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HUMANISING THE COMPUTATIONAL DESIGN PROCESS

Integrating Parametric Models with Qualitative Dimensions

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Abstract

Parametric design is a computational based approach used for understanding the logic and the language embedded in the design process algorithmically and mathematically. Currently, the main focus of computational models, such as shape grammar and space syntax, is primarily limited to formal and spatial requirements of the design problem. Yet, qualitative factors, such as social, cultural and contextual aspects are also important dimensions in solving architectural design problems. In this paper, an overview of the advantages and implications of the current methods is presented. It also puts forward a 'structured analytical system' that combines the formal and geometric properties of the design, with descriptions that reflect the spatial, social, and environmental patterns. This syntactic-discursive model is applied for encoding vernacular courtyard houses in the hot-arid regions of the Middle-East and North-Africa, and utilising the potentials of these cases in reflecting the life-style and the cultural values of the society, such as privacy, human-spatial behaviour, the social life inside the house, the hierarchy of spaces, the segregation and seclusion of family members from visitors, and the orientation of spaces. The output of this analytical phase prepares the ground work for the development of socio-spatial grammar for contemporary tall residential buildings that gives the designer the ability to reveal logical spatial topologies based on social-environmental restrictions, and to produce alternatives that have an identity, and at the same time respect the context, the place, and the needs of users.

1. Introduction and Research Context

Computational design is about manipulating ideas, concepts and processes in a clearly defined steps and instructions that are routinely made by computer (Terzidis 2009). This precise procedure offers to conceive operations, ideas, and solutions not easily predictable. In the field of architecture, parametric design is an interactive computational based approach, used for understanding the logic and the language embedded in the design process algorithmically and mathematically (Paper and Technion 2015; Woodbury 2010; Jabi 2013). It offers the designer control of the conversion of properties of objects and inputs into solutions and different alternatives accordingly with the minimum time needed; by defining, encoding and clarifying relationships between objects that are associated with specific rules and parameters (Jabi 2013; Fernandes 2013).

Currently, the main focus of computational models is primarily limited to building performance, optimisation, and the functional requirements of the design problem. Yet, qualitative factors, such as social, cultural and contextual aspects are also important dimensions in solving architectural design problems. The aim of this research is to combine all of these dimensions through applying a model of analysis on vernacular courtyard houses in the hot-arid regions of the Middle-East and North-Africa (MENA region) as a case. Different studies in the field of vernacular architecture show that these precedents are good examples of a socially cohesive and healthy environment, and have various features that reflect the life-style, the local context, the climate, and the cultural values of the society. Such elements include the courtyard, hierarchy of public/private spaces, different degrees of openness and enclosures, patterns of movement, and geometric properties of spaces, which have the potentials for achieving sustainability (see Figures 1 and 2).

Figure 1. Courtyard houses in Damascus, Syria (www.pinterest.com)

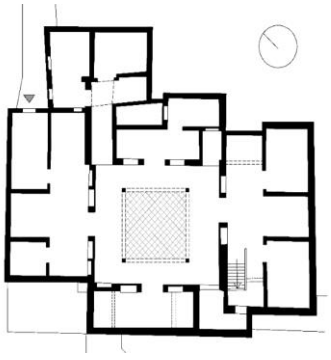

Figure 2. courtyard house in Tunis ((Redrawn by Authors after (Ragette 2003))

2. Reviewing Analytical and Generative Design Systems

Architects are trying to transform all design requirements into forms and spaces through adopting processes, and series of goal-oriented steps. However, a successful design means that it has an identity where all components are in harmony with the context and the requirements of the modern and future time (Mehrpoya et al. 2015). This issue needs from designers to understand and analyse two sets of relationships between components. The first set addresses space-form languages, which includes lexical (geometrical) and syntactical levels. Different methods, such as shape grammar and space syntax, consider the morphology and the internal structure of the overall form and its components. The second set considers semantic and semiotic levels that are related to the meanings, symbols and values of elements and treatments. However, the syntactical level is also related to the second aspect which addresses the social life of users.

2.1. SPACE-FORM LANGUAGES

One of the useful tools for generating designs is to convert ideas into abstracted forms. Space syntax approach, developed by Hillier and Hanson in 1984, is used to understand spatial topologies and social relations implicit in the architectural setting through representing spaces by circles (nodes), and relationships within the overall configuration by lines. However, studies focusing on how such an approach might be used to generate or inspire new designs are limited (Lee et al. 2013). On the other hand, shape grammar, developed by George Stiny and James Gips in 1972, is based on the use of typological analysis methods by formulating spatial relationships, parameters, rules and restrictions. Moreover, it is a systematic process for generating new alternatives that depend on the use of shapes rather than symbolic computations. To control the process of form generation and the production of distinguished solutions, George Stiny (1980) introduced labels, such as letters; symbols; or points, associated with shapes, to reduce symmetries. Moreover, Stiny specified parameters in terms of equations, constraints and transformations, such as translation; rotation; reflection; or scale, which could be applied on shapes to increase the number of solutions and the flexibility in design.

However, there are some limitations that faced the designers when they applied such formal approach. Shape grammars do not show the social, cultural and environmental aspects of the composition as it do not go deep with semantic and semiotic levels of the layout (Colakoglu 2000). Moreover, some of the design possibilities that are produced after applying shape grammar have no architectural meaning or irrelevant (Eilouti and Al-Jokhadar 2007). To cope with such limitations, scholars suggest different

tools combined with shape grammars, such as descriptions, expressions, and textual information.

2.2. DESCRIPTION AND DISCURSIVE GRAMMARS

Usually, details of design elements are provided in text and descriptions. To address this issue, George Sting (1985) proposed the concept of adding description functions, such as numbers, strings, lists, operators, and parameters, to the shape rules to generate relevant solutions. Rudi Stouffs (2015) defined three schemes for descriptions. The first scheme, which is called 'reflections', reveals the spatial vocabularies that form the design and the combination of elements. For instance, description rules have been included in the shape grammar of the *Yingzao Fashi* architectural style constructed by Andrew Li (2001, p.30) for one of the spaces as the following: "*6-rafter building, centrally divided, 1-rafter beam in front and back, with 5 columns*". The second scheme, 'expressions', used to describe some properties such as volume, cost or manufacturing plan.

'Design brief' is the third scheme that defines the user input data at the rule application; or the site data, such as functional zones and their adjacency relations; or conditional specifications, such as the enumeration of 'true' and 'false' that allows a function or rule label to be constrained beyond a single value (Eloy and Duarte 2011). José Duarte (2005) applied this scheme in the grammar of the 'Siza's Malagueira housing program guidelines', through organizing descriptions into three groups: (a) *contextual, typological and morphological features*, which include plot size, urban context, solar orientation, number of bedrooms, type of house, number of floors, and existence of balconies; (b) *function and aesthetic qualities*, such as dwelling capacity, room capacity, articulations, distances between spaces, and proportions; and (c) *construction cost*, through specifying areas, materials, and thickness of walls.

Another attempt has been implemented by Teresa Heitor, José Duarte and Rafaela Pinto (2003). They concerned with how two different computational approaches to design: shape grammars (large set of design solutions) and space syntax (that consider the context), could be combined into a single framework for formulating, evaluating, and generating designs. They utilised the spaces syntax to determine whether the applied formal and spatial principles are in the language and the contents of the grammar, by measuring three parameters: (a) depth, which is the topological distance of one space to all other; (b) control value, which reflect the relationship between spaces and immediate neighbours; and (c) contiguity that express the number of connections to adjacent spaces (Heitor et al. 2003).

3. A 'Syntactic-Discursive' Model for Encoding Traditional Courtyard Houses as a Trace of Social and Environmental Qualities

Integrating the embedded qualitative criteria of the architectural design problem with formal and spatial requirements remains a challenge in the computational process due to the difficulty of converting the abstracted issues into basic parameters that can be algorithmically represented. Therefore, feeding the parametric model with qualitative/quantitative data needs additional tools of analysis. This study adopts 'typology' as an instrumental tool of analysis, associated with different formal, syntactical, analytical and generative methods, such as space syntax, shape grammar, and descriptive grammars. The developed 'syntactic-discursive' model has been implemented on different vernacular houses from the Middle-East and North-Africa, as an attempt to define similarities and explore relationships between social, spatial and environmental dimensions.

The model depends on combining the syntactical analysis with three aspects of design: (a) geometric characteristics (e.g. shapes, areas, and proportions); (b) social indicators (e.g. relationships, users, privacy, patterns of movement); and (c) environmental treatments (e.g. orientation, and type of enclosures). These aspects are presented in five categories (see Figure 3):

1) *As-built plan*: showing the different patterns of movement and distances between the centre of the courtyard and the centre of each space.

2) *Visual analysis diagram:* showing the spatial organisation of spaces with visual connections between public and private domains.

3) *Space syntax analysis*: showing spatial relationships between spaces, courtyard, and entrance, through measuring:

a. *Connectivity (NCn),* which represents the number of immediate neighbours that are directly connected to each space.
b. *Integration value (i),* which describes the average depth of space to all other spaces. The highest value indicates the maximum integration.
c. *Control value (CV),* which measures the degree to which space controls access to its immediate neighbours taking into account the number of alternative connections that each of these neighbours has.

4) *Depth and hierarchy of spaces*: each space is represented by its actual shape rather than symbolic nodes, and arranged to show the hierarchy of spaces (public, semi-public, semi-private, private, and intimate); orientation (West (W), East (E), North (N), South (S), North-East (NE), North-West (NW), South-East (SE), and South-West (SW)); type of enclosure (covered, open, semi-open), shared surfaces between adjacent spaces; the entry access of each space; and the actual distance between the centre of spaces and the centre of adjacent rooms.

5) *Spatial and geometric relationships*: showing the proportions of each space (X:Y); percentage of space area from the overall area of the house (%All); proportions related to the courtyard (1:C); actual distance (D1) in

metres from the main entrance (N1) to the centre of the space; actual distance (D2) from the centre of the courtyard (N2) to the centre of the space; and the dominant users of each space (male, female, or both).

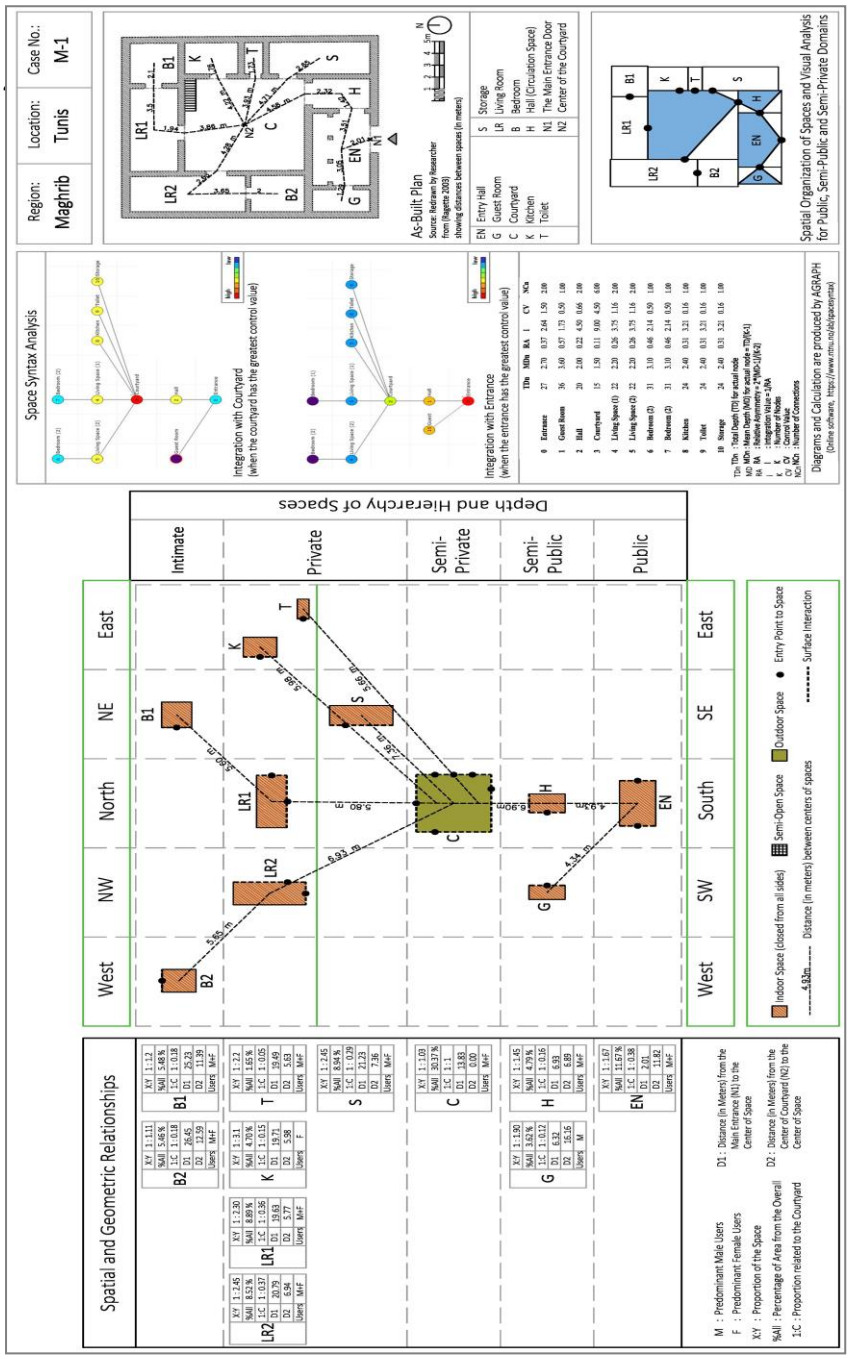

Figure 3. A syntactic-discursive model for analysing a vernacular courtyard house in Tunis (Authors)

4. Results and Discussion

Based on the syntactical-discursive model of analysis, it is obvious that the human-spatial behaviour, the social life inside the house, the hierarchy of spaces, and the segregation and seclusion of family members from visitors are regulated by a series of syntactic elements. After applying the analysis on a vernacular courtyard house in Tunis, different qualities are observed.

- Most spaces follow the geometric patterns of the courtyard with a symmetrical layout arrangement.
- The space syntax analysis shows that the courtyard, which is a semi-private space, has both the greatest control value (CV = 4.50) and the greatest integration value (i = 9.00), which means that other spaces, mostly private zones, are controlled and accessed through the central space of the house, where most of the daily functions are located. This arrangement provides a protected and suitable area for family gatherings.
- The hall (H), which is a semi-public circulation space, connects the entrance with the main courtyard. It is a mediator between the inside of the house and the outside world. However, the bent entrance passageway preserves the visual privacy of the family.
- Guest reception room is a shallow space used for male visitors, and it has the lowest integration value (i = 1.73), as it is suited off the courtyard and next to the entry hall. There is no visual connection between this space and semi-private/private domains, so the privacy of the family members could be achieved.
- All private spaces face the courtyard, and have approximately the same distance between the centre of the courtyard and the entry point of that space. This depth, which ranges between 5.65 and 7.30 meters, provides a suitable distance for the residents live in a comfortable atmosphere. All intimate spaces (bedrooms) should be accessed through private spaces to give more privacy.

The results of analysis are translated into 39-variables to define social, spatial, and environmental descriptions and constraints (see Table 1) that are used for constructing the grammar for vernacular courtyard houses in the study area (see Figure 4). This type of grammar and model of analysis differs from shape grammar and space syntax method in many aspects. In terms of components, all geometric properties, proportions, functions, and type of enclosure are defined. Moreover, spaces are arranged according to the public-private hierarchal system and the solar orientation. In terms of relationships, the actual distances between spaces, the pattern of movement, and the physical-facial (wall-to-wall) relations are associated with rules. Finally, aspects related to the social dimension, such as visual privacy, interaction and the dominant users of each space are specified.

TABLE 1: Variable Descriptions (Spatial, Social and Environmental Parameters)

Features	Variables		
Morphology	v1	Type of house < detached, attached from one/two/three sides >	
	v2	Number of floors < number >	
Overall Geometry	v3	Overall Layout	Shape < square, rectangle, irregular >
	v4		Total width < m >
	v5		Total length < m >
	v6		Area < m^2 >
Spatial Description	v7	Name of interior spaces < name (space ID) >	
	v8	Number of courtyards < number >	
	v9	Main courtyard location < centre, front, back, side edge >	
	v10	Type of outdoor spaces < balcony, terrace, courtyard, gallery, iwan >	
	v11	Area of outdoor spaces < m^2 >	
	v12	Percentage of outdoor spaces from the overall < % >	
	v13	Total number of rooms < number >	
	v14	Number of living spaces < number >	
	v15	Number of bedrooms < number >	
	v16	Staircase < true, false >	
Geometric Properties for Each Space	v17	Room layout	Shape < square, rectangle, irregular >
	v18		Width < m >
	v19		Length < m >
	v20		Height < m >
	v21		Area < m^2 >
	v22	Proportion of the space < space ID: X:Y >	
	v23	Percentage of area from overall < space ID: % All >	
	v24	Proportion related to courtyard < space ID: 1:C >	
	v25	Distance from the entrance to the centre of the spaces < space ID: D1=m >	
	v26	Distance from the centre of the main courtyard to the centre of the spaces < space ID: D2=m >	
Spatial Topologies	v27	Relation with adjacent spaces < space ID: adjacent spaces, Orientation>	
	v28	Changes in levels between spaces < number of steps, spaces ID (1), (2) >	
	v29	Changes in levels between outside and the entrance hall < no. of steps >	
Social Qualities	v30	Predominance users < space ID: male, female, male/female >	
	v31	Type of space < space ID: intimate, private, semi-private/public, public >	
	v32	Spaces that have direct visual connection with the courtyard < space ID >	
	v33	Spaces that have direct visual connection with entrance < space ID >	
	v34 v35	Integration with the entrance and with the courtyard < sort spaces from the lowest integration value to the highest integration value >	
	v36	Hierarchy of spaces < true, false >	
Environmental Considerations	v37	Orientation < space ID: N, S, E, W, NE, NW, SE, SW >	
	v38	Thickness of exterior walls < thickness cm >	
	v39	Thickness of interior walls < thickness cm >	

Descriptions

v(1)→ attached from 3 sides
v(2)→ 1 floor
v(3-6)→ square, w_L , L_L , m^2
v(7)→ C: Courtyard, A: Reception, B: Circulation Hall
v(8-9)→ 1, center
v(10-12)→ courtyard, m^2, 27.5%
v(13-16)→ 1, 0, 0, 0
v(17-26)→ ID#A↔ Rec., W_A, L_A, H_A, A_A, X:Y, %All, 1:C, D1, D2
ID#B↔ Rec., W_B, L_B, H_B, A_B, X:Y, %All, 1:C, D1, D2
ID#C↔ Squ., W_C, L_C, H_C, A_C, X:Y, %All, 1:C, D1, D2

v(27)→ ID#A↔B(E), C(N); ID#B↔A(W), C(N); ID#C↔A(S), B(S)
v(28)→ zero
v(30-31)→ M+F, semi-private
v(32-33)→ C↔B, A↔EN
v(34)→ G < B1 < B2 < EN < K < T < LR1, LR2 < H < C
v(36)→ true
v(37)→ A↔S, B↔S
v(38-39)→ 60cm, 40cm

Figure 4. Rules associated with descriptions for generating courtyard and reception.

5. Conclusion

Shape grammars and space syntax methods are useful tools for exploring formal and spatial relationships. Yet, these approaches do not show the social, environmental and semantic levels of the composition. The use of syntactic-discursive analysis for encoding historical cases and the needs of users gives the designer the ability to reveal logical spatial topologies based on social-environmental restrictions that control the overall configuration of solutions. The model combines descriptions with shape grammars and syntactic relationships to define the geometric properties of spaces that are associated with its qualitative dimensions. In the next stages of this ongoing research, this analytical phase for traditional houses in the hot-arid regions of the Middle-East and North-Africa prepares the ground for the development of socio-spatial grammar for generating parametric solutions for contemporary tall residential buildings that encourage social interaction between families, and respect their needs, lifestyle, and the context.

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