Abstract. The analogue definition of studies on urban planning can be very time consuming in the top-down process of designing. Keeping in mind the rapid urbanization we had in Brazil, and the continuous migration to the capital of the country located in Federal District, our aim is to use digital aid models that could be flexible and make quicker responses to urban issues. Algorithms as finite sequences of instructions have broad application. Designing cities demands the interpretation of variables linked to the territory and takes into account the current legislation in order to develop urban plans. This research creates an algorithmic basis using Grasshopper® to propose a mathematical solution for interpreting the existing space, and from it, to model urban scenes. The territorial analysis uses the user’s perspective, with the interpretation of pre-existing characteristics, such as main roads, function and equipment distributions that make up the basic services. It is based on parameters extracted from theoretical repertoire and community facilities optimization through Galapagos evolutionary solver to deliver different proposed scenarios.

Keywords. Urban algorithms; master planning; Grasshopper; Galapagos; Federal District.

1. Introduction

With the advent of computing, the endless databases and the difficulty of processing data in an analogous way, we understand that it is necessary to take advantage of machines to comprehend and study the evolution of urban results. Considering the complexity inherent in cities, the use of algorithms tries to approximate some aspects to be worked on projects for the materialization and definition of project guideline.

Machines work to help and give us more strategic and intelligent responses for urban planning. This paper analyzes the behavior and human needs and the territorial context to generate reliable propositions to fulfill the urban fabric through computational algorithms. It is a review of a master’s thesis research which has a more detailed approach (Pereira, 2016).

The discussion about the traditional development of urban projects considers that decision-making occurs from top-down process, with the designer making
decisions taking into account the knowledge obtained, while the use of generative, parametric and algorithmic computational tools leads to a bottom-up approach, in which, from the definition of basic parameters by the architect, the computer makes the big decisions. (Terzidis, 2006; Verebes, 2013). After creating the shape grammar based on algorithms that will define the study, using procedural modeling is possible to change different parameters, to manipulate features and get different scenarios in a fast exploration.

The contribution of algorithms and parameterization as a response to manage complex systems inherent to urbanism has been used in different contexts as promising tools for urban planning. The complexity and the dynamic of a livable space is tough to predict without using computer-aided projects. Therefore, many algorithmic components have been build up to simplify the application of methods with the concern both in the creation of a dynamic project method and in the pre-analysis of the issues of urban insertion and integration of new occupations (Beirão, 2012; Beirão et. al., 2012; Aparicio, 2013; Koenig et. al., 2016).

Much more than creating new spaces, we need to integrate the existing ones, using the consolidated infrastructure to fill urban voids that have potential for urbanization, since the urban population in Federal District at Brazil is still increasing. Our goal is to deal with the aforementioned tools to elaborate urban planning and meet demand for residential areas, exploring variables and requirements that will make a vibrant urban neighborhood.

2. Methods

Regarding the propositions of the city, a theoretical repertoire was elaborated on urban vitality, elements, their distributions, the characteristics of living and active spaces. From authors such as Jacobs (1961), Rogers (2001), Gehl (2010), and a research about urban development in Vienna, Austria (Irschik et.al., 2013), we extracted the minimum parameters for dimensioning the blocks and to calculate the influence of public facilities for the algorithmic structure to generate master plans.

The methods for this research were divided in two stages: the parameterization, which permeates the whole study, and the elaboration of the algorithm that draws up instructions to be taken for urban design considering the aforementioned parameters. The algorithm creates the urban mesh from stipulated constraints - road system, public equipment and criteria for dimensioning blocks - and afterwards is articulated to elaborate the occupation plan integrated to the urban coefficients, in order to generate different scenarios with the variability of the parameters. The chosen urban area to evaluate the proposed method is a residential neighborhood in the capital of Brazil.

The input parameters selected for inclusion in the urban study are shown at Table 1.
The base defined for the urban studies is, first, an algorithm that uses input parameters that were stipulated during the contextualization of the project and that are composed by the road axes (with spaces defined in ‘1’) and by existing public facilities (‘2’, ‘3’, ‘4’, and ‘5’). It engenders the urban grid of the new installment, according to criteria molded in reference to the project objective.

2.1. FIRST STAGE: ALGORITHM TO CREATE THE URBAN MESH

1. Marking of the road axes that extending will reach or perpass the perimeter of the polygonal;
2. Launching of the roadways of the urban network from the interconnections of the roads adjacent to the new parceling, considering a regular mesh with variable dimensions by means of parameters, in order to allow the interconnection of the road systems (see Figure 1);
3. Categorization of existing public facilities in the urban grid and adjacent to the project perimeter;
4. Mapping of the radius of coverage of each equipment, by type, to enable the analysis that precedes the insertion of additional equipment in the project polygon;
5. Use of the evolutionary solver Galápagos to insert additional equipment in the project polygon, according to the distance of the existing ones in relation to the centers of the blocks, considering that all the blocks must be within the range of all types of equipment (see Figure 2);

The mapping of the existing or designed facilities in the project influence area was used as input for the Galápagos. This considered the maximum radii of influence for each type of equipment. The Galapagos´ calculus pointed to the optimized location for the new facility, also calculating the minimum necessary equipment to contemplate every block. For the zoning of land functions, attraction curves were inserted. Therefore the manipulation of the curves allows flexibility in the distribution of uses and changing of the characteristics of the urban area.
2.2 SECOND STAGE: ALGORITHM FOR THE OCCUPATION PLAN

The occupation plan was conceived considering the scenario development and consistent with current urban planning practices. The algorithmic basis formulated includes parameters whenever possible, so that, with the benefit of computational
support for the processing of multiple data, the quantitative can be reassessed and manipulated to obtain new urban calculations. The steps of the algorithm was as follows:

1. The surface of the polygon was trimmed by the road axes to generate the surfaces of the blocks;
2. The blocks suffered a decrease of area through the offset component according to the width stipulated for the road system, so that we obtain only the area of the mesh that will be parceled out;
3. An average area was used to split the blocks. When the court area is more than four times the stipulated area, the court is, by default, divided in half through the midpoint of the smallest length and his opposite, so the other dimension is later divided into more parts. This division also generated the split of the surface of the court, so each block that met the division criteria by area was subdivided into two parts.
4. After the subdivision of the surface, the distance criterion was used to select the blocks that will contain public facilities, whose point references was obtained in step 05 stage 1;
5. Then, the blocks that will contain the equipment were split according to the area demanded for each kind of facility. The lots for the facilities were selected through proximity criteria, using as input the points obtained from Galapagos;
6. The remaining areas, which will not be included in equipment, were redivided with a new area reference, average, for other uses (economic development area - ADE, mixed, residential and commercial)
7. Attraction curves were inserted to define the distribution of uses. This selection can be executed through an automated criteria, which were not used in this research because there are different ways of analyzing the territory, and the flexibility of the curves allows the manipulation of the characteristics of the area, needed in our politic context;
8. Then, the urbanization indexes ‘occupation rate’ and ‘feedback’ were added, composing the volume of urban planning and also allowing the calculation of the population density, the area constructed by destination and the coefficient of utilization of the polygon. Such indexes are important to obtain scenarios, considering the urban rules that define legal limits for the occupation, still allowing the manipulation of the quantitative in each destination, separately.

3. Urban design experiment

As a kick off for the macro spatial organization resulting from the analysis of the surroundings of the enterprise, we elaborated a map with information raised in the projects. The topography was ignored in the stage that this research fits. These data were the inputs for the urban study. The alternatives of articulation of the territory will be obtained from urban algorithms in light of the connection of the existing axes and the rays of coverage of the equipment.

Since the launching of the road axes, the subdivision of the polygonal area was made in order to separate the blocks, with the highlight of those that will contain the public equipment designed in the previous stages: offset; division squares; area of public facilities; proximity of the point launched by Galapagos with the square...
division for the best location; division of the remainder after the insertion of public facilities, considering the area of new lots; distribution of uses through attraction lines - articulated polyline in Rhinoceros.

The generative method used for the urban mesh generated some triangular areas due to the compensation in the vertical divisions of the traverse. We understand that these blocks can function as visual landmarks in the subdivision.

Afterwards, we elaborate maps with the equipment layout according to the use, with the radius of equivalent coverage according to each destination. A simplified criterion for the insertion of new equipment in the study polygon was used measuring the distance of the equipment to the center of the new blocks, so that all the equipment was accessible according to the criteria of destination and range. It was reductionist because, as this is a basic launch of the preliminary plan, there are not the actual distances to be traveled, bearing in mind the road system and the direction conversions that a route requires.

The use of the Galapagos, called evolutionary solver, uses the variables inserted in the Grasshopper® to mathematically find the most adequate, best performing solution. The Galápagos was used to equate the insertion of new equipment, considering each of the types under study. By equalizing the number of equipment and an input index of possible arrangements - called seed -, the Galapagos returned as a result the option with the lowest possible number of equipment to meet all the blocks inside the range of each equipment.

Once the grid already has the blocks delimited and the lots split, the urban parameters were adjusted to create occupation plans. The basic urban rules defined by the legislation for the polygon under study are:

- Permissible population density: mean = 50 to 150 person per hectare (local law)
- Population per household: 3.79 inhabitants / household (local law)
- Comfort rate per household unit: 86m².
- Maximum area of construction = 2 (two times the polygon area)

The urban parameters of ‘maximum lot coverage’ and ‘maximum building height’ were added for the elaboration of scenarios and three-dimensional models. With these parameters, it is possible to calculate the permeability rate and the plot ratio. As a result, we have the urban indexes of the scenarios, which are the ‘gross floor area - GFA’ for each land use, the area of lots by land use, the population density and the plot ratios. These results are automatically updated with the parameters manipulation, which allows the elaboration of comparative studies and different scenarios.

From the elaborated parametric algorithmic base, it is possible to change the parameters, from the dimensioning of the blocks to the urban parameters, to obtain the prospection of different scenarios and variabilities that allow the discussion of the results and the technical and political analysis of the best result.

It is possible to use the evolutionary solver Galapagos, and to obtain solution with better performance using, for example, the maximum housing density. However, keeping in mind that political decisions guide the preparation of projects and do not necessarily correspond to technical criteria, a structure was chosen that
generates a plan of occupation that allows manipulation both in the parameters and in the distribution of uses.

As a research, we use the same basis of the urban grid and change some parameters to elaborate the scenarios (see Figure 3).

Three scenarios show possibilities of urban settings using the proposed method and considering the density parameter as a limit. The first scenario is distributed throughout the polygonal. The second include green areas and thickens residential plots. The third is developed in high mixed-use buildings, occupying a smaller polygonal. The result demonstrates the method versatility and the possibility of tailoring data through editable curves and parameters from the parametric algorithm. It also shows the applicability of the method in both the academic and professional fields for building prospective scenarios.

The experiment had the objective of reaching an end product to validate the proposed method. The answer of this research was to obtain an urban study based on the linear and punctual elements that were obtained by reading the territory and the parameters that were inserted to elaborate the occupation plan. Such an approach was simplified, considering the complexity of the present study, and aims
to guide more in-depth research and consider the insertion of more variables.

4. Discussion and conclusion

The explicit theory in this research, which considers the history of cities, the provisions on regular meshes and especially the content that projects urban vitality in the city do not together form the basis of the algorithm applied in this chapter. It must take into account the author’s professional path, which is loaded with convictions and permeates the results of the study. Even if there is controversy about the learning, applications and attitudes taken, this methodology can serve as a generator for variabilities that contain other beliefs.

As a parameter of methodology with a focus on replicability, the launch of the urban mesh follows steps that allow the variability of parameters, but fixes the design of the mesh, since we understand that the regular urban mesh presents characteristics that adapt more easily to different situations besides favoring the integration with other areas and the expansion of the territory. Also, with the exception of the launching of public equipment, the division of lots took place based on a single area parameter for the various uses, which can be handled later in the occupation plan or developed within the algorithm using programming.

The generality, inherent to the possibility of replication of methods, and the synthesis necessary for the dimensioning of the research, can miss specifics important to the urban design, that must be worked in a step after the occupation plan, product of this study.

The choice of three different parties for occupancy plans leads to a discussion about the impact on the environment and the characteristics of urban vitality. What is the medium term the coexistence of permeable areas and dwellers, so as to allow the natural drainage of the soil, create areas of conviviality with nature without causing urban voids that cause the fear of circulating in the areas?

The use of the parametric algorithmic project is presented as a viable means of proposing an urban project because it allows the insertion of several elements present in the territory. It means that also allows the substitution of the original elements, admitting the application of the algorithmic model in several situations, and the manipulation of variables, to adapt the response options and generate design alternatives.

The study of characteristics of intelligent cities and spaces with urban vitality leads us to believe that, with the use of distances, radius of action, concepts of spatial distribution of uses and other parameterizable characteristics, we can obtain urbanistic designs with great possibilities of become active.

We understand that the results of this study compose occupancy plans that are, by definition, prospective launches that will drive urban development projects. We intend to take the discussion to the academy and to the field of work, since such methodology is based essentially on the reading of the existing territory, which sustains a coherent justification for the traces of the spaces complementary to the implanted mesh.
4.1. CONTRIBUTIONS

Thinking about the other solutions presented, on this research was decided to create a grammar based on the existent roads and public facilities. We realized that choosing one of those types without starting from the existent parts of the neighborhood would be a mistake. So, after define which one would be the variables to consider in square dimensioning and other vitality exponentials, we started the ‘grammar’ with the selection of existing roads.

The public facilities were put on the same archive, the ideal radius of coverage was defined and inserted as a variable - to be able to change the size - and the Galapagos tool was used to locate in an optimized way the new facilities over the territory under study. The calculus gave us the minimum amount of each public facility to cover the whole surface of squares. So, each one of the squares was inserted in the radius of one equipment, existent, projected or even prospected.

Regarding the algorithmic basis, the major contribution of this procedure is the ability to calculate and locate urban public equipment using predetermined and changeable factors, which, in this case, are the scope and scale of such equipment. The launch of the Galapagos positioning in the Grasshopper optimizes this distribution in order to distribute the minimum equipment required to attend the entire project traverse.

In addition, the study, through the guidelines that generated the parameterized urban grammar allows several different polygons to be studied with a very fast result. It is possible to generate different views, to change land uses, to dimension blocks, and to have results in a range of computational processing.

In times of dynamization of land use, flexibility of use, alteration, displacement, and decentralization of urban centers, such tool emerges as an auxiliary component in the launching of parties. The application is for urban studies, before the development of the project in a Building Information Modeling (BIM) system.

References

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