STREET FACTORY: PHOTOGRAMMETRIC 3D URBAN MODELS

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Abstract: This paper aims to present a new and innovative way to consider 3D urban database through the generation of automatic textured triangular irregular network over cities from oblique imageries. The novelty of this approach lies in the fast and automated algorithms capable of extracting dense 3D volume from airborne imageries compared to traditional methods where such 3D models are usually manually measured.

INTRODUCTION

During last few years, lots of developments have been done to generate semi-automatically three dimensional urban models from airborne imagery in combination with LIDAR height measurements. As a matter of fact, visualization of such 3D urban models has become quite common and range from simple box model with complex one with real texture. Moreover, new digital acquisition means are now available in order to take direct measurements for 3D modeling like oblique camera and mobile mapping system. This paper will focus on the automated processing of oblique imageries with a clear goal of generating high detailed 3D urban models.

Processing of oblique imageries is still a very tedious process. At least three main issues need to be solved in order to have a highly automated production workflow: amount of data, geometry and generalization from 3D point cloud. This paper will present techniques put in place in order to tackle those issues. Parallel GPU servers are demonstrated in order to process thousands of images in few hours. Advanced frame camera sensor model will be explained allowing precise geometric calibration of the camera (for both internal and external parameters). Thanks to this precise and fine geometric measurement, it is then possible to have full photogrammetric measurements between all different views from the oblique acquisition. Demonstration of precise and full 3D point cloud generalization allowing generation of so-called 3D triangular irregular network will be shown through numerous real oblique airborne acquisitions. Those examples will clearly show fine and detailed 3D models in urban areas of building, trees, man-made object with full detail like chimneys, balconies.

In a final statement, this paper will present an integrated solution named Street Factory™ and based on the merge of well-known Pixel Factory™ system and dedicated technology for 3D data base manufacturing; and showing also multiple applications of this new dense 3D textured TIN

3D DATABASE CLASSIFICATION

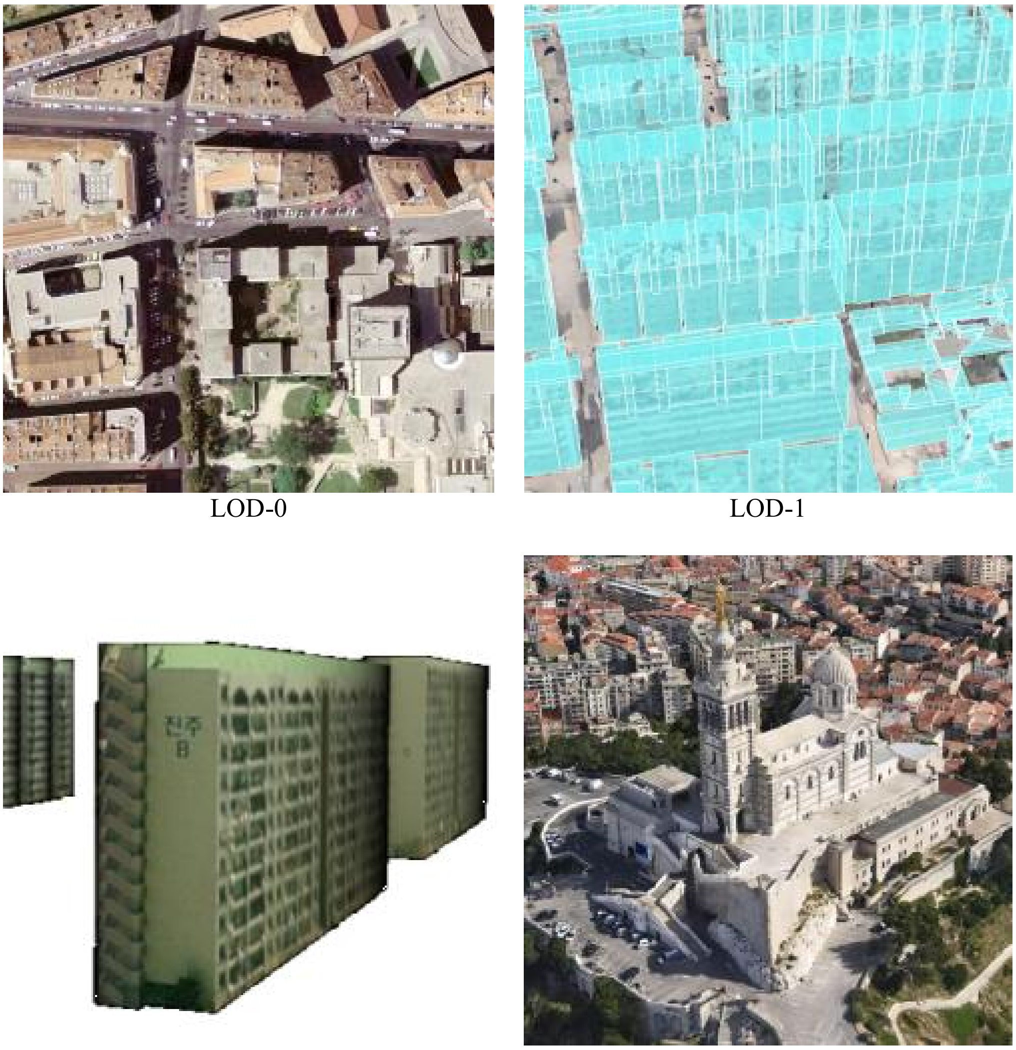
3D database can mean a lot of different things depending on the final application and also the processing methodology used to generate such database. A common notion for such database is referred as Level of Detail (LOD) which ranges from LOD-0 to LOD-4, with the latest having the most detailed and accurate information as demonstrated in next figure.

LOD-0 databases are the classic 2D representation of the world comprised of orthoimage mosaic and digital surface model. This is the core mapping of all applications and widely used in all GIS system as easy to integrate and manipulate.

LOD-1 databases are the first step to generate building information in 3D mainly by having simple 3D shape (like rectangular blocks) for all man-made objects in the landscape. This information is usually manually extracted directly from the digital surface model (either from stereoscopic measurements or LIDAR measurements) with the outline of each shape measured from orthoimage. This information can fit in numerous GIS system and its accuracy is usually around few meters as no precise measurements are available for the building façade and small objects like balconies / chimneys…

LOD-2 databases are an extension of the previous LOD-1 database with more detailed roof information and also texture information for the building. The updated roof information will depict different general roof geometry in order to have a better representation of buildings. Accuracy of such model is then directly linked to the manual time spent on digitalization from images. Moreover such database does not represent non man-made objects like trees. Texture information is most of the time applied automatically as soon after the manual edition of geometry meshes.

LOD-3 databases are the most detailed outdoor 3D database. All objects shall have accurate and dense 3D information (buildings, trees, bridges…). Small details like balconies, chimneys, fences shall be represented with a defined accuracy. Texture information shall be made available for all those objects. Usually such database is generated from terrestrial mapping system with dense LIDAR data complemented with 360 degrees photo acquisition. Aim of this paper is to show how to compute such database fully automatically and from airborne multi-view imagery acquisition.



LOD-0 LOD-1

LOD-2 LOD-3

Figure 1: 3D Database classification from LOD-0 to LOD-3

Regarding LOD-4 database, it will not be taken into account in this paper as LOD-4 are usually referred for indoor mapping which is not the topic of this paper.

AIRBORNE MULTI-VIEW IMAGERY ACQUISITION

Introduction

Airborne multi-view imagery acquisition, named also oblique airborne acquisition, has been promoted since many years with some famous companies like Pictometry, Leica and TrackAir. Such oblique images have been used in many GIS application but not directly for 3D automatic modeling. Nowadays all major camera manufacturers are releasing their oblique camera system as shown in next table.

Table 1: Main oblique camera system

Company	Camera name
GeoVision	SWDC-5
IGI	Quadra – Penta Digicam
Leica	RCD30 Oblique
Pictometry	Pictometry
TrackAir	Midas
VisionMap	A3 (need specific flight)

Processing of oblique imageries

Processing of such oblique imageries require some specific steps in the overall database processing workflow. Indeed the acquisition does no longer have one consistent viewpoint, nadir acquisition, but is comprised of five different viewpoints. This particularity is very important when managing the bundle adjustment of all those images as generation of tie-points between images has to take it into account. Moreover techniques used for bundle adjustment must be fully 3D and no longer have some hypothesis regarding a single viewpoint. Next figure shows how Street Factory™ system is able to generate thousands of tie-points between all views from an oblique data acquisition in few hours.

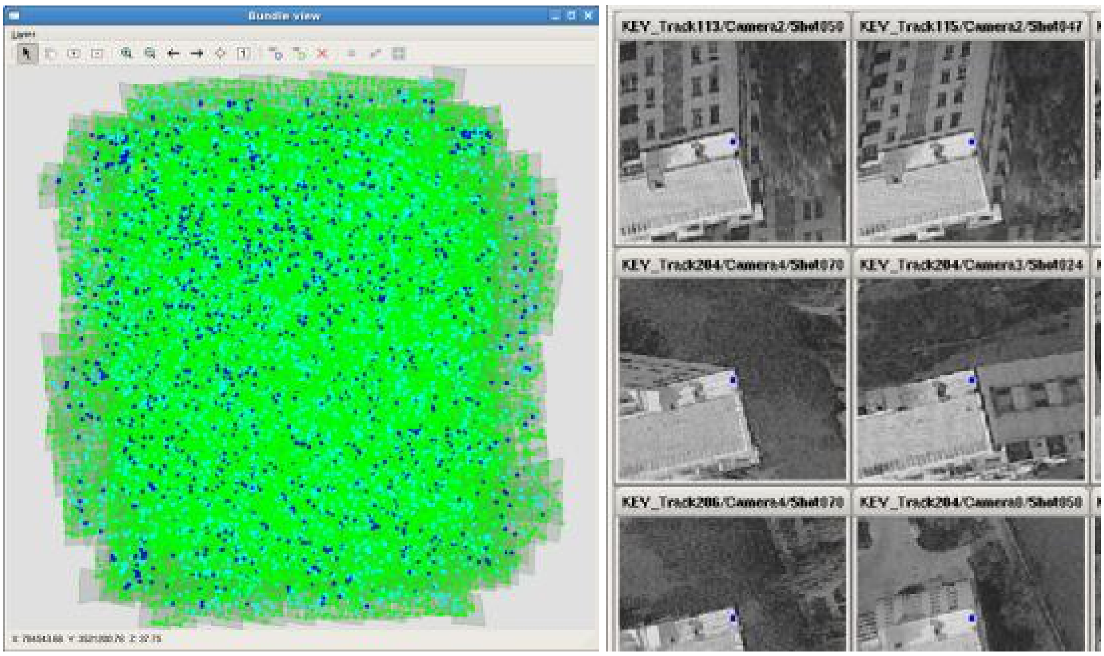


Figure 2: (left) Tie-point generation (40’000 for 6’000 images), **(right)** view of one tie-point on multiple images

Thanks to an advanced frame camera sensor model embedded into Street Factory™, it is possible directly during the production flow to auto-calibrate all five cameras internal and external parameters even without any ground control points. This robust and accurate sensor modeling is a key factor of the automatic 3D database generation as it will assess that all stereoscopic measurements from any views are consistent to each other even on large areas with thousands of images.

LOD-3 AUTOMATIC DATABASE CREATION

Multi-view stereoscopic measurement

Thanks to a perfect geometric adjustment available through Street Factory™ system for all oblique images, it is possible to have stereoscopic measurement from all available image pairs. The 3D stereoscopic measurement will generate 3D points not only from nadir pairs but also from all oblique pairs allowing precise and full 3D measurements of all objects like façade details, trees, bridges and so on. For that purpose high overlap between all images is required in order to achieve best accuracy for point cloud generation.

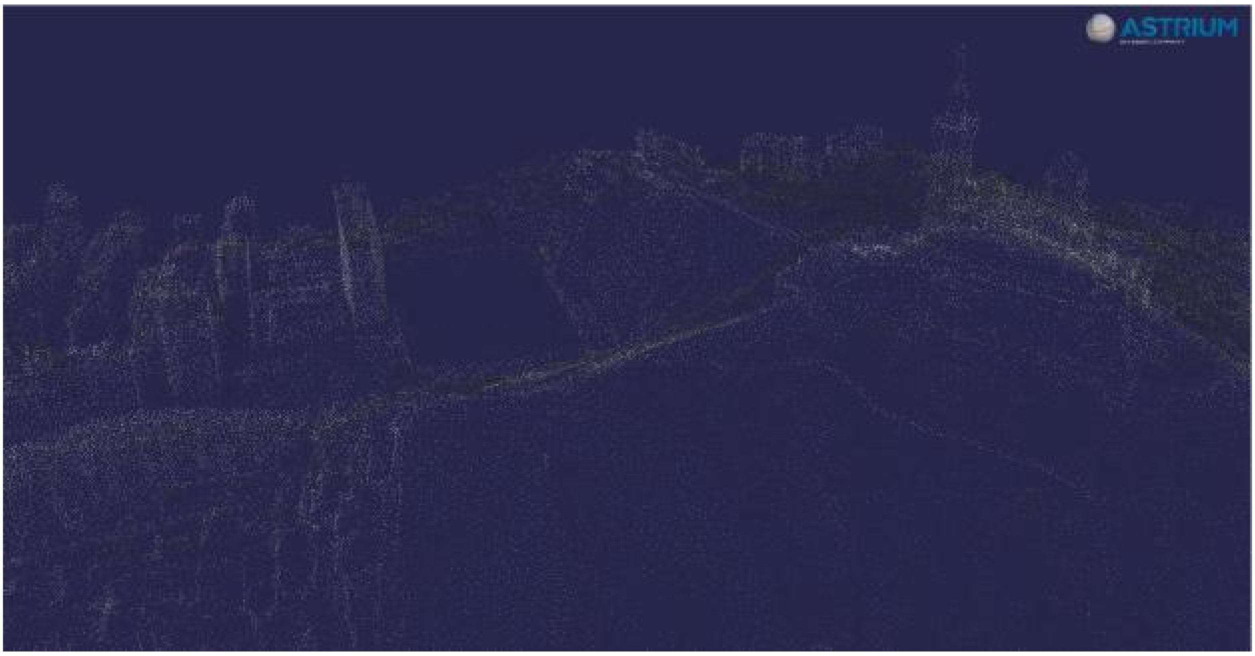


Figure 3: Example of 3D point cloud generation

Triangular Irregular Network generation

Having a dense 3D point clouds, the next steps of the automatic generation of 3D database is to filter and to generate a 3D triangular irregular network. The innovative algorithm used in Street Factory™ allows for real 3D volume TIN generation meaning it is possible to have disconnected 3D volume and also possible to see behind objects if like that in reality. This is achieved as the system is not only taking into account 3D position but also visibility information in order to constrain the 3D TIN generation.

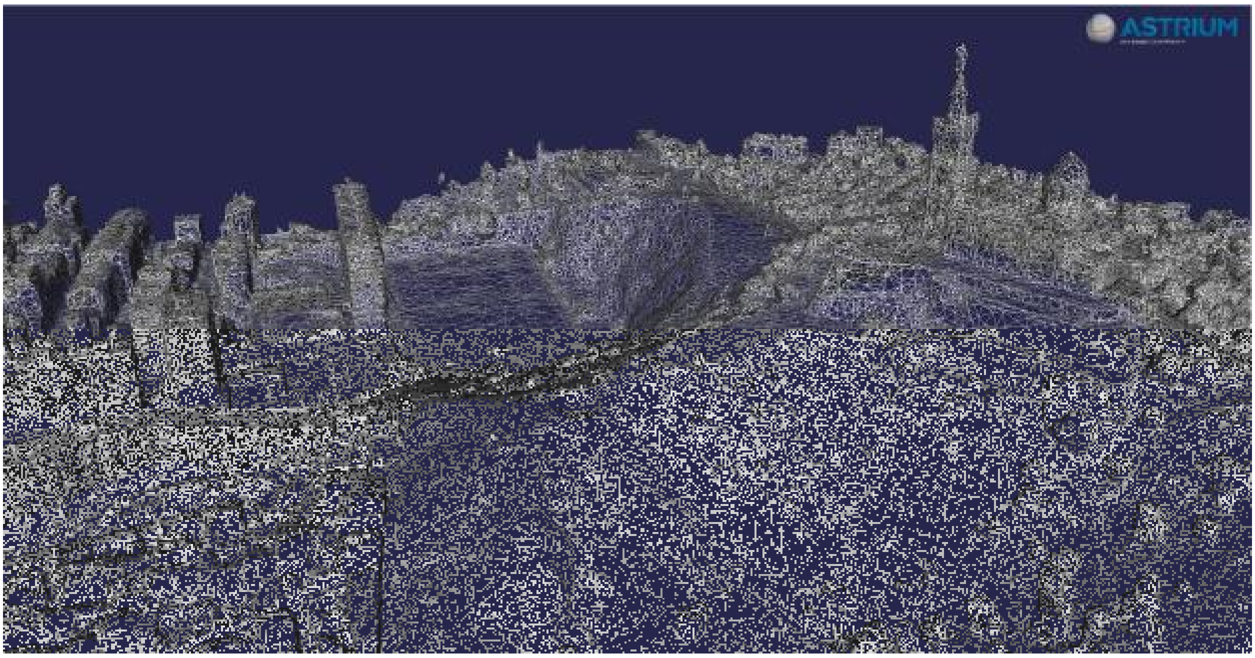


Figure 4: 3D TIN from previous 3D point cloud

As illustrated with following figure, major achievement of this TIN generation algorithm is the preservation of all 3D volume. On next figure, one can clearly see the benefit of preserving 3D volume where buildings are correctly mapped with roofs, columns and parterre. This precise and realistic modeling is important for numerous simulation applications and was not available through automated processes up to now.

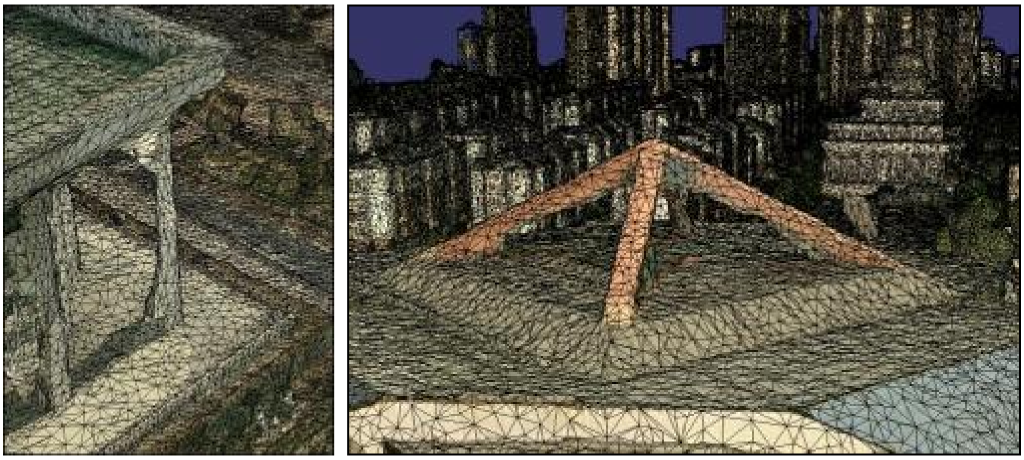


Figure 5: Example of full automatic 3D volume reconstruction

Multi-view texturing

Then using all oblique views and previous 3D TIN meshes, a multi-view texturing algorithm is applied in order to find the best texture for each position in the 3D scene. At the same time, color balancing is done between the different textures in order to keep consistent color information. Shadows and natural lighting are not removed to keep the natural and realistic look of the database.

Figure 6: Full textured 3D database model

STREET FACTORY™

Street Factory™ is a product using the technology and algorithms presented earlier in order to generate as fast as possible such 3D dense database, named 3D MOSAIC™. In order to achieve fast processing, major algorithms are taking benefit of multi-core and also multi-GPU capabilities. All computations are distributed on cluster of GPUs to be run in parallel thus speeding tremendously processing time. As a matter of fact, processing of such 3D MOSAIC™ over one square kilometers takes only 3 hours on an 8 GPUs cluster system from data ingestion to 3D MOSAIC™ generation.

Figure 7: (left) GPUs cluster system**, (right)** Example of 3D MOSAIC™

3D MOSAIC™ APPLICATIONS

Thanks to dense information available inside the generated 3D MOSAIC™ product, applications requiring direct measurements are possible using this kind of data. Moreover, 3D MOSAIC™ is using OpenSceneGraph format which is an open-source available 3D platform allowing numerous applications development using 3D MOSAIC™ product.

As an example, 3D MOSAIC™ are used in flood simulation application and risk management application as illustrated below.

Figure 8: 3D MOSAIC™ for flood simulation and risk management

Accuracy of 3D MOSAIC™ is directly linked to the airborne data acquisition. Without any external Ground Control Points, it is expected to have XYZ accuracy between 0.5 to 1.5 times initial image ground sampling distance. It means that for an acquisition with 10cm imageries it is possible to have XYZ accuracy up to 5cm. As example, the database illustrated below has been fully automatically processed from MIDAS images; and both planimetry and altimetry output accuracy is between 15cm to 25cm.

Figure 9: 3D MOSAIC™ over Marseille city

CONCLUSIONS

This article has introduced a new concept of 3D database named 3D MOSAIC™ which is generated automatically from airborne oblique imagery acquisition. 3D MOSAIC™ can be processed quickly and fully automatically thanks to new technology Street Factory™ introduced this year. Major benefits of such 3D information are full availability of real 3D measurements including building façade details, bridges, and real natural details like trees.

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