

Modern Representation Technologies for the Implementation of 3D Cadastres in Latin America

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SUMMARY

Latin America is a diverse region, where social and legal inequities can be seen in many ways. The region is very rich in natural resources, such as minerals, water, forests and productive land; however, its distribution and access are limited and uneven. The concentration of property and resources, as well as the high value of the urban land, leads to illegal and informal uses of the territory.

If this situation is a product of exclusionary land policies, the existence of incomplete and inappropriate 2D cadastres and weak land registries, it is valid to ask: Can a 3D cadastre implementation reduce land property concentration, improve the use of natural resources and reduce informality with the new information system? To convince administrators about the relevance of a 3D cadastre, it is very important to have a clear answer to this question because the demand for a 2D-to-3D transformation is huge in terms of time, money, and human resources.

The construction of the answer must start by analyzing the traditional aspects involved in the cadastral area: the legislation, the information technologies, and the land valuation methods in use. After several years studying the current cadastral law frameworks of the countries in Latin America, it is possible to anticipate that the construction of a common concept of “3D parcel” and “3D property” for the entire region is still a utopia. It will be more useful to create appropriate 3D concepts for the jurisdictions now and, in the near future, compare them to identify the points in common and the differences.

The strategy followed during the first period of the research consisted of the identification and classification of the concepts related to parcel, property, and territorial object. The first results showed that in some jurisdictions they should be represented by flat figures and, in others, by spatial objects. Having done this, it was clear that it was necessary to identify the mapping technologies available in the region, and apply them in order to represent the objects' extensions.

The study about the better contributions of a 3D cadastre implementation to reduce informality in the region showed that there are several initiatives which are already using spatial data and representations. Among these examples, there were selected two cases, one in Colombia and the other in Brazil. Both of them show, in different ways, how the use of 3D data makes the difference and how it can improve urban planning in slums. In this paper,

these cases are described with the purpose of showing how a 3D cadastre of tenure can become a 3D cadastre of property.

Some representations of the formal city in the region are being done through LiDAR and Pictometry surveys, besides the traditional photogrammetry and topography. The examples selected for this paper come from Mexico and Brazil, and they are more oriented to the physical aspects of the cadastre than the legal ones. Precisely, this paper discusses whether these technologies really contribute to make the geometric-legal-economic connection in the space toward a full 3D cadastre construction.

The other part of the territory is the subsoil. The use of a ground 3D laser scanner, the Ground Penetration Radar (GPR), and global navigation satellite systems (GNSS) is widespread along the region to identify ground level and underground objects. Among the several examples identified, there was selected a case which integrates all of those technologies into a tridimensional model, starting with dotted clouds and finishing with the representation of the legal territorial objects.

The first conclusion points out that there are several, but atomized, initiatives which could be capitalized into a full 3D cadastre in different jurisdictions. Their description and correlation through publications and conferences will contribute to disseminate the spatial ideas and will open new opportunities for 3D cadastre implementations.

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1. INTRODUCTION

Most of the concerns showed by researchers on 3D cadastres in Latin America have to do with identifying and classifying the definitions of “property” and “parcel” contained in such countries’ legislations and supplementary rules. Based on current descriptions, the purpose of this paper is to create models and propose concepts for “3D parcel” and “3D property” for future legislation.

Previous research done by the authors show that almost all the cadastres in the region are oriented toward storing private property parcels, by representing and describing them with the geometrical shape of a polygon in their respective property titles. The rest of the urban space, i.e., public spaces and informal settlements, are generally outside cadastral databases.

Public spaces, mainly streets, appear as simple remainders of private property, with the exception of public administration buildings and certain squares, which are indeed considered parcels in the cadastral databases. Informal urban settlements are rarely recorded in cadastres and, when they are, records consist of very general data about the settlements, with no individualization of the housing units and their residents.

Identification of territorial objects on the ground surface is generally simpler, but not easier, than underground identification. Based on countless experiences observed throughout the region, we selected one developed by a research team from Universidade do Vale do Rio dos Sinos (UNISINOS), Brazil, due to its technical features and the possibility of mapping the surfaces that delimit underground territorial objects.

In view of this situation, it is possible to conclude that, if the reality of Latin American cadastres is complex and, in many cases, precarious in 2D, just the thought of trying to develop 3D cadastre alternatives seems a utopia. Notwithstanding this, research is being made on compared legislation, and the results of this initial work show that it is possible to find many creative technological initiatives in the region, that are oriented to generating spatial objects (instead of flat figures) that can be considered 3D proto-parcels and which may give way to 3D public or private property.

2. GIS-BASED VIRTUAL 3D CITIES

Google Earth has popularized geographic information by allowing users to visualize a virtual 3D location at the desired level of detail and in a global environment. Google Earth and other geographic software can be used quite easily to change the viewpoint of reality. Moving from a top-down view, which shows the city as a flat area, to an oblique perspective permits the viewer to see the relief and height of buildings, trees, aerial utility networks, and other objects in space.

This type of 3D visualization can identify undeveloped spaces, buildings of different heights, scattered suburban housing, structures in isolated rural areas, and precarious slum constructions, thus helping to infer changes in land uses. Even when 3D images are represented on a flat screen or printed surface, they show details that are hard to identify in a 2D map, such as shadow movements during the day, views from an apartment window, and spatial relationships between buildings.

The first idea that usually comes to mind regarding a 3D image is its representation in regular shapes such as cubes, prisms, and cylinders, but these simple forms have proved insufficient to analyze urban space. Seeking a closer match with reality, researchers and designers have developed techniques to overlay photographs of building facades on building contours, and to represent all architectural characteristics of a building using 3D computer-aided design (CAD) software.

A geographic information system (GIS) contributes to the process of building a virtual 3D city by permitting linkages between statistical data and geometric shapes to generate thematic information images that can be applied to a variety of land policy issues. The 3D image created in a GIS platform is frequently more useful for urban planning purposes than a photograph of the same sector because the 3D platform makes it possible to highlight certain information of interest, create prospective scenarios that anticipate the economical effects of the land policy decisions, or evaluate the environmental impacts of new development.

In Latin America, many jurisdictions have taken the initiative to build virtual 3D models of their cities by using GIS tools. For example, in the city of Medellin, Colombia, the cadastral technical team develops a gradual structuring of the virtual city model by means of building extrusions, both downwards and upwards regarding ground surface. Figure 1 shows the sequence of operations carried out in order to generate the buildings as 3D spatial objects.



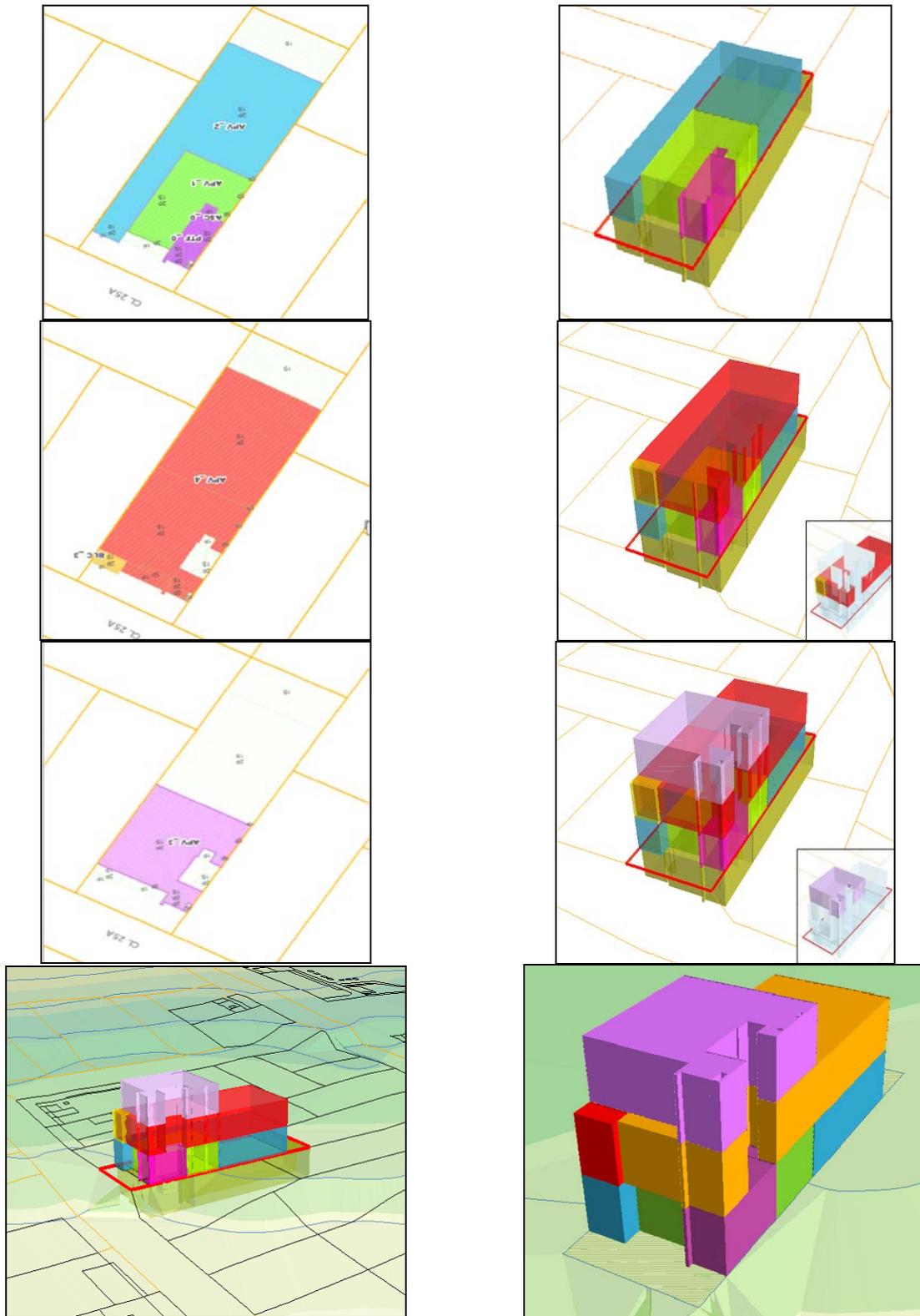


Figure 1. Sequence of objects generated by extrusion in a GIS environment

Source: Sub-Department of Cadastre of the Municipality of Medellin, Colombia.

In order to build virtual 3D cities using GIS tools, it is essential to have the 2D figures corresponding to the contour of each floor of the buildings included in the cadastre, connected to complete alphanumeric databases.

3. PHOTOGRAPH-BASED VIRTUAL 3D CITIES

Traditional aerial photogrammetry allows for generating 3D topographic data on the cities. This is still one of the most widely used techniques in Latin America for detailed city mapping, mainly due to its capacity to map objects in space with high precision. The quality of fully-digital cameras and processes has consolidated this method even more; however, photogrammetric restitution is still based on vertical aerial photographs and, therefore, many data are missed because they remain hidden. The use (frequently indiscriminate) of urban space by private owners, who neither comply with city planning rules nor respect public spaces, and informal settlers who often settle in risky or environmentally-protected areas, is not always detected by means of vertical aerial photography, so it became necessary to develop new alternatives.

The new technology consisting of metric and georeferenced oblique aerial photographs generated new possibilities to develop better 3D databases in the cadastres, particularly for the purpose of recording legal territorial objects (LTOs) which, seen from above, are overlaid in the projection plan. Thus, oblique photographs seem to be the best option to capture and record geometric data in these cases. Pictometry is the technique that allows for reconstructing 3D territorial objects based on 5 photographs, a vertical one and four oblique photographs, and it is currently being applied in Latin America for city mapping purposes. Figure 2 shows some interface views of the Pictometry On Line (POL) web application, which allows for managing vertical and oblique photographs. In this example, the top image relates to the east perspective of the Macroplaza in Monterrey, Mexico, while the bottom series of images relates to the orthophotograph (vertical capture), south and north views, respectively.

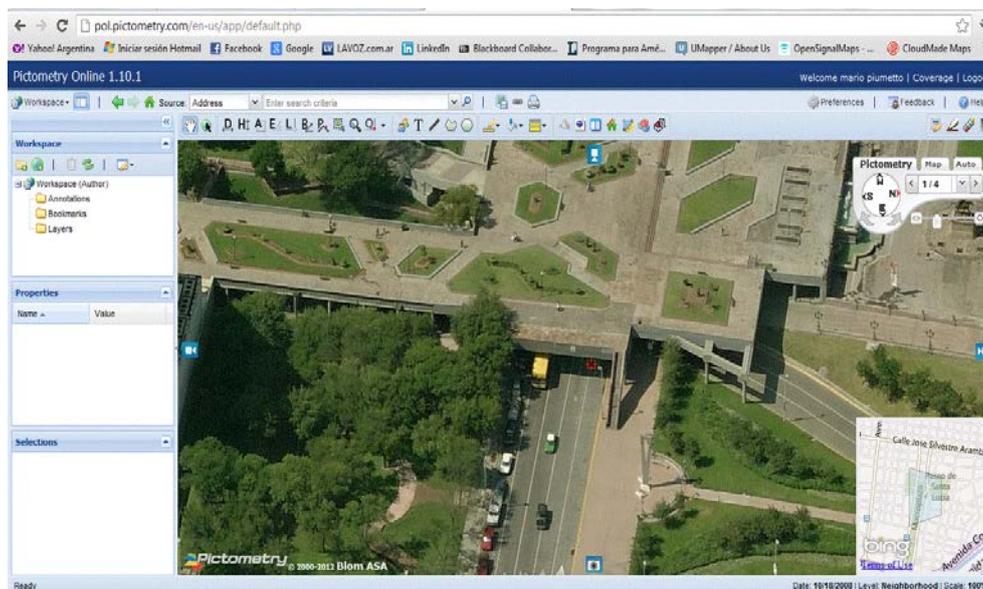




Figure 2. Vertical and oblique aerial photographs from Monterrey, Mexico, used in Pictometry

Figure 3 shows the final result of the processing and generation of 3D geometric objects, based on which it is possible to analyze the distribution of public and private property rights. Obviously, this technology allows for mapping LTOs at a higher detail, as well as structuring more complete 3D spatial databases.



Figure 3. Result of the integration of aerial photographs and oblique photographs

Yet another technique began to be applied in Latin America, and it is also based on photographs, although they are obtained with land cameras that capture 360° space images. This product allows for producing 3D georeferenced data, such as the case of Earthmine.

Figure 4 shows 360° metric-quality georeferenced photographic shots of the city of Fortaleza, Brazil. The top image shows that the projection of the apartments over the land overlays the public space; therefore, it is necessary to solve this by using a 3D data model generated from aerial and ground data. The bottom image shows that the use of 360° ground photographs can also greatly supplement informal zones in order to, for example, identify the limits between unrecorded housing units or partial settlement zones in public streets.

With the aid of this technology, it is possible to greatly reduce the field work relating to a mass cadastre census with the purpose of identifying the settlement profile (residential, commercial, etc.). It is also an excellent supplement to Pictometry, since it allows for identifying a significant portion of details that cannot be identified with vertical or oblique photographs. For example, the modeling of small properties surrounded by high buildings or apartment buildings (each one considered as a separate LTO) with complex architectural designs could be completed by using a 360° land survey.



Figure 4. Views of Fortaleza, Brazil, obtained from the Earthmine website

Pictometry and 360° land photographic surveys are technologies that use their own data-management software tools, and they can be integrated in the market's standard GIS and CAD platforms, both desktop and server, such as ESRI and Autodesk. As regards tools, it is possible to take several vertical, horizontal and oblique measurements, as well as to extract 3D data. For example, with regard to Pictometry, the operator may, based on the POL application, identify situations requiring a rectification in the originally-developed 3D model (such as from a restitution of vertical photographs), construct the 3D model of the building or situation that needs rectification, and finally export such data in KML format to be incorporated in the GIS or CAD supported by the cadastre's territorial information system, or even in Google Maps or Google Earth.

In Latin America, cadastres can have access to Pictometry or Earthmine through exclusive representatives for this region. However, this is not the only alternative. For oblique aerial photographs, another option is the A3 technology by Visionmap and Oblix. In all cases, these are Mexican companies that have developed and/or represent the above-mentioned technologies to be used in most locations throughout the region.

4. VIRTUAL 3D CITIES BASED ON LiDAR SURVEYS

The aerial LiDAR (Light Detection And Ranging) is a system that allows for obtaining a scatter diagram that covers the land and the existing elements based on an airborne laser scanner supplemented by GNSS equipment and an inertial sensor that ensures high geometric quality results. From each dot in the scatter diagram the topographic coordinates (X, Y) and height (Z) are obtained, due to the possibility of knowing the distance between the sensor and the measured dot.

The particular difference of this method compared with photogrammetry-based 3D data generation relies on the fact that the LiDAR data processing allows for automatically obtaining a first (primitive) version of objects on the ground surface and its coordinates. Even though object quadrature model algorithms and contour refining must be applied – as well as a final review to be done by a specialized operator – data processing and generation times are significantly reduced.

LiDAR technology has been used in Latin America for several years now; however, not many examples of effective applications in urban areas are to be found.

In Mexico, the Cadastral Upgrade Program, fostered by the government through institutions at the different administrative levels, can be implemented by using different technologies. In certain locations within the State of Durango, the cartography obtained from LiDAR flights is now being used for urban studies, civil protection action plans, and urban infrastructure projects, among others. The LiDAR survey generates the frame of the buildings – i.e., their volumetry – and the existing cadastral information is used to supplement the inside part of the buildings in their different levels by applying extrusions in GIS. Additionally, the LiDAR scattered diagram, combined with the existing cadastral cartography, allows for detecting changes in buildings and new housing units, whether in the form of mergers, subdivisions or omissions. Figure 5 shows this process: the 2D cadastral cartography (light-blue sections) is

overlaid with the natural relief (orange sections), new buildings in 3D (white sections), existing buildings in 3D (yellow sections), and building extensions in 3D detected by means of the LiDAR survey (red sections).

However, a significant limitation here is that LiDAR data are not real images. Notwithstanding this, the combination of LiDAR images with photographs is more generalized now, particularly in terms of urban surveys applied to cadastres. Thus, 3D objects obtained from LiDAR may be combined with covers (roofs and floors) obtained from aerial photographs in order to generate realistic 3D city models; and even better results can also be obtained if we add facade images obtained from 360° cameras from the street (such as Earthmine), thus generating final city models that are complete and extremely realistic.

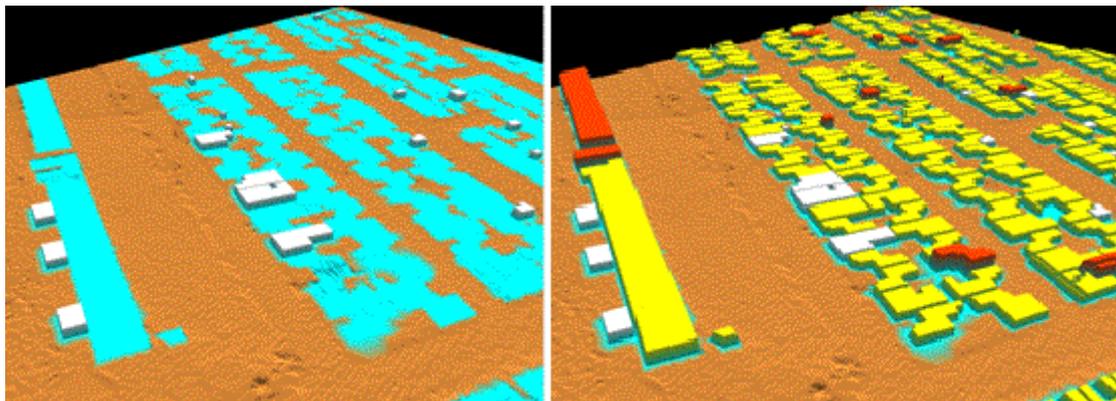


Figure 5. Integration of 2D cadastral map and 3D LiDAR data, Gomez Palacio, Durango, Mexico
Source: MAPA Merrick Advanced Photogrammetry of the Americas

The offer of aerial LiDAR flights in the region, including the integration of photogrammetric cameras, is considerably more available than the offer of oblique photography and 360° street surveys. Most countries have local suppliers and equipment, which ensures availability and promptness in the event of a project.

5. 3D INFORMALITY

In Latin America, there are different geo-technology applications for multi-data survey and management related to informal urban settlements, and each of such technologies adjusts better to the different social, topographic, economic, and environmental realities of the neighborhoods. In this topic there is a description of two particular cases involving the participatory planning of informal neighborhoods, which began by carrying out 3D topographic surveys in order to represent the use and settlement of the space, and ended with the development of re-urbanization proposals – also in 3D. The cases in Colombia and Brazil here presented were selected due to the fact that the view in perspective clearly changed the way to see reality and project changes, by understanding how public and private rights are developed in space.

5.1 Neighborhood of Potreritos, Bogotá, Colombia¹

The neighborhood of Potreritos was selected due to its location in one of the poorest zones of southern Bogotá, the district of Bosa Occidental, in an urban sprawl area. Within this district, the neighborhood of Potreritos originated entirely in an informal sprawl, and is one of the last neighborhoods built by people that migrated from the countryside in the 1980s. Another particular feature of this neighborhood is that it is surrounded by different types of social housing built by the company Metrovivienda.

The name “Potreritos” derives from the constant floods experienced by the location due to the frequent rains, converting it into a big mud pit (“*potrero*”, in the local language). This situation results in constant poor conditions for the inhabitants, which was another reason why this neighborhood was selected for this research, in order to develop an urban project and submit it to the Mayor’s office in Bogotá in the form of an effective proposal.

The study on the evolution of the settlement was carried out based on aerial photographs taken during the period 1950-1999 and stored at the Agustin Codazzi Geographic Institute. During such period, this area – which was initially rural – began to show urban features and, by the end of the 2000s, it was densely inhabited. These photographs, together with 24 frames obtained from Google Earth, allowed the making of a photo montage in the Photoshop application. By making a correlation of the photo montage with the 2D cadastral database corresponding to the 17 blocks that make up the neighborhood, it was possible to identify some of the informal housing that had already been drawn. One of the most important issues in the research was precisely the comparison between cadastral records and real settlement, which allowed for establishing the cadastre’s level of outdated records. Subsequently, the cartographic database was updated in CAD, by carrying out house-to-house field work, during which the height of the 330 buildings was also surveyed, separating the polygons in layers according to the floor number they represented. Figure 6 shows the result of the mapping in one of the blocks under study, which is considered the study area in this paper.



Figure 6. Construction levels of housing units in the study area

The georeferencing of housing units and the survey of their heights allowed for generating the simplified objects corresponding to the constructions in their true dimension and position. Figure 7 shows a portion of the virtual 3D neighborhood, containing a representation of all

¹ Adapted from Maceratini 2009.

useful building details and the spaces between buildings in order to analyze hours of daily sunshine, density, and other urban variables. Buildings were represented in a CAD environment, by creating different layers depending on the number of floors.

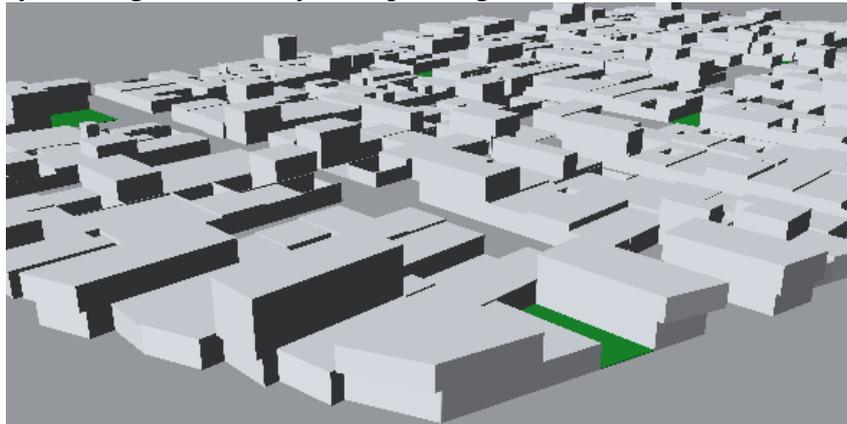


Figure 7. Perspective of existing housing units in the study area

In view of the diversity of building types, and in order to give a higher level of realism to the virtual city, each housing unit was surveyed with photographs. By applying the ground photographs to each external face of the objects generated in the virtual 3D city it was possible to build the neighborhood perspectives with a much more realistic vision along the streets (Figure 8). This shows a clear image of how the inhabitants settled in the space and built their rights.



Figure 8. Perspectives of streets and housing units with photographs of their facades

The neighborhood's urban profile is defined by self-constructions using different types of materials, which result in colorful facades and variable heights (Figure 9a). A re-urbanization and regularization project could basically follow either of two paths: ignoring this reality and importing a standard official plan developed by housing agencies (Figure 9b), or else developing projects together with the community to maintain some of the original characteristics of the neighborhood, such as the color diversity (Figure 9c).



Figure 9. Self-constructed facades (a) and alternative re-urbanization plans (b and c)

Once the distribution of private rights for the inhabitants is defined, it is necessary to deal with public rights and discuss the alternatives relating to the location and size of green spaces and urban equipment. The possibility of visualizing alternative space scenarios under different perspectives simplifies these complex decision-making processes and speeds up criteria convergence. Figure 10 shows, to the left, a colored axonometry relating to the types of housing and, to the right, a general top down view of the project.

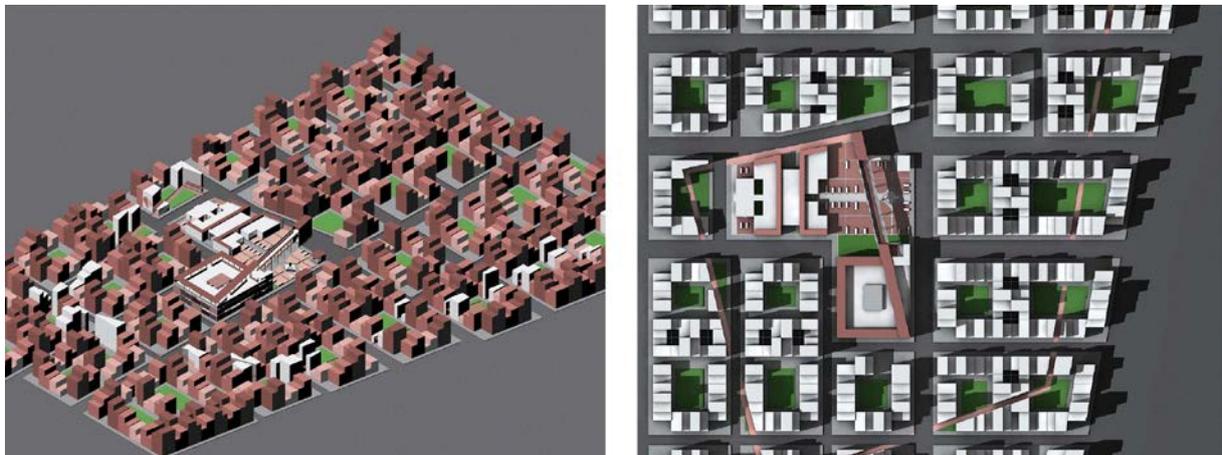


Figure 10. Proposal of the installation of urban equipment under different perspectives

These images show how public and private spaces and rights would be redistributed upon the implementation of the urban project.

5.2 Neighborhood of Martin Pilger, Novo Hamburgo, RS, Brazil²

In this city, informality is scattered and it is present in urban spaces with different characteristics. Among the many experiences found in this city, it was selected because of the distinction between this case and the Colombian example, particularly in terms of relief. As

² Adapted from Néri Martins et al.

shown in Figure 11, formality and informality coexist within small distances, so it is very important for all inhabitants to eliminate isolation patches and make urban integration feasible.

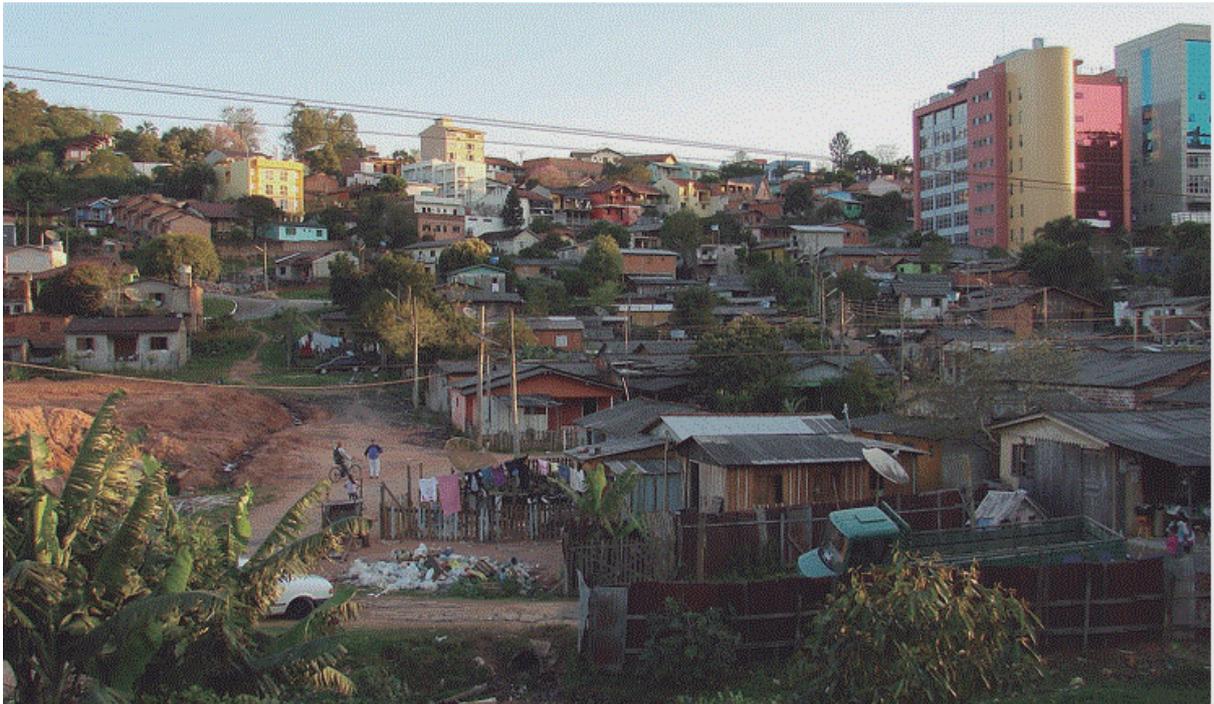


Figure 11. Informal settlement Martin Pilger and buildings of Campus II Fevale in the background

Source: Architecture and Community Outreach Project, 2011.

Searching for solutions for tenure regularization, and taking large-scale cartography generated by traditional photogrammetric and topographic methods as the basis for our project, both the land and the existing buildings were represented in 3D. Discussions over which buildings should remain and which should be eliminated, the redefinition of public spaces, and the distribution of urban equipment and infrastructure were coordinated by the planning teams together with the participation of the inhabitants.

The fact of modifying the view direction – from a top-down perspective (2D) to an oblique perspective (3D) of the neighborhood – definitely changed decision-making paradigms. Using the electronic model, architects and urban planners can develop and propose, based on its true size and spatial position, the available housing solutions.

In the neighborhoods of Novo Hamburgo, the proposal provides for different types of housing: from one- or two-story single-family houses to up to 3-story condominiums. The generation of 3D private property spaces – instead of the traditional 2D view – creates for the inhabitants a vision of density that is considered a relevant variable for life quality.

Most of the regularization and re-urbanization projects prioritize the granting of individual ownership titles, placing the discussion about public spaces and urban equipment on a second level. Precisely, these projects in Novo Hamburgo were selected due to the relevance they

gave to common spaces, such as squares and parks, which, when represented in 3D models with an accentuated relief, stood out for the inhabitants to make decisions (Figure 12).



Figure 12. Public space proposed for the community of Martin Pilger

The examples of participatory planning initiatives oriented toward structuring proposals for the redistribution of public and private rights, both in the Brazilian and the Colombian cases described above, show that in informal settlements it is also important to visualize neighborhoods as spaces. Complex rights-reassignment processes in settled spaces are definitely simplified by using 3D geo-technologies, which provide a highly favorable cost-benefit ratio.

6. UNDERGROUND SURFACES: BOUNDARIES OF NATURAL TERRITORIAL OBJECTS

Identifying and positioning the surfaces that delimit natural territorial objects (NTOs) and legal territorial objects (LTOs) underground require the application of quite complex surveying and mapping methods.

LTOs that restrict property are, in general, more easily represented, since they derive from a literal description contained in a given rule or regulation. Thus, the construction of LTO geometry in space implies interpreting the particular rule and reproducing in a 3D model the literal description which is frequently depicted in 2D. That is one of the most critical aspects in implementing 3D cadastres, since it will allow for eliminating the plane-based paradigms

and developing new space-based ones, which will result in a gradual change of current legislation.

The NTOs located underground, such as mineral, water, or oil deposits, among others, are concrete objects with a physical existence and a spatial development that can be identified, measured, and represented by means of different methods. Among the different techniques developed for this purpose, one of the most widely used methods consists of materializing a dotted mesh over the ground surface, drilling a well at each dot, and obtaining a stratigraphic column that shows the vertical distribution of the materials located underground. The flat coordinates (X, Y) of each vertex of the mesh are determined using GNSS receptors, and the height of each layer is determined along the column by obtaining the difference between the height of the wellbore in relation to sea level and the vertical distance of the layer up to the ground surface (Figure 13. L1, L2, L3). NTOs are delimited by the surfaces obtained as a result of the spatial interpolation between the spatial coordinates (Figure 13. O1, O2, O3). This process is precise, but quite expensive and time-consuming.

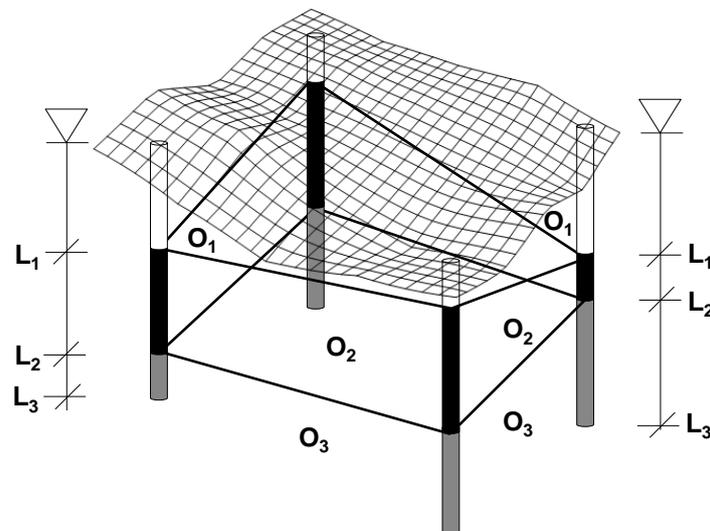


Figure 13. Regular mesh and stratigraphic columns at the main vertices

Another widespread technique to identify underground surfaces is based on the use of Ground Penetration Radars (GPR), which detect anomalies and generate images (technically known as “radargrams”) that are used to infer whether there are contact surfaces between different lithologies or object contours underground. By correlating the radargrams with the stratigraphic columns extracted from certain wells, it is possible to construct the surfaces that delimit certain objects and determine their location in space with high precision³.

Positioning of radargrams generated by the GPR is achieved by geo-referencing the lines followed by the instrument on the ground surface, using GNSS receptors (green lines in Figures 14 and 15). In certain specific applications, such as GOCAD, it is possible to integrate data in graphic form, as shown in Figure 14.

³ Adapted from da Silva 2012.

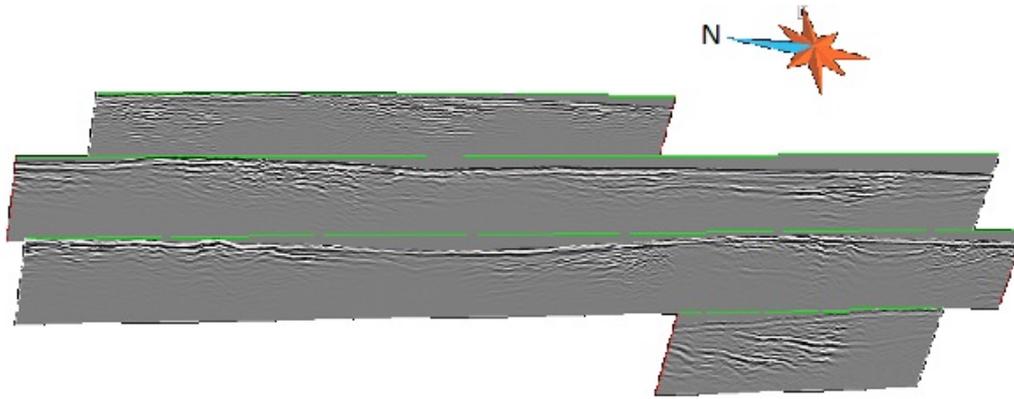


Figure 14. Radargram spatial geo-referencing

Based on such a spatial model, a specialist then interprets each radargram and connects the dots relating to anomalies that bear similar characteristics, obtaining surfaces that divide different materials underground (Figure 15).

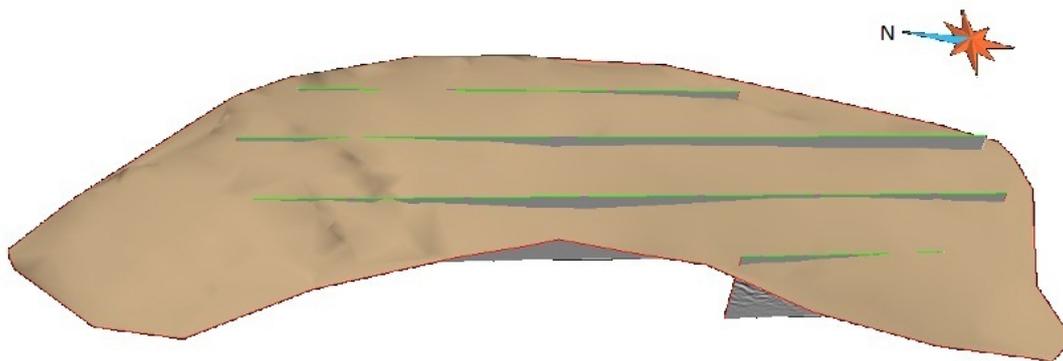


Figure 15. Configuration of underground surfaces from radargrams

By intersecting the vertical plans relating to the contours of the properties with the surfaces that delimit LTOs or NTOs, it is possible to obtain objects that represent the restrictions to property or physical objects that are perfectly geo-referenced and positioned in space.

7. CONCLUSIONS

Formal and informal spaces in Latin American cities are gradually being constructed in virtual 3D environments.

The generation of 3D objects by means of the extrusion of the existing 2D figures contained in the cadastral databases is certainly the most frequently used technique in the region. By using standard heights of approximately 3m for each floor, the construction of virtual buildings is fast and produces good visual results.

The use of vertical and oblique aerial photographs, supplemented with photographic land surveys, is producing very good results at competitive costs, when compared with other techniques that generate similar graphic results.

LiDAR surveys for the construction of virtual cities are still only a few, but the case described show the great potential of this technology to survey urban spaces, particularly in relation to spaces of difficult access.

As regards urban informality, and precisely due to its being excluded from many Latin American cadastres, many spaces are yet to be identified, represented, described, and recognized in Latin America. On the other hand, initiatives such as the ones described in this paper show that certain informal sectors have more urban, social, and environmental information than some urban spaces inhabited by high-income classes.

Representations and urban development plans that are based on virtual 3D models change the perspective of the analysis and allow for integrating formal and informal spaces for a better understanding of social and environmental phenomena by urban planners and society in general.

It should be pointed out that, for proper 3D object management, it is essential to work with software-based GIS and databases that are capable of managing 3D objects. The term “3D object management” does not mean drawing or visualizing elements in three dimensions, but rather being able to store objects having 3D properties and topology, edit in 3D, apply 3D symbology, and even perform an analysis in 3D (such as observing the buildings involved in an aerial restriction upon evaluating the location of a new airport), among others. There is a great difference between drawing a building by using its perimeter and height and visualizing this frame in 3 dimensions, on the one hand, and obtaining a 3D object for each apartment, with its respective morphology, particular symbology and attributes, such as its owner’s name, on the other hand. GIS software such as ESRI and Bentley, among others, have these capabilities, as well as special databases such as Oracle Spatial.

The spatial representation of informal settlements and their inclusion in territorial cadastres will certainly contribute to a better and more comprehensive understanding of cities and their projection, by including the most vulnerable sectors in order for each citizen to be able to effectively exercise his right to the city.

The costs involved in the application of geo-technologies for 3D survey and representation tasks are insignificant compared with the extra benefits the urban population may obtain from the definition of participative urban plans that improve neighborhood functionality, are customized for the community and, consequently, avoid the import of alien styles, working with volumetry more efficiently in terms of redistribution of rights.

Finally, we venture to say that the above-mentioned costs can be covered indeed, since the city will have more elements to redefine its financing policy, making it fairer and more equitable.

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REFERENCES

Barros de Souza, G. H. and Amorim, A. (2012). LiDAR data integration for 3D Cadastre: some experiences from Brazil. In: FIG Working Week 2012, Rome, Italy, 6-10 May 2012.

Barros de Souza, G. H., Amorim, A. and Holzschuh, M. L. (2009). Terrestrial Laser Scanner for the 3D Cadastre: Feasibility for Acquisition, Modeling and Representation. In: IV Brazilian Geodetic Sciences Conference 2009, Curitiba: UFPR.

Erba, Diego and Graciani, Silvio (2011). 3D Cadastre in Argentina: Maps and Future Perspectives. In: Proceeding of the 2nd International Workshop on 3D Cadastres. 16-18 November 2011, Delft, the Netherlands.

Maceratini, Elisa (2009). Análisi e rilievo della vivienda informal colombiana, Barrio Potreritos, Bogotá, Colombia. Rome, 2009.

Néri Martins, Luciana et al. (organizers) (2012). Arquitetura e comunidade: projetos de reurbanização e regularização fundiária em comunidades de Novo Hamburgo. Novo Hamburgo: Feevale, 2012. 192 p.

Pineda Marín, Fabián Albeiro (2012). Proyecto de Catastro 3D y 4D. Subsecretaría de Tecnología de Información, Municipio de Medellín, 2012.

Silva, Reginaldo Macedônio da (2012). Modelagem Geológica de Afloramento em Potenciais Rochas-Reservatório, a partir de Técnicas de Sensoriamento Remoto (Doctorate thesis under development). 2012.

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