3D Modeling and Representation of the Spanish Cadastral Cartography

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Key words: Cadastre Mapping, Web Map Service (WMS), 3D Modeling, Building

SUMMARY

This paper describes the solutions provided by the Directorate General for Cadastre of Spain for the representation and modeling of three-dimensional component (3D) of buildings as objects of cadastral parcels. A first solution is based on incorporating new layers in the Web Map Service (WMS) for static image representation of the 3D component. The other solution is based on 3D modeling in vector format by plot, based on the volumetric attributes of the mapping or the local geometry of each floor of a building.

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1. INTRODUCTION

The Spanish Cadastral cartography, by its scale and its nature, has a component "z" defined indirectly as an volumetric attribute of the enclosures of the constructions and sub parcels. The two-dimensional representation of this cartography, such as cadastral map or as a flat raster image in a Web Map Service (WMS), has not traditionally included this three-dimensional (3D) component, except as a banner in roman numerals by referring to the number of plants of the buildings.

Two new layers have been added to the cadastre WMS to try to represent this three-dimensional space component: one of these layers is a representation of the perspective of buildings according to its number of plants; the other layer uses the constructive elements with volumetric representation and simply casts a shadow. These new layers, very innovative in the map services, they are integrated with the rest that already exist in the WMS and provide, separately, a new more plastic insight into the urban framework defined by its buildings. Its use is particularly indicated for urban zones, facilitating and improving the interpretation of them.

On the other hand, there are new geographical viewers that allow the representation of 3D models, as it is the case of Google Earth with KML format which makes it possible to work with 3D geometries.

The Spanish General Directorate for Cadastre (SDGC), has KML files generation systems in real time with three-dimensional modeling of the cadastral parcels with their 3D buildings, perfectly integrality in this type of geographical viewers.

One based on the volumetric attributes of the general plant of the cadastral parcel through modeling by extrusion; and the other based on the vector information in the format FXCC (official exchange format of SDGC graphical information associated with cadastral parcels), where we have the information from each of the premises comprising a building for every plant. In this model we rebuild geospatial position of each premise of the building, constructing the full 3D geometry of each parcel.

2. BACKGROUND

The population maps, the cadastral maps and the street directories are, represented currently from a nadiral perspective: We see the city from above.

This has not always happened; the topographic representation of these maps has not been defined until very late. In earlier times we used oblique panoramic, which represented the streets with their buildings in perspective, showing us their roofs and facades. They were very elaborate artistic works, widely used in Cartography from the 16th century, they lacked practical use as maps but they had a great decorative acceptance. Important were the esthetic aspects and they gave a very clear vision of the city and the 3D component of buildings and of their features.
One of the first maps in which these techniques have been used is already in the 17TH century, with the name *"Villa de Madrid, Corte de los Reyes Católicos"* 1635 and attributed to the Flemish Frederick de Wit, It represented buildings in Cavalier perspective. But the most representative is the one carried out by the Portuguese Pedro Texeira in 1656, entitled "*Mantua Carpetanorum sive Matritum Urbis Regni*" scale 1: 1,840 and better known as "Texeira map" where a bird's-eye view of the city of Madrid is represented in perspective, with a high degree of quality and detail.

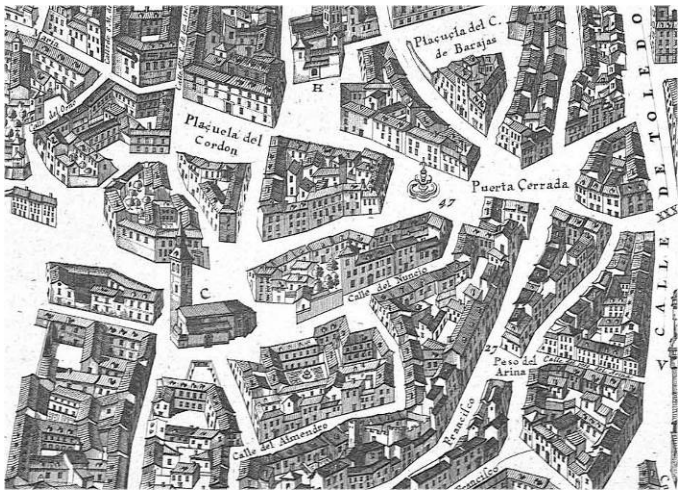

Figure 1. Fragment of Texeira Map (1656) (Martín López, 2002)

Currently there are very significant examples where the representation used perspective to show us cities from another point of view. Google Maps Viewer uses it to show the buildings in some cities in the world and the Chinese company Edushi has digitized the major Chinese cities and represents these cities with a high degree of detail, using the perspective

In essence, we believe that the way to see a map should allow to take advantage of the conceptualization of the old well-known cartographers and should not be very different from how they did in the past, but keeping the terms of current quality and geometric rigor.

Figure 2. Image of Edushi in the city of Hong Kong (Visor de cartografía de ciudades chinas: http: www.edushi.com [16/02/2011]) and of Google Maps in the center of Madrid (Google Maps: http://maps.google.es/ [16/02/2011])

The WMS services used to publish of maps on the Internet have been widely accepted, they are the reference for the representation of the new cartography, they serve to enable interoperability and to make maps available to any user via Internet, and are based precisely on the dissemination of static screenshots of maps (Olivares García and Virgós Soriano, 2006).

3. 3D REPRESENTATION OF THE CADASTRAL CARTOGRAPHY AND WMS

The Spanish Cadastre is a register describing rural and urban real estates. This description includes physical, legal and economic characteristics, featuring location, cadastral reference, surface, usages, class of crop, buildings, graphic representation, cadastral value and title holders.

The parcel is defined as the portion of land delimited by a closed line, owned by a single individual or by several.

The Spanish Cadastre distinguishes between two basic types of properties, based on the type of land on which they are located and the applicable assessment model: these are urban real estate and rural real estate. A third residual category exists for special real estates, whose characteristics require different treatment, especially with regard to assessment (motorways, airports, nuclear plants, etc.).

The Spanish cadastre has information of - 12 million urban parcels, - 32 million urban units and - 42 million rural parcels.

The buildings are build by sub parcels, the feature for buildings is the sub parcel (as volume constructed). Cadastral cartography, even in only 2D, has the volumetric information of the buildings by number of plants in roman numerals in their maps.

We start with the use of the service WMS where we can generate our own map using various techniques of representation of cartography; the symbols, the colors and the toponymy allow us to represent with the highest level of detail and clarity of

interpretation, the map that we want to spread in Internet: there is a basic layer of reference called "Cadastre" in this service, there are other layers that can be invoked separately, which are those that contain all the geographic and cadastral information stored in vector form, in the graphical databases.

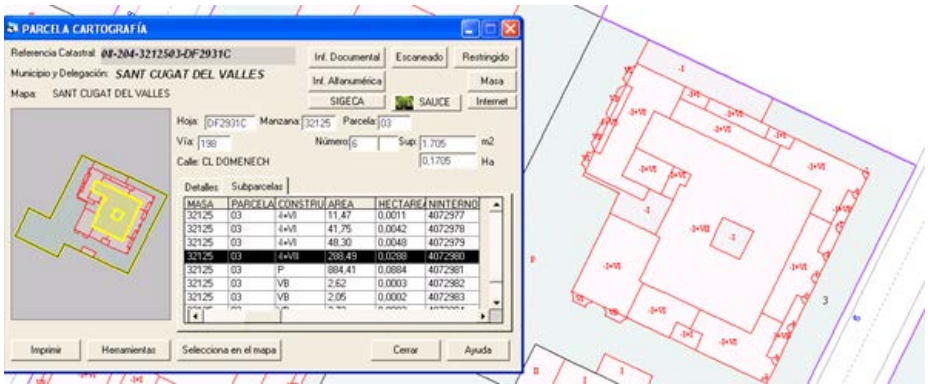

Figure 3. Cadastral map fragment and window showing several attributes

The cadastral parcel as main layer of the cadastre data model has premises ("recintos" in Spanish) with polygon topology and its geometry is captured in 2D, this constitutes a continuous model of the territory, without overlaps or holes.

Between all the layers of information that the model of cadastral cartography has, there is a topology layer which is the so-called "CONSTRU".

The layer "CONSTRU" has some special characteristics, its geometry defines the different volumes of the buildings and the various uses which may have the divisions of the parcels in the urban area as: terraces, gardens, swimming pools, etc.

Each cadastral parcel where a building is located is subdivided in "*recintos*", *premises*, where the different parts of the building are separate: by their very nature (IP pool, JD Garden, TZA terrace,...) or by number of plants (-I+IV basement plus four plants, -II+SOP+X two basements plus veranda plus ten floors,...).

These texts (the numbers) are attributes of the construction layer (CONSTRU) in the data model.

The WMS service of the SDGC is developed with our own media and technology, which allow us to manipulate information obtained directly from the spatial selection of the graphic database in vector format, and to generate the resulting image of the map with the characteristics of the symbols and representations that we want to.

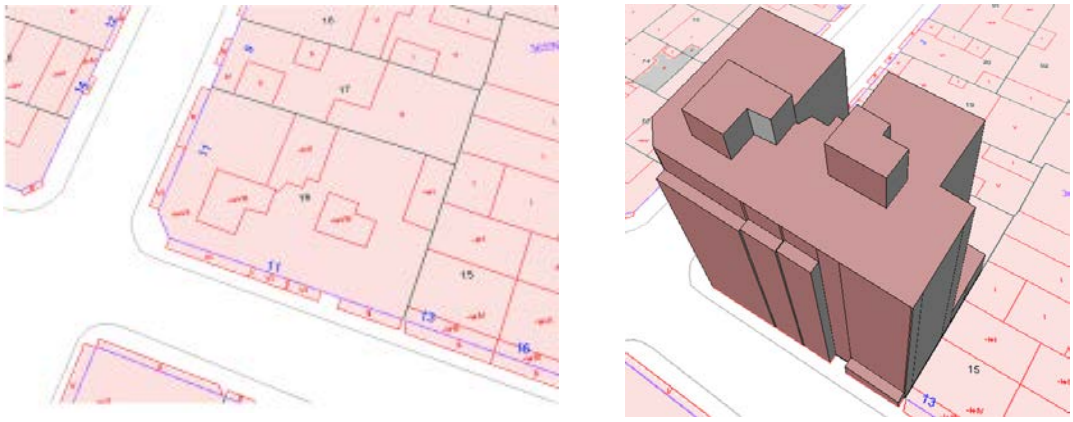

Figure 4. Cadastral map combined with 3D representation

The CONSTRU layer is going to serve as a basis for use in the 3D representation. Two new layers in the service WMS, providing two different solutions have been defined: one using a shading to give highlight aspect to the buildings and another solution that is the representation in Cavalier perspective each constructive element.

These two solutions are very innovative contributions in the WMS services that are offered within the framework of the spatial data infrastructure (IDE), that allow enhance 3D components and integrate them with the rest of the information which already supports the service

3.1 CONSTRU3D Layer

This layer of course allows perfect integration with the rest of the layers of the cadastre WMS service. The departure information is the geometry of the "CONSTRU" layer. We first select only the sub parcels that have as volumetric attribute floors above ground level, they are the only ones that are going to try to give the shading effect. The shading effect is achieved doing a shift from the geometry of these compounds in the Southeast direction applying a symbolism of drawing of semitransparent fill in grey and without borders, this does not hinder the rest of the information on the map. Then we draw the all CONSTRU layer with its own symbolism. The result is an image in which the constructions that are over the ground floor give a shadow as if they were an illumination from the Northwest. It is the visual effect that produces the feeling of relief.

This layer has a threshold of visualization for smaller scale to the representation of the "CATASTRO" layer. It provides a more aesthetic vision of the fabric of the buildings in a city, and although no difference heights independently for each of the sites, but represents pretty well that three-dimensional buildings set component.

Figure 5. WMS service of SDGC. Layers: Cadastre and cadastre+construu3D

3.2 "EDIFICIOS" "BUILDINGS" layer

The "EDIFICIOS" (BUILDINGS) layer represents only CONSTRU layer compounds defined with buildings on ground level. With this data we generate an image of the CONSTRU layer in Cavalier perspective, sub parcel by sub parcel, taking into account the height in number of plants of each object. The algorithm of representation of this perspective is based on the following steps:

- First, we order the resulting sub parcels of the selection in a descending order from North to South of the image, in this way, if there is overlapping of objects we draw in last position the sub parcels who are closer to the point of view, south ones.
- Second, each sub parcel is drawn in its real position, defining the basis of the construction, with a semi-transparent fill in a red color very clear.
- Third, for each pair of consecutive coordinates that make up the sub parcel, we construct a parallelogram in the North-South direction and scale a factor multiplied by the number of floors above ground level. This number of plants is obtained from a function of the transformation of the text of the attribute in the Roman number to integer. The symbols for these parallelograms is semitransparent fill in darker red that one for the plant, producing an aesthetic effect with greater sense of depth or highlighted.
- The last process of the algorithm is to draw the cover of the generated prism. It is a object with the same geometry of the base but with a shift towards the North of the image, based on a factor by the number of plants.

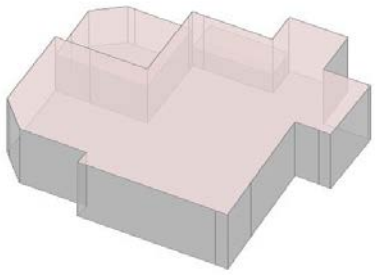

Figure 6. Representation of the constructions of a parcel in Cavalier perspective

The result allows that this layer can be integrated perfectly with the rest of the layers of the WMS service, since it retains the position of the base with the CONSTRU layer and, by the effect of semi-transparency, it do not hide the information from other layers.

To use this layer in the WMS service, as well as provide a new aesthetic to the cadastral cartography, it also provides a greater understanding of the urban fabric and the configuration of buildings and constructions, differentiating clearly as structured by heights.

Figure 7. SDGC WMS. Layers: Building and building+cadastre

Figure 8. Superposition of the WMS service of cadastre with the orthophoto

4. CADASTRAL CARTOGRAPHY 3D MODELLING

Since its inception, Google Earth has meant a revolution in the world of the dissemination of cartography. This tool has allowed to show an image of the globe in three dimensions, and the KML format (KML: http://code.google.com/intl/es/apis/kml/documentation/kmlreference.html [10/02/2011]) to be able to generate georeferenced

3D information by any user and then to be viewed on Google Earth (Olivares García, 2006) for the entire community of Internet users.

There are other formats for the modeling of 3D geographic objects, but the KML format that is standard for the Open Geospatial Consortium (OGC) offers many advantages, as its popularity and the facility to generate it, what makes it ever more present in the data that are integrated into geographic information systems and other applications which allow to visualize three-dimensional objects.

For this reason and based on the three-dimensional component of the constructions and that it is collected as attribute of the sub parcels which constitute the cadastral parcels, and the geometry of the premises, the SDGC has developed a vector 3D modeling by parcel in KML format. This modeling is not stored in the database, it is performed in "real time" on the basis of the vector information of the geometry of objects.

Two products can be defined on the basis of the origin of the information, one is based on modeling by extrusion (Wernecke, 2009) on the basis of cadastral mapping and the attribute of construction geometry to get the "z" component and the other model is based on the generation of independent units models with the vector information of the cadastral sketch by plants, which are in the format FXCC.

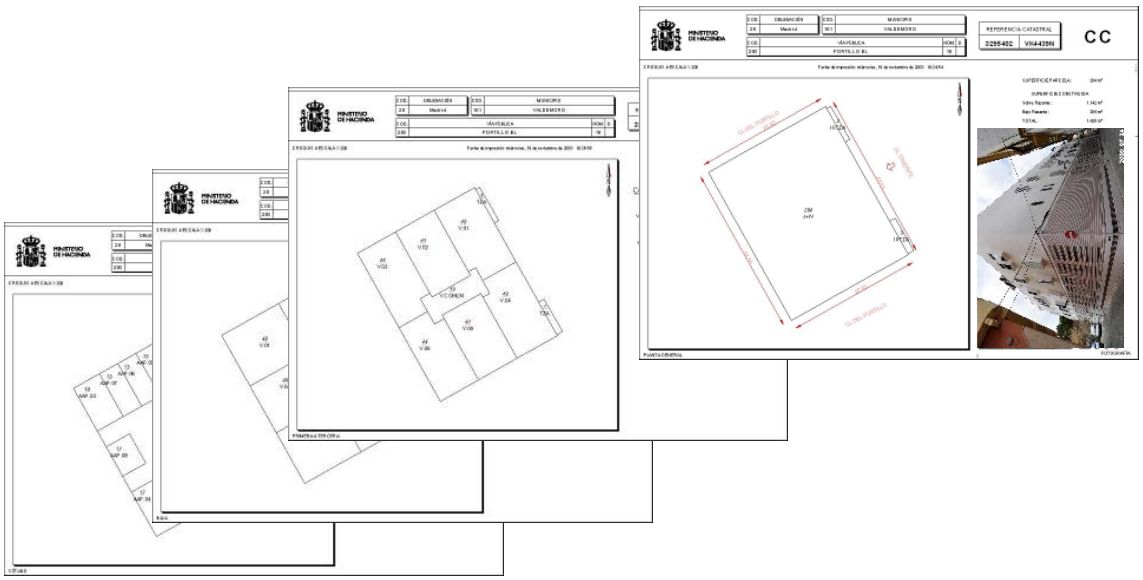

Figure 9. FXCC exchange format

The FXCC document is a scaled graphic representation of the properties forming an urban real estate building.

In every FXCC the different floors and interior spaces are represented. The FXCC contains a digital photo of the building too.

This document is available via Cadastral Virtual Office and it is stored in the system as documental information and link up to parcel data by means of the cadastral reference. Every unit of a building (for example one apartment) has its own cadastral reference.

Currently individual apartments are usually not visible on the cadastral map, only the outline of the apartment building as related to the ground is visible. However, the rights are attached to the individual apartments and the citizens and other users are interesting in these individual data.

4.1 General floor 3D Model

To this end, we use the cadastral cartography in vector format of each parcel, "CONSTRU" and "PARCELA" layers. The volumetric attribute of the buildings that it is a test in roman numeral , by means of a mathematical function, becomes the number of plants. With the number of plants, multiplied by 3 (that it is what we have estimated a priori, in meters, as the average height of each plant), a 3D model by extrusion is generated for each sub parcel of the parcel.

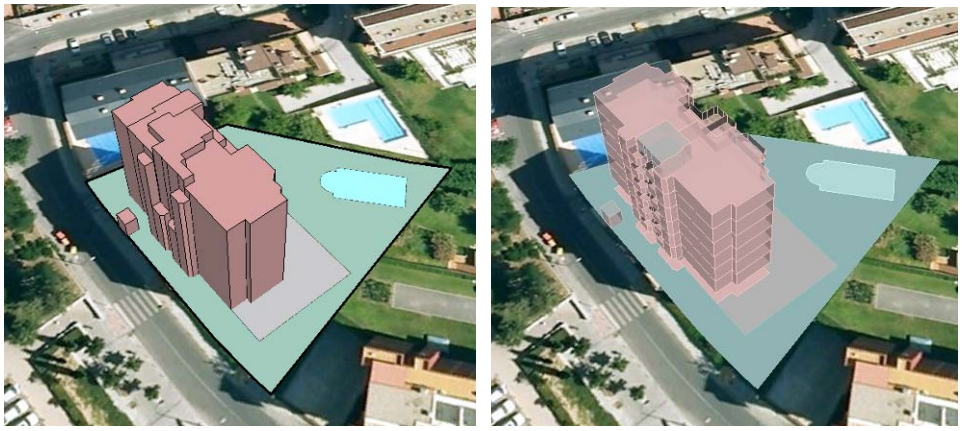

Figure 10. 3D modeling of a cadastral parcel. By extrusion of general floor and by each floor

The resulting KML as well as the 3D model of the constructions, adds the geometry and the text of the address, as well as a link with the cadastral reference to get all the free data of the parcel within the electronics site of the Spanish of the cadastre (SEC) (Electronic site of SDGC (SEC): http://sedecatastro.gob.es) and (Spanish Directorate General for Cadastre (SDGC): http://catastro.meh.es).

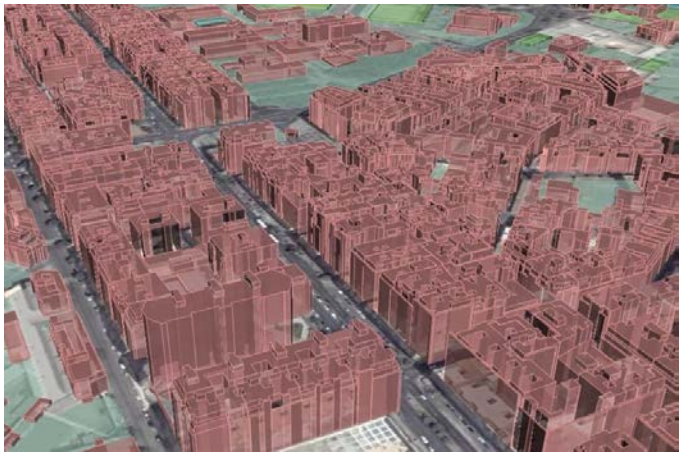

Figure 11. General floor 3D model

4.2 3D Model by floors

For the generation of this 3D model, it is used as a source of information the geometry in vector format from the cadastral sketch in FXCC format.

It is information that is stored in database, parcel by parcel, independently but georeferenced. The FXCC format contains vector information in DXF format of each significant floor of the building with its distribution in premises

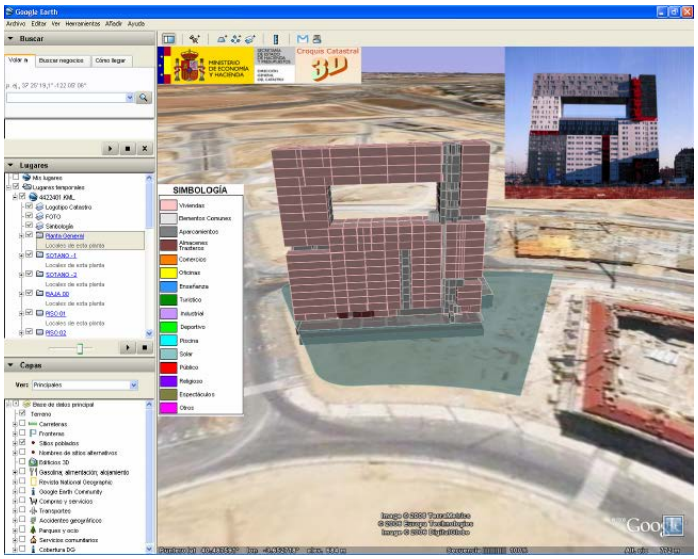

Figure 12. Representation of the KML file in Google Earth of the 3D modelling local to local of a parcel obtained by reconstruction of premise by premise

Each local can be geometrically represented in three dimensions within the physical space in the building. Geometric reconstruction of each local 3D is done through maps in space and is constituted by: soil (horizontal plane geometry 2D surface and the dimension of the surface multiplied by 3 meters), walls (as rectangular vertical planes of 3 meters in height of each pair of coordinates), roof (horizontal plane geometry of the local 3 metres above the ground).

There are some exceptions based on the attribute of the element, in the case of the terraces the objects are defined by a floor and walls of 1.5 meters in height.

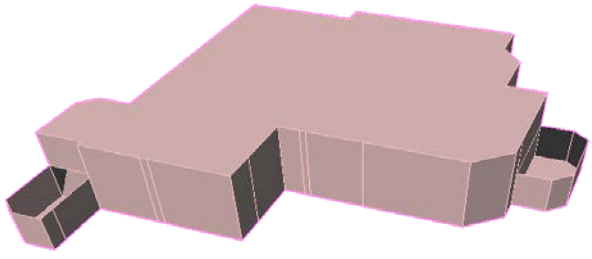

Figure 13. 3D model of a premise

Reconstruction of a building element by element, unit by unit is represented in 3D is as follows, assigning to each unit a color depending on its use.

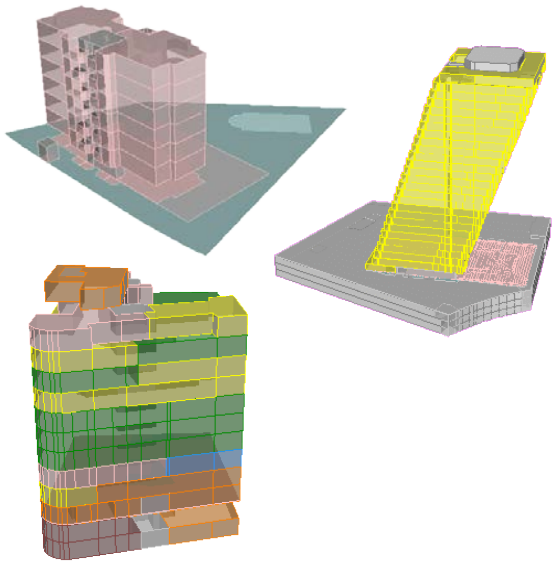

Figure 14. 3D model of the distribution of use

The format that we have chosen to view the buildings in cadastre is KML, which allows viewing in a 3D navigation through Google Earth each premise independently.

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BIOGRAPHICAL NOTES

José Miguel Olivares García is a Technical Engineer in Topography by the Polytechnic University of Madrid (1982). Civil servant of the National Geographic Institute from 1984 to 1992. From 1992 until now, he is Chief of service in the area of cartography of the Spanish General Directorate for Cadastre. These years he has been working on GIS development, Web maps services, publication of cartography in Internet and 3D cadastre.

Luis Ignacio Virgós Soriano is a Mining Engineer by the University of Oviedo (Spain) (1980). Civil servant of the Spanish General Directorate for Cadastre since 1997. Since 1999 he is the Head of cartography , working on the GIS of the Spanish Cadastre.

Amalia Velasco Martín-Varés is a Doctor Agricultural Engineer (Polytechnic University of Madrid, University of Michigan (USA) and Wageningen University (The Netherlands)). Master in Political and Economic Organization of the European Union. (University of Madrid). Since 1988 Civil servant of the Spanish General Directorate for Cadastre. She has been working in several technical and management tasks and now occupies the position of International Affairs Coordinator.

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