Automated Processing for 3D Mosaic Generation, a Change of Paradigm

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Abstract: This paper aims to present the change in paradigm introduced by automatic methods for 3D database processing either from oblique airborne imageries or from mobile mapping system. This change in paradigm is now allowing multiple applications to be derived from those 3D databases which was not possible just few years ago.

INTRODUCTION

During last two years, a boom has been seen in the use of new generation of 3D database mainly pushed by the automatic processing of oblique imageries into real 3D models, known as example as 3D Mosaic. The introduction of such product has changed the way how people are interacting with 3D information and using that 3D information into their geographic system and organization. This paper will focus on the advantages of automated processing for 3D mosaic generation with some real case applications of such final product.

Indeed, introducing automatic processing for such database has changed the current paradigm that 3D realistic database can only be acquired and generated with lots of manual work and taking months to get small area. Introducing fast automatic processing gives ability to map a whole city in few weeks and then to make available such data with very dense 3D details to numerous actors which can then integrate it into their application. It opens also real possibilities of asset monitoring, urban management on large scale while lowering the overall cost of 3D database management and maintenance.

Demonstration of such automatic processing of large 3D dataset in short time and comparison with classic technology will be shown through numerous real-case examples. Real end-user applications will also be provided showing the benefit of such approach compared to classic means of 3D database production.

3D MOSAIC

Database classification

3D database have different meanings depending on final applications and also 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.

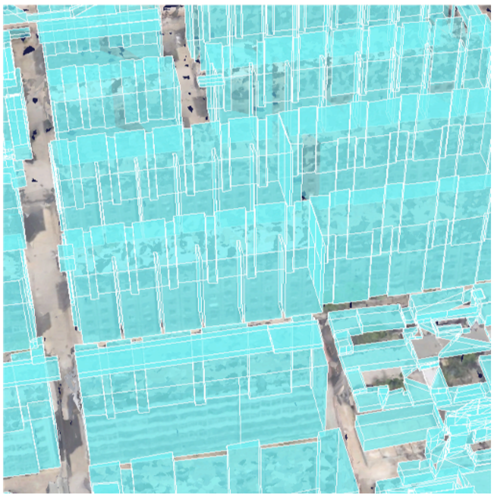
LOD-0 databases are the classic 2D representation of the world comprised of orthoimage mosaic and digital surface model. This is the core mapping of all applications and widely used in all GIS system as easy to integrate and manipulate.

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

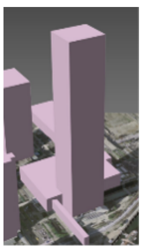
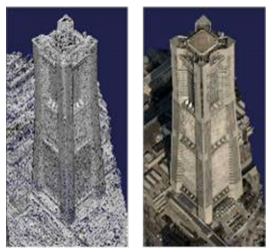
LOD-2 LOD-3

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

Processing methodology classification

The processing methodology for 3D database can also differ a lot depending on the targeted LOD model and application. This can range from a totally manual process to a full automated process using tools like Street Factory. The following table illustrates some of the processing methodologies and their pros / cons.

Table 1: 3D Database processing methodology classification

	Block building	**Nadir building**	**CG modeling**	**3D Mosaic**
				
Reality	Not good Cubic shape	Normal Detailed ground & roof	Good Realistic models only done manually	Excellent Realistic thanks to high density 3D TIN
Data size	Not large Ground and cubic model only	Large Need a lot of NADIR image	Large CG building with pseudo – real texture	Quite Large Need a lot of multi-view images
Automation	Normal Needs 2D footprints	Good Almost automatic	Not Good Ground is same as previous but many building manually extracted	Good Fully automated
Methodology	Stereo Plotting, LIDAR, DSM LPS, SUMMIT, etc	Nadir image matching, Bundle, DSM PIXELFACTORY,LPS etc.	CG manual labor Pseudo texture 3DSMAX, etc.	Multi-views image matching Bundle, Dense TIN STREETFACTORY, etc.

3D MOSAIC GENERATION

Sensors

In order to generate fully automatically a dense 3D database as shown previously and named 3D Mosaic, it is important to have lots of measurements which can be obtained by airborne multi-view acquisition with oblique cameras, and also by combining ground mobile acquisition. Next table lists some of those sensors which can be used for 3D Mosaic automatic generation.

Table 2: Sensors for 3D Mosaic generation

Company	Camera name
GeoVision	SWDC-5
IGI	Quadra – Penta Digicam
Leica	RCD30 Oblique
Pictometry	Pictometry
TrackAir	Midas
VisionMap	A3 (need cross flight)
Microsoft	UltraCam Osprey
Shanghai Hangyao	AMC580
TopRS	TopRS
PointGrey	LadyBug

Street Factory automatic processing

Processing of such imageries require specific steps in the overall database processing workflow. Indeed the acquisition does no longer have one consistent viewpoint, nadir acquisition, but is comprised of multiple different viewpoints which can mix also airborne and ground acquisition. 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.

Thanks to an advanced frame camera sensor model embedded into Street Factory™, it is possible directly during the production flow to auto-calibrate all 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, and even between airborne and ground acquisition simultaneously. The 3D stereoscopic measurement will generate 3D points from all views 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. 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. Innovative algorithms used in Street Factory™ allow for real 3D volume TIN generation as depicted in the following figures. Then using all 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

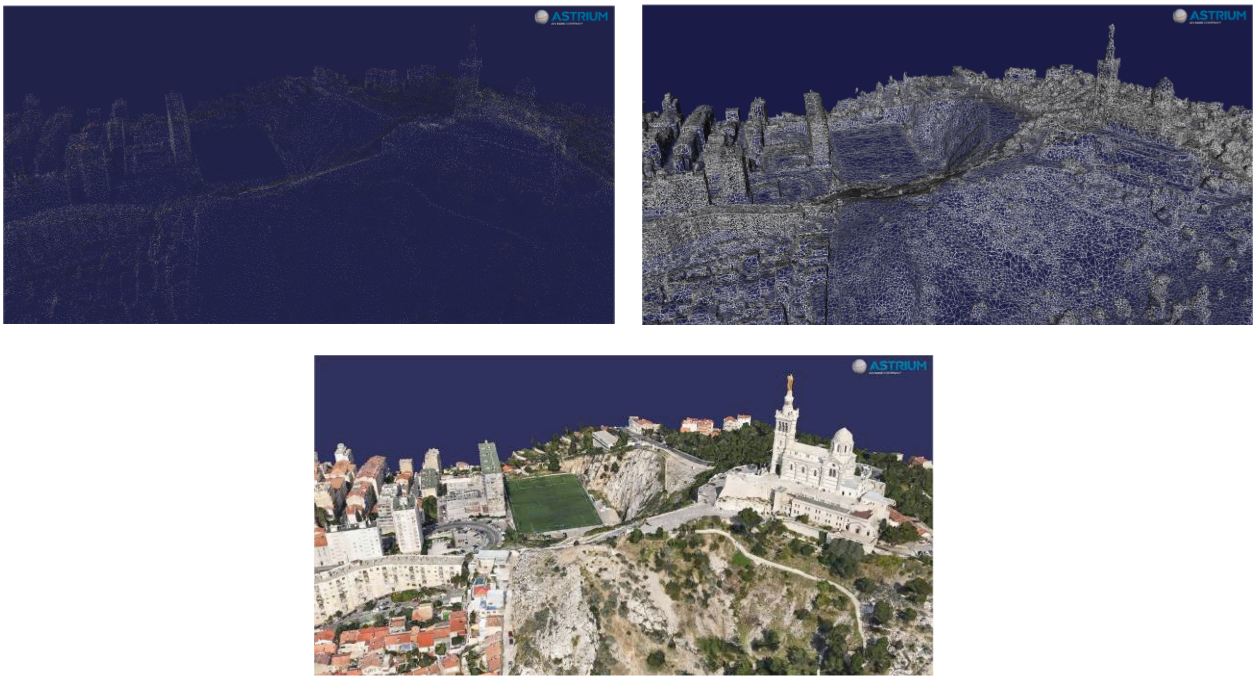
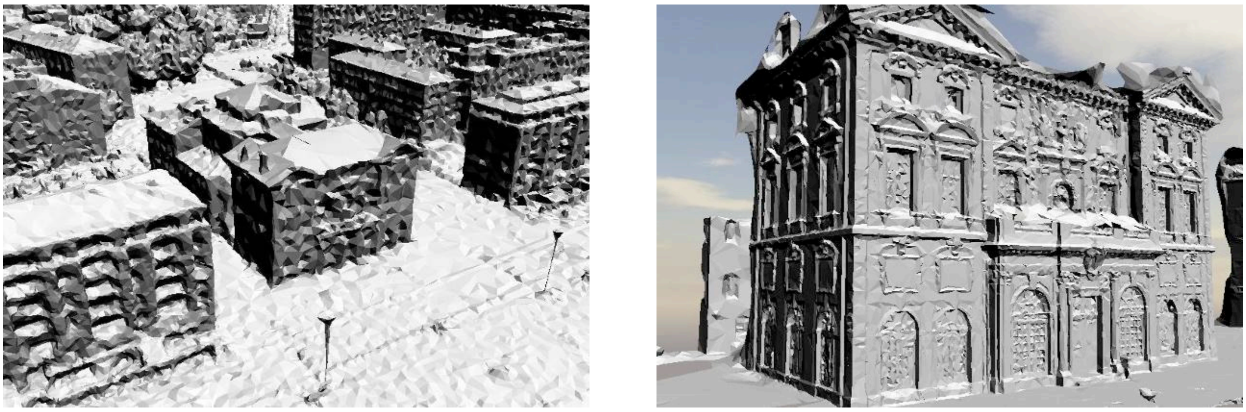


Figure 2: From cloud of 3D points to textured 3D Mosaic automatically processed

Airborne / Ground acquisition fusion

In order to improve details and accuracy of such 3D Mosaic generation, Street Factory allows simultaneously processing of both airborne and ground acquisitions. This is only possible thanks to the advanced sensor modeling and full 3D bundle adjustment technique which can simultaneously mix heteregenous measurements / acquisitions and still optimize correctly the geometry of all acquired data. Then the 3D generation will take the best accurate information from a given sensor and automatically fusion or mosaic it with the other sensors. Result is a seamless integration of both airborne and ground acquisition in the final 3D Mosaic as shown by following figure.



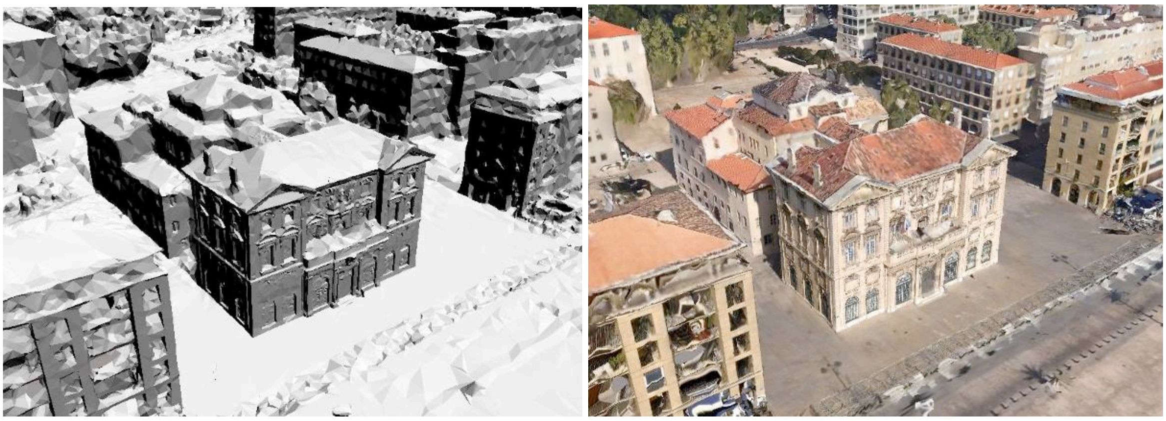


Figure 3: (**top-left**) Airborne 3D Model (**top-right**) Ground 3D Model
(**bottom**) Automatic fusion of airborne / ground

3D MOSAIC APPLICATIONS

3D Mosaic Advantages

Thanks to dense information available inside the generated 3D Mosaic product, applications requiring direct measurements are possible using this kind of data. Accuracy of 3D Mosaic has already been validated by numerous mapping institutes and private mapping companies showing its excellence in terms of accuracy and also its compliance with stringent mapping standards. 3D Mosaic accuracy ranges from 5cm to 30cm in XYZ from airborne sensors up to few millimeters accuracy for database computed from ground mapping system.

Moreover, 3D Mosaic is using OpenSceneGraph format which is an open-source available 3D platform allowing numerous applications development using 3D Mosaic product.

Urban mapping / Urban Asset Management

3D Mosaic is used in few urban mapping and urban asset management application. This can ranges from classic mapping applications to more sophisticated tax applications or CAD urban database update. Thanks to its 3D nature, it is possible to do full 3D mapping of urban environment as show of following picture. You can see from this image, that even complex highway ramps are measured in full 3D allowing both to measure the ramps but also the road below it.

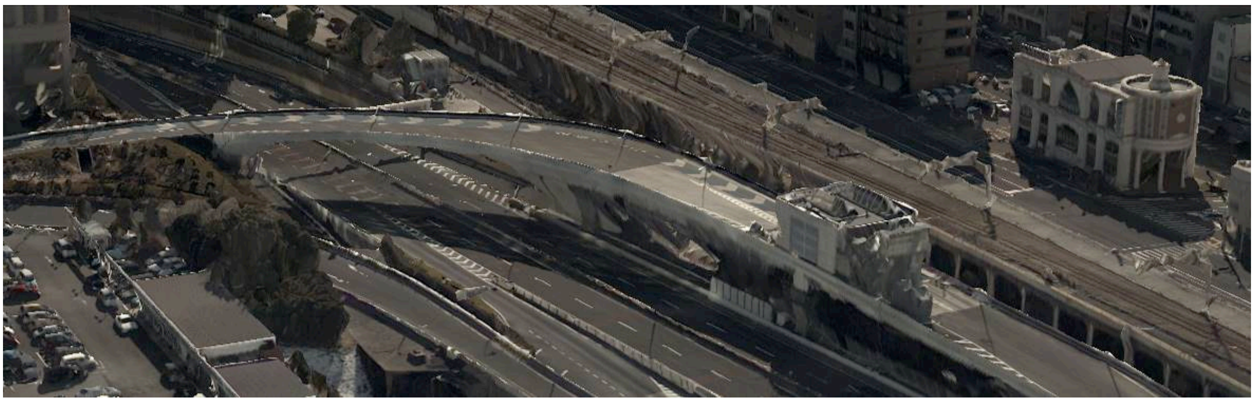


Figure 4: Example of 3D highway ramp from 3D Mosaic (image courtesy PASCO company)

For some specific landmarks, 3D Mosaic is able to measure with full detailed the 3D nature of those landmarks. This is then used to update CAD database and also to help in the urban management of the city (landscape management…).

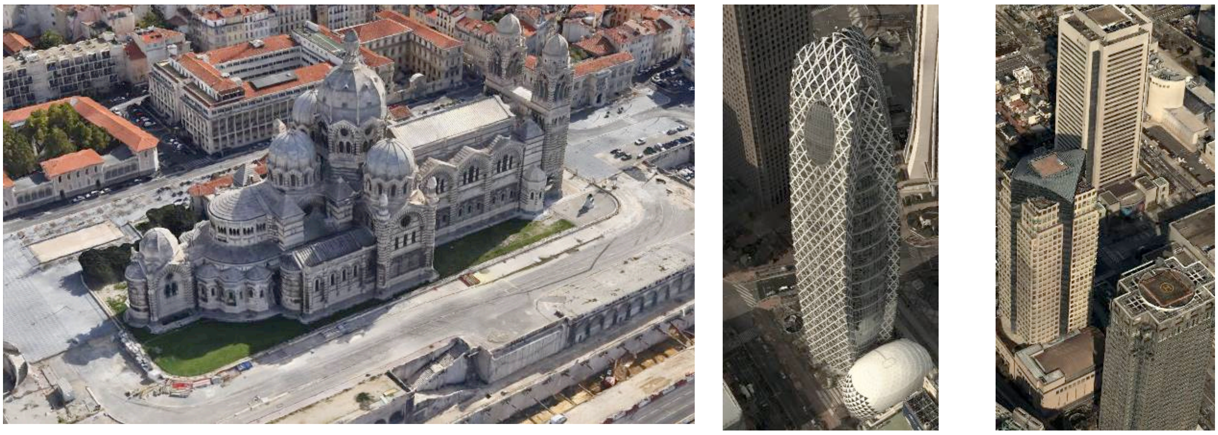


Figure 5: Example of 3D landmarks from 3D Mosaic (image courtesy PASCO company)

Risk & Crisis Management

3D Mosaic is a perfect database for risk and crisis management applications. It can be used either for planning purpose (like simulation), during the crisis in order to help the rescue forces to plan their effort (thanks to its high detailed and also quick production), and after the crisis to help in the management of reconstruction and damage assessment. As an example, 3D Mosaic are used in flood simulation application and risk management application as illustrated below.

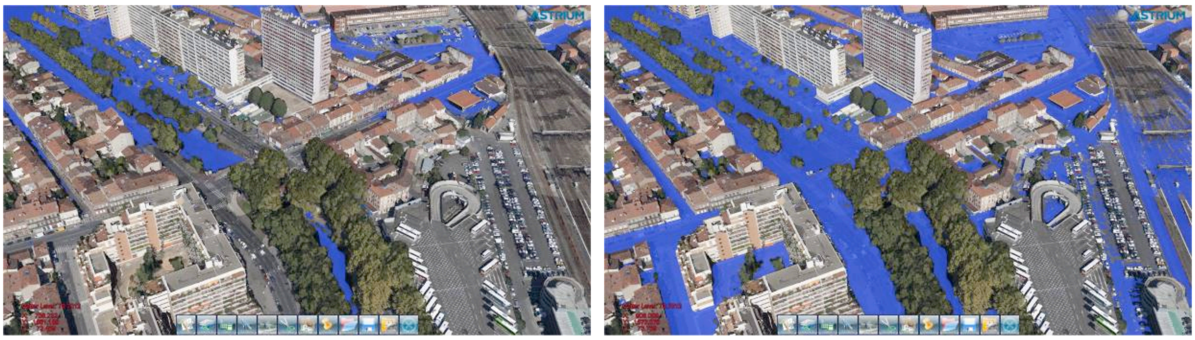


Figure 6: 3D Mosaic for flood simulation and risk management

CONCLUSIONS

This article has listed the different kind of 3D database and production methodologies available for 3D modeling. Through extensive description of 3D Mosaic database generation and applications, it shows that a change in paradigm is now available for all key organizations. Indeed, it is now possible to have quick (a matter of few hours), dense (with all 3D details) and accurate (centimeters to millimeters accuracy) 3D database available and fully automatically generated from a broad range of sensors (airborne or ground systems).

Thanks also to the open nature of such database, it is possible to derive numerous applications which were not accessible with previous 3D databases such as accurate simulation, embedded data into mobile systems, urban management, CAD database update, risk management.

The author is assured that we will see in the future many more applications using that kind of automated database and that a new trend is now popping up for 3D mapping which will help and enhance the use of 3D database.

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