simulation: by using accurate surveying methods, the 3D model can easily be used for simulations of storage, design and possible implementation of the created model into real world.

2. Capture and modelling techniques

The techniques can be divided into two main categories:

2.1 Terrestrial, such as

- Active 3D or range capture using laser scanners;
- Photogrammetric method provides exact and definite interpretation results;
- Geometric modelling by a CAD modeller based on surveying data, existing engineering diagrams and drawings such as floor plans.

and

2.2 Aerial, such as:

- Aerial photogrammetry (automatic extraction of buildings)
- Aerial laser scanning (extract buildings from discontinuities in height model)

2.1.1 Laser scanning provides highly and accurate representations of most shapes. Combined with colour information, either from scanner itself or from digital camera, a realistic model can be created. For all scanners, the accuracy depends not only on the technology used but also on the range, angle of incidence and surface characteristics. For the generation of 3D city models, a density of more than 2 points/square metre is required. The method is fast and accurate but requires expensive hardware and software plus highly trained staff as well.

2.1.2 Photogrammetric method is not as fast as laser scanning but is more accurate; The images are measured to an accuracy corresponding to camera quality, usually by precision comparator or by subpixel operators for digital images. 3D object coordinates are calculated by bundle adjustment with simultaneous camera calibration and the inclusion of any additional geodetic measurements. To generate 3D city models we don't need high resolution and expensive cameras but we need professional photogrammetric software and highly trained staff.

2.1.3 Geometric modelling based on surveying data is the classical approach where we use surveying techniques to acquire terrain details, digital cameras to get colour information and a 3D modelling software. To generate 3D city models we already have the surveying equipment and software to process raw data, we have digital cameras so the only investment is a professional 3D modelling software.

2.2 Aerial Imagery is well suited for the economic acquisition of 3D city models, making possible to recover structures as well as dimensions. In this case, for capturing a 3D point cloud, stereo pair of images are needed with forward and side overlaps of 30% and 60% respectively. To increase the accuracy in position we need to have buildings footprint measured by total station; the height accuracy is claimed to be about 0.2 to 0.5 metres.

3. Case study

3.1 Location

A specific town area, where there are buildings form 50s' and 60s', needs to be redeveloped; some of buildings need to be demolished and build new premises instead and other buildings need to be refurbished.

In this case, the Urban Planning and Architecture Department asked for a 3D model to be used in order to determine the best location and proper architecture of new premises, so the integration into the existing landscape will be made without disturbances for citizens that live in the area.(Fig.1)

Fig.1 Area of interest

3.2 Survey specification

Details required to be shown are fences, roads, footways, dropped kerbs, changes in surface, extents of vegetation, street furniture, service covers, drainage manhole covers, overhead lines and poles, buried service marker posts etc.

Roads should show levels to crown, channels, top of kerb and back of footway to enable a cross section to be determined. Cross – sections of existing roads (including those adjacent) shall be carried out at appropriate centres to enable the exact profile of the road to be determined. Kerb, channel, centre-line and back of footpath levels are to be included together with all street furniture, manholes, service covers etc.

Also, levels are to be taken to a 10m grid or as necessary to best define ground slopes /steps and contours to be shown at 0.5m intervals.

Floor levels and ridge/eaves heights of all existing buildings on the site should be provided in order to create a proper 3D model.

3.3 Survey equipment, techniques and precision

The equipment used for this job was Leica TCRP 1205 one man with traverse kit and for determining the right height it has been used a Leica RX1250X.

Because of the size of the area, 3.2 ha, configuration and volume of details, has been decided that the GPS points to be settled somewhere in the middle of area and we shall have 2 traverses, one for residential area, North side, an one for industrial area, South side, both closed on GPS points.

The geodetic network has been created using the VRS method with SR antenna on tripod and different acquisition time sessions (Table No.1)

First session of measurements (t)		Second session of measurements (t+1H)	
First RTK initialisation	Second RTK initialisation	First RTK initialisation	Second RTK initialisation
4 sessions/50 seconds each	4 sessions/50 seconds each	4 sessions/50 seconds each	4 sessions/50 seconds each
Final coordinates are averaged out of 16 measurement sessions			

Table No.1 – Schedule of VRS sessions

At time t we had 4 sessions of 50 seconds each, acquisition rate at 1second, same again with different initialisation. After 1 hour (at least) we had measured them again using the same method. At the end we had 16 sessions for the same point, and the internal software computed the averaged value for each control point.

Using this rule, we have measured 4 points as main geodetic control: S1, S2, S8 and S21. The accuracy for planimetric coordinates measured this way is about 2mm and for height is about 4mm(Table No.2)

S2	Class:	AVGE	Plan	CQ:	1mm	Height	CQ:	4mm
S1	Class:	AVGE	Plan	CQ:	2mm	Height	CQ:	2mm
S18	Class:	AVGE	Plan	CQ:	2mm	Height	CQ:	4mm
S21	Class:	AVGE	Plan	CQ:	3mm	Height	CQ:	4mm

Table No.2 Accuracy of GPS points

As I mentioned before, we have 2 different traverses, first one goes around the residential area, starts and closes on S1 and S2; second traverse starts on S1 and S2 but closes on S8 and S21

Traverses were measured having prisms on tripods and by measuring minimum 2 sets of angles Face Left/Face Right for backside and foreside.

3.4 Software

The software used for all survey computations, adjustments and reductions is N4ce Lite.

The adjustment of traverses was done using Bowdich method (a Bowditch adjustment distributes the linear misclosure proportionate to the distance of each leg of the traverse).

The software provides differences between provisional and final coordinates, so we can easily check if there is something wrong with one setup.

Details were picked up using codes, comma codes, strings, dimensions and macros, all being defined in the code table.

Traverse No.1 - misclosures		Traverse No.2 - misclosures	
Easting	4.0 mm	Easting	-8.5 mm
Northing	-6.6 mm	Northing	-9.2 mm
Height	3.0 mm	Height	-1.8 mm
Angular	13.3"	Angular	47.9"
LF Error	52049	LF Error	49289

Table No.3 Precision of traverses

The drawing was exported into the DTM module for editing and generating new features; here you can edit and manipulate survey data graphically. (Fig.2)

Fig. 2 The DTM model

DTM module is used to generate contours, volumes and sections as required.

At the end, if we were interested, we could go to CAD module for final drawing to be plotted; but this is not our case; we shall export the DTM using DXF format and this will be uploaded into SketchUp Pro for 3D modelling.

SketchUp Pro is professional software for 3D modelling but in the same time is very easy to use. You can build models from scratch or you can import DXF format file and use all information to model your premises. Based on real accurate 3D models we can extract sections, elevations, section-elevation, floor plans and real time information using software applications. In the next photo (Fig.3) you can see how the

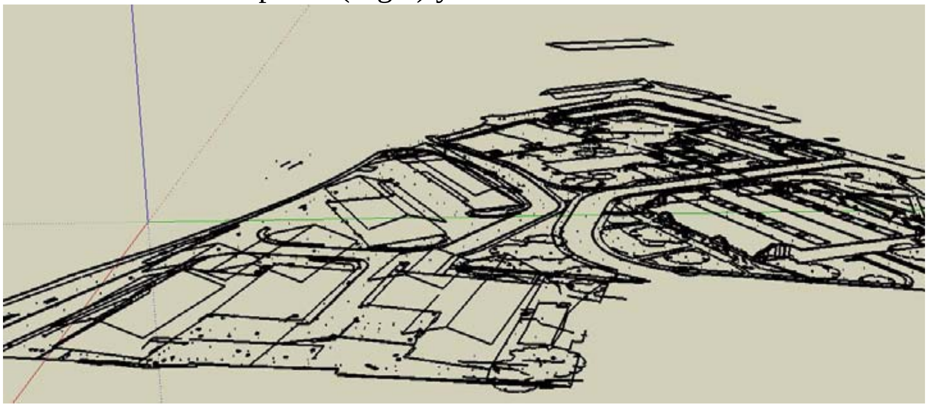

Fig.3 Sketch Up imports DXF

final data is imported and looks like in Sketch Up. You can see ridges, eves and ground detail in the same format; they even are split on layers; all layers have the same colour for now, but we can adjust that later.

Now we start to create the 3D model: buildings –using proper footprint and height information we define the building, roof and details above the roof; walls, stairs, slopes, pavement – using survey data we define elements and surfaces for each one; trees and bushes – there are specific routines to generate vegetation using field details and photo information.

After modelling process is finished, 3D model looks like our see next picture (Fig4)

Fig.4 Final 3D model in SketchUp

At the end, to complete our tasks and provide all information that client required, we shall provide sections for roads, schedule for trees and control data – all these plus the 3D model.

4. Conclusions

Geometric modelling based on surveying data it might be the lowest speed method for generating 3D models but the investment into hardware, software and training staff is minimum. In the same time, using this method requires less resources than any other method.

All the above were measured, processed and sent to client in less than 3 weeks in final version. You can believe is a long time but the resources were only one man, one instrument, one GPS unit and a computer.

Other advantage is that we can choose final accuracy depending of client requirements; some models can get photogrammetric accuracy as for urban planning and some can achieve low accuracy as for 3D city models, 3D maps and geo location

Counting all these, you can see there are clear advantages in using geometric modelling in order to generate 3D building models.

5. References

1. *Tunc, E.,Karsli, F.,Aihan, E. – KTU: 3D City reconstruction by different technologies to manage and reorganize the current situation. Commission IV, WGIV/6;*
2. *El-Hakim, S.F.,Beraldin, JA. – Sensor integration and visualization, chapter 10 of "Applications of 3D measurement from images", edited by Fryer J., Mitchell H., and Chandler J., Whittles Publishing 2007*
3. *Luhmann, T., Robson, S., Kyle, S., Harley, I., - Architecture and cultural heritage – 3D models, part of chapter 8 of " Close range photogrammetry", Whittles Publishing 2006*
4. *N4ce Lite – User manual and Training Book, AiC –UK*
5. *SketchUp Pro – User manual*