Visualisation Tools in Grasshopper+Rhino3D to Improve Multi-Criteria Analysis in Urban Policies – Case Study of Pampulha, Brazil

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Introduction

The Multi-Criteria Analysis is a classic analysis model for urban and environmental studies that intents to understand the main elements that affect a system, separate them in layers, and promote an integration among them through the assessment of the impacts caused by the variation on the relevancy of each one of the components on a synthesis procedure. It is part of the systemic approach origins and its use was expanded by the easier access to GIS tools.

According to Moura (2003), the steps on a Multi-Criteria Analysis (MCDA) are: a clear definition of the goals; the selection of the main suitable variables for the cause of investigation; the database assembly; the organisation of potential surfaces for each variable that indicate its suitability for the cause of investigation; the assignment of weights for each layer indicating the level of relevancy. The result of the integration among the variable elements is a map that indicates a spatial distribution of the values from the worst to the best result considering the cause of investigation.

The problem of facing the decision on the importance of each criteria is a classic question in this method. Some researchers proposed processes, as Saaty in AHP - Analytic Hierarchy Process (Saaty, 1980), as the Delphi Method, proposed by the American Research and Development - RAND (Dankey and Helmer, 1963; Linstone and Turoff, 2002). Others classified the process according axis of investigation, as data-driven evaluation or knowledge-driven evaluation (Bonham-Carter, 1994). And there were authors that worked with the control of the output verifying the uncertainty of the results, based on Sensitivity Analysis (Ligmann-Zielinska, Jankowski and Watkins, 2012).

The paper presents contributions to this step of choosing the importance of each criteria, based on visualisation aspects: the user can test the importance of the decision controlling the results in the case study area. To present the visualisation we discuss the graphics semiology and the rules to arrive there developed in digital representation.

As this work is based on the visualisation improvement of the results to favour the involvement of the different society actors, its main contribution occurs during the calibration of the result according to the expectations e values from the citizens. It is necessary that the participants – whether people of the place, technicians from design professions, technicians from geographic sciences, technicians from information technologies, or people from administrative staff – have total access to the data and are able to understand the transformation of the data into information so that they can transform the information into knowledge. In this sense, the visualisation of the results is an essential instrument to support the planning activity.

The main contribution of this work is the improvement on the visualisation of the MCDA process for the understanding of the integration among the variables (step performed inside InViTo © environment) as much as for the step of visualization of the results that was possible through the three-dimensional representation performed inside the Grasshopper© environment and visualised with Rhino3D©.

As a contribution from the researcher Stefano Pensa, a project was elaborated based in InViTo© for Multi-Criteria Analysis and with the goal of exploring the areas with urban transformation potential (growth and occupancy densification). First, ten criteria were tested as they were the main components according to the cause of investigation. Then, the user defined the relevancy of each variable through a scrollbar according to a hierarchy of the relative importance of each criterion, and dynamically reaching a map with the integration response. With an authorization from administrator, the user can also insert a new analysis layer using a Json format.

The dynamic cartography can be either the result of the weights variation with the selection of the portions of interest (for example the 30% most adequate areas), or the selection of the areas of interest (for example the result reached for the regions with specific land use). (Figure 1).

The final product from InViTo is the result from the MCDA visualised as 2D maps and their final data present the possibility of been exported and used in other applications. Our contribution is the increase on the results visualisation programmed with GH and visualised in Rhino 3D, and trying different ways of the information representation. The reached results assessment is oriented by the methodology of Semiology of Graphics proposed by Bertin (1967) for the assessment of the power in maps communication.

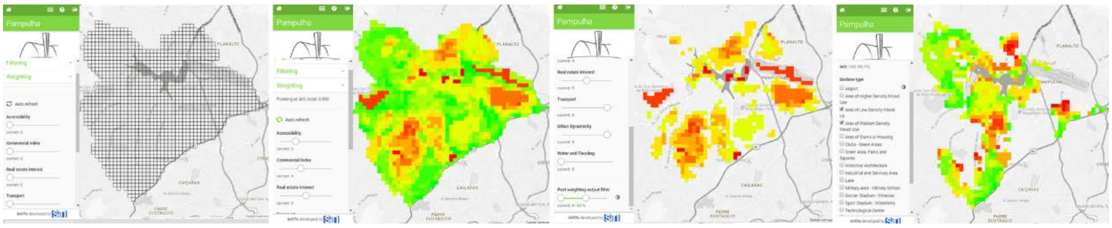

Fig. 1. The use of InViTo Pampulha – Multi-Criteria Analysis, visualization of results according to classes of probability and/or according to land use distribution.

Methodology

The MCDA occurred in the InViTo environment whit the possibility of executing the Analysis with the use of a grid that covers the space, or through existing spatial elements such as lots or blocks. Once the integration between the variables happens in InViTo, the resulting numeric data from the MCDA are associated as attributes to the graphic elements and exported in a Geojson file format while a table containing the resulting data is generated and exported in a Csv file format. For its use as an input file inside the Grasshopper (GH) environment, it is necessary to convert the Geojson file to Shapefile format (shp). The conversion happened with the support of the online tool Mapshaper.

To use the shp file as an input in GH, one can import the file using either the @it plugin or the Heron plugin. Both @it and Heron will keep the georeferencing information after importing the shp to GH, but the Heron plugin has the advantage of changing the reference of the Rhino coordinate system to a place closer to a specific area through a tool called “Anchor Point”. This change facilitates the visualisation for the users.

The GH algorithm reads the geographic georeferenced information (grid or spatial elements) and associates the value from MCDA to each one of the graphic elements which can be either a point or a cell in a grid, or polygons that represent elements such as blocks and lots. The values from the Multi-Criteria Analysis are then used as attributes of the “Z” scale to generate different ways of visualisation of the results.

The relation between the values from the MCDA and the geometric parameters from the visualization format is modelled in a way to allow the control by the user of their behaviour and the relation between them. The user can choose a linear behaviour in relation to the original distribution curve or define a certain exaggeration or smoothness of the extreme values visualizing them in a geometry. The user can also choose a gradient colour to be applied to the geometry of visualization.

Among the ways of visualization, the following possibilities were tested with the aim of analysing their potentials and limitations: extrusion, creation of a surface, and the use of gradient colours. In the simple extrusion visualization, the elements from the layer are elevated up to a “Z” value which refers to the adjusted value from the MCDA. The extrusion can happen either directly from the cartographic element (lots or blocks), or from graphic primitives generated from the grid format. In the grid example of visualization, two circular forms were tested where one of them had its diameters varying depending on the MCDA value, but at the same time its height could increase in the Z direction also according to the MCDA result. In the visualization with the surface, a NURBS mesh was interpolated in points where the “X” e “Y” overlap the centre of each one of the elements from the layer and the “Z” parameter is the adjusted value from the MCDA. A gradient colour can be applied to all the presented ways of visualization.

Once a visualization result is reached, the user can work on the increase or reduction of the contrasts thought the exaggeration or smoothness the behavioural curve. The user can also choose other gradient patterns for the colour. The process ends with the user acceptance of the visualization model. The aim is to choose the most eloquent way to better understand the information generated. (Figure 2).

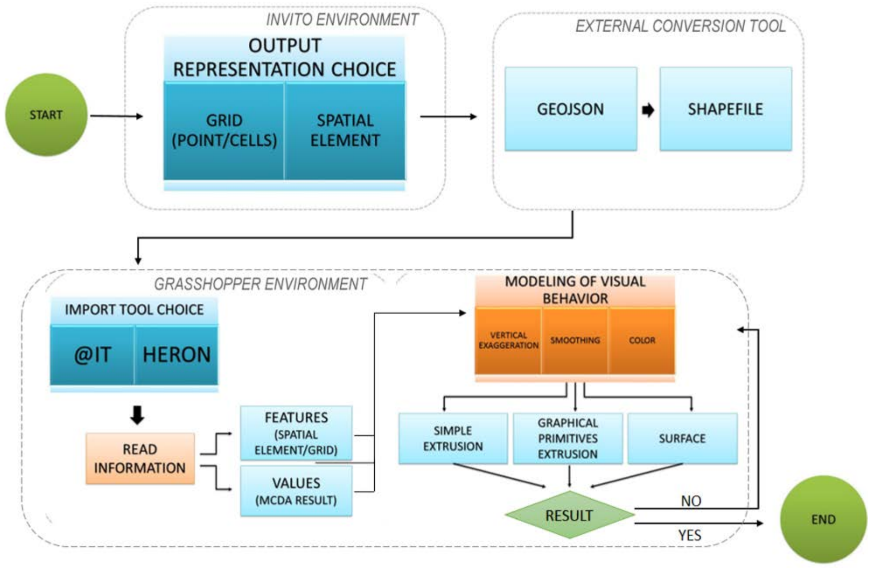

Fig. 2. The logic in Grasshopper programming.

Results

The results consideration followed the logic proposed by Bertin for the Semiology of Graphics (1967). The author proposed a table of choices for the graphic treatment of the information with the goal of achieving the best possible eloquence through the graphic aspect relatively to the main goals of the communication desired (Figure 3). Bertin (op. cit.) and Bonin (1975) argue that the visual communication is developed from the general to the particular as the assimilation of the total form happens before the observation of the details. Thus, the graphic communication follows a process that is reverse to the spoken and written communication which happen from the particular (letters, syllables, words) to the general (the construction of the sentence and its understanding). According to the authors, at any moment during this process, whether in the verbal and written communication, or in the graphic expression, there is a risk of having some noise in communication.

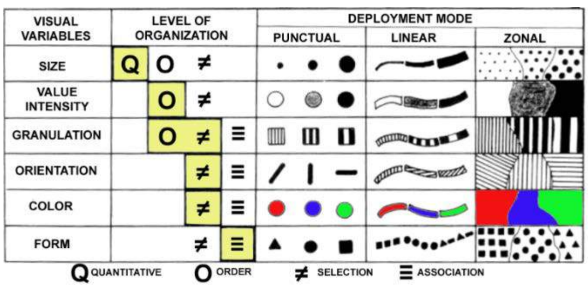

Fig. 3. Graphics Semiology – key of interpretation. (Adapted from Bertin, 1967).

However, the cartographic visualisation is an "Open Art" in Eco's sense (1962) as even if everybody gets a common initial information, during the process of mental construction we can associate additional information according to our analysis expectations. In this sense, according to Moura (2016) visual communication is initially monosemic in the sense of "where", "how", "how much"; but the comprehension of "why" and "what if" must be provided to develop its understanding and decoding. This makes it polysemic.

In order to compare the most adequate results and analysis from the graphics expressions according to specific goals of visualisation, the simulations were elaborated in the following formats: grids (regular or in a circular form), or spatial elements (blocks were used in the shown example). They were done with simple extrusion, increase in the element and extrusion, composition of a surface, and with the use of a gradient colour. (Figure 4).

One can observe that the composition of the use of the graphic element can be characterized as the use of the "form" what the Semiology of Graphics consider to be related to the "associative" information (Figure 4e). As the name infers, the associative makes an association of an information to existing references. That is the case of associating the symbol of an equal sides cross to health related subjects as drugstores. In this sense, the observer mind associates the 3D representation to the heights of the buildings imagining that the growth will happen through the expansion of the building and not according to potential indexes or coefficients that have different ways to occur in the space.

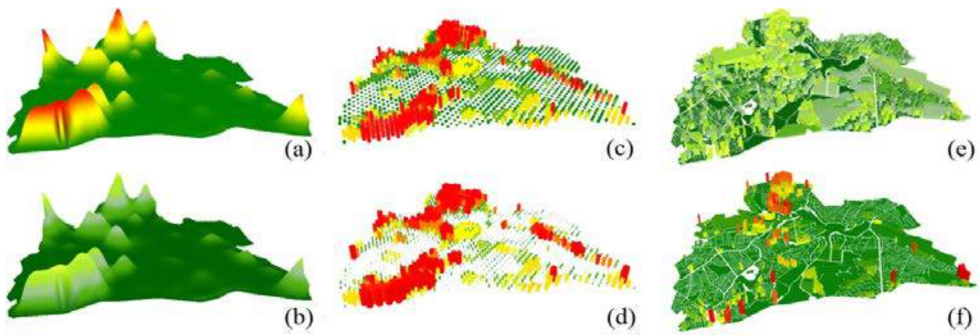

Fig. 4. Visualization. (a) surface+size+colour; (b) surface+size+value/intensity; (c) grid + size z+ colour; (d) grid + size xyz+ colour; (e) spatial element + value/intensity (f) spatial element + vertical exaggeration + colour.

Still in the Figure 4e, "value/intensity" is applied to favour an understanding of ordered scale. When "size" and "colour" are applied to the same base of representation (Figure 4f), the size favours a "quantitative" understanding while the different colours break the notion of order and lead to an understanding of differentiation. It happens because colour is "selective" and indicates a specific meaning for each class.

In the figure 4b, the surface element is treated with "size", which is adequate for quantitative variables, but if it is also applied a gradient colour of "value/intensity", it can represent the principle of "ordered." The treatment "colour" used in the figure 4a with different colours presents a risk of showing slicing classes more than ordered scale. It is important to verify whether or not it is intentional. The figure 4c shows a regular grid (a cylinder) where "size" was applied to represent "quantitative," and "colour" was used to separate the values in "selective" representation. Using the "value/intensity," the "ordered" aspect would be clearer. In the figure 4d, a redundancy was used when the scale was applied both in "Z" and in "X/Y" reinforcing the intention of showing quantitative values.

Conclusions

MCDA is intended for political strategic choices in favour of variables that are axes of importance during possible futures simulations, and the InViTo Pampulha is an instrument for this visualization. For example, a user can understand that for a specific area, the increase of a market distribution variable importance can lead to more interesting results than the increase of transportation conditions. Starting from the use of InViTo, our work was focused on increasing the visualization power and trying the most adequate representations according to different goals.

In the InViTo application, the knowledge driven evaluation was applied, which means: through its expert knowledge or through its specific investigation intention proposes, the user assesses the relevancy of the weights on integrated variables. For future works, the studies will be enlarged towards programming with GH to apply the data driven evaluation so the system can simulate different weights for the variables until specific spatial distributions and conditions as objective functions are reached.

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