CItyMaker Workshop

An Urban Design Studio to experience the dynamic interaction between design exploration and data flow on density-based indicators

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This paper shows the results of a workshop on parametric urban design. A pattern based parametric urban design platform provides a common platform for urban design and analysis by linking GIS with a parametric CAD environment. Urban plans are developed by combining design patterns taken from a large set of parametric urban design patterns acknowledged as a generic urban design language. Urban plan instances are obtained through a specific composition of patterns and a specific assignment of parameters to the patterns. The models provide simultaneous analysis by confronting formal solutions with density indicators that are automatically provided by a set of density calculation patterns.

Keywords: *parametric urban design, CItyMaker, urban design workshop, design methodology*

INTRODUCTION

The present paper is part of a research project that uses parametric and algorithmic design methods for the generation of public spaces in housing developments assuming that these methods contribute to a wider and more in-depth exploration of solution spaces. The possibility of manipulating parameters for generating different alternatives on-the-fly has had a great impact on design methods since the early 2000's. Many discussions have been established about the extent to which parametric design can change the way we design, and about the relation between parametric design and other types of computer-supported design methods, such as algorithmic and generative design.

Parametric modelling is a powerful method for generating urban plans, in which many variables must be taken into account, such as street, sidewalk and block widths (Canuto and Amorim, 2012). However, there is a limit to which extent parametric modelling can generate diverse results without being combined with parametric design rules (Celani, Duarte, Beirão and Vaz, 2011). The approach presented in this paper combines standard codes recurrently used in the urban design practice or design patterns (Gamma et al, 1995), (Woodbury, 2010) with parametric design to generate urban design solutions. The combinatorial structure can be said to be rule based due to the relational structure defined between the objects computed by patterns. In addition to the urban design patterns a second set of patterns provides calculations on density properties of the designs.

In order to test the application of parametric modelling, a workshop was held at the University of Campinas in Brazil for the development of a new neighbourhood located in the outskirts of a metropolitan area, in Campinas. The set of tools used in the workshop, here called CItyMaker (Beirão, 2012), consists of the use of geographic information flow within a parametric design platform to support decision-making in urban design.

OBJECTIVES

The goal of this paper is to present a methodology for approaching the urban design process using parametric urban patterns to deliver a system of alternative solutions instead of a single, definitive solution. This methodology was applied in a one month workshop in the University of Campinas. The experiment consisted of having students develop an urban plan for a new residential neighbourhood using a parametric design system and supporting decisions on the calculation of density indicators. The area is located in the outskirts of Campinas' metropolitan area, in an empty space among existing low-income residential and industrial areas. Results were then analysed with the goal of assessing and refining the tools and design methodology.

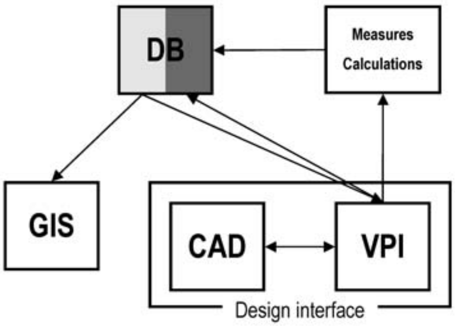

Figure 1
The structure of a City Information Modelling platform

DESIGN METHODOLOGY

A similar teaching methodology including parametric and algorithmic tools had been previously used in two design studios (Duarte and Beirão, 2011) and two workshops (Measurb - Faculty of Architecture, Technical University of Lisbon [1] and Tarlabaşi Datascope - Faculty of Architecture, Istanbul Technical University [2]. In all events the fusion between rule-based design and parametric design was addressed as a methodological approach to the urban design problems given as design tasks to the participants. We argue that the use of parametric modelling alone is not as effective as their combination with rules. In the two workshops, a set of tools was given to the participants to solve their design problems. The tools link information provided by a geographical database with a CAD parametric design environment. In detail (see Figure 1), the proposed working environment integrates a geographic database (DB) with a CAD software (in this case, Rhinoceros(C)) and a parametric Visual Programing Interface (VPI - Grasshopper(C)) including a set of predefined patterns previously programmed to generate typical urban design actions (like grids, arterial streets and main squares) as well as patterns designed to calculate density indicators helping designers choosing their options within the design space provided by the parametric tools. Such design system integrates analytical and synthesis tools in the same working environment allowing designers to react on real time properties measured from the design models. For this reason, the design system has been called CItyMaker. The name includes the acronym CIM which stands for City Information Modelling, a term that congregates the fusion between information flow and design exploration. Information flow here means the calculation of properties of the design in the context during the design exploration process as well as real time assessment of GIS data and generated data. CIM systems not only integrate analysis and synthesis, but they also put together rule based design and parametric design. The rule based behaviour is accomplished by combining patterns or choosing between available options within the patterns; the parametric behaviour is intrinsic to the patterns defined in the VPI where the input parameters are variables within predefined ranges.

In the above mentioned workshops the students were introduced to the several available design and analysis tools. They had three days of thematic lectures divided in two parts: (1) a theoretical lecture introducing concepts to be applied and explored in the practical lecture and (2) a practical lecture where the tools were introduced and students solved small applied problems using those tools. The two workshops had slight differences with respect to their thematic contents. The Lisbon workshop involved three main themes: context analysis and program formulation; design generation involving goals defined in terms of density indicators; and evaluation. The Istanbul workshop was more intensively focused on analysis and included also three main themes: spatial analysis; data mining; and integrated design generation. The two workshops substantiated the basis of the Campinas workshop shown in this paper.

The workshop held at the University of Campinas was attended by graduate and undergraduate architecture students and involved an extended mix of the previously mentioned workshops. The design brief proposed the development of a new neighbourhood in the outskirts of a metropolitan area localized in Campinas, Brazil. The students were asked to examine the relationship between urban design ideals, urban design action, and the built environment through readings, discussions and a final presentation of the proposed neighbourhood plan.

The main objective of the CItyMaker tool was to integrate the flow of information related to design configuration during the design process in order to support decision-making in urban design. This tool explores three aspects: (1) the integration of a platform for parametric design with a geographic information system; (2) a set of "design patterns" for urban design, generating small individual design actions, from which compound arrangements of those "design patterns" generate urban plans; (3) interactive calculation of properties and indicators associated with the urban design exploratory model.

The plans designed following the described method produced interactive parametric design models from which the calculation of precise urban indicators is continuously updated at each change in inputs, either numerical inputs or geometric configurational inputs.

The generative urban design system allows for dynamic interaction between design exploration and data flow on density-based indicators in order to support design decisions and henceforth improve design quality. The system also aims at responding to input needs and provide dynamic information on the measurements and properties of the solutions being explored. The main idea is that the quality of design decisions improves with the quality of the information flow (Beirão, 2012).

The lectures in Campinas dealt with the following themes: (1) shape grammars and rule based design; (2) parametric urban design; (3) 'spacematrix' and density studies on the urban form; and (4) studies on spatial configuration by assessing the topological relations of the elements of urban space including an introductory lecture on 'space syntax' (Hillier and Hanson, 1984). Additional support was given in studio format following a thematic discussion on finding the good city form (Lynch, 1984), (Duany and Plater-Zyberk, 2005) with a specific emphasis on the particular problems of the Brazilian city (Angélil and Hehl, 2013).

CASE STUDY

Intervention area

The intervention area proposed for the development of the urban design exercise in the Campinas workshop included irregular settlements, low and middle-income housing developments and industries. The area is located more or less halfway between the airport and the city centre. Close to the intervention area there is a large sector of informal housing located at the junction of two major state highways: Santos Dumont and Anhanguera. The formation process of this settlement began in the late 1990s, on the grounds of a large empty area, referring to the history of the development of low-income housing in Brazilian cities (Ghilardi, 2012). Thus, the analysis and intervention proposal in this workshop first proposes a reflection on issues that relate to the theme of urban form, the production of slums and the consequent production of urban informality in Brazil.

The design brief included the development of an urban design for this region considering the following requirements: (1) housing for 5-10 thousand people distributed by three predefined sets according to their monthly income; (2) structures to facilitate and encourage local trade; (3) facilities (schools, health clinics, day care centre, parks, sports centre); (4) structures for production and service activities (possibly related to airport activities, such as catering, laundry, etc.); (5) infrastructure for transport connection to the city and the airport.

Workshop

The workshop held at the School of Civil Engineering, Architecture and Urban Design in the University of Campinas was attended by sixteen graduate and undergraduate architecture students during the month of August 2013.

During the workshop the students had lectures on concepts of urban design and analysed the diverse design ideals that influence cities and settlements, and investigated how urban designers use them to shape urban form. Students used a set of design tools defined as CItyMaker (Beirão, 2012). These tools include a set of parametric design patterns programmed to design typical urban design operations like streets, grids and public spaces, and a second set of tools used to measure density properties of urban spaces following the conventions developed by Berghauser-Pont and Haupt (2010). Therefore, the tools comprise design and analytical tools that can be used interactively within the same working platform.

In detail, the design patterns given to the students included:

Urban Design Patterns. Urban design patterns are codes designed to replicate typical urban design actions. Different arrangements of these patterns produce different urban designs.

1. Street design pattern: This design pattern receives as input a set of polylines designed in Rhinoceros or Grasshopper, a polygon as intervention area and a value (variable) for street width. It outputs the resulting grid (the set of polygons resulting from the subtraction of street surfaces from the intervention area); the set of street surfaces; the set of street centre lines; and the total street length.

2. Rectangular grid pattern: The rectangular grid pattern receives as input a polygon as intervention area; a point (which sets the rotation centre of the grid); and four input variables: grid rotation angle in degrees; street width; block size in U direction; and block size in V direction. Units are in meters expect for the rotation angle. The pattern outputs the grid (the set of blocks or islands found within the intervention area); the street centre lines; and the total street length. The latter is calculated following the theory defined in Spacematrix (Berghauser-Pont and Haupt, 2010), i.e., the length of the street defined as boundary is considered only as half the length because its length is shared with the neighbouring areas.

3. Filter 1 (filtering small areas): Receives a grid (a set of polygons representing islands in a grid) and filters polygons with an area smaller than an input value. Outputs the resulting grid and its inverse - the filtered islands.

4. Filter 2 (polygon selection filter): This pattern allows the selection of areas (polygons) within a grid. The selection process separates the polygons in a grid in two separate information flows, one the set of selected polygons and

the other its inverse, that is, the resulting grid polygons. The inputs for selection are points either defined automatically or manually. The algorithm filters islands containing a point.

5. Maximum Building Height Distribution Pattern: Maximum building height is commonly set as a regulatory device for urban planning. Typically this device is used by setting a maximum height or maximum number of floors in an area. Usually such areas correspond to reasonably large areas (district size) for which uniform regulations are set. The present pattern allows the designer to extend the regulation diversity automatically to island level by distributing a different constraint on the maximum number of floors per island. Planning regulations can therefore be different per island and also easily controlled parametrically. The distribution of building height is defined by setting locations as attractor points and then manipulating the constraint distribution according to a distribution function. This pattern processes four inputs: the set of polygons representing islands; and three variables: the maximum number of floors; average floor height; and average ground floor height.

6. Open Space / Coverage Distribution Pattern: Following the Spacematrix theory Open Space Ratio at island level (OSR_i) gives an indicator on the amount of private open space of the plan as it is giving information based on the private open space found within an island. OSR calculated at district level (OSR_d) is based on the total amount of open space found in the district, private and public open space. Therefore, the public open space ratio (OSR) is given by the equation $\Delta OSR = OSR_d - OSR_i$ (page 114). The open space distribution pattern distributes private open space differently per island. Similarly to the previous pattern, this pattern considers a distribution function according to the position of a set of attractor points. The pattern processes three inputs: the set of polygons representing islands; and two values varying between 0 and 1 used to set the minimum and maximum accepted coverage (GSI) variation range. The distribution pattern distributes along the grid different coverage and private open space within the GSI variation range and according to the attraction effect set through the distribution function.

Data Import Patterns. Data import patterns import data from GIS databases. In the Campinas workshop these patterns were not used because the GIS data was incomplete and the needed data was already available in the geometric model.

Analysis Patterns. The analysis patterns used in this workshop were essentially density analysis patterns. Other kinds of analysis were programmed directly in Grasshopper by the students.

7. Spacematrix indicators patterns: Floor space index (FSI) calculation; Ground space index (GSI) calculation; Open space ratio (OSR) calculation; Average number of floors (L) calculation; and Network density (N) calculation patterns. The patterns are identical for every level of aggregation, but this means that users need to be aware that the input geometries have to be consistent within the level of aggregation being calculated. All the patterns receive the base geometries as defined in the spacematrix theory (pages 107-114).

8. Spacematrix indicator converter pattern: This pattern was developed by Pirouz Nourian; it receives 2 spacematrix indicators and outputs the 2 indicators missing. The indicators are Floor space index (FSI); Ground space index (GSI); Open space ratio (OSR); and Average number of floors (L).

The practical part of the workshop started with an analysis of the existing urban tissues by measuring their density indicators. Students started by identifying homogeneous areas and neighbourhoods for which they calculated the above mentioned indicators and produced maps for visualization of the several topics of analysis (Figure 2).

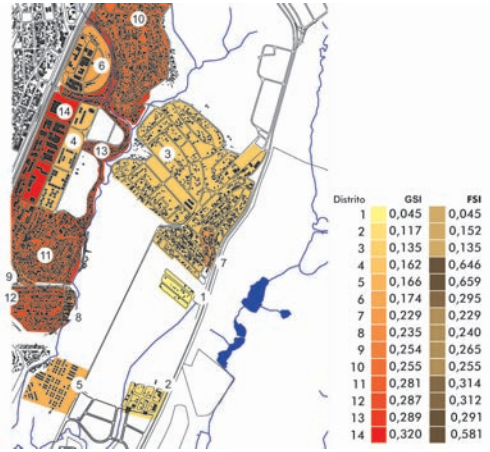

Figure 2
Density analysis using the CItyMaker analysis tools

From the several on-going analyses a discussion regarding the pros and cons of certain morphological types was raised. Specifically, the issue of density was discussed using parametric models to compare the tower-based block with the traditional peripheral block breaking the myth that the tower-based block would necessarily respond to higher density requirements. Having acknowledged that such myth was false the students engaged in a more critical attitude towards the standard speculative construction in Brazil and explored other design concepts in their designs.

RESULTS

The results were evaluated in terms of the quality of the designs in relation to the outcomes of similar projects developed by students with traditional methods and the participants' impressions about the workshop. The designs developed in this workshop show a greater variety among the different teams than in regular workshops (Figure 3). They also present a big variety of urban morphotypes within a single project, i.e., students did not restrict the solutions to a single grid for the entire area under development but rather explored many variations available by the tools before freezing a solution. Regarding students' opinions about the method, they have deliberately acknowledged how the CItyMaker environment has helped them in generating a number of different spatial configurations and testing different parameters, thus generating a more diverse plan. A local professor of urban design who was not familiar with parametric design techniques was invited to assess the results. She was surprised with the variety of the results and the quality of the plans produced in such a short period of time.

During the workshop students were allured to use the tools to perform several urban analyses and to measure density indicators as a means to support design decision. A discussion questioning the morphological solutions commonly developed by Brazilian housing promoters was raised, in particular questioning the recurrent use of the isolated skyscraper in gated communities. Several preconceptions regarding the formal expression of density were broken and reconsidered allowing the students to more freely explore unconventional solution spaces. The CItyMaker tools and spacematrix theory proved quite useful to support this process especially because the tools provide measurements with simultaneous visualization while still allowing for further formal exploration. At the final presentation, the set of density measures calculated from the model was mandatory. Students had to show the proposed indicators that should rule their plans and also support the reason for such indicators based on the developed analyses. This task showed two contrasting behaviours. On one hand students could easily produce measurements taken from their designs with a readiness they had never experienced before. Measuring proved to be easy. On the other hand, measuring required a lot of attention both methodologically while defining the design model and interpretatively while consid-

ering the meaning and impacts of the obtained measures as a way for supporting design decision. This situation raised remarks regarding the necessary attention to the parametric model development and correct theoretical knowledge. Firstly, regarding the development of the parametric model students were alerted for the need of having a clear notion about the concept of 'level of aggregation' in order to objectively define the indicators calculations at the required levels. Secondly, the meaning of density indicators require detailed interpretation developed at the light of the intervention context. The latter involves a rather complex theoretical approach supporting how density indicators relate, first to urban form and moreover to urban qualities. Here, the analytical methods proved useful as they provided a better insight on the behaviour of urban environments.
Although the workshop results were acknowledged by all participants as positive and highly formative, it is still possible to abstract from students comments and presentations that better results could only have been possible with more intensive lectures on urban

Figure 3
Two examples of outputs produced by the students. Volumes indicate constraints on building height defined at island level. These constraints were generated automatically using attraction points that distribute height constraints according to an assigned weight.

design theory, especially on the identification and meaning of quality indicators and in particular within the context of Brazilian urban environments.

DISCUSSION

Since the Design Methods Movement - period of discussions, conferences and publications on design methods in architecture, engineering and industrial design in the 1960s - two approaches have been employed in order to optimize the design process and provide greater flexibility for architectural design: parametric design and rule-based design. The first strategy consists of defining topological relations between parts of a composition, while the definition of the precise measures is a subsequent phase of the design process. In general these dimensions can be selected from a desirable range, with minimum and maximum values established beforehand, usually taking into consideration values that are multiple of building components dimensions, resulting in greater flexibility and variety (Monedero, 2000). A strategy based on rules (rule-based design) (Broadbent, 1970) allows defining situations in which a particular element can be connected to another, and how this may occur. This method allows a greater variety of designs, since the application of the rules in different orders can result in completely different compositions.

In the exercises developed in this workshop this could be easily noticed, for example, when some the students subdivided the intervention area initially according to a specific pattern, and then applied a different pattern within each generated cell. The system allowed to easily make changes to each embedded pattern in terms of type and/or parameters, allowing for the evaluation of a virtually infinite number of possibilities.

Although the work platform is essentially parametric, the design patterns aggregation define the topological structure of the model that is produced in the design process, constituting a limited set of rules that are interpreted by the corresponding parametric code. Therefore, the design contains an algorithmic and a parametric dimension that can be represented more abstractly through a shape grammar. In other words, the set of patterns available, here called CItyMaker, is a generic grammar for urban design where each pattern encodes a typical urban design operation by means of a shape grammar and is implemented in a parametric design platform. Each instantiated urban plan can be seen as a specific grammar translated by the specific combination of patterns with a specific assignment of parameters (Beirão, 2014).

The workshop showed (1) how easily some students unfamiliar with programming get enrolled in the exploration of design solution spaces via parametric visual programming, (2) the possibility of conjoining analytical models with design exploration models which provide students with (3) the ability of justifying their design solutions with supporting analysis directly derived from the geometric models.

As stated in the beginning of this paper, the workshop herein described was also part of a larger research, proposing the use of parametric and rule-based strategies for the development of public housing in Brazil. One of the plans developed in this workshop was chosen as a basis for the next workshop, in which students used shape grammar to design a housing complex in which issues of population growth, evolving plans and function mix were addressed. We considered that it would not make sense to develop this type of exercise on a traditional, square-grid urban area.

Beyond the contribution to the field of rule-based parametric design, this research was an opportunity to show how the fusion of different types of knowledge can lead to new insights. In this case we were able to fuse (1) research and teaching, (2) undergraduate and graduate students, (3) Latin American and European cultures, (4) analysis and design, (5) the use of parameters and rules combined in the design process, (6) researchers specialized both in architectural and urban design, and (7) the research developed by two PhD researchers.

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