

# GEOMETRIC AND THEMATIC ENRICHMENT OF FRONTAGES IN 3D CITY-MODELS

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## ABSTRACT :

Urban space is a three-dimensional space. That is why the 3D is often required when it is a question of representing it. G.I.S. existing applications already propose 3D tools, but actually, these tools are only visualization tools, mainly designed to facilitate the understanding of the urban space. The tools developed within the laboratory MAP-PAGE propose to enrich the urban models generally resulting from aerial photogrammetry by using photographs of the frontages of the buildings. Indeed, these images make it possible to integrate a certain number of data by describing three-dimensional phenomenon pushed aside by the mono-surface representation of the frontages (number of stories, overhanging parts of the building, balconies, etc). Beside contributing to a thematic enrichment of the urban model, the possibility of measuring on the pictures will also allow a geometrical enrichment of the model.

## RESUME :

L'espace urbain est tridimensionnel. Ainsi a-t-on très souvent recours à la 3D quand il s'agit d'en faire une représentation. Les applications fonctionnant dans des environnements S.I.G. proposent une large panoplie d'outils 3D, mais ces outils sont souvent restreints à des outils de visualisation permettant une représentation et une compréhension plus aisée de l'espace urbain. Les outils qui ont été développés dans le laboratoire MAP-PAGE proposent d'enrichir les modèles urbains généralement issus de la photogrammétrie aérienne en utilisant des photographies des façades des bâtiments. En effet, ces images rendent possible l'intégration d'un certain nombre de données complémentaires concernant des phénomènes 3D. La simple face de la façade peut ainsi être enrichie de données thématiques concernant notamment le nombre d'étages, la présence de parties en surplomb, de balcons, etc. Enfin, l'enrichissement thématique du modèle est accompagné d'un enrichissement géométrique du modèle à partir des mêmes images qui permettent d'y faire des mesures.

## 1. INTRODUCTION

### 1.1 Aim of the system

The MAP-PAGE laboratory has now a good experience in the construction of 3D city models. These models are realized by using techniques and initial measurements from aerial photogrammetry. They are then build by using some projection algorithms developed internally. In a first time, the models are only geometric models and are based on constitution and construction concepts developed in different works like Koehl [1999].

The models have a precision in keeping with the initial data in particular with the resolution of the aerial photographs used. Even if the use of the models seems to be easy and the needs of visualization of urban scenes seems to be good in adequation with these models particularly for small scales, we must conclude that these models are really poor structured and offers no real possibilities to make thematic queries.

The aim of the system designed is to enrich the models by using the techniques of the terrestrial photogrammetry and images of the frontage of the buildings described in the models. These complementary data are packed full of new information which allows in the same time to understand and to complete a lot of

thematic aspects of the buildings. Like it will be demonstrated in the following part of this paper, images allow also to perform measurements on geometric data and so to extend the models with a more detailed geometry of the frontages, which are, together with the rooves the visible parts of the city models.

### 1.2 Method

The method decided to be used to perform the integration of supplementary information and which is the central point of this project is the using of images (photographies, snapshots) of the frontages of the buildings.

This idea find his justification in some interests :

- very fast data acquisition,
- not too much information, but only relevant information,
- the photographs provide also the texture material later used for the texturing of the model,
- the accuracy of the GIS for the later exploitation of the model does not often need to use specific methods for the shooting of the images. This makes it possible to use existing images.

The aim of the tools we have developed is to perform the data extraction from a set of images and the data integration in the 3D model and in an associated database.

### 1.3 Components of the system

The system developed is composed by 3 steps which will be defined in this paper. The first step consists in the measure and the construction of the initial 3D geometric city model. The second step consists in the structuration of the model according to a topologic model and the translation from a graphical (design file) format to a specific structure into a database. The third step consists in the utilization of images from the frontages. The setting up of an expeditious rectification process of the images allows to determine the orientation parameters and then to exploit the geometric and thematic characteristics. This last step has been developed by Gaïotti [2003] who used intermediate experimentations of visualization with VRML and fast texturing methods.

This first system has been implemented on a Bentley Microstation platform.

## 2. 3D CITY MODEL

### 2.1 Basic system

The ground system used for the constitution of the initial 3D model is a digital terrain model build from a photogrammetric plotting. This digital terrain model is not particularly structured, it is composed by irregular triangular facets. The digital terrain model is useful as a reference surface for a set of projection processes used in the following steps of the reconstruction operations.

### 2.2 Formalism for the model

The features used for the reconstruction of the model are measured in aerial images. The measurement operations are made accordingly to composition rules of the rooves. The 3D city model will have a precision in appropriateness with the precision compatible for a Topographic Information System. More details for the description and the composition of a roof are given in Koehl [2003]. We remind here the major principles.

**2.2.1 The rooves :** Concerning the buildings, it is important to notice that after this process, only the constitutive rooves points were been measured. According to the importance given to the roof's details while the data acquisition, we will find in the model the element measured onto the different constitutive parts of the rooves (Figure 1) :

- tail of rooftop contour line,
- ridge-line (point, in case of prismatic rooftops...),
- skylight contour line,
- rooftop terrace contour line
- hole in rooftop-terrace
- element onto rooftop contour line

**2.2.2 The vertical faces :** The vertical faces are built from the contour lines of the rooves. The reconstruction is performed by using vertical projections of the contour lines on a reference surface here the digital terrain model. This surface as reference could be another surface defined as origin.

It can be distinguished two types of models. The definition of the inferior part of each vertical face of the model would be different in these two models.

After this first data acquisition work, a reconstruction step, mostly manual is needed. The roof is then completed by the operator. (Figure 2).

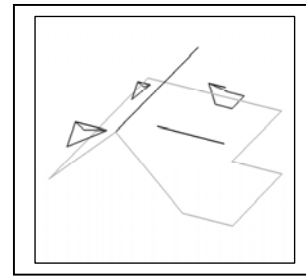


Figure 1. Rooftop elements measured

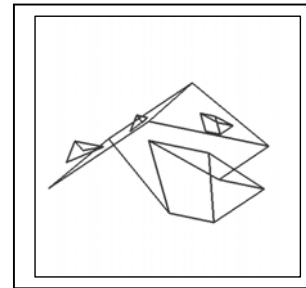


Figure 2. Rooftop manually reconstructed

### 2.3 Two types of models

**2.3.1 Solid model :** In this model, the vertical faces of the buildings are regrouped to form only one solid entity (cell or block). To distinguish easily each solid entity, the contour of each rooftop has to be measured as only one close polyline. This polyline will then be projected after the vertical direction onto the digital terrain model. The height of the lowest edge of the face (which can be defined as parameter) will be the lowest height of the intersection between the building frontages and the digital terrain model.

Sometimes, to minimize the redundancy, the solid is constituted with the two superior and inferior faces linked with vertical edges.

**2.3.2 Surface model :** In this model, each vertical face is computed independantly of the others. In this case, the contour line of the rooftop is not necessary only one polyline. This is for the operator a simplification in the measurement process.

The inferior surface is not existing because all of the faces have different and independant inferior intersections with de digital terrain model. In fact, each face will have an inferior edge from which height corresponds to the lowest height of the intersection with the digital terrain model.

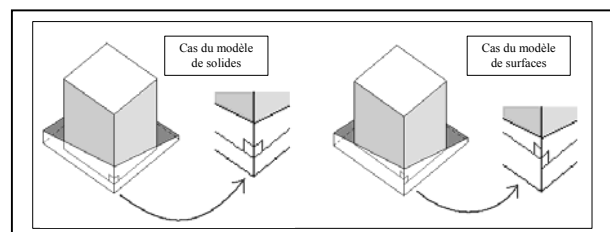


Figure 3. Solid model, Surface model

## 2.4 Export of 3D models

Once built, these 3D models are exported in form of topologic models to a Topographic Information System or in different CAD formats like DGN, DWG, DXF...

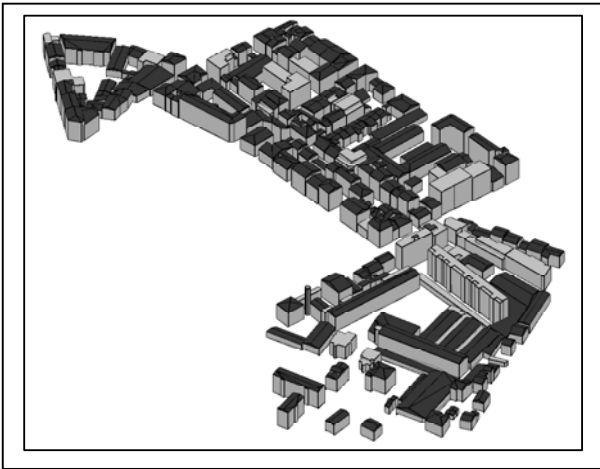


Figure 4. Sample of exported model

## 3. DATA INTEGRATION IN A TOPOGRAPHIC INFORMATION SYSTEM

The geometric data of the model are integrated into a Topographic Information System as geometric datasets, graphic datasets and topologic datasets. The different datasets are registered in a relational database structure. The topologic integration is made while an internal data translation process. The graphic data are structured in a table system adapted from the concept of 3D-FDS from Molenaar [1990]. (Figure 5).

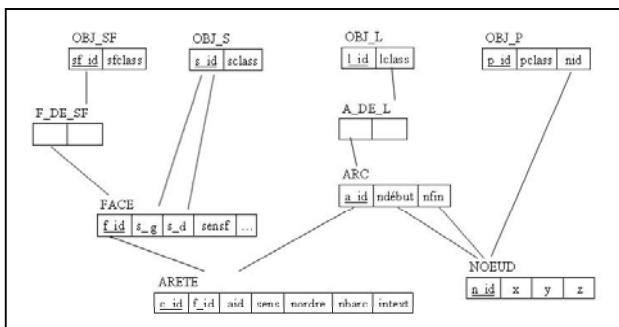


Figure 5. Graphic data model

The integration can be considered as a sort of step that allow to formalise the graphical data of the initial poor graphical model.

## 4. TOOLS FOR ENRICHMENT OF THE FRONTAGES

This tool is the central part of the project implementation. It will be used for the integration of supplementary 3D data in the model and in the associated database.

In order to make this we decide to use images and photographs (existent or to be shooted). In fact, it concerns the use of images of the frontages of the different buildings from which we can extract helpful information to enrich our 3D model. The information which depends on the users point of view has to be quantifiable. This implies the notion of measurement. Then it seems to be important to provide the tools which fonctions allowing to measure directly on the photographed frontages.

The software package actually used for the visualization of the models is Bentley-Microstation. This is the reason why we continue to implement the new described tools onto this platform.

### 4.1 Image contribution

At a first time the asked question is the following one : outward of the pure visual aspect of a photography, what are the concrete information that can be extracted from the image of a frontage ?

At first the number of stories can be counted, then their size can be measured if the tool performs it. In a next step it will make it possible to localize a significant recess which is not plotted at the time of a classical approach of aerial photogrammetry. It will be the same in case of balconies, loggias, porchs. On another level, it will allow to identify shops, offices in the same way as to define the allocation of the different stories (habitations, shops, offices, etc). The postal addresses may also be checked on this same way.

### 4.2 Objectives

The first objective is to permit the measurement of frontage elements directly in the image. After this step is realized, it will be possible to acquire some important informations like described in the previous paragraph.

### 4.3 Measurement in the images

The aim was not to rewrite a tool for photogrammetric plotting. In the developed system only one image at same time can be used. The basic principle is that a frontage is a planar object and with this approximation we can estimate that one photography can be sufficient to make some measurements.

**4.3.1 Required conditions** : the following equations define the projective relation between two plans (1) :

$$X = \frac{b1.x + b2.y + b3}{b7.x + b8.x + 1} \quad Y = \frac{b4.x + b5.y + b6}{b7.x + b8.x + 1}$$

When the 8 parameters b1 to b8 are determined, these equations allows to compute from the coordinates of a planar object laying in a certain plan its coordinates in another plan. In this case we can compute the coordinates of a given point in the frontage from its image-coordinates measured in the photography.

They are 8 unknown parameters, two data for each point (X, Y), this implies that we have to know four couples of points in the two systems. We have to know four points that we can digitize in the image and for which we know the real position in a coordinate system associated to the frontage.

**4.3.2 Known points** : It is necessary to know 4 points to solve the system of equations and at same time compute the eight parameters. But in our topologic 3D model each frontage surface is described by four points. To make measurements in the photography, the only requirement needed is that the photography of the frontage contains these four predefined points and allows to digitize them.

We can observe that the initial 3D model was obtained from aerial photogrammetry. For better accuracy we have to take in account the recess of the frontage from the rooftop counter line we used to compute the vertical walls.

**4.3.3 Computing of parameters** : Now four known points are available. The aim is to find out a way to digitize their image-coordinates and then it is possible to compute the eight parameters.

The to (1) corresponding linear equations are given in (2) :

$$b1.x + b2.y + b3 - X.(b7.x + b8.y + 1) = 0$$

$$b1.x + b2.y + b3 - X.(b7.x + b8.y) = X$$

$$b4.x + b5.y + b6 - Y.(b7.x + b8.y + 1) = 0$$

$$b4.x + b5.y + b6 - Y.(b7.x + b8.y) = Y$$

#### 4.4 Measurement tools

**4.4.1 Image-coordinates measurement** : The first element that could be exploited is the possibility to measure now image-coordinates directly in the photography.



Figure 6. Photography of a frontage

The management of the display size of the image and the metric units is one of the encountered problems. There is given a scale ratio from 4/3 to obtain the real pixel-coordinates. Whatever we use as unit or scale ratio, the homogeneity of the system provides correct results, but we choose to apply this scale ratio of 4/3 to obtain real pixel-coordinates in order to compute the parameters b1 to b8 which can be used in the futur with the same image and eventually other applications.

#### 4.5 Information extraction

**4.5.1 Horizontal division** : The first information we want to extract from the photography of a frontage is simply the number of stories of the building. This operation is generally easy to realize. But in the same time, we can determine the size of each story and in this way find out not only a thematic but also a geometric information.

The implemented tool performs to associate a measured height to each story.

A semi-automatic process consist in a first time to measure the height of the first floor often different than the height of the other floors, then to measure the cumulative height of the supplementary upper floors.

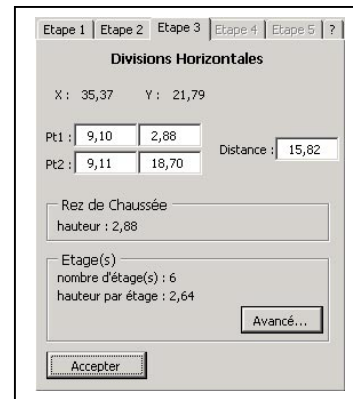


Figure 7. Interface for the measurement of the stories

An easy operation gives the number of stories from the cumulative height and the means height of the stories. This procedure needs to define a minimal story-height and can proving out to be insufficient in the case of a great number of stories.

We can observe that for the measurement of the heights of the stories we use only the Y component because the coordinate system is oriented accordingly to the frontage (X-axis oriented from left to right, Y-axis oriented from down to up). This allows to measure to points (first down, second up) that are not place onto a same strength vertical.

**4.5.2 Other divisions** : The aim of this fonction is to describe other phenomenon localized directly on a precise floor. It can be indeed of interest to point out for instance balconies, loggias, recesses, porchs (Figure 8), etc.

In order to simplify the designation of such elements, it has been decided to subdivide vertically the previous defined stories.

The tool perfoms to realize this step quickly. In fact, the only operator's manipulation is to digitize one point for each vertical subdividing line.



Figure 8. Particular subdividing parts of frontages

The following example (Figure 9) shows how to proceed with a recess part. In this case, the operator must digitize a point on each side but he has to remain in the plane of the frontage. Here we have to measure two points on the lower part of the recess and move lightly the cursor on the same X-coordinates. In this

way, the tool detect automatically the associated floor (with the Y-component), then it subdivide the floor vertically into three parts according to the X1 and X2 coordinates.

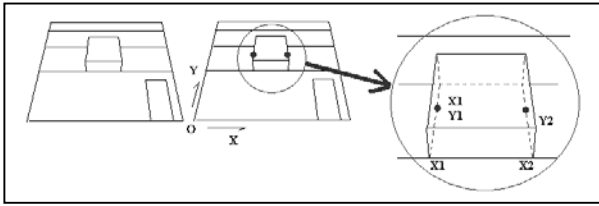


Figure 9. Vertical subdividing of a floor

This cutting is displayed for control and the limits are registered into the database.

In the case of the upper right image in the Figure 8 we can proceed in the same manner for each floor concerned by the recess.

**4.5.3 Limitation of the process :** All observably phenomenons on a frontage are not valid for the whole floor height and some of them present a more complex geometry. It's the case of the porch shown in Figure 8, lower left image. It can be of interest to extend our tool with polyline subdividing functionalities.

**4.5.4 Information on subdivided parts :** The second tool offers the possibility to assign thematic informations to each subdivided part.

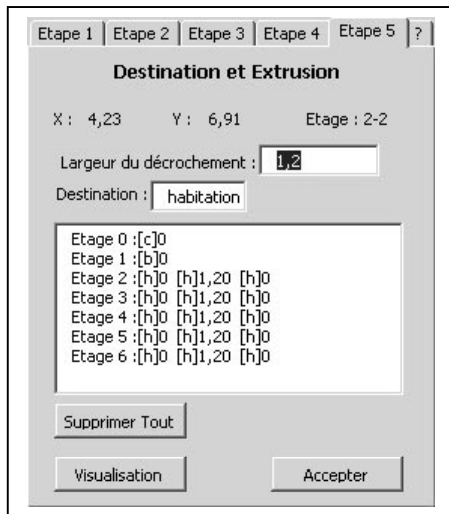


Figure 10. Interface for subdividing a frontage

For instance, when a recess has to be described, it is important to indicate its position onto the frontage but its depth is also important. The value of the depth cannot be measured precisely with our system because the measurement are only accurate if done in the plane of the frontage. A solution is given by complementary terrain data that can notice how important the depth is. On the photography the depth can only be roughlyly evaluated.

Another information like the assignement of the frontage part can also be added. This information can directly derive from the photo-interpretation or stemmed from other documents or data.

The example shown in the Figure 10 illustrates a 1.20 meter recess in the center of the frontage localized on the floors 2 to 6. The two first floors contain only one part.

The depth and the destination of the different parts are only example of information that it is possible to assign at this step of the process.

Observations are following ones :

- the depth can also be defined by a negativ value in the case of an entering part in the frontage.
- it is possible to add an "empty" value for the destination of the different parts in the case of a hole crossing entirely the frontage (porch).

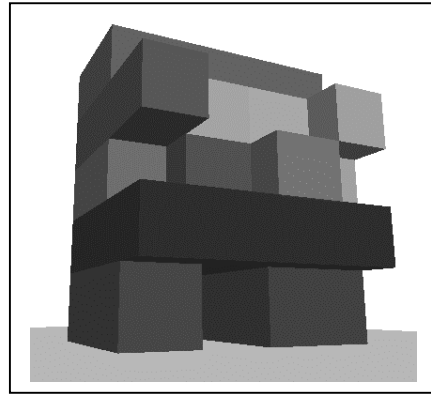


Figure 11. Different possibilities of subdividing a frontage

## 4.6 Texture mapping

**4.6.1 Textures :** The addition of textures allows a more natural comprehension of the 3D model and of the GIS derived. For these reasons it seems to be very useful to add some functionalities for frontage texture mapping.

The definition of the texture can be obtained from sample materials or for more realistic rendering from the rectified image of the frontage derived from the second step tools.

**4.6.2 Texture images :** The aim of this last process is to cut out from the rectified image of the whole frontage all the texture- images corresponding to each subdivided part.

## 5. EXPERIMENTATION

### 5.1 Initial 3D model

For the illustration of the experimentations we use a part of a 3D model plotted and reconstructed accordingly to the methods described in the part 2 of this paper. The initial model is not very accurate (1 meter). The rooftop details where not plotted in this case. The Figure 12 shows a boundary representation of the defined sample.

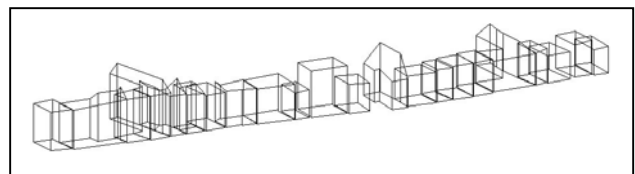


Figure 12. Boundary representation of the defined sample model

## 5.2 Topologic model

After the use of the first tool, the frontage faces and the rooftop contour lines are identified and structured into a database working on MySQL and EasyPHP. (Figure 13).

Only the structured four-points-faces are recorded in the database, the initial model is recorded as graphical design and can be displayed on demand.

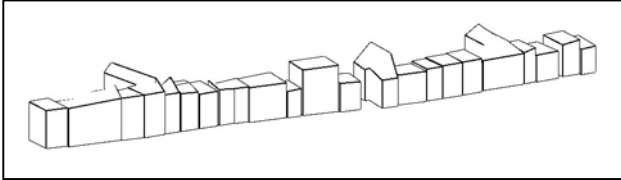


Figure 13. Model in hidden line rendering mode extracted from database

## 5.3 Images

The photography of each frontage (Figure 14) can be used into the second tools to enrich geometrically and thematically the model. The Figure 15 shows the model geometrically enriched.



Figure 14 : Images of frontages

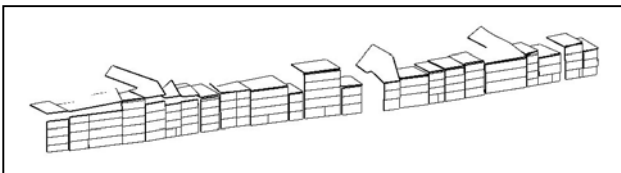


Figure 15 : Frontages geometrically enriched

## 5.4 Texture images

With the orientation parameters defined in the second step, the third tools realize the computing of texture-images of the frontage associated to each part of the frontage (Figure 16).



## 5.5 Final 3D model

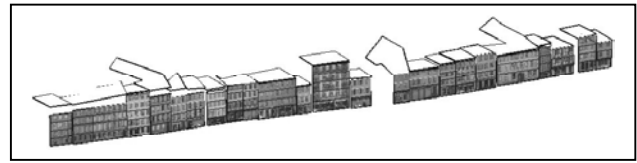


Figure 16 : Frontages geometrically enriched and textured

## 6. CONCLUSION

The tools described in this paper allow to overpass the first level of the description of a building. In this first level, the frontage surfaces are considered as planar vertical faces. From now, the frontage have acquired a new dimension and a higher detailing grade because it is now possible to decompose a frontage into stories (horizontal division) and each story into different parts according to characteristics of interest for the end user. Besides, the geometric definition of the frontage is refined. The different architectural entities that constitute the frontage (balconie, porch, recess, etc) are identified and can be quantified with a depth or a shift value from the frontage plane. In a geometric point of view, the obtained definition level is more in accordance with the needs of a 3D-GIS and its applications.

At this time, we did not want to replace the old frontage faces by the new computed frontage parts. This will not prevent from 3D analyzes.

The use of photographs from the frontage of the modeled buildings seems to be a relevant way to access to 3D informations and allows to represent and to use them into system we can qualify as 3D-systems.

A lot of improvements can be added to the in this paper three presented groups of tools.

The first tools could be able to define the whole topologic relations in more complex 3D models.

The second tools could allow the definition of whatever divisions of the frontage by using a polyline for the division trace. This would offer the possibilities to describe and represent phenomenon with a more complex geometry.

The third tools should be able to create rectified textures for overhanging objects. They also have to integrate algorithms for resampling and for creating texture-images for complex divisions.

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