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A data-driven approach to inform planning process in informal settlements

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Abstract

Official data on informal settlements are outdated, scarce, and sometimes nonexistent. Also, existing digital tools to produce spatial data on urban form are not prepared to deal with their degree of heterogeneity. We then propose a method to obtain, structure and analyze georeferenced data, aiming to support participatory planning of precarious settlements in Brazil. The results include mapping basic elements of urban form and also automatic extraction of urban parameters. The method proved relevant to allow not only the collaboration between team members but also the dialogue with community members, revealing its role in fostering a transformative design process.

Keywords: City Information Modeling; Parametric modeling; Informal settlements; Geographic Information System.

INTRODUCTION

In a context where urban settings grow and change at a dramatic rate, having data that can improve the perception of reality and support decision-making processes is critical (Pereira, 2001). However, in Global South cities, which have significant parts of their urban fabric built outside of the purview of state policies, official data is outdated, scarce, and sometimes nonexistent. In the current data deluge context, missing information assumes new significance. This research aligns with the claim that invisibility, i.e. the lack of information or the misrepresentation of informal settlements, is a structural component in understanding the limits of urban planning policies in major cities of the Global South, as suggested by Roy (2005).

Current digital tools available to tackle the problem of urban disinformation are biased toward the spatial realities of developed cities. Even though it's possible to find some tools aimed at producing spatial data on urban form, none of them is prepared to deal with the complex relation among entities and features of informal settlements, neither their degree of heterogeneity/ irregularity. This matter will be discussed in the first session following this introduction, which summarizes the state of art on the production and manipulation of urban morphological data, seeking to understand the challenges of these processes when dealing with the informal settlements in Brazil. Within this broader discussion, we are interested in developing some strategies based on information technologies to obtain, structure and analyse georeferenced data from informal settlements. To this aim, the second session explains the proposed method, which was used to support the elaboration of special regulations and urban plans in a sample of informally developed areas. The final session discusses the results of the method, considering its relevance in fostering a transformative design process of existing urban realities of Global South cities.

STATE OF ART

The simulation of the built environment allows the development and evaluation of scenarios and design alternatives as an instrument to guide decision-making in solving urban problems. The conceptualization and use of digital tools for descriptive and prescriptive purposes is rapidly expanding in recent urban morphology literature. Fernando Lima et al. (2020) describes and compares five computational tools with algorithmic-parametric logic applied to the urban context: Urban Network Analysis - UNA (Sevtsuk & Mekonnen, 2012; Sevtsuk & Kalvo, 2015); CityMaker (Beirão, 2012); Configurbanist (Nourian et al., 2015), CityMetrics (Lima, 2017); Urbano Toolbox (Dogan et al., 2018).

These computational tools conduct parametric manipulation of urban morphological data that allows several functionalities: to measure urban indicators on active transport and urban accessibility (UNA, Configurbanist, Urbano Toolbox); to optimize the performance of urban configurations through analysis of use diversity and density (CityMetrics); to develop urban design solutions based on shape grammar (CityMaker). However, much of these tools are focused on the context of developed countries. At best they target the formally developed portions of cities of developing countries, where the pattern of occupation and the urban spatial configuration is consolidated.

Among the five tools analysed by Lima et al. (2020) only one (CityMetrics) is developed in the Global South, more specifically in Brazil. Yet, it does not target these urban realities, in spite of the fact that they comprise a major portion of Brazilian cities. According to the national census, around 11.4 million people (6% of the Brazilian population) lived in informal settlements (IBGE, 2010), and these portions have grown much faster than the formally developed areas.

Studies on informal settlements tend to focus on their political and legal challenges, mostly ignoring their morphological questions. In the few instances where we find the relation between political-economic and spatial issues (e.g. Maricato, 2013), there is no analysis of specific case studies. However, there has been significant progress related to the production of official data on precarious settlements in the last 20 years in Brazil (e.g. Ancona, 2010), even though little has been done at the institutional level to study these settlements' urban form. Also, in the last decades some Brazilian scholars have advanced in adapting existing information technologies for the study of informal settlements, with descriptive or prescriptive purposes.

In Rio de Janeiro, some researchers have been focusing on the representation of Rio's favelas on maps. The authors argue that Rio's favelas moved from a "cartographic void" to the "spectacle of integration", a process marked by tourist interest in the favelas in the context of mega-events (Ferraz, Leme & Maia, 2018). In addition, also studying Rio's favelas visibility, Luque-Ayala and Maia (2018) claim that digital visibility initiatives presented as empowerers and promoters of urban inclusion are usually part of a much more complex network of power. In this case, the authors critically examine the mobilization of spatial media technologies for digitally mapping informal settlements. Yet, the mapping process studied by them refers mostly to tourist maps and the decision-making process of online mapping, not exploring the morphological aspect of the settlements.

A research group in Belo Horizonte, coordinated by Ana Clara Mourão Moura, called "Parametric Modeling of Territorial Occupation", studies the possibility of simulating, with Esri City Engine, the landscapes resulting from zoning proposals, occupation models and urban parameters (Moura, 2015). As this methodology is about simulating the landscape proposed by urban laws, it is usually applied on formally developed areas (e.g. Castro et al, 2018). This group has also been using Geodesign, as a land-use planning strategy, which was used in participatory processes within precarious settlements (Monteiro et al, 2018). Their method consisted of presenting thematic maps (e.g. "environment", "commerce, service and industries", "public facilities and services"), classified according to the intensity of the need for projects in the area. In this case, they did not take measures of urban form indicators.

Cardoso (2007) investigates the inequality of access to better living conditions - education, health, work, and income - of the informal territories of Belém, a Brazilian Amazonian city, through a socio-spatial approach to the spatial configuration of informal settlements. The author argues that one cannot simply transfer analysis tools from developed to developing countries, especially considering that most cities in those countries are produced informally. As pointed out by the author, in addition to their inherent particularities, the non-availability of the data on informal settlements is an obstacle. Cardoso (2007) then adapts Space Syntax theories and tools to this reality, a methodology that allows her to analyse the design performance of street network. She establishes the relevance of this method by arguing that the streets are "the most lasting elements of urban occupation" (Cardoso, 2007, p. 22), as in general, the urban form of the settlements is in a constant process of transformation, produced according to the self-construction process of its dwellers. Her approach is thus focused on analyzing syntactic measures (such as connectivity and integration) in the studied settlements. She does not evaluate plot and buildings configurations.

In Campina Grande and Recife, Mauro Barros Filho has been researching for many years pattern recognition in satellite images, especially in precarious urban areas (e.g. Barros Filho & Sobreira, 2005; Amorim & Barros Filho, 2017). Dealing with fractal and lacunarity analysis, as well as Visibility Graph Analysis (VGA), the author aims to identify distinct socio-spatial patterns, with potential to support, for example, slum mapping. Their efforts are to automate the process of recognizing geometric features of urban forms, they do not aim at informing relevant actors in the decision-making process of urban development.

Building on such experiences, we have a twofold objective: (1) to produce and manipulate non-existent data about urban form, and (2) to deliver them to stakeholders, in order to foster a collaborative and participatory design process.

THE RESEARCH CONTEXT

In the northeast Brazilian city of Fortaleza, a research group, in which the authors of this article participate, has been undertaking several academic studies regarding the manipulation and production of morphological data about the city, with a special focus on how the paradigm of information modeling can be applied to assist the decision-making process in urban planning, both on formal and informal urban tissues. The challenge has been the understanding on how the official data is organized, on identifying its limitations, and in finding effective ways to manipulate it, applying for each specific demand.

The starting point was the development of a methodology of City Information Model (CIM), based on the work of Beirão et al. (2012) and whose proof of concept is described in Moreira & Cardoso (2017) and Sousa (2018). Its main purpose is to organize an integrated set of computational applications that can exchange data with each other without the need for data format conversions, allowing the management of this flow of information in order to promote collaboration, ensuring consistency. This is done by using a Relational Database Management System - RDBMS (PostgreSQL and its extension PostGIS) as the backbone of the model, allowing connection of different analysis tools, management of different access level for the different stakeholders, storage and manipulation of geometry and attribute information simultaneously, import a wide range of data formats, storage of a very large quantities of information, and management from a single central repository that can be access locally or remotely (Gil et al, 2011). The workflow also admits the use of a Geographical Information System - GIS (QGIS) for its analytical tools and data visualization capabilities. Finally,

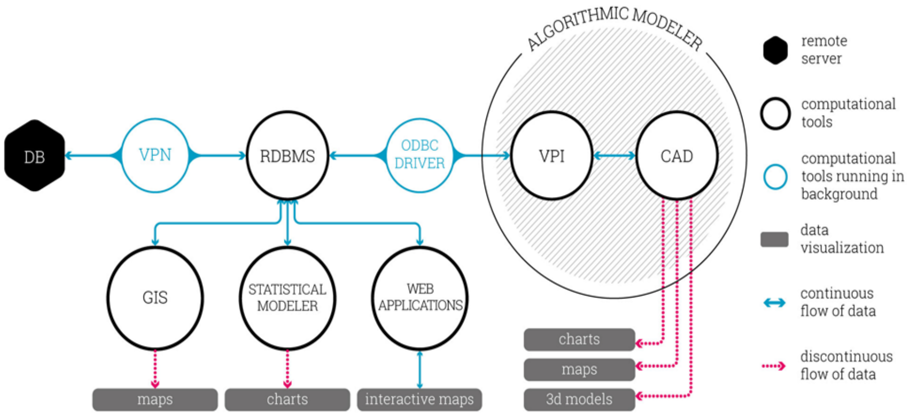

Figure 1: Structure adopted for the City Information Model. It´s possible to see that the RDBMS act as a hub for the interoperability between several computational tools. Others not explored in this research are Statistical Modelers to data mining correlations between urban measures and Web Applications to communicate with non-technical stakeholders.

a set called *algorithmic modeler* is integrated into the system, which consists of a CAD software and a Visual Programming Interface - VPI (Rhinoceros 3D and Grasshopper 3D, respectively). Within this modeler, a series of customized components were created, allowing the communication with the RDBMS through the organization of a series of typical queries using Structured Query Language (SQL). This transforms the algorithmic modeler into a digital framework capable of representing the urban space by emulating some basic functions of a GIS, such as the application of spatial filters, allowing access to specific portions of the data present in the database, be it geometry or tabular information attributes. Also, the VPI is a fruitful platform where one can automate several kinds of analytical processes in a graphical manner, softening the programming task to architects and urban planners (Figure 1).

Using an early version of the system, Costa Lima (2017) worked on creating algorithms to measure urban form in informal settlements. She has used Berghauser Pont & Haupt's (2010) density measures and codified some evaluation procedures based on recommendations for urbanization of informal settlements, such as Bueno's (2000) parameters of access to urban services.

Seeking to apply this expertise, a local planning agency commissioned the research team to develop a proposal of special regulation and urban plan for 3 informally developed areas in the city of Fortaleza. The team used the CIM environment to represent the 3 settlements' spatial patterns and incorporate urban measures algorithms (also creating new ones) to enhance and expand our perception about them, producing relevant data capable of informing decision-making process, fostering dialogue. The methods and techniques applied are discussed below.

METHODOLOGY

The first challenge was the lack of information on the urban morphology of the settlements, which, as previously discussed, is a recurring problem in informal settlements (Cardoso, 2007; Barros Filho & Sobreira, 2005). To compose its initial database, the research team had access to official data provided by the local government. The set was composed by:

1. Suborbital images captured in 2010 and 2016, with a spatial resolution of 0.10m;
2. Vector datasets consistent with the images' time span, including the representation of basic elements of urban morphology: street axis lines, islands, lots and buildings footprints;
3. Vector datasets with the location of public facilities.

Although the images had good spatial resolution and the location of equipment and infrastructure was reasonably up to date, there were significant gaps in the mapping of the basic elements of urban morphology. Street axis lines and building footprints were quite consistent, but the lot layer has about only 15% of the actual land parceling, which imposes the first challenge (Figure 2).

One of the possible approaches was the use of automated data extraction from the imagery set. The provided one, even with a good spatial resolution, doesn't have a good spectral resolution, which can decrease the accuracy of the classification. Due to the team's lack of resources to access high resolution orbital images, they have attempted to use the available free sets, but they were proved to be unsuitable for this purpose (Andrade, 2019). Therefore, the research team used the capability of collaboration provided by the RDBMS to manually vectorize the lot parcels. The workflow was organized using the following steps:

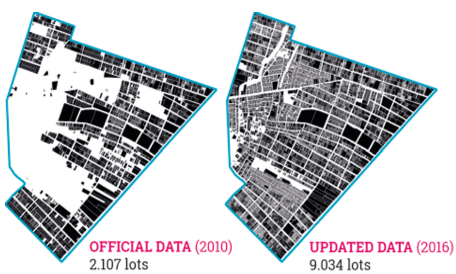

Figure 2: Comparison between number of lots in the official database and in the database updated by the team.

1. All vector layers received were stored in a database hosted on a remote server;
2. All team members were given permission to access the server by sharing permission keys for establishing a Virtual Private Network (VPN) between their equipment and the server and were given a username and password to access the database.
3. In QGIS, a vector layer was created containing the limits of each sector, which was then stored in the database, available to everyone;
4. In RDBMS, using SQL, a copy of the official layer of lots was created for each sector, establishing an independent editable space for updating the elements present in each sector;
5. In RDBMS, using SQL, a concatenation of spatial filters based on sector geometry was used to create a linked table that would aggregate all updates made in all sectors (formally, a "view").

Thus, all members were able to work simultaneously on updating the geometrical data of the territories in QGIS, reading and writing data from/on the database, increasing productivity and decreasing working times through the distribution of tasks. Also, the use of a "view", by allowing a real-time update of the result, allowed not only the process manager to follow the progress but also served as the basis for initial tests of the analysis algorithms. For the process, classification categories were established for a) registered and existing lots, b) registered lots not consistent with the observation of the image, c) new lots designed to correct registered lots, and d) new lots in regions that did not have any registered lot. The task was conducted, first, by comparing the existing vector layer with the 2010 image and the updated base was compared with the 2016 image for a new update. To record the process, attribute columns for each year were created to store the categories, allowing the use of filters to prepare thematic maps. A similar process was carried out to update other vector layers, but they did not need as much elaboration, since they were already quite consistent, as explained before.

Once all the vector layers were updated, it became possible to retrieve its data on the algorithmic modeler, allowing the feeding of analysis algorithms for the extraction of urban measures. The first algorithm classifies the streets according to their ability to allow access by service vehicles and the installation of infrastructure. The algorithm uses the parameters established by Bueno (2000) and the structure presented by Lima et al. (2019), working with: identification of blind alleys, detecting the connection of both endpoints to the street network; calculation of street width, by creating a series of perpendicular vectors to the street segments, project them in both directions on the lot polygons, calculating the distances between the points and extracting the average, excluding outliers; calculation of the distances between a narrow street segment and the nearest wide street, using Shortest Walk, a add-on for Grasshopper that implements a topology calculator based on the A* logic; and several boolean operators to evaluate if a street meets some of the Bueno's criteria.

Although we agree with Cardoso's (2007) statement classifying the street as "the most lasting element", the team had been commissioned to evaluate current housing conditions of the individual dwellings. So, every measure about the streets should be projectable in the lots, working as an indicator. Notwithstanding UNA (Sevtsuk E Mekonnen, 2012; Sevtsuk and Kalvo, 2015) and Configurbanist (Nourian et al., 2015) provide some tools to undertake such task. Both use the strategy of calculating the centroid of the plot polygon, evaluating the curve's closest point to the network of streets axis lines, in order to retrieve the closest one. This technique could work in most of the cases in the formal tissue of Global North cities, but often fails when applied to the irregular heterogeneous informal urban fabrics analysed. It was quite common the configuration of a plot with 2 or 3 (even 4) front lot lines, making it accessible by up to 4 street segments, as well as narrow plots, which has their centroids closer to a lateral street than the one that serves as their access.

To deal with such geometrical specificities, the team proposed a process (Figure 3) that starts by exploding the lot polygon on its constituent segments, then creating vectors perpendicular to each segment passing through its midpoint and projecting that point in both directions of the vectors. The projected points are tested against all surrounding lot polygons. If any of them is not within a lot, the associated segment is considered a free face. Using only these segments, their midpoints are projected against the street axes, allowing the creation of one or more points that represents the lot tied to its access streets and identifying the front lot lines. The algorithm measures the length of these lines and incorporates it to the lot data. A corner lot, for example, will have two points projected on two street axis lines and two segments identified as front

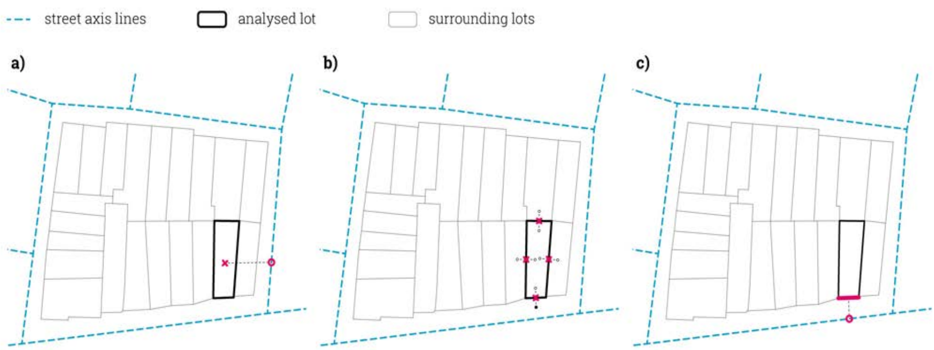

Figure 3: Process of front lot line identification and association with access street: a) in some situations, it's not possible to project the centroid of the lot polygon to the closest street; b) the process adopted consists in evaluate which sides of the polygon are "free of neighbors"; c) the "free faces" are identified as front lot lines and its midpoint is projected to the closest street.

lot lines, in which case the minimum, maximum and total length are calculated. It is a lot-to-lot calculation whose result is accumulated through an algorithmic loop.

Finally, the points on the street network are used to calculate the distances of each lot to a set of amenities (bus stops, schools, hospitals etc.) using the street network. Here, the Shortest Walk add-on is also used. But, since the component operates with the network topology, the path calculated between the points only computes entire segments, discarding the stretches of the street segment in which the points are inserted and that need to be traveled until the nearest intersection is reached. So, the team created an algorithm structured to incorporate those stretches, making the measures more precise. Some benchmarks found in the literature (e.g. Moretti, 1997) were used to evaluate the accessibility of the lots to the surrounding amenities.

In addition to the lot's accessibility to urban services, another algorithm calculates, from buildings and lots geometries, indicators generally adopted by land use regulation in Brazil, which are consistent with some of Berghauser Pont & Haupt's (2010) density indicators, such as building intensity (FSI) and coverage (GSI). Since some building footprints were described by concave polygons (e.g. L-shape polygons), a small analysis module developed by Sousa (2018) determines a point within the polygon using two steps. First, the centroid is calculated and is tested if it is inside the original polygon. If this is true, the point is stored as the building footprint reference. If this is false, a set of 10 random points are generated inside the polygon. The distance to the boundaries is calculated and the farthest one is chosen as the building reference. All references are used to test if a building is inside a lot, grouping them by location. Those groups allows the calculation of the occupied area in each lot and then to determine lot coverage, for example.

All the processes mentioned here faced the difficulty of being applied to a large number of entities (the largest analysed territory has more than 9000 lots). The algorithmic modeler used, based on Grasshopper 3D, presents the disadvantage of having several functions that are unable to access the multiple processing cores of the computer, causing errors due to insufficient memory when the whole set is processed at once. To overcome this pitfall, the team used another add-on, the Anemone, to implement a iteration loop, working with the calculations about one entity at a time and recording a list of results. Every data produced by any of those processes could be sent to the database using custom components made by Sousa (2018) that organizes the data using SQL syntax for creating new tables.

DISCUSSION AND CONCLUSIONS

Since 2015, our research team has been developing efforts to meet two requirements: 1) manipulation and production of morphological data about the city in a collaborative manner, and 2) make this data available for relevant actors, fostering an informed decision making process. These requirements seem even more relevant in the context of a lack of information on precarious settlements, which occupy a significant part of Brazilian cities. We were then interested in developing a methodology based on information technologies to obtain, structure and analyze georeferenced data from informally developed settlements.

In 2018, the prototype of the method was ready for academic purposes. However, when this method had to be applied institutionally, it required improvements aiming at increasing its accuracy, promoting collaboration between team members and, subsequently, and providing an interface with the community members, within participatory processes.

Thanks to the above-described methodology the team managed to work on the database of three precarious settlements that had, on average, only 15% of their lots registered in official databases. The results include not only the production of geometric representations of the mapped entities but also automatic extraction of building height, front lot line, lot coverage, street width, among others. The method also allowed crossing data between entities, making it possible, for example, to analyse the accessibility of lots to public amenities and facilities based on the characteristics of the streets that give it access and the location of these facilities. While proposing a processual modeling methodology, this paper goes beyond the empirical results, since the measures' operationalization can be repurposed for different case-studies and/or time frames. As other parametric design methodologies, the numerical values of the parameters used to measure design performance can also be changed easily, according to new findings in the literature, or to residents' preferences.

The methodology has also proven very useful to strengthen the dialogue with the residents. The output data was the fundamental element to inform the design charrettes undertaken with a group of residents of each of the three settlements. Some of these charretes, aimed at defining the threshold of urban indicators that would legally establish the "minimum housing conditions". As the team had available a large amount of measurements and possibilities of design performance indicators, they were able to openly discuss with residents and collectively define what were the most suitable values and indicators. These decisions were also informed by the number of dwellings that meet those requirements. As a result, each of the three cases adopted different values for some indicators (such as lot coverage). They have also adopted a different set of indicators as they had distinguishing spatial/morphological features (some are denser, or more verticalized than others, for example). The parametric methodology allowed for the technical team to incorporate residents' suggestions easily as the redrawing of maps was not a very time-consuming task.

In order to achieve this informed dialogue, it was necessary to make a translation between technical and community language going from digital to analogical tools. Participatory workshops were designed based on the "creation of interfaces" (Kapp et al., 2012) that could generate discussions with residents about urban form parameters, having as main objective a more informed decision making by the residents. The team used, for example, maps printed in transparent paper to show how many lots have indicators below a certain parameter value, to support residents' decision on minimum parameters to be adopted by special regulation. While it was a challenge to move from the thinking of their individual houses to the general idea of parameter as legislation most participants demonstrated to understand the concept of each parameter and its impact on the built environment. Even though we had to use analogic tools to present the gathered data, it was only possible thanks to the method of production and structuring of spatial data described here. By using a wide range of digital and analogical tools the proposed methodology was able to meet the two goals initially set, in order to foster a collaborative and participatory design process. It not only contributed to current literature on city information modelling, but also delivered a relatively accessible method to support bottom-up decision making about urban regulations more suitable to the distinguishing realities of cities of the Global South.

REFERENCES

Amorim, L. M., & Barros Filho, M. (2017). Convergência de métodos de descrição da forma urbana: análise de textura de imagens de satélite e análise gráfica visual. Revista de Morfologia Urbana, 5(2), 65-81.

Ancona, A.L. (2010). Guia para o Mapeamento e Caracterização de Assentamentos Precários, Brasília: MCidades/SNH:.

Barros Filho, M., & Sobreira, F. (2005). Assessing texture pattern in slum across scales: an unsupervised approach. London, UK: Centre for Advanced Spatial Analysis (UCL).

Beirão, J. N., Montenegro, N., & Arrobas, P. (2012). City Information Modelling: Parametric urban models including design support data. PNUM: Morfologia Urbana nos Países Lusófonos. Lisbon: ISCTE, 1122-1134.

Beirao, J.N. (2012). CItyMaker: Designing Grammars for Urban Design. Delft: ABE TU Delft.

Berghauser-Pont, M. & Haupt, P. (2010). Spacematrix: Space, Density and Urban Form. Rotterdam: NAi Publishers.

Bueno, L. M. (2000). Projeto e favela: metodologia para projetos de urbanização (Doctoral dissertation). Universidade de São Paulo, São Paulo.

Cardoso, A. C. (2007). O Espaço Alternativo: vida e forma urbana nas baixadas de Belém. Belém: EDUFPA.

Castro, M. M., Moura, A. C. M., Herculano, R. N., de Aguiar, T., & de Oliveira, F. H. (2018). Parametric Modeling as an Alternative Tool for Planning and Management of the Urban Landscape in Brazil–Case Study of Balneario Camboriu. DISEGNARECON, 11(20), 17-1.

Costa Lima, M. Q. (2017). Ver a cidade: Modelagem da informação para regulação de assentamentos informais [Dissertação (Mestrado em Arquitetura e Urbanismo e Design)]. Universidade Federal do Ceará.

Dogan, T., Samaranayake, S., & Saraf, N. (2018). Urbano: A New Tool to Promote Mobility-Aware Urban Design, Active Transportation Modeling and Access Analysis for Amenities and Public Transport. Proceedings of the Symposium for Architecture and Urban Design. Delft, Netherlands, doi: 10.22360/simaud.2018.simaud.028.

Ferraz, N. S., Leme, F. B. P., & Maia, F. N. (2018). A history of the representation of Rio de Janeiro's slums in maps. Arquiteturarevista, 14(1), 59.

IBGE. (2010). Aglomerados Subnormais: primeiros resultados. Demographic census, Rio de Janeiro.

Lima, F. (2017). Métricas Urbanas: Sistema (para)métrico para análise e otimização de configurações urbanas de acordo com métricas de avaliação de desempenho. (Doctoral dissertation). Universidade Federal do Rio de Janeiro, Rio de Janeiro.

Lima, F., Costa, F. R., & Rosa, A. (2020). Lógica algorítmica-paramétrica e urbanismo. Gestão & Tecnologia De Projetos, 15(2), 84-97.

Lima, M. Q. C., Freitas, C. F. S., & Cardoso, D. R. (2019). Modelagem da informação para a regulação urbanística dos assentamentos precários em Fortaleza. urbe. Revista Brasileira de Gestão Urbana, 11, 1-20.

Luque-Ayala, A., & Neves Maia, F. (2019). Digital territories: Google maps as a political technique in the re-making of urban informality. Environment and Planning D: Society and space, 37(3), 449-467.

Maricato, E. (2013). As ideias fora do lugar e o lugar fora das ideias. In Vainer, C., Arantes, O., & Maricato, E. (eds). (2013). A cidade do pensamento único: Desmanchando consensos. Petrópolis: Vozes, 121-192.

Monteiro, L. O., Moura, A. C. M., Zyngier, C. M., Sena, Í. S., & de Paula, P. L. (2018). Geodesign facing the urgency of reducing poverty: the cases of Belo Horizonte. DISEGNARECON, 11(20), 6-1.

Moreira, E., & Cardoso, D. (2017). Sistema integrado de modelagem da informação como suporte ao planejamento e ao projeto urbanos. In E. M. S. Mendonça & M. E. Junior (Orgs.), Anais da 6ª Conferência da Rede Lusófona de Morfologia Urbana (p. 349–357). UFES.

Moretti, R. S. (1997). Normas Urbanísticas para habitação de interesse social: recomendações para elaboração. São Paulo: Instituto de Pesquisas Tecnológicas.

Moura, A. C. M. (2015). Geodesign in Parametric Modeling of urban landscape. Cartography and Geographic Information Science, 42(4), 323-332.

Nourian, P., Rezvani, S., Sariyildiz, S., & Hoeven, F. (2015). Configurbanist: Urban Configuration Analysis for Walking and Cycling via Easiest Paths. 33rd eCAADe CONFERENCE. Viena, Áustria: Universidade Técnica de Viena, 553-564.

Roy, A. (2005), 'Urban Informality: Toward an Epistemology of Planning'. Journal of the American Planning Association, 71(2), 147-158.

Sevtsuk, A., & Karvo, R. (2015). Urban Network Analysis Toolbox for Rhinoceros 3D. Singapore: City Form Lab.

Sevtsuk, A., & Mekonnen, M. (2012). Urban Network Analysis Toolbox. International Journal of Geomatics and Spatial Analysis, 22(2), 287–305, doi: 10.3166/RIG.22.287-305.

Sousa, C. E. M. de. (2018). Modelando a percepção: O ambiente do patrimônio cultural edificado na regulação da forma urbana (Master thesis). Universidade Federal do Ceará.