DESIGN OF GENERATIVE MODEL FOR THE LANGUAGE OF TRADITIONAL SUAKIN USING PARAMETRIC SHAPE GRAMMAR

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ABSTRACT

This paper aims at presenting a parametric shape grammar of traditional Suakin houses (Red Sea state, Sudan). This work systematically attempts to generate appropriate plans arrangement that allows required functional relationships between spaces to be satisfied. The topological and geometrical properties of old Suakin houses were analyzed. These properties were originated and incorporated into the traditional Suakin buildings for the past ten centuries. The shape rules, dimensional, geometric and topological patterns of houses in the corpus are used as the generative model for the language of traditional suakin style This paper concludes with a discussion of the creative and generative value of the parametric shape grammars. Moreover, it facilitates the understanding of the formal composition of Suakin old style and the revival of a contemporary Suakin building style.

KEYWORDS: *Generative model, Parametric shape grammar, Suakin*

1. INTRODUCTION

Shape grammars were first defined by Stiny and Gips [1], later this formalism was refined by Stiny [2]. Shape grammar is a type of formal productive system that is used to assist design process by means of continuous applying of shape rule to initial shape [2].

In conventional shape grammar approach, Stiny in [3] stated that pictorial representations are expressed according to sub-shapes and spatial elements within well defined algebras of design. For these purposes algebras, shape manipulation reflects the flexible modes that are utilized by designers with their pictorial representation.

Stiny in [3] stated that the maximal representation of shapes that is used in shape grammar does not constrain the component of a shape to those initially defined as in common in geometric modelers, instead the components of a shape are defined to the perception of the designer and are free to change continuously, via application of shape rule.

Shape grammar theories have been developed for a number of works, specifically for architectural styles. Among these work are shape grammars for the architecture of The palladian grammar [4] Giuseppe Terragni [5], Frank Lloyd Wright [6], Lebanese House Shape Grammar [7], Glenn Murcutt [8], Christopher Wren [9], and Irving Gill (J.Gibbs 1981), for the vernacular styles of Japanese tearooms [10], bungalows of Buffalo [11], Queen Anne houses [12], and Taiwanese traditional houses [13], Chinese traditional architecture [14] and for the landscape architecture of Mughul gardens (G.Stiny and W.j.Mitchell 1980), courtyard houses [15], the architectural style of the Yingzao fashi [16],[17], Landscape grammar [18], patio-house [19],

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architectural style for Siza's Malagueira houses [20], mamluk madrasa [21], Traditional Malay Long-Roof Type Houses [22], the Palladian grammar (Palladio's rules of architecture) is earliest of these works notable for being the first architectural grammar which generates villa ground plans in the Palladian style --motivated in part by Stiny's [23] recent book presents the shape grammar formalism both with respect to its philosophical and formal level and the alleged influence of shape computation on Palladian's architecture.

According to stiny [3], a shape computation is defined by the application of shape rule in a grammar. At philosophical and formal aspects, shape grammar provides a formal representation that allows designers to manipulate pictorial representation in a natural and infinitive way, without reference to symbolic representation. Indeed, on the general level, shape grammar Similar to a mathematical statement and natural language components, architectural language components are: semantics (meaning and context) and syntax (structure and form). Language has its own syntax, that is, it has its alphabet (primitive elements), vocabulary (elements composed from the alphabet, words, phrases and sentences) and grammar (legal composition of vocabulary, rules and operators) and the mathematical statement formulated in this language. These are concept that could be of greatest interest if computer to undertake design task of manipulating the symbolic representation. This is the mathematical challenge Wittgenstein have posed and used the research question to address "what would arithmetic have been like if shape, not number, had been of greatest interest to us?" [24]

This study focuses on the application of the modularity rule of architecture of the Ancient traditional houses of Suakin inland city. This is built upon the arithmetic formalism of shape grammar by [25]. With a bottom-up approach architectural language, a vocabulary element of Suakin traditional style were defined, then this vocabulary elements were transformed into a Suakin shape grammar and finally a variety of Suakin plan layouts were generated.

2. THE ANCIENT TRADITIONAL HOUSES OF SUAKIN INLAND CITY

Suakin is found at the north-eastern tip of the Arabian-African Coastal Region, bordered by Saudi Arabia to the north across the Red Sea and Sudan to the north and west across an oval-shaped island. It is approximately 750 m. long and less than 500 m. wide in size and is almost entirely flat desert plain (Figure 1).

Figure 1. Map of Sudan showing the location of Suakin. Source: www.mapsof.net\map\suakinsudan

According to several references, Qezar, et al [26], Dirar [27] Salim [28], and Mallison [29], the earliest history of Suakin dated back to three thousand years BC, where it was used by ancient Egyptians on their way to the Kingdom of girl (Punt) in the East Africa to hunt Elephants. Suakin have been the Roman port of Evangelon Portus used by Ptolemy (Figure 2 and 3). In the 10th-12th Centuries, Suakin formed a trading point for the Arabs (Figure 4). Suakin gained importance after the advent of Islam and became the Africa's number one Port which the pilgrim travelled to the holy land Mecca and Medina. By the fifteenth century, it had become a central point's commercially for Mamluk Egypt, attracting Venetian and Indian merchants, who traded up to Ottoman invasion of 1517. And from then on, into 19th century, it was during the Ottoman occupation that many of the distinctive Coral Building were built and by the 1922 (Figure 5), Suakin had fallen into a ruin with the opening of the Port Sudan at Sheikh Al Bargath.

Figure 2. Roman Red Sea map a.ortelius 1595

Figure 3. ptolemy graeco-roman world map 150AD

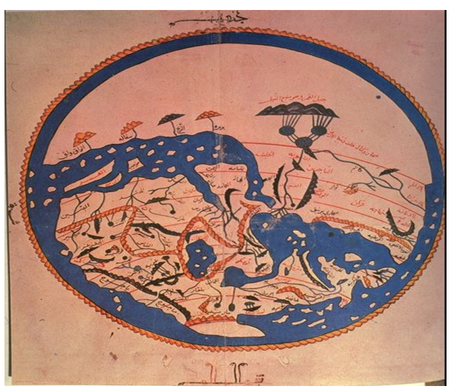


Figure 4. Medieval Arab map

Figure 5. Suakin 1922

The Coral Buildings of Suakin developed a distinctive art and architectural style, which was applied throughout the coastal (one of the largest in the Africa and Arab Muslim world at the time). Through a long period of time, between 2000 BC to 21th AD, It contributes and shares specific distinctive culture and social values which are included in their everyday social system and social organization, also had its influence on their architecture as well.

Suakin Architecture is instantly recognizable in the view of its largely predictable standardized, modular and symmetrical nature [30]. The most important legacy of Suakin is in its unique architecture that implements most of the rules of architecture, relying on local materials like locally available coral stones, reefs paved with white lime. Suakin used these coral stones like the burn modular unit, which gave it the shape and white color that reflects the exquisite beauty of wood configuration.

Although, the making of the standardized oriels building of Suakin was not fingerprints in the details but each one of them is a unique work of art with a high artistic value which needs to be preserved.

Suakin traditional style in the majority of its building often consists of one or two floors. Ground floor contains the business and commercials; the shops and stores. Usually the ground floor contains seats for men and used for the reception of guests by the owner of the house, while the first floor comprises of women apartments, bedrooms and everything related to family life and privacy if there is first floor or on a separate majlis and bedrooms for women apartments on the same ground floor. The roof-terraces ("kharjahs") which is the last or third floor often comprise the small room for servants and food preparation.

The characteristic building standards and almost all the rules of architecture were found in almost all parts of the buildings and is repeated from one building to another, the dimensions or measurement of the rooms and stairs, doors, windows and oriels are uniform within close ranges of each other. This uniformity demonstrates great skill in the art and architecture. The idea of standardization in modern buildings is an idea known to man in the twentieth century to facilitate the construction and erection of parts of buildings, which helped in the conceptual analysis of building. This uniqueness of uniformity, modularity and symmetry are suitable factors for the application of parametric shape grammar theory which intend to be the focus of this study.

3. VOCABULARY ELEMENTS OF THE PLANS:

According to Downing and Flemming, all shape grammars dealing with the generation of architectural plans create at the initial stage a geometric pattern which determines the compositional characteristics of the plans (Downing and Flemming, 1981). Smallest bilaterally symmetric grid were used at the initial shape of generation of the grammar of Japanese tea house (Knight, 1981). Downing and Flemming have used rectangle by divide into two horizontal, two or three vertical zone to start generating the grammar of bungalow(Downing and Flemming, 1981). Using Hall at the first stage of generating the grammar of Queen Anne house, room, kitchen, stair hall and other vocabulary elements was located at the progressive stage. In the generation of Palladian plan, the initial shape of the generation is the definition of a grid, these were used to determined the location of walls (Stiny and Mitchell, 1978). The author used the grid form for the generation of two dimensional plans and also stiny found that two dimensional shape grammars can be used in plan composition. In the grammar of traditional Turkish houses, the initial shape of the grammar is a labelled coordinate point Cagdas [31]. In the grammar of Hayat house, a labelled coordinate point is specified to define type of hayat house to be generated and which vocabulary elements of each type of hayat house are going to be put together [32]. In the discursive grammar of Siza's Malagueira houses, a rectangular schema with a label "Lot" representing the lot is dissected perpendicular into two horizontal and two or three vertical zones at the first stage of the generation [33]. In the grammar of Queen Anne houses, the vocabulary element representing the hall is located at the first stage of the generation; at the progressive stages, the rooms, the kitchen, and the stair hall are located so as to generate the plan layouts according to the shape rules. The authors concluded that in the grammar of traditional Suakin houses, the initial shape of the grammar is a labelled point (K) which is placed on a coordinate system. The generation process begins by locating the hall (majlis), represented by a polygon, whose upper left corner coincides with point K and proceeds by applying the shape rule schemata.

The main vocabulary elements in the language of traditional Suakin houses are court yard, rooms, services and halls (majlis) as shown in Figure 6 with their particular divisions of primary (majlis) and secondary space (rooms). As Stiny states, two-dimensional shape grammars can be used in plan compositions (Stiny 1976). The vocabulary elements in this grammar are represented as parametric and constrained shapes, which totally represents the spaces and topologies in traditional Suakin houses. As the dimensions of these spaces may vary in different plan layouts, the shapes are fully parameterized as shown in Figure 7-13, where both x and y coordinates of the end points of the lines representing the edges of the shapes in a schema are defined as parameters in table 1.

In this shape grammar, straight lines are used; relative dimensions of these lines and the angles between them may vary as Stiny 1982 noted that in all parametric shape grammar constraint within shape, around both X and Y axes were possible. Rotation about the shape was also limited by the length of lines and its angles. Therefore, this grammar can be used in defining the language of shapes with proportional relationships represented by a grid system with specific layer and pattern.

Figure 6- The vocabulary elements for Suakin's Grammar

3.1 Spatial Relations between the Vocabulary Elements:

Stiny (Stiny, 1980) noted that in all parametric shape grammar constrain within block shape should satisfy the following requirements: Each partial relation is specified by a pair of blocks, One block overlaps with another block on the edge shared by two blocks and The blocks do not interpenetrate in any way.

The dimensional properties of Suakin corpus floor plan may be described by means of x and y dimensioning vectors as applied to its minimum representation, as shown in Table 1 and by applying different dimensioning vectors to a minimum representation will produce different family of Suakin style floor plans as shown in table 3 and 4 in which the spaces have different dimensions and areas, but the adjacency relations between the spaces remain constrained.

NO.	SPACE	HEIGHT m		EVERAGE	WIDTH m		EVERAGE	AREA m^2		EVERAGE
		MAXIMUM	MINIMUM		MAXIMUM	MINIMUM		MAXIMUM	MINIMUM	
1	DIWAN	8	4	6	7	4	6	42	20	31
2	DHLIS	8	4	6	7	4	6	42	20	31
3	COURT YARD	———	———		———	———		163	14	85
4	STORE	10	4	7	15	4	10	120	12	66
5	MAJLIS	11	3	7	9	4	7	44	12	28
6	KHARJIA	5	4	5	7	5	6	35	20	28
7	DARWA	6	4	5	6	3	5	18	18	18
8	HARIM ENT.	5	4	5	4	3	4	20	12	16
9	KHAZANA	7	4	5	5	4	5	28	20	24
10	GREAT MAJLIS	4	4	4	8	8	8	32	32	32
11	STAIRS	2	4	3	7	3	5	28	8	18

Table 1. Shows a typical Optimal Suakin Design rules for a Residential Design written in a table format.

Topological relations like adjacency indicate the location of a vocabulary element representing the function for a space with respect to another vocabulary element representing a different space in the plan layout (Table 2). These are some general decisions about building elements, dimensions, proportions and plan schemes. Based on all traditional Suakin houses, the geometrical and topological constraints are the followings:

• The entrance must be from the short front side;
• Axes of entrance and big majlis must be on the same direction;
• If there are side majlis, they must be in the middle;
• If there are side majlis, they must be smaller than great majlis;
• There must be courtyard in front of women's majliss;
• Dimensions of the axes of service zone and rooms must be chosen from knowledge base.

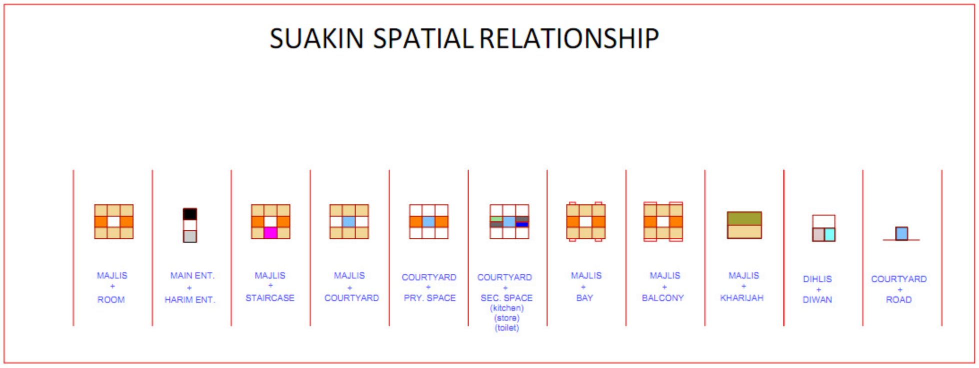
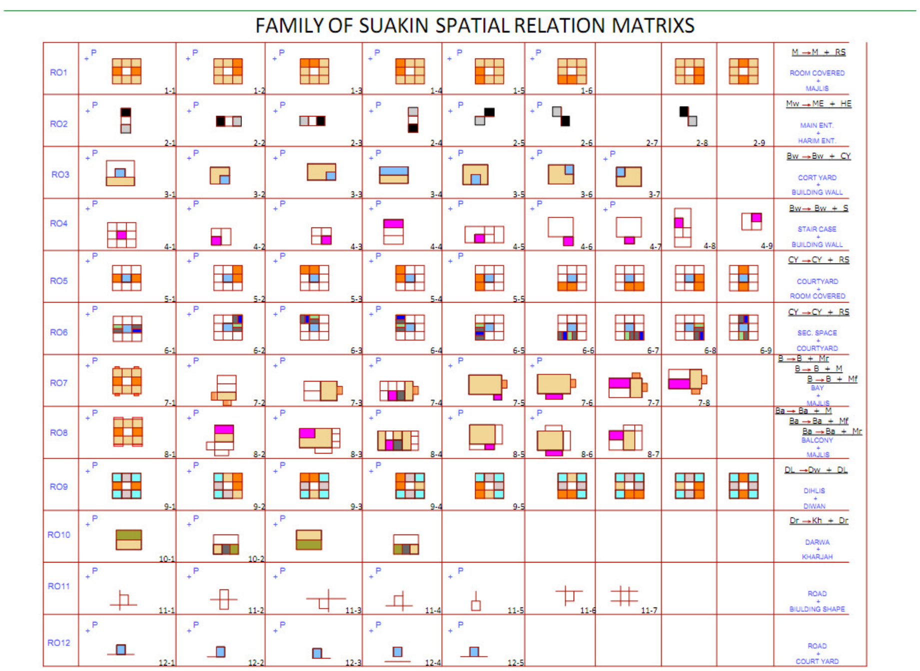


Table-2. The shapes relationship for Suakin's Grammar

Table-3. The family of shapes matrix for Suakin's Grammar, showing all possible alternatives that may be applied in the grammar utilizing parametric design rules



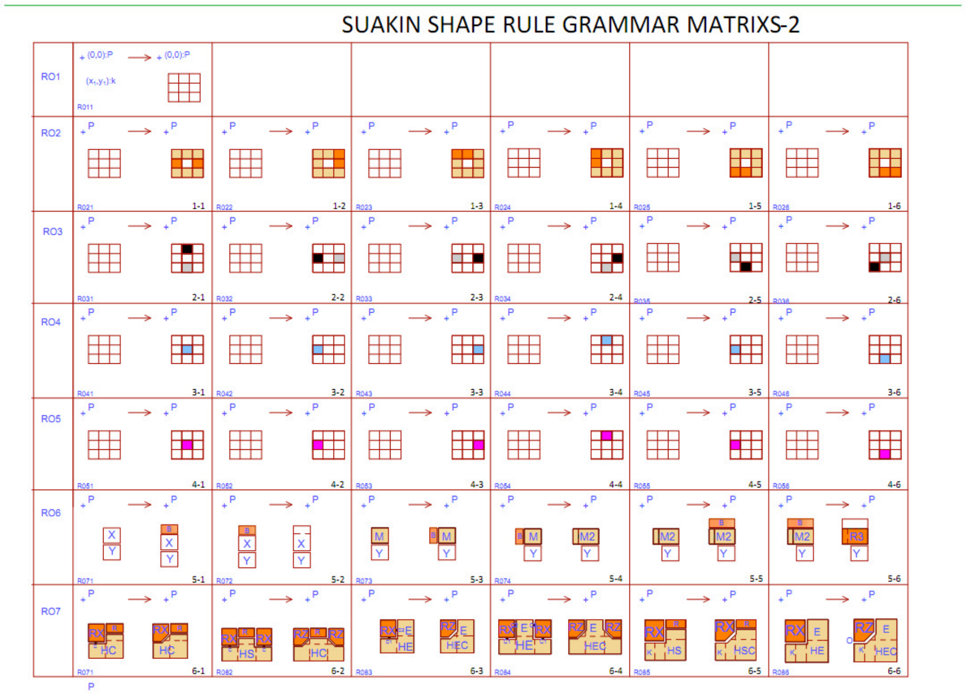


Table-4. The shapes matrix for Suakin's Grammar, showing all possible alternatives that may be applied in the grammar utilizing parametric design rules

3.2 The Design Generation Process

Modelling the design process [34], [3] and Knight [35] divided design process into three main levels: Idea generation phase, Level one, the Conceptual phase, the development or "adjustment" phase and the detailed phase.

The current work addresses the first two levels of this design process; the configuration of the plan and its adjustment, as it clearly demonstrates the full capabilities of the suggested design creative and generative approach in the early phases of design.

In order to convey the paramount advantage in conferring strong creative design process with the proposed approach, a new design using the proposed design generative model for Suakin's design is presented in Figure 14.

3.2.1 The steps of generation

The design of generative model for the language of traditional Suakin style session starts by defining an initial shape:

- A point anywhere on the screen.
- Defining Housing grammar
- Defining general schematic grid dimensions of layout
- Defining the primary space
- Locating Harem and main entrances

- Defining the secondary space
- Dividing the primary space
- Extending functional space
- Locating the circulation
- Defining the openings
- Defining the doors
- Adding the details
-

R1. DEFINING A POINT AND HOUSING GRAMMAR

The point position and orientation are to be decided according to the site coordinates of Qibla position and defining the Suakin housing grammar is beyond the scope this paper.

R2. DEFINING GENERAL SCHEMATIC GRID DIMENSIONS OF LAYOUT

a: parallel to the x axis and 21<= x<=27
b: parallel to the x axis and 26<= x<=43
a<=b
proportion of a\b : 1<a\b1.6
a<b

DEFINATION: Main shape is generated by starting from point A. Generally main shape is in rectangular form

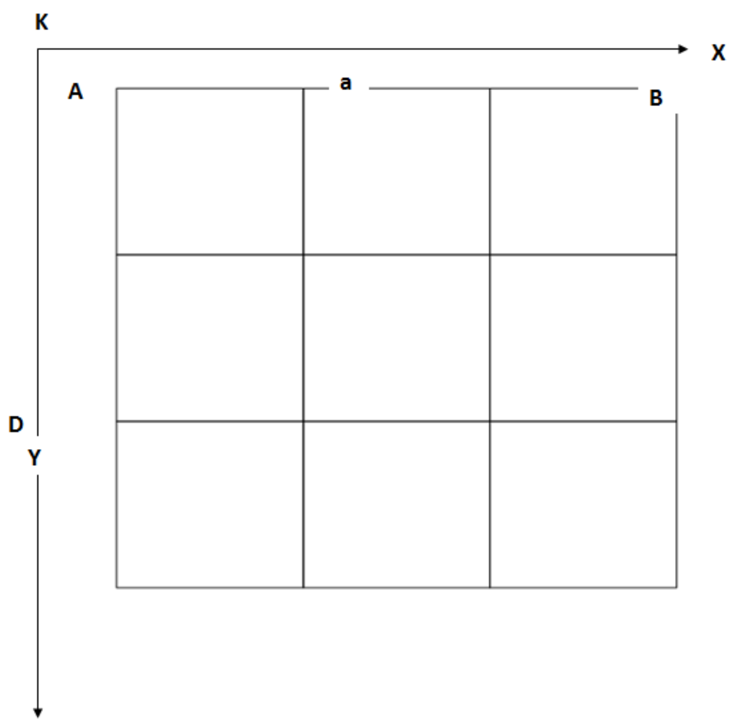


Figure-7 Defining general schematic grid dimensions of layout

R3. DEFINING THE PRIMARY SPACE

R3.1 WIDTH OF PRIMARY SPACE

Primary space (ps) must be just in the middle of short side width of the site (W1): $3<W1<7$
Primary space (ps) and site side (W1) may be in the same dimensions
Primary space (ps)'s width cannot be more than site side (W1)'s width

R3.2 LENGTH OF PRIMARY SPACE

Length of primary space (L1): $3< L1 < 7$

Length of primary space can be defined parallel to the |CD| direction, with measurements written above in table 1

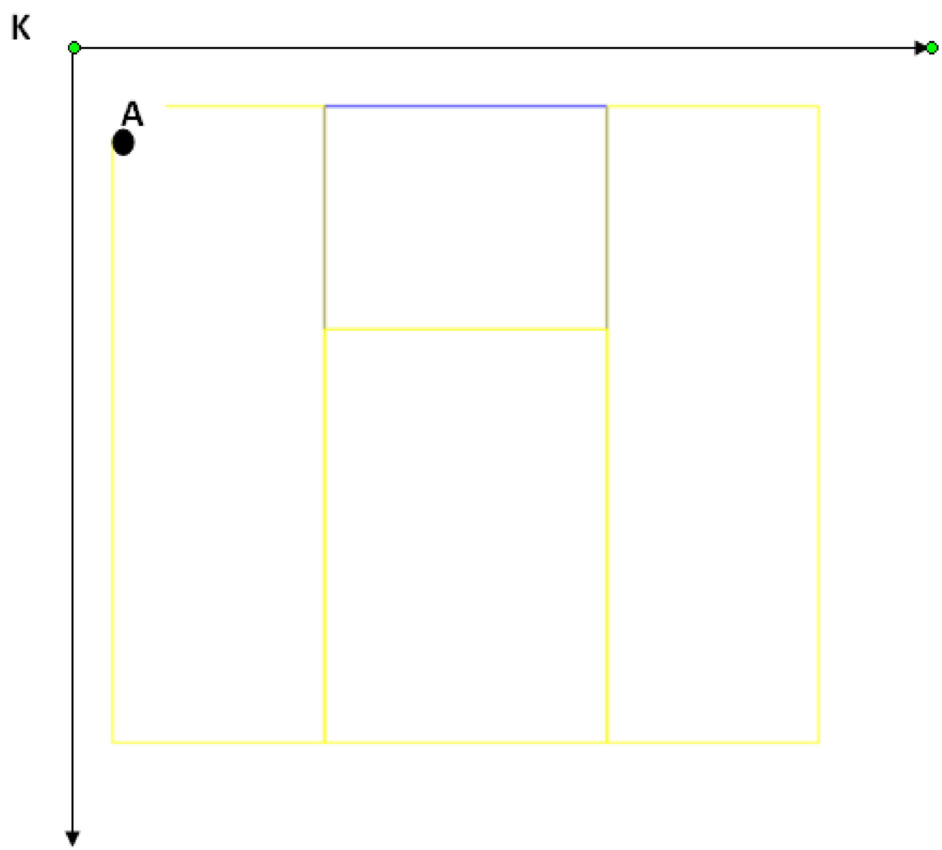


Figure-8 Defining the primary space

R4. LOCATING HAREM AND MAIN ENTRANCES

R4.1 WIDTH OF HAREM ENTRANCE

Width of the harem entrance (WHe) : 4< WHe < 5

R4.2 LENGTH OF HAREM ENTRANCE

Length of the harem entrance (LHe) : 3< LHe < 4

Length of the harem entrance can be defined parallel to the |AB| direction, with measurements written above in table 1

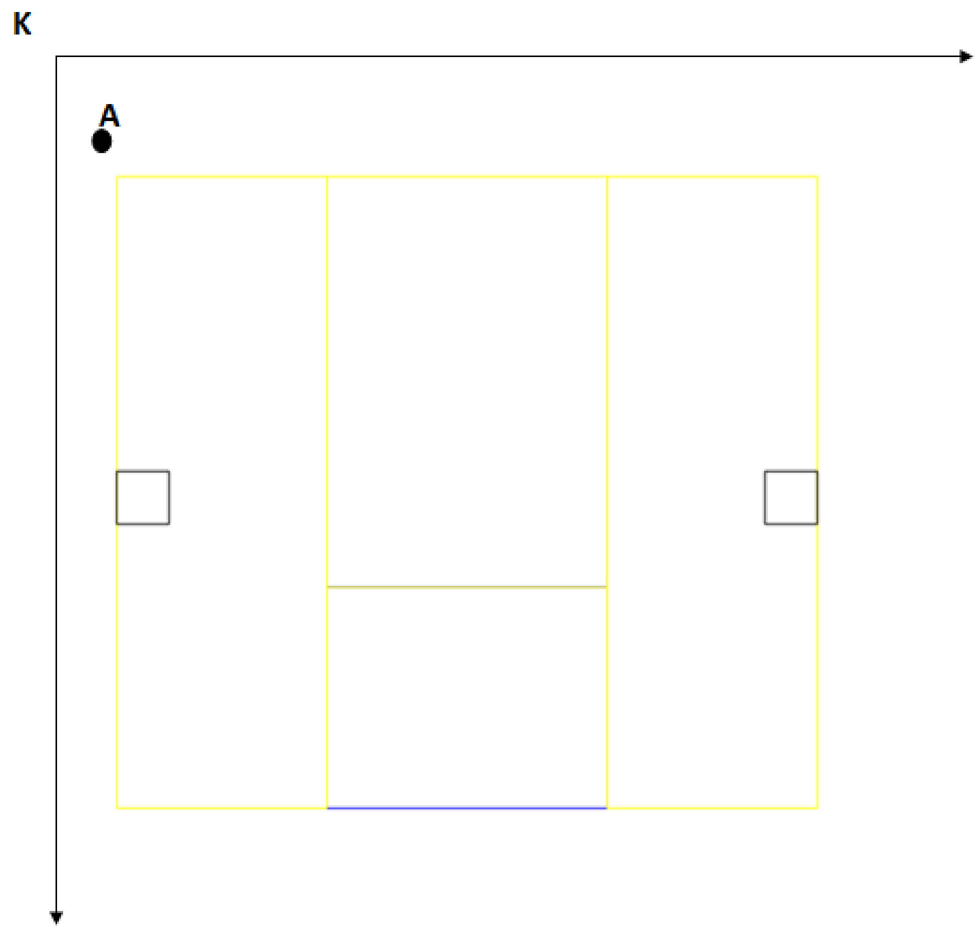


Figure-9 Locating harem and main entrances

R5. DEFINING THE SECONDARY SPACE

R5.1 IF THERE IS COURTYARD: ROOMS AND COURTYARD

(After defining dimensions of harem entrance and main entrance there are points: 1 2 3 4 5)

R5.1.1 WIDTH OF ROOM

Width of room (wor) : 5< wor < 10

R5.1.1 LENDTH OF ROOM (lor)

Lendth of room (lor) : 5< lor < 10

R5.2 IF THERE IS NOT COURTYARD: ROOMS AND COURTYARD

(After defining dimensions of harem entrance and main entrance there are points: 1 2 3 4 5)

R5.1.1 WIDTH OF ROOM (wor)

Width of room (wor) : 5< wor < 10

R5.1.1 LENDTH OF ROOM (lor)

Lendth of room (lor) : 5< lor < 10

At the end of this process, (topological and dimensional patterns) different kinds of layouts and variations of them are generated.

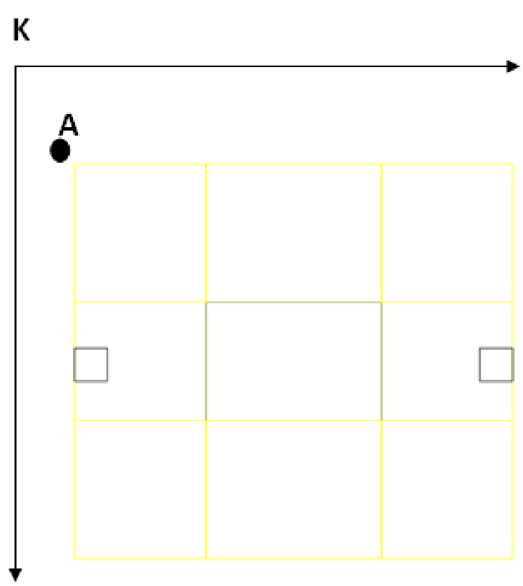


Figure-10 Defining the secondary space

R6. DIVIDING THE PRIMARY SPACE

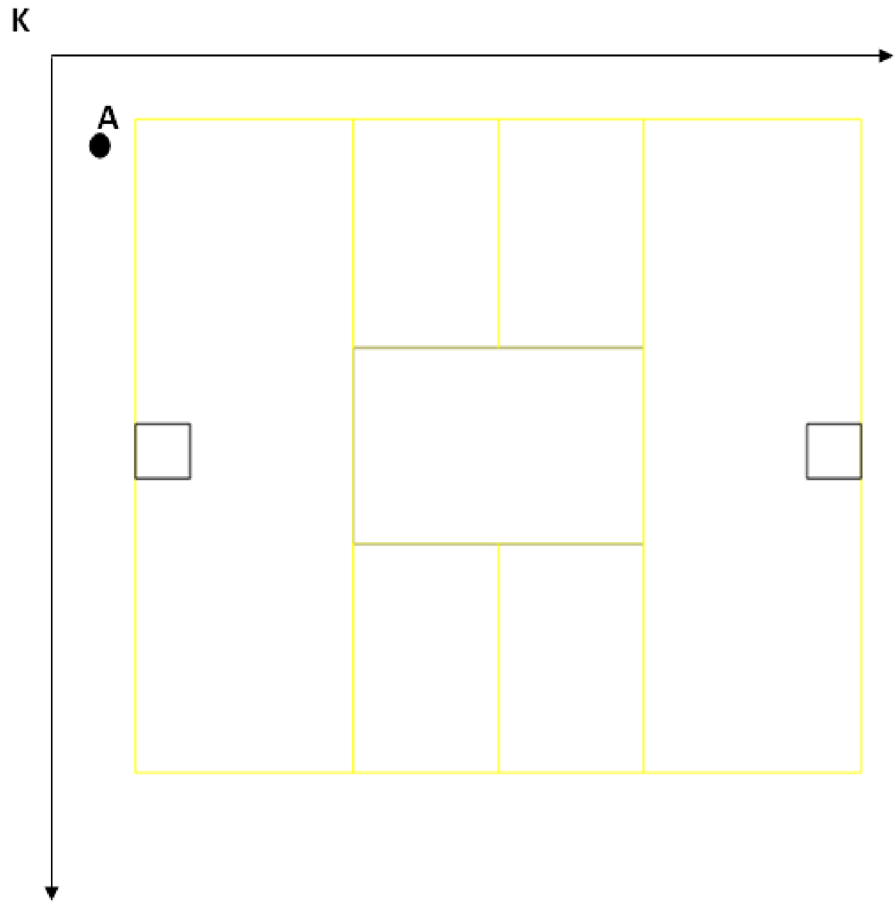


Figure-11 Dividing the primary space

R6.1 WIDTH OF PRIMARY SPACE

Primary space (ps) must be just in the middle of short side width of the site (W1): 3<WP1<7

Primary space (ps) and site side (W1) may be in the same dimensions
Primary space (ps)'s width cannot be more than site side (W1)'s width

R6.2 LENGTH OF PRIMARY SPACE

Length of primary space (LP1): 3< L1 < 7
Length of primary space can be defined parallel to the |CD| direction, with measurements written above in table 1

R7. EXTENDING THE FUNCTIONAL SPACE

R7.1 WIDTH OF FUNCTIONAL SPACE

Width of Functional space (wfs) must be just in the middle of short side width of the site (W1): 3<WF1<7

Functional space (wfs) and site side (W1) may be in the same dimensions
Functional space (wfs)'s width cannot be more than site side (W1)'s width

R7.2 LENGTH OF FUNCTIONAL SPACE

Length of Functional space (LF1): 3< L1 < 7
Length of Functional space can be defined parallel to the x-axis direction, with measurements written above in table 1

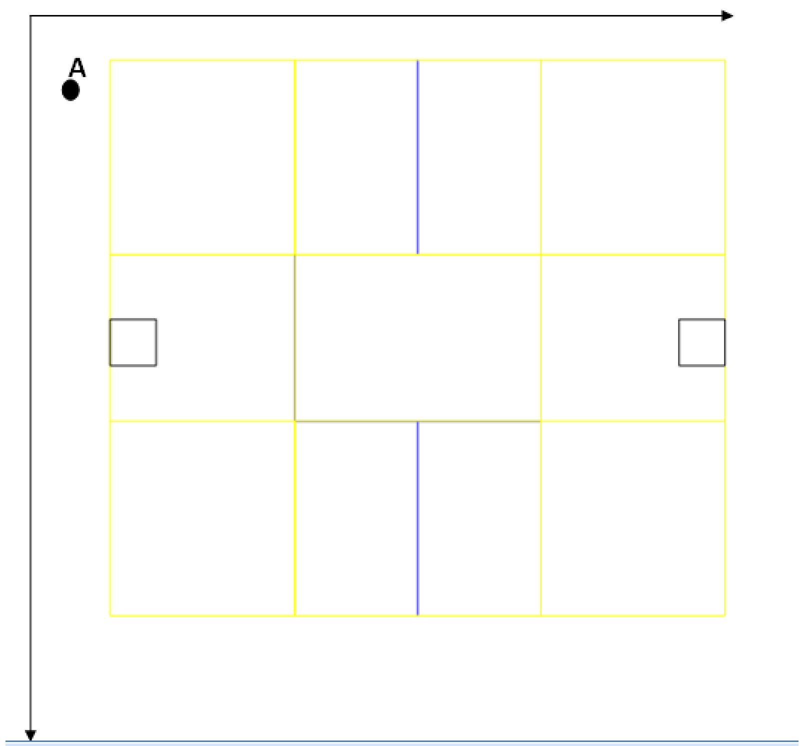


Figure-12 Extending the functional space

R8. DEFINING THE OPENING

R8.1 WIDTH OF OPENING

Opening (os) must be just in the middle of short side width of the site (WO1): 2<WO1<3
Opening (os) and site side (W1) may be in the same dimensions
Opening (os)'s width cannot be more than site side (W1)'s width

R8.2 LENGTH OF OPENING

Length of Opening space (LO): 2< LO < 3
Length of Opening space can be defined parallel to the x-axis direction, with measurements written above in table 1.

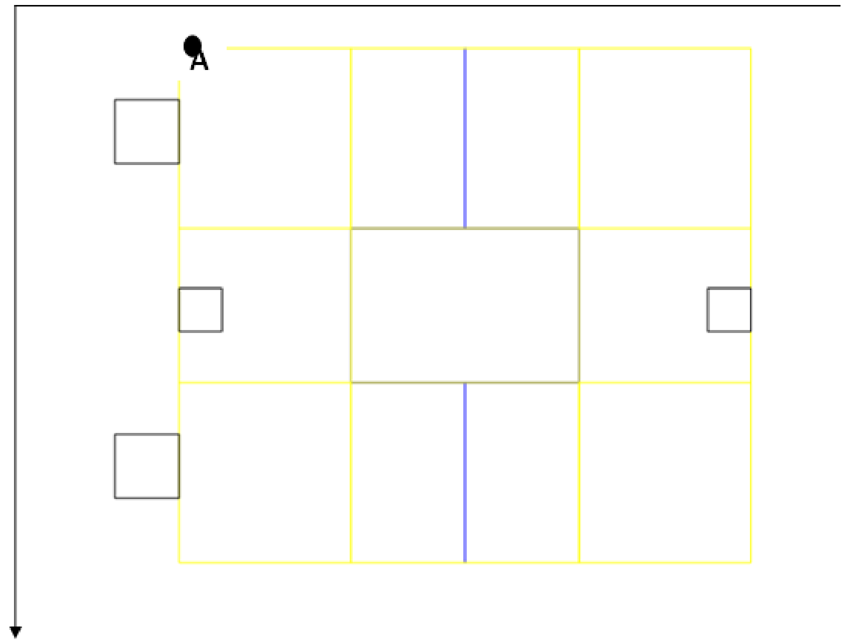


Figure-13- defining the opening

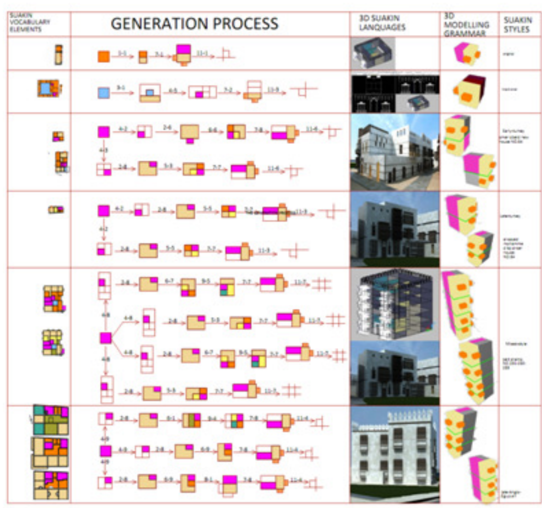


Figure -14 illustrates Suakin Grammar Generative process.

4.0 THE GENERATIVE VALUE OF THE PARAMETRIC SHAPE GRAMMARS

Many 3D of the suakin language produce extra 3D modeling grammar during generative process of Suakin style. From the result of the generative design process, the original style, traditional style, early Turkish style and most of the vernacular styles were identified as Selim stated that many Suakin styles are instantly recognizable in the view of its largely predictable standardized, modular and symmetrical nature [30]. This generative method is similar to the generative pattern In the grammar of traditional Turkish houses, the initial shape of the grammar is a labelled coordinate point Cagdas [31] while Downing and Flemming have used rectangle by divide into two horizontal, two or three vertical zone to start generating the grammar of bungalow(Downing and Flemming, 1981). Some rectangle plans and 3Dlanguages produce new styles in the idea generation phase, whereas some others (new styles) in mid style detailing development phase. Though the styles of Suakin city have similarities, the generative design levels for these styles differ widely, depending upon the rules application.

The Suakin grammar is an example of an analytic grammar, and formalizes certain aspects of Suakina designs. Like the majority of analytic grammars it applies a top-down approach to study and analysis Suakin city and a bottom-up methodology to derivate of artifacts and to generate design. The shape grammar presented in this paper is flexible enough to be able to define both analytic and synthetic grammars according to the users needs but still follows Suakin’s style and Suakin’s rule of architecture.

5. CONCLUSION

The main objective of this work is to analyze the precedent for generating architectural knowledge about Suakin traditional style. The most important part is to understand design generative process and architectural content of Suakin traditional styles’ and adapt this knowledge today’s design. For this significant part, parametrical shape grammar rules and generation methods are used.

The creative and generative value of the shape grammars is clear. The Suakin style generation process of designs can be made explicit by specifying and applying the Suakin shape rules. The Suakin shape grammar developed in this study helps to facilitate the designer and students’ understanding of the formal compositions of Suakin traditional style clearly.

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