

---

## URBAN 3-D MODELS FOR PLANNING OF MOBILE TELEPHONY SYSTEMS

Francesco COPPOLA<sup>\*</sup>, Mauro LO BRUTTO<sup>\*</sup>  
Patrizia MIDULLA<sup>\*\*</sup>, Benedetto VILLA<sup>\*</sup>

<sup>\*</sup>University of Palermo, Italy  
Department of Representation  
[bevilla@unipa.it](mailto:bevilla@unipa.it)

<sup>\*\*</sup>University of Palermo, Italy  
Town and Land Department  
[pmidulla@unipa.it](mailto:pmidulla@unipa.it)

Working Group V/3

**KEY WORDS:** CAD, Modelling, Photogrammetry, Rendering, Texture Mapping.

### ABSTRACT

This paper deals with an application of numerical cartography, carried out by means of digital photogrammetry techniques, aimed at the planning of mobile telephony cells. Particularly, urban 3-D vector models (wireframe), got by digital restitution and integrated by raster images referred to rectified buildings facades, were carried out in a sample area selected inside the Orleans Park, seat of the Palermo University. Then such models were processed by computer graphics techniques owing to the operations of rendering and animation. These 3-D representations could come in very useful for study and planning of mobile telephony networks in urban areas.

### 1. INTRODUCTION

Problems referred to 3-D urban models are now the subject of numerous researches aimed, particularly, at carrying out automatic techniques for extraction of buildings from DTM (Brenner, 1996; Forstner, 1996; Gruen and Wang, 1996) and visualization of urban 3-D data (Gruber, 1996).

In various applications - such as the urban planning, the positioning of telecommunication antennas, or the simulation of radio waves propagation - data obtained by a 3-D rendered model, which have both the metric information of the cartography and the qualitative one of the photographs (kind of building, features of materials), are of great interest. Integration between simple volumetric reconstruction of buildings and rendering allows *virtual reality model*; besides, animations carried out along fixed paths give an opportunity to move on the inside of the same model.

For many years rendering techniques have been prerogative of fields, such as publicity graphics, whose metric side was far less important than the qualitative one. Therefore it's obvious that rendering software favours the qualitative side of the representation.

Sample area is located besides Orleans Park, the campus site of Palermo University (fig. 1), which has been chosen for a long time by researchers of topographic sector as the laboratory in which to experiment with new techniques of surveying and representation.

### 2. TOPOGRAPHIC SURVEY

Photogrammetric survey, both terrestrial and aerial, required a topographic basic network aimed at locating planimetric and/or altimetric control points. This network, surveyed by a Topcon GTS 702 total station, was adjusted according to a local reference system (fig. 2) and afterwards fitted in the national one (Gauss-Boaga) using a strict adjustment software (ReTop rel. 2.0), worked out with Windows 95 at the Department of Representation. To fit in with the national reference system two fixed points were used, belonging to a GPS network carried out for a mapping on a large scale of Orleans Park.

Measurements of the necessary control points to survey the facades were carried out by a Leica DIOR 3002S electronic distantiometer, integrated to a Leica T1010 electronic theodolite.

In the facades without well identifiable architectural particulars on the photos, presignalization was used, resorting to adhesive black-and-white signals having size of 10cm x 10cm. About 200 control points were surveyed in all.



Figure 1. Aerial photograph of Orleans Park with specification of sample area.

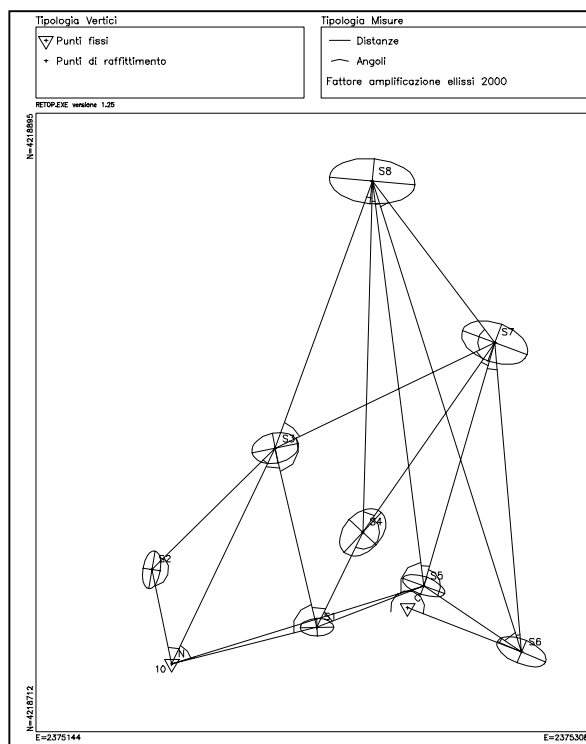


Figure 2. Network plan with error ellipses.

### 3. CLOSE RANGE PHOTOGRAMMETRIC SURVEY

The photographs were taken by a Rollei 6008 semimetric camera with focal distance of 50 mm and image size of 6cm x 6cm, using a Kodak Ektacolor pro gold 160 GPX 120 colour film.

Object distances ranged from 10 m to 30 m; therefore photographic scales ranged from 1/200 to 1/600. Eleven facades were surveyed in all. Figure 3 shows one of the five photographs used to represent facade A.

The photo scanning was carried out in RGB colours by a flat scanner Epson GT-12000 directly from negative at a resolution of 800 dpi. The images were subjected only to a calibration of brightness and contrast using Adobe PhotoShop rel. 5.0 software.

Digital rectification was executed by Rolleimetric MSR rel.2.20 software. Figure 4 shows the results of the absolute orientation carried out on the above mentioned photographs. Small values of residuals (all less than centimetre) depend besides on good result of the topographic surveying also on activation of the distortion adjustment.

The choice of the sequence is of great importance for photo-mosaic operations. In fact, the software places every rectified image on the previous one; so, by a proper choosing of the sequence of the photographs to rectify, differences in chromatic tonality or perspective errors or objects, such as trees or other obstacles which come between camera and facade, can be removed. When watching the rectified image of facade A (fig. 5), it may be noticed for instance, that the tree visible on the photograph of figure 3 is almost completely disappeared.



Figure 3. Photograph of facade A.

Inattiva	Nr.	x	y	Resid. x	Resid. y
<input type="checkbox"/>	8	67.390	46.260	-0.001	0.003
<input type="checkbox"/>	9	76.858	46.370	-0.000	0.007
<input type="checkbox"/>	10	86.510	46.280	0.004	0.000
<input type="checkbox"/>	99	86.340	53.290	-0.007	-0.000
<input type="checkbox"/>	50	86.340	63.150	0.001	0.005
<input type="checkbox"/>	61	67.670	58.240	0.003	-0.000
<input type="checkbox"/>					
<input type="checkbox"/>					
<input type="checkbox"/>					
<input type="checkbox"/>					
<input type="checkbox"/>					
<input type="checkbox"/>					
<input type="checkbox"/>					

Figure 4. Results of absolute orientation for photograph in figure 3.



Figure 5. Photo-mosaic of the rectified images of facade A.

#### 4. AERIAL PHOTOGRAMMETRIC SURVEY

Sample area was placed on two photographs related to a photogrammetric flight carried out over the Orleans Park in 1998, using a Wild RC 30 30/4 Nat-S camera with a focal distance of 300 mm and a Kodak Panatomic X 2412 colour film. Photographic scale was about 1:3 000.

Also in this case the photo scanning was executed by a Epson GT 12000 scanner at a resolution of 800dpi.

Seven control points, surveyed by fast static GPS techniques inside Orleans Park, were used for the phase of the absolute orientation.

Photogrammetric restitution, was carried out by Geotop RFD rel. 2.0 software. Afterwards, the vector file yielded from restitution was processed by AutoCad rel. 14 software, also inserting topographic data particularly related to survey architectural elements located on the ground surface (arcades, steps, pavements etc.). Figures 6 show axonometric representations of the yielded 3-D model.

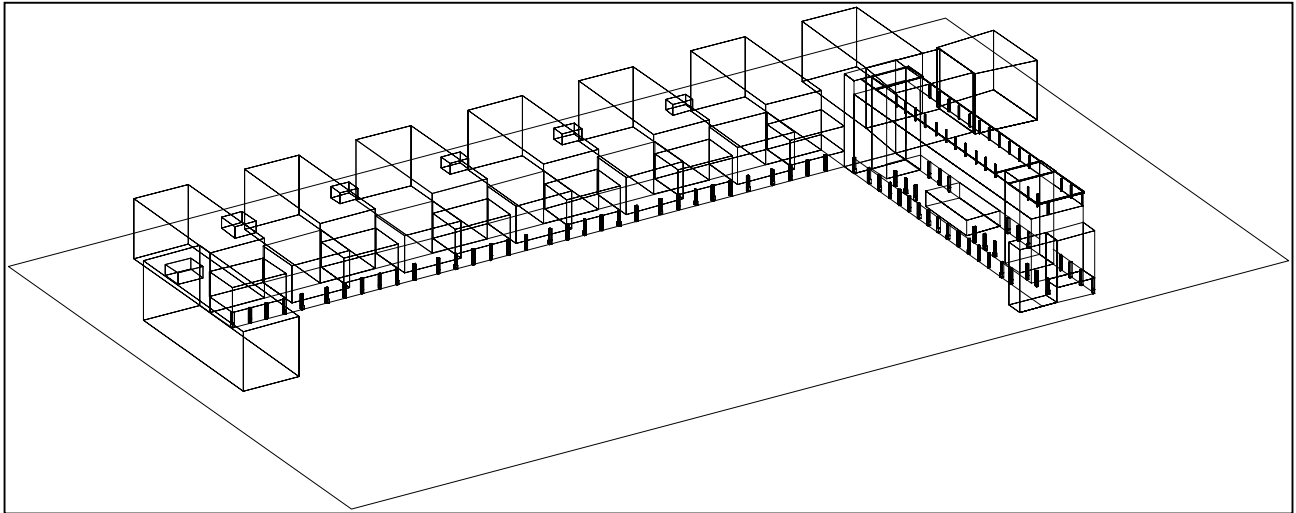


Figura 6. Wireframe 3-D model.

#### 5. THREE DIMENSIONAL MODELS

Three dimensional models representing urban areas can be distinguished into 3-D wireframe models and 3-D conventional and photorealistic models, depending on the kind of data they are based upon. Geographical space is represented, in the first model, by vector data structure and, in the second one, by raster-vector structure.

The case study described below was carried out with regard to the second kind of models, the conventional and photorealistic ones. Its aim was to find a suitable model both for planning and simulating the positioning of mobile telephony antennas.

##### 5.1 Rendered 3-D models

A rendered 3-D model is a digital representation which contains geometric data about the shape, dimension and location of objects, described by using coloured surfaces. This allows a visualization of the terrain morphology, of the objects surfaces and volumes, and of the lighting effects produced by natural or artificial light sources. Various methods can be used to create such a model:

- a) Draping of only one colour surface over the wireframe model in one step, so that a monochromatic visualization of volumes is obtained. This method is quite quick, and requires only one command, if one already has a wireframe 3D model;
- b) draping of various colours surfaces over the faces of a wireframe model, to display thematic data or to simulate the quality of materials and surfaces;
- c) draping of raster data over the faces of a wireframe model, in particular rectified photographs or orthophotos, in order to obtain realistic data about facades and roofs. ;

Models a) and c) will be analysed below. They will be named monochromatic conventional 3-D model and photorealistic rendered 3-D model respectively.

**Monochromatic conventional 3-D model.** A monochromatic conventional 3-D model can be produced in one step by projecting a coloured surface on a wireframe 3-D model. This is how one can obtain a visualization of both terrain and objects as if they were volumes. The model is useful to study morphological relationship and natural or artificial lighting. Carrying out of such a model is simple and fast, if one can count on a 3-D survey. It is possible to use CAD software, generally provided by specific functions, to display volumes as solids, and also use rendering software.

In this case, 3D Studio VIZ rel. 2.0, by Autodesk, was used. This is a software for the PC compatible environment, with a variety of modelling, rendering, animation and panorama features. It includes CAD features suitable to create or to modify objects. Vector files can be imported in DWG and DXF formats, images in TGA and JPEG formats. For this experiment, 3D Studio was chosen for the following reasons: information about co-ordinates is preserved in the original Cartesian system, and is displayed on screen in connection with the movement of the mouse. As a result, one can obtain information about the position of every point in real time. Further, it offers complete and advanced CAD features, which are useful when one needs to interact with the model and create visual simulations.

The following hardware was used: computer Pentium II, 300 MHz; 256 MB of RAM; hard disk 6.3 GB; graphic accelerator 64 bit; 6 MB video SGRAM; audio-video in/out 24 bit; audio recording/reproduction a 16 bit; printer Epson Stylus Photo 700.

The experiment was conducted as follows:

Step 1 - a vector DXF 14 file representing the area was imported into a 3D Studio file;

Step 2 - it was draped of a monochromatic coloured surface, chosen from a library of predefined materials;

Step 3 - sun-lighting was simulated, according to geographical co-ordinates, time and date.

The result is shown in figure 7.

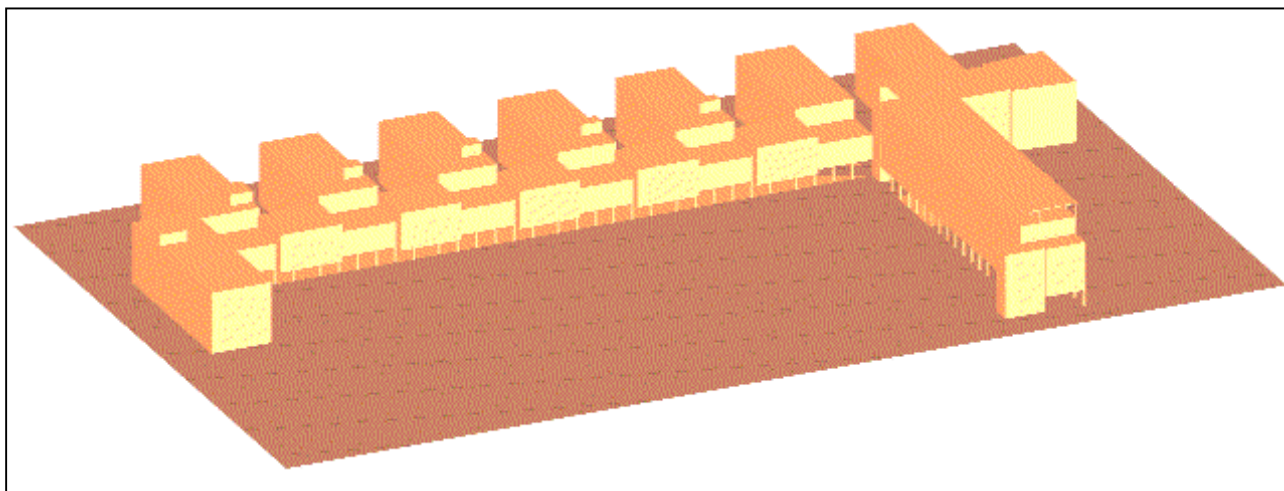


Figure 7. Monochromatic conventional 3-D model.

The created model allows the user to interact: it is possible to rotate it, to zoom in and out and look at it from every angle, at a mouse click. It is also possible to zoom, or also to export images as snapshots, taken from different points of view. Finally, it is also possible to create animations, by simulating a “walk through” movement around and inside the model.

**Photorealistic rendered 3-D model.** A photorealistic rendered 3-D model can be created by using two different methods:

- a) A “quick” one, which combines a DTM data with raster data, such as orthophotos and remote sensing images; it can successfully represent extraurban areas, on a medium and small scale.
- b) A method consisting of the draping of raster data over the surfaces of a wireframe model, in particular rectified photos or orthophotos; it can be applied to represent the urban environment on a medium and large scale.

In this experiment, the second method was used. Coloured rectified images of the facades and the roofs were projected on the various sides of a vector model. This was done by using the software Art.lantis, by Abvent. This software is specifically devised for rendering models, animations and panoramas. It runs on both Macintosh and Windows systems. It doesn't offer CAD features. Therefore a vector model must be modified with the help of some cad software, and then imported into an Art.lantis file. Having analysed the most used rendering software, this program was chosen because it combines a functional interface with rendering quality; it is easy and quick to use when treating and positioning the



images on the sides of the model. A drawback, on the other hand, is the absence of information about metric data, such as point co-ordinates or distance measurements. Therefore, this software can be used only to create images of landscapes and animations.

For this experiment, the following hardware was used: computer PowerMac G3 a 300 MHz; 64 MB of RAM; hard disk 7.8 GB; graphic accelerator 64 bit; 6 MB video SGRAM; audio-video in/out 24 bit; audio recording/reproduction 16 bit; printer Epson Stylus Photo 700.

A model was created as follows:

Step 1 - radiometric calibrating and photo treatment of the rectified images of facades and roofs. The images were improved and elements, such as trees, hedges and cars were eliminated. PhotoShop 5.0 software was used. The images were in TIFF format (fig. 8);

Step 2 - manipulating of the vector file of the area in DXF 12 format with MiniCAD 7 to be exported in OPT/DB format;

Step 3 - importing the file as OPT/DB format into Art.lantis and projecting the rectified images on the corresponding sides of the vector model;

Step 4 - setting various 3-D views and animation \*.

The result is shown in figure 9-10.



Figure 8. Improved rectified image of facade A.



Figure 9. Photorealistic rendered 3-D model.



Figure 10. Detail of the photorealistic rendered 3-D model.

## 6. CONCLUSIONS

The described experiment permitted the analysis of 3-D models, and the evaluation of their characteristics, in relation to time and cost. As a result, it can be said that 3-D photorealistic models can be very useful to represent urban areas, through both perspective views and animations, in particular because 3-D models can be very detailed and easy to use at the same time. Nevertheless, long processing time is needed to create such models and this can affect costs. From a more technical point of view, the textures displayed on the screen are of poor quality; this is because the rendering software is mainly conceived to produce pictures taken from different points of view and animations. So, it can be more appropriately used to create printed images or films, integrating CAD representations of buildings and the urban environment with information about building surfaces, materials and their state.

If other application are implemented, i.e. the simulation of physical phenomena within in some urban space, and particularly the propagation of electro-magnetic waves, the time and expense necessary to produce a photorealistic 3-D model are to high. In these cases, it would be probably better to use monochromatic 3-D models.

Indeed, notwithstanding this kind of model is made up of simple surfaces, it is useful to study the intervisibility of points, and the presence of obstacles to lightwaves, radio waves etc. It can be useful, for example, for planning of mobile-telephony antennas, and simulating the signal propagation from broadcasting antennas to receiving ones. Radiation used in mobile telephony communications is radio frequency (RF) one. The propagation of radio waves depends on the intensity of the signals, and on the absence of obstacles in the way of the signals. Therefore, it is important to know well the morphology of the territory and the layout of the objects and building volumes on it.

By modelling the electro-magnetic radiation given out by a source, and fixing the position, signal intensity and frequency of their source, it is possible to show the direction of rays, and control their transmission range and field. Moreover, by assigning different colours to the various represented areas, in relation to signal intensity, one can asses the best antenna positions, and control possible shadow areas, that is where the signal is interrupted.

As a result of these considerations, the monochromatic conventional model was chosen as a suitable support for monitoring and testing the behaviour of radio waves employed for mobile telephony communication in urban areas.

## REFERENCES

Brenner C., 1999. Interactive modelling tools for 3-D building reconstruction. Photogrammetric Week '99, Fritsch/Spiller (Eds.), pp. 23-34.

Cacopardi F., Coppola F., Messina A., Villa B., 1990. Il rilievo a grandissima scala del Parco d'Orleans (PA). Un'applicazione di cartografia numerica con metodologie integrate. Boll. SIFET, N.2/1990, pp. 127-140.

Forstner W., 1999. 3-D City Models: Automatic and Semiautomatic Acquisition methods. Photogrammetric Week '99, Fritsch/Spiller (Eds.), pp. 291-303.

Gruber M., 1999. Managing large 3-D urban database. Photogrammetric Week '99, Fritsch/Spiller (Eds.), pp. 341-349.

Gruen A., Wang X., 1999. Cyber City Modeler, tool for interactive 3-D city model generation. Photogrammetric Week '99, Fritsch/Spiller (Eds.), pp. 317-327.

Messana A., Villa B. 1992. Il sistema cartografico del Parco d'Orleans. Le carte tecniche numeriche alle scale 1:1000 e 1:2000. Boll. dell'Ordine degli Ingegneri della Provincia di Palermo, n. 2, pp. 26-33.

Messana A., Villa B., 1992. Il sistema cartografico del Parco d'Orleans. Fotopiano a colori alla scala 1:1000. Boll. dell'Ordine degli Ingegneri della Provincia di Palermo, n.3, pp. 18-23.

Midulla P., 1995. Applicazioni informatiche all'integrazione tra cartografia e prospetti raddrizzati. Boll. SIFET, n.1/1995, pp. 103-118.

Midulla P., 1996. La rappresentazione del paesaggio. Boll. SIFET, n. 1/1996, pp. 193-230.

Midulla P., 1996. Un modello tridimensionale fotorealistico per la rappresentazione del territorio urbanizzato. In: Proceeding of VI Congreso International de Expresion Grafica Arquitectonica (EGA '96), Pamplona 9-10 maggio 1996, T6 Edition SL, Pamplona 1996, Vol. III, pp. 193-201.

Sinning-Meister M., Gruen A., Dan H., 1996. 3-D City models for CAAD-supported analysis and design of urban area. Photogrammetry and Remote Sensing, 51 (4), pp. 196-208.