

# **Overlapping Characterization of Spatial Parcels in Brazil: Case in Florianopolis**

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**Key words:** 3D Cadastre, Laser Scanner, Property Right

## **SUMMARY**

This article aims to characterize a property right overlap situation and evaluate different possibilities and proposals for a 3D Cadastre in Brazil using laser scanning data. The complexity and the high density of urban areas, in Brazil and all over the world, have contributed to the increasingly verticalized occupation of the land surface. As new buildings under or on the surface appear, the structures of the cadastral systems must accompany them. These changes occur in a three dimensional continuous space that cannot be adequately represented in two dimensions. In developed countries and many developing countries the cadastral systems have migrated to incorporate the third dimension, developing data models based on their current records and techniques available, in order to ensure that intricate cases overlay of property rights can be addressed. Different models have been proposed around the world, since the maintenance of traditional land records with increase warning in property titles about the use of airspace or subsoil, through hybrid models for the sub-parcels above and below of the earth surface, to the complete volumetric spatial parcel models. The proposition of such models is powered by an actual technical and technological reality in which it became possible to collect, process and represent three-dimensional data on a large scale, needing then to update the legal and evaluation components. In Brazil, although there is no a parcel-based registration structure in international terms, the same problems are present and there is the possibility of considering the application of a third dimension in the context of national legislation.

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## 1. 3D CADASTRAL SCENARIO IN BRAZIL

In developed countries and many developing countries the cadastral systems have migrated to incorporate the third dimension, by developing data models-based in their current records and techniques available. In Brazil, at the moment that sedimenting propositions for Cadastre parcel-based, defined by coordinates and connected to the land register, arises the appropriate setting for research and to insert the 3D Cadastre topic in the discussions of the scientific community.

In terms of 3D Cadastre, although Brazil still does not have the cadastral structure required for implementation, intensive occupation of urban areas will eventually force the appearance of specific legislation to deal with the third dimension, and regulate both the use of airspace and the underground, which is starting to happen in some places.

We highlight the case of Recife-PE City which has since 2003 bylaw that regulates the installation of walkways over public places. Law 16,873 / 03 (Prefeitura do Recife, 2010) takes as municipal jurisdiction to grant rights over the airspace above public roads provided that certain conditions are achieved. These are the minimum and maximum height above the street (with reference to the longitudinal axis of the roadway), the minimum widths for circulation, the demand for movement of pedestrians exclusive, installing removable physical structures (the grant is reviewed every two years), the structure maintenance guarantee the accountability of the applicant for damages that may be caused by the presence of the runway, the existence of a common owner in the properties on both sides of the street, the seal installation over squares, parks and nature reserves, and the annual payment of an amount corresponding to the concession granted the right to build over public roads in the air space of the city.

As viewed, there are a number of requirements to be fulfilled, but there is a possibility that the grant is made and therefore a law clearly associated with the third dimension to take effect. There are two cases in Recife city related to the use of the aforementioned law that deserve note: the Hope Hospital (Figures 1a and 1b) and the Guararapes International Airport (Figures 2a and 2b). In the first case, analyzed by Souza et al. (2011), although the specific legislation, the results are disconnected from Recife city fiscal cadastre and the land registry.

In the second case, the walkway installation was performed in order to provide greater mobility between the airport and the nearest subway station on the occasion of the football World Cup in 2014, however, several of the requirements of own municipal law were breached : the owner on both sides is not common (international airport is administered by Infraero and the terminal subway integration by the state government), the walkway crosses part of the Square Salgado Filho, crosses the Av Mascarenhas de Moraes, part of the Barão de

Souza Leão St. and several private properties (airspace use concession was granted over the stores, warehouses and condominiums) and the structure is not removable.



**Figure 1. a) Top view (left) and b) View (right) of the walkway on the Av. Beira Rio, Recife-PE, connecting the Hope and Esperança Hospitals. Source: Google Earth**



**Figure 2. a) Aerial (left) and b) terrestrial (left) image of the walkway connecting the Guararapes International Airport and metro station. Source: Government of the State of Pernambuco**

The cases presented above are emblematic for being inserted in a city that has a legal instrument which can be related to a three-dimensional cadastral perspective and that would give excellent studies of the definition of the point of view of space parcels involved and property rights associated with each one of them. However, they are not the only ones, as the Brazilian urbanization occurred at an accelerated rate and the high demand for occupying spaces in the territory facilitated the verticalization of cities and generated a multitude of other cases, many in cities without the same legal apparatus. Below is a collection of photographs (Figures 3-6) which depicts other situations in Brazilian cities where the application of 3D Cadastre allow a better definition of rights, restrictions and responsibilities.



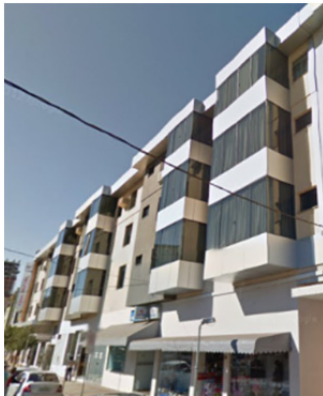
**Figure 3. Rio Branco College (left) and Unimed Hospital (right), Blumenau-SC**



**Figure 4. Walkway between buildings in a condominium (left) and walkway between Muller Shopping and Bourbon (right), Joinville-SC**



**Figure 5. São Marcos Hospital, Teresina-PI**



**Figure 6. Hotel balconies cantilevered over public tour, Pato Branco-PR**

In order to understand the limitations of the problem facing the Brazilian legislation and to seek characterizing a case quite evident overlapping legal rights over the territory, this article presents a case study in the city of Florianópolis-SC.

To collect field data has been chosen the laser scanning technique, although it is understood that other techniques (more conventional, such as topography, for example) could be applied. It is not intended here to make a comparison between different techniques but only to demonstrate the use and functionality, taking into account that laser scanning is currently one of the most modern techniques for collecting three-dimensional data used, with great possibilities of become increasingly common due to the reduction in size and weight of the equipment available, increasing the sweep speed and storage capacity as well as improvements to the development of methods for processing of increasingly efficient data.

## 2. CASE STUDY: CHARACTERIZATION OF UNDERGROUND PASSAGE IN FLORIANOPOLIS-SC

In order to conduct the case study, the site chosen was the underpass connecting the two parts of the campus of Federal University of Santa Catarina – UFSC, separated by Av. Prof. Henrique da Silva Fontes, on the outskirts of the neighborhood Córrego Grande. The passage has about 38m long and offers access to pedestrians, cyclists and small vehicles of the university's maintenance sector (Figures 7a, 7b and 7c).



**Figure 7. a) View of Av. Prof. Henrique da Silva Fontes (above); b) Underpass, West entrance (below left); c) Underpass, East entrance (below right)**

On the website of the Federal University of Santa Catarina, the campus map highlights the existence of the tunnel referencing it with dashed lines that intersect the Av. Henrique da Silva Fontes, although the map does not show a legend that explains the meaning of these lines (Figure 8a). The map displayed in Google Earth also makes reference to the tunnel presenting a continuous line in gray under the avenue indicating that it is a path or pedestrian access (Figure 8b). On the website of Corporative GIS of Florianópolis City Hall (Prefeitura Municipal de Florianópolis, 2015) there is no reference to the existence of the underpass (Figure 8c), only the two parcels (here called lots) that compose the property of UFSC appear numbered as 102445 (west of the avenue) and 101279 (east of the avenue). Of course, as there is no cadastral logic implemented (parcel-based) that makes up the Avenue Prof. Henrique da Silva Fontes does not appear characterized as a parcel in the city hall system. As it does not generate dividends to municipal coffers for the payment of Urban Building and Land Tax, the portion of the avenue is not registered, confirming the strictly fiscal nature (thematic Cadastre) than municipalities in Brazil call Cadastre.





**Figure 8.** a) Map of UFSC (left). Source: Adapted from Federal University of Santa Catarina (2014); b) Surrounding of the neighborhood Córrego Grande (center). Source: Google Earth; c) Numbering of lots on the website of the Corporate GIS (right). Source: Adapted from Prefeitura Municipal de Florianópolis (2015)

## 2.1 Laser scanning data used and processing procedures

Data collection for the case study was performed with a terrestrial laser scanner, Focus3D X330 model, manufactured by FARO and assigned by the Federal Institute of Santa Catarina, Florianópolis Campus (Figure 9a).



**Figure 9.** a) Terrestrial laser scanner Faro Focus3D x 330 (left) and b) spherical target positioned on the tripod with tribrach (right)

The equipment was set to a density point cloud of 7mm/10m, which was sufficient to ensure the minimum reading points in spherical targets (80 points in optimal conditions and 60 points in bad conditions) to the adopted distances, as indicated by the manufacturer. Although different types of targets can be used to record the scenes - such as rectangular targets, visible spots and common plans for two scenes, it was decided to use only the spheres to make possible to replace them with the assistance of leveling bases on tripods by GNSS receivers in order to perform coordinate data collection UTM of some points and, therefore, proceed the georeferencing of the cloud points, which would be more difficult using other type of target (Figures 9a and 9b).

According to the manufacturer's recommendations for the distance to be covered in subsequent scenes and the resolution adopted (7mm / 10m) for surveying in underpass, it was estimated a number of six scenes distant about 15m from each other with the use of 3 to 4 spherical targets between them (Figure 10).



**Figure 10. a) Laser scanner positioning in the tunnel entrance (above left); b) distribution of spherical targets inside the tunnel (top right); c) distribution of the six scenes in the survey of the underpass at UFSC (below)**

To proceed with the registration of the six scenes was used a total of 20 spherical targets, four of which were occupied with GNSS receivers (two in each tunnel entrance) to collect UTM coordinates of the points and thus georeference the cloud of registered points. For transformation and adjustment between the cloud coordinate points system and the projection system UTM would be needed only two points (one on each side of the tunnel), however, it was decided to use four for security, if any of them presented no adequate precision or fixed ambiguities solution.

Among the collection, data processing and generation of three-dimensional models the data passed through different software, as Scene, Autodesk Recap and Autodesk AutoCAD2015.

### 3. RESULTS

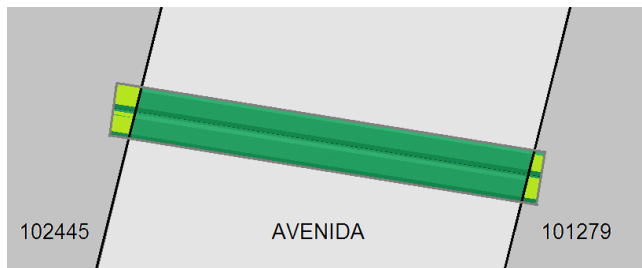
The registration procedure of the six point clouds and georeferencing conducted in Scene software showed satisfactory results with minimum and maximum tensions between scenes of 1.4mm to 3.3mm (Figure 11).

Ajustes gerenciados:

Objeto de ajuste	Tensão alvo média	Tensão média de pon...	Varredura/Grupo
ScanFit	0.0033	---	Tese2004
ScanFit	0.0026	---	Tese2003
ScanFit	0.0024	---	Tese2002
ScanFit	0.0022	---	Tese2001
ScanFit	0.0014	---	Tese2000
ScanFit	0.0020	---	Tese2005
References	---	---	Workspace

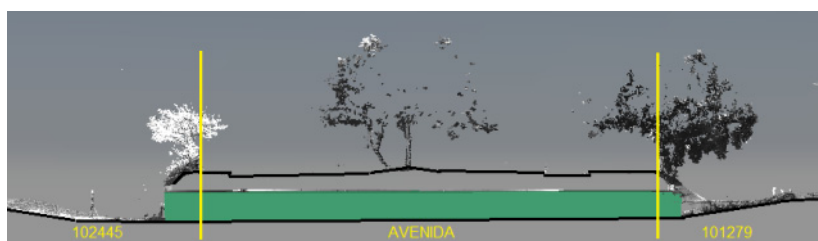
**Figure 11. Result of the scenes registering process in Scene software**

Once the cloud of data points have been properly registered, georeferenced and incorporated into AutoCAD 2015, there was continuation to promoting the 3D modeling of the parcels in question. It was used the same numbering given by the website of the Corporate GIS of Florianópolis City Hall to the UFSC parcels (102445 and 101279 on the west and east side of Av. Prof. Henrique da Silva Fontes, respectively). Regarding to the parcel formed by the street, it is not numbered on the website (as seen in item 2). We chose to present it under the code name "AVENIDA", although it is understood that a cadastral system in the strict sense the correct way would be to sequential numbering of that parcel. The territorial arrangements of the parcels and the interconnection between the UFSC parcels and the underpass is shown in Figure 12.



**Figure 12. Territorial parcels of UFSC, and Avenue underpass**

Figure 12 shows that the underground passage originates in each of the territorial parcels on UFSC and extends under the entire avenue. Referring to Figure 13, a profile view of the underpass, it shows a better image of the conformation of the different plans and how is configured the overlapping problem of property rights in the parcel "Avenida". There is clearly a topographic surface plane on which sit the six lanes, sidewalks, cycleway and the central site. "Avenida" parcel should be part of the Register and be registered in the name of Florianópolis City Hall. Under the parcel Avenue there is a second plan where takes place the underpass (in green). This plan sets a new situation and would be part of the Register with a proper identification and registered in the name of UFSC.

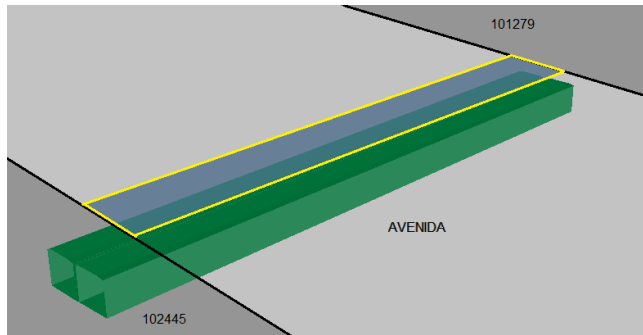


**Figure 13. Profile view of UFSC parcels, avenue and underpass**



Both plans, avenue and passage, have distinct legal states. Avenue parcel is public property, inalienable and not subject to prescription, probably resulting from expropriation when installing the circulation structure (lanes, sidewalks, cycleway and central site). The 102445 and 101279 parcels have their own registrations and are part of the property belonging to the UFSC, federal autarchy with its own legal personality.

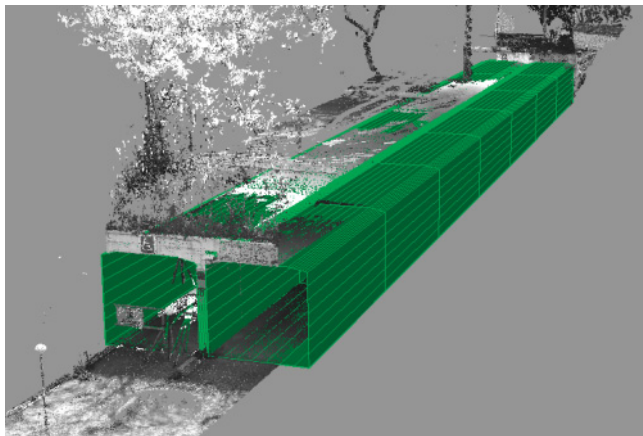
The projection of the underpass on the “Avenida” parcel is shown graphically in Figure 14 and its coordinates in Table 1. The complete 3D model of the underground passage is shown in Figure 15 and the defining coordinates of their volume in Table 2.



**Figure 14. Territorial parcel dismemberment in hybrid model of 3D Cadastre**

**Table 1. Vertices of the territorial parcel dismembered in the hybrid model of 3D Cadastre (Zone 22S SIRGAS2000)**

Vertex	North Coord. (m)	East Coord. (m)
1	6944755.4083	745125.3949
2	6944760.4639	745126.6355
3	6944749.2778	745164.0874
4	6944754.3095	745165.3311



**Figure 15 - Characterization of the spatial parcel in full 3D Cadastral model**

**Table 2. Vertices of the spatial parcel in full 3D Cadastral model (Zone 22S SIRGAS2000)**

Vertex	Coord. North (m)	Coord. East (m)	Ortometric Altitude (m)
1	6944754.1772	745166.3882	5.9504
2	6944749.0786	745165.5587	5.9258
3	6944749.0836	745165.5832	8.0065
4	6944749.4675	745165.6313	8.1009
5	6944753.7343	745166.2933	8.0852
6	6944754.1630	745166.3462	7.9782
7	6944755.7678	745123.4380	5.7827
8	6944755.7754	745123.4278	8.0443
9	6944756.2182	745123.4791	8.1357
10	6944760.4745	745124.1922	8.1345
11	6944760.8677	745124.2137	8.0240
12	6944760.8893	745124.2352	5.7840

#### 4. CONCLUSIONS

The modeling of the problem of ownership right of the underpass seems to point to the existence of a kind of easement, although of a different nature from that which normally occurs. An easement is understood, in the Brazilian civil law, as a transit easement that allows the passage through a neighboring property. Thus, to achieve a public road or highway, sometimes it is necessary to establish an easement, and this is perpetual (unless they fall into disuse) and inalienable. As an easement does not settle by a presumed way is necessary that its materialization occurs through properly registered deed. Constituting real right to improve the use of the property, the easement is characterized by allowing access from a property to the public road through another property, which does not fit fully in the above problem, since access in this case is " through "the public road linking two parts of the same property. Still, although the bondage of the figure is on the surface right, it was the best seemed to represent the configuration of overlapping right to the underpass can be applied in other cases remains to how it could be registered.

Taking into account the warnings models, hybrid and full 3D Cadastre proposed by Stoter et al (2004a), Ploeger and Stoter (2004) and Oosterom et al (2004) reached to some possible hypothetical results:

- i. In 2D Cadastre model with 3D warnings the underpass would be registered with the registration of "Avenida" parcel, which would contain a warning that under that parcel, at -4,084m altitude, there is an easement connecting the parcels 102445 and 101279. In this model the delimitation of the territorial parcel, its registration, and the existence of the easement warning (possibly in the form of a annotation) would be sufficient to characterize the situation.
- ii. In 3D Cadastre hybrid model the volume corresponding to the parcel formed by the underpass would be registered in the name of Florianópolis City Hall as an easement with maximum and minimum limits of orthometric altitude (8,135m to 5,776m, respectively). The "Avenida" parcel would be dismembered leading to a corresponding new territorial parcel resulting of the projection surface remain registered as a public property (Figure 14). The coding of the new parcel would follow the logic numbering adopted (sequential, by spatial hierarchy, by combining centroid of the parcel coordinates, etc.). The remaining parcels also would receive new codes. The spatial parcel would remain linked to the territorial parcel and its codification

would refer to this with positive or negative statement, or with the use of mirror-codes (territorial parcel 152, spatial parcel 452, for example). In the case of underground passage in question, the two-dimensional coordinates of the vertices of the territorial parcel dismembered are presented in Table 1. In this model the dismemberment of a territorial parcel and the registration of a spatial parcel (possibly a defined passage servitude with minimum altitude and maximum) would be sufficient to equate the problem.

- iii. In full 3D Cadastre model the spatial parcel corresponding to the underpass would be configured independently from its connection or vertical overlapping with the territorial parcels and would be registered in the name of UFSC as a volume defined by delimiters vertices (Figure 15). This is certainly the most complex solution to implement, given that a series of reforms in the legislation should be made. The three-dimensional coordinates of the defining vertices of the spatial parcel of this model are presented in Table 2.

Facing the absence of cadastral legislation in Brazil (both 2D and 3D), and according to the perspective of the authors cited, the most immediate solution and less legal impact is first presented, registration of warnings, which could take effect in title registration as a kind of annotation, indicating the existence of rights, restrictions and responsibilities above or below the surface at a certain altitude. This option is not entirely incompatible with some instruments of Brazilian legislation, such as the City Statute and local master plans. The other two options, hybrid and full model, still seem very complex and far from the legal reality as it currently presents in Brazil.

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## **BIOGRAPHICAL NOTES**

**Adolfo Lino de Araújo** is graduated in Civil Engineering by the Federal University of Paraíba, master's degree in Geodetic Sciences and Geoinformation Technology by the Federal University of Pernambuco and doctorate in Territorial Cadastre by the Federal University of Santa Catarina. He is currently a professor at the Federal Institute of Santa Catarina where he teaches Geodesy, Topography and Surveying. Has experience in the area of geodesy and GIS with emphasis on Engineering, acting on the following topics: Territorial Cadastre Cadastre 3D Laser Scanner, Geodesy, Topography, geoinformation systems and registration databases.

**Francisco Henrique de Oliveira** is graduated in Cartographic Engineering by the Universidade Estadual Paulista Julio de Mesquita Filho, has obtained a doctorate in Production Engineering from the Federal University of Santa Catarina. In 2012, a scholarship from CNPq held in the first half his post-doctorate at the RWTH - Aachen University - Institute of Geodesy - Germany, and in the second half of the year continued his postdoctoral studies at UNI - University of Northern Iowa - Department of Geography - USA, focusing on the theme of the Territorial Multipurpose Cadastre. He is currently associate professor at the State University of Santa Catarina (UDESC), associate professor at the Federal University of Santa Catarina (UFSC) and guest professor at the Lincoln Institute of Land Policy - Boston - USA.



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