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Re-read of Court's Form and Related Spaces with Shape Grammar Case Study: 100 Houses of Qajar Dynasty in Kashan City

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Abstract

There are several reasons why the maintenance of spatial relationships is important in residential homes. Research in this area is being performed on more than 100 homes from the Qajar era in Kashan City to determine the presence of open, half open, and closed spaces, and based on these relationships shape grammar is being used to create a variety of designs. Shape grammar is a manufacturing system within which a set of rules leads from the desired form to the design.

In this study, three spatial types are considered: a courtyard space (open space), an eyvan (partial closed space), and a closed space. Based on these three spatial elements, design plans consist of three types: single court, double court, and complex. Spatial relationships within the homes are defined using the manufacturer's specified rules and this algorithm. As it turns out, with the use of these specified rules and allowable spatial types an infinite number of design solutions can be provided. The use of shape grammar to interpret tradition home design in Kashan City lead to the creation of many new designs that are displayed through the use of a decision tree. The goal of this research is to allow for novel home designs while maintaining the essence of traditional Qajar home architectural style.

Keywords

Court, Shape Grammar, Houses of Kashan, Parametric shape grammar.

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Introduction

In most parts of Iran, spatial accommodations have traditionally included both enclosed and open spaces. One of the most important points that must be accounted for in home design and construction is how to combine these spaces. In this study, according to research conducted on homes in Kashan City from the Qajar period, the use of shape grammar, involves the deployment of language forms and etiquette to provide design flexibility based as a set of rules which allows for form to be fitted to design, an understanding was achieved for the relationship between yards and home spaces for a number of these homes in Kashan City. Shape grammar consists of set of rules that begin with a basic form, and utilizes an algorithm that iteratively fits and selects engineering processes to achieve that desired form. This study begins with the premise that understanding past patterns of home design allows these patterns to be contextually fitted into new construction designs better suited to living in estuary homes.

This research uses qualitative review methods to design new spaces based on the premise that the first quality issue in defining residential space is the presence of, and the relationship between, the yard and residential spaces, and shape grammar is used to pay attention to this aspect of production. The outcome of this research is that, with the use of shape grammar, an infinite number of design solutions can be achieved. This research has both theoretical and practically applicable aspects. This theory provides for the use of shape grammar to re-think the proper fitting of forms to historical home design in other parts of the country, and may provide other practically applicable returns in future Iranian design measures.

Background research

Researchers have studied the history of home spaces for a long time and from different angles. The dominant theory revolves around the three main themes of local climate, relevant cultural aspects, and the role of tradition and construction methods. One of

a variety of approaches to the study of architectural spaces is shape grammar, in which used to provide proper fit. This research method has two aspects , analytical and productive, so that the optimal family environment is produced within a contemporary home. In the early 1990s shape grammar was used to teach architectural composition to students at Harvard University, MIT, UCLA, and the University of Lille. With the use of shape grammar, students were in fact able to apply design language in building design (Knight, 1981: 172). During the decades of the 1980s and 1990s, shape grammar was used to analyze the work of Frank Lloyd Wright and Ren, as well as the design of small Japanese style restaurants, traditional Taiwanese homes, and Mongolian desert gardens. Golan¹ evaluated shape grammar in homes built during five century in Alanya² and Romelia³ area with regard to the elements of rooms, halls, and stairs usage, and was able to categorize these homes into plans in which no halls, inner halls, and central halls respectively were used to define the home's shape grammar. Tepavcevic In his article entitled "Shape Grammar in Contemporary Architecture" he states: "One specific feature of shape language is that for a specified series of rules and forms, there may be an unspecified number of number of design solutions produced".

Research method and case-study

This study is based on qualitative methods and data analysis methods is shape grammar. The study of the documents in library is also base of this research. Qualitative research interpret the terms of the condition and emphasis on the role of the researcher as a vital element in the result of research (Grout and Wang, 2011: 88). Case-study is the 100 houses of traditional architecture in warm and dry climate in Kashan in the Qajar period . these home categorize to three groups of single court, double courts and complex. production process start with the of locating yard . The process of working on this shape grammar is that a space is added to the initial space. For example, if the initial space, the single

court home with three-side build ,in the next phase, basement space add it fitted and continue. The main element is the courtyard, fitted with a definition of the quadrilateral. selected sub shapes: square, rectangle and triangle are fitted. All the elements of the result of the combination of two or more rectangles, squares and triangles are fitted and curved lines not used.

Habitation and Traditional Houses in Kashan city

What distinguishes human from other creatures is the ability to understand and analyze the signs and symbols as well as the ability to optimally use the tools. Mankind attributes symbolic and non-material dimensions to his natural needs. Likewise, habitation is not only to have a harbor but also it is a cultural concept. "Habitation doesn't mean to have only a hovel for living or have some square meters for settling down", Heidegger said (Schulz, 2009: 35). Regarding cultural aspect of habitation and also human dependency on habitation, Heidegger does not believe that habitation is just to construct a building and stay on it. Based on his opinion, habitation is a consequence of creating a balance between four elements including "ego, God, the Earth and the Sky"(Gaznavian, 2009: 36). Amos Rapoport believes that the desire to habitation is the one of fundamental characteristics of human, and he also believes ancient habitations did not have only protectoral functionality but also they had cultural aspects (Rapoport, 1997: 101). In the other words, house is not only a construction but also it is an identity in order to achieve a complex collection of goals. On the other hand, house is a social phenomenon and its orders, space types, and seeming forms are affected by cultural, social and economic factors. Main goal of a house is to create a compatible and versatile environment with human life style. In addition to providing personal needs, house should also provide social needs of human (Poordeihimi, 2011: 18).

Habitation concept is expandable for all human habitations and Kashan is not excluded in this regard.

Investigations in historical spatial forms of Kashan's houses which were based on habitation methods reveal that architecture of historical houses has met requirements like dimension variety and dynamic life style in the house; it has also represented Iranian architectural culture and Iranian architect awareness in the life variety, the awareness in the detailed levels of behaviors and needs. Accordingly, spatial forms of historical houses have provided spatial variety for its inhabitants and have encouraged them to do various experiences and activities and have also increased aspects of every seemingly simple activity by providing spatial variety (Haeri, 2009: 87). Toward used materials, every building in Kashan and in its countryside is made of mud and relevant derivatives. Architecture has thought about nothing except than mud and has used only mud between other materials because he knew nothing else can be like mud even if stone and wood were available for him (Kasaei, 1984: 901). Typology studies on Kashan houses architecture show that formation of buildings in both singular and complex cases can be observable based on combination of three patterns including open spaces, semi-open spaces and closed spaces. Shah Neshin, Talar, Gooshvareh, Pastoo, Konj, Balakhane are examples of closed space. Eyvan is an example for semi-open space and Mahtabi, BaharKhab, Posht e Bam and Court are examples for open space. Habitants' life style has been in accordance and harmony with all three above mentioned patterns and each pattern individually and in relation with other patterns has had very important value. Nature presence in all of these three spaces is directly or indirectly sensible. Open space was included as the main space of nature presence in habitation scope and has created most opportunities for habitants to use nature. Utilizing these three patterns simultaneously and together in the most oldest extant houses from Islamic antiquities through a combination of room, porch and yard and continuous applying these three patterns in the period of post-Islamic architecture and that's distinguished presence in the studied houses in

this research define role and importance of applying spatial forms in Iranian architecture and demonstrates that applying of these patterns in studied historical houses was based on the support of Iranian architecture that has several thousand years background. Closed spaces are mostly and indirectly connected to yard through indoor spaces. Yards are acting like a room from spatial sense viewpoint. On each side of the yard, combination of vertical and horizontal layers of space like intertwined network provide various spaces with different dimensions and heights for several types of life-styles-related public and private activities.

Shape grammar

Shape grammar have been used in theory and practice for more than four decades. Shape Grammar based on the language form and rules and deployment system that lead to design .this is a way of making the complex shapes from simple elements . The term is generally used in the two form of Visual and Computational data. In the computational attitude, the organized group of expert system, produced geometric shapes (Tepavcevic & Stojakovic, 2012: 170). Shape grammar also refers to visual design as was mentioned. In this sense, shape grammar back into the world of form, not through the imposition of the complexity of the forklift, but offering through practical means at that point of time, (Ozkar, 2009). The most feature of shape grammar is to set a finite number of rule and shape, allowing the production of infinite number of ways to solve possible design . In addition, shape grammar is used as a tool for generating complex form of simple shapes (Stiny, 1976: 187). shape grammar has four parts:

- Sub-shape
- Shape relations
- Shape rules
- Desired form

In Shape grammar, Forms combine with the shape rules to manufacture a set of designs with desirable characteristics (Stiny, 1980: 343-351). Certainly revision of the space elements and relationships needs the coordinates axes to define the algebraic space accurate.

How to design with shape grammar

One of the ways for the use of shape grammar, is parametric method that is description: At the beginning of the work , three elements of the House has been reviews, that is: court (open space), closed space and semi-closed space (eyvan). Based on the three elements , the plan includes three modes: single court, double courts, complex. The production process starts with the General layout of the courtyard.houses with one court as are specified in Table 1 ,have two-side build in parallel and sticking, three- side build and four- side build. The number and the direction of the eyvan and basement is also specified in the table.the number and direction of green spaces and water pool is specified in court.

Adding space to the initial space is the work process in shape grammar. for example, in the home with one court and three side build , basement space add in the next phase. The basic form of the shape grammar is a point that is located at the coordinate system The court element defines as a quadrilateral. Sub-shape selected are square, rectangle and triangle. All the elements of the result are the combination of two or more rectangles, squares and triangles and curved lines are not used. Each block is shown by a matrix. Each matrix introduces a polygon and consist of nine section. Zero display empty cells, one display filled cell and zero-one-zero display semi-filled cell. The necessary condition for the polygon is being parallel to the x and y axes (Stiny,1980: 420). Neighbourhood relations in polygons are: corner relation. Partial relation and complete relation (Fig.1).two courts houses and complex are shown in table 2 and 3.

The production process starts with the general layout of the courtyard. Houses with one court are specified in Table 1, having two sides built in parallel with sticking, three sides built, and four sides built. The number and orientation of the eyvan and basement are also specified in the table. The number and orientation of green spaces and pools are also specified in the court(s).

Adding additional spaces to the initial space is the

work process in shape grammar. For example, in the homes with one court and three sides built, a basement space is added in the next phase. The basic form is a point located in the coordinate system of the shape grammar. The court element is defined as a quadrilateral. Sub-spaces are selected as squares, rectangles, and triangles. All of the resulting elements are a combination of two or more rectangles, while squares, triangles, and curved lines are not employed. Each block is demonstrated by a matrix. Each matrix introduces a polygon and consists of nine sections. A zero describes empty cells, a one describes a filled cell, and a zero-one-zero describes a partially filled cell. The condition required for a polygon is that it be parallel to the x and y axes (Stiny, 1980: 420). Neighboring relations in polygons include: corner relations, partial relations, and complete relations (Fig. 1).

Dual court houses and complex houses are shown in Table 2 and Table 3 respectively.

In the collection of rules (R1C) that have been specified in Table 4, “R” showing the closed space(room) , “C” showing the closed space, “B” showing basement, E showing eyvan, “L” showing landscape, “W” showing water and “S” showing supplement space. R1C22 is the rule of conversion ‘yard’ to ‘yard, room’. According to R1C24 rule, yard, room ‘convert to ‘court and two rooms’. in the R1C23 rule, the ‘yard’ convert to ‘court ,basement ,room,’. According to the R1C25 rule add ‘eyvan’ to ‘room’ and also according to R1C26 Both rooms have eyvan. According to R1C27 rule, yard gain landscape and water dock. In R1C32 rule a room convert to the basement . eyvan added a room in the R1C33 rule And in the R1C34 rule added eyvan to both room.

Table1. Type of single court's houses. Source: authors

		With Basement	With Basement in two side	Single Eyvan	Double Eyvan	Triple Eyvan	Quadruple Eyvan	2 Greenpatch	2 Greenpatch and Water	4 Greenpatch and Water	Supplement
Single court with parallel two-sided building	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21
Single court with connected two-sided building	A31	A32	A33	A34	A35	A36	A37	A38	A39	A40	A41
Single court with connected three-sided building	A51	A52	A53	A54	A55	A56	A57	A58	A59	A60	A61
Single court with connected four-sided building	A71	A72	A73	A74	A75	A76	A77	A78	A79	A80	A81

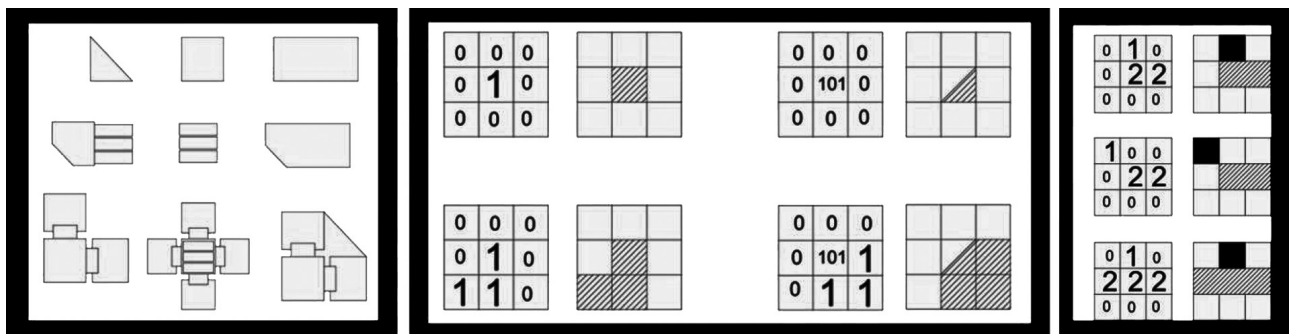


Fig.1. From left to right: main sub- shapes of shape grammar and predicated shapes, blocks show in matrix, show of Neighbourhood relations in the 9 numeric matrix Source: authors.

Table 2. Type of double courtyard's houses. Source: authors.

		One-sided basement	Single Eyvan	Double Eyvan	Triple Eyvan	Greenpatch	Greenpatch& Landscape
Double court with two-sided building							
Double court with three-sided building							
Double court L shape							
Double court with three-sided building & two-sided building							
Double court with linear two-sided building							
Double court with three-sided building and one-sided building							
Double court with connection							
Double court with two-sided building and four-sided building							

Table 3. Type of complex. Source: authors.

	Open space & colsed space	Basement	One Courtyard with Eyvan	Two Courtyards with Eyvan	Three Courtyards with Eyvan	Water & Greenpatch
Tabatabaee's house						
Borojerd's house						
Abassian's house						

the collection of rules (R2C) for double courts, have been specified in Table 5. with R2C22, court convert to 'court,2 rooms' and with the R2C23 this shape convert to '2courts,2 rooms' and one of the rooms adds eyvan with R2C25 rule. with R2C27 , greenpatch and water dock add to courts and with R2C28 rule, supplement space add to shape. In R2c42 rule court convert to 'court,2 rooms' and

with R2C43 rule convert to '2rooms,2 courts'. With R2C44 rule one of rooms gain basement and with R2C45 rule two rooms gain eyvan. With R2C46 rule all of rooms gain eyvan and with R2C47 add greenpatch and water dock to courts. the collection of rules (RNC) for complex, have been specified in Table 6 .all of rules and work process is same as R2C and R1C that is explained.

Table 4. Ruleset in single court plans. Source: authors.

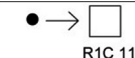
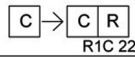
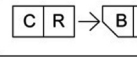
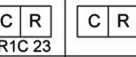
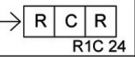

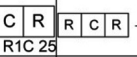

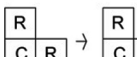
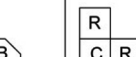

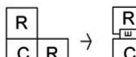

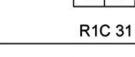
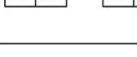
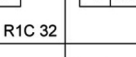
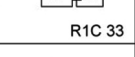
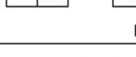
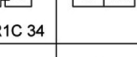






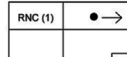
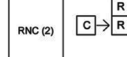
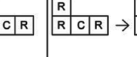

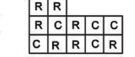
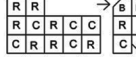
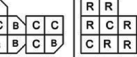

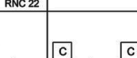
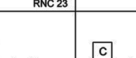
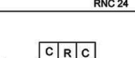

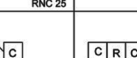
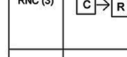
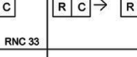
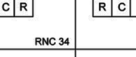

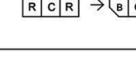
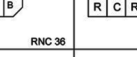
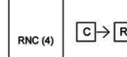
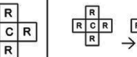


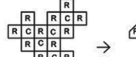



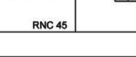
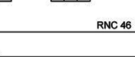
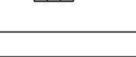
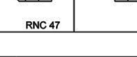




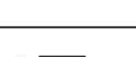

R1C (1)						
R1C (2)						
R1C (3)						
R1C (4)						
R1C (5)						

Table 5. Ruleset in complex plans. Source: authors.

RNC (1)						
RNC (2)						
RNC (3)						
RNC (4)						
RNC (2)						
RNC (3)						
RNC (4)						

Conclusions and Design

Finally with use of three type of space that are traditional pattern in history and culture of Iran and shape grammar, we can produce different pattern that are useful for ours culture, nature and life style. In the following in Diagram 1 decision tree we can extract a design process. This figure is for single court only.

Decision tree of double court and complex are showed in the following. Design process start with the point that is converted to space in R1C11 rule. Court convert to court-room in R1C22 that is showed in Table 7 (Number 22 on the line is law enforcement of R1C22). This space convert to court-2room with R1C23 rule. This space lead to new design with Compound of R1C23 & R1C25. This shape is final product. Design in double court is showed in Table 2. End of each branch, The new design is showed. starting is with point shape that with R2C11 law convert to court. Court converts to another spaces With the R2C22, R2C32, R2C82, R2C92, R2C72 rules. For example court converts to 'court, 3 rooms' in R2C82 rule and converts to '2 courts, 3 room' with R2C83 rule. Finally lead to new design in branch that never no one of double court have it. Design process in complex is showed in Diagram 2 & 3. Design process start with the point that is converted to court in RNC11 rule. Court converts to another space with RNC22, RNC33, RNC44 rules. . For example court converts to 'court, 3 rooms' in RNC23 rule and converts to '2 courts, 3 room' with RNC24 rule and in the following with another rules lead to new design.

Table.6. Ruleset in double court plans. Source: authors.

R2C (6)						
R2C (7)						
R2C (8)						
R2C (9)						

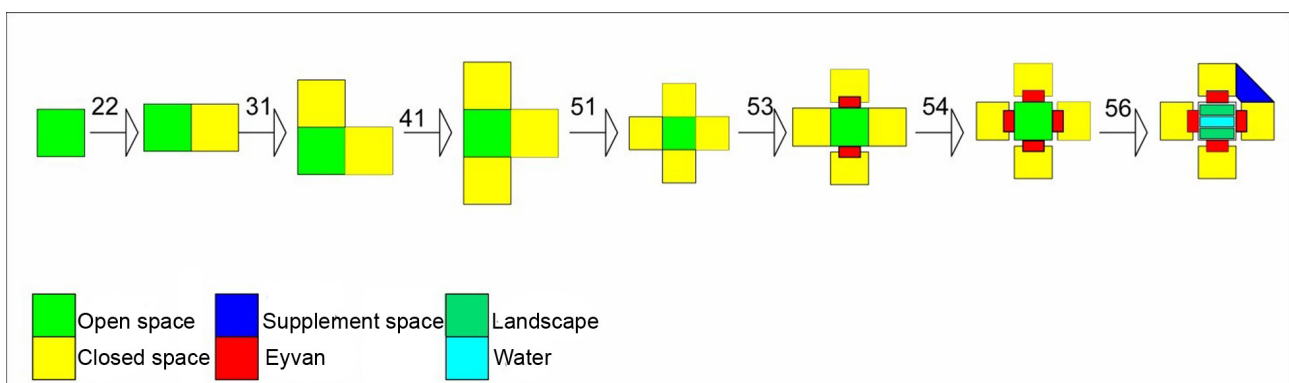


Fig. 2. Displays an example of the conversion process of basic form to new design with shape grammar. Source: authors.

Conclusion

What is concerning today is that there is a lack of understanding in the last decade of the architectural consequences of not allowing past architectural design to light our way in the future. The lack of a deep understanding and knowledge of what has happened causes several problems, and so we should try to lose

these current conditions and apply a new attitude. Such a view is the process that was able to produce at that time the Thakt-e-Jamshid, and with other shape grammars the Sheikh-lotfollah mosque.

In this study, it was also used to view the shape grammar in one hundred traditional homes in the town of Kashan. By means of an algorithm using a defined set of rules for fitting spatial relationships in the decision tree, designs were recreated. In other words, using shape grammar a finite set of shapes and rules can provide an infinite number of design solutions. As you can see in Fig. 2, beginning with a base shape of a court (open house) and following shape grammar rules, in seven steps one can reach a new design containing the essence of the traditional architecture of homes in Qajar. That is the method for achieving a balance of design theory in shape grammar and for following it in practice.

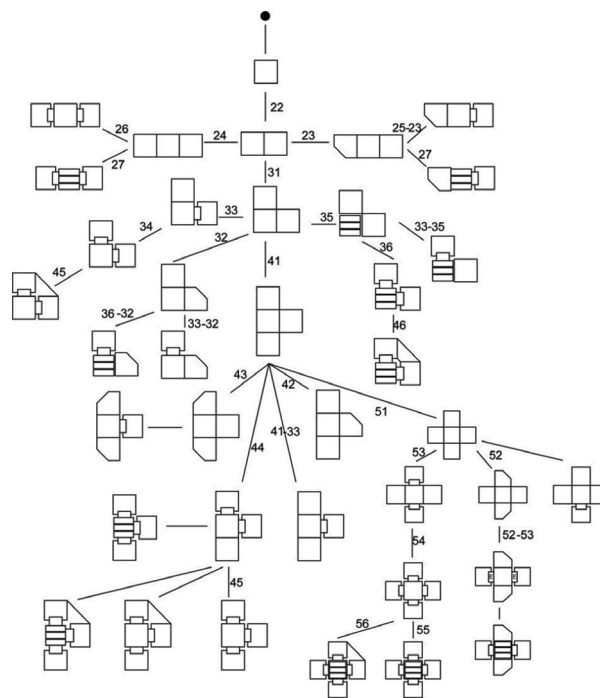


Diagram 1. Decision tree in single court houses. Source: authors.

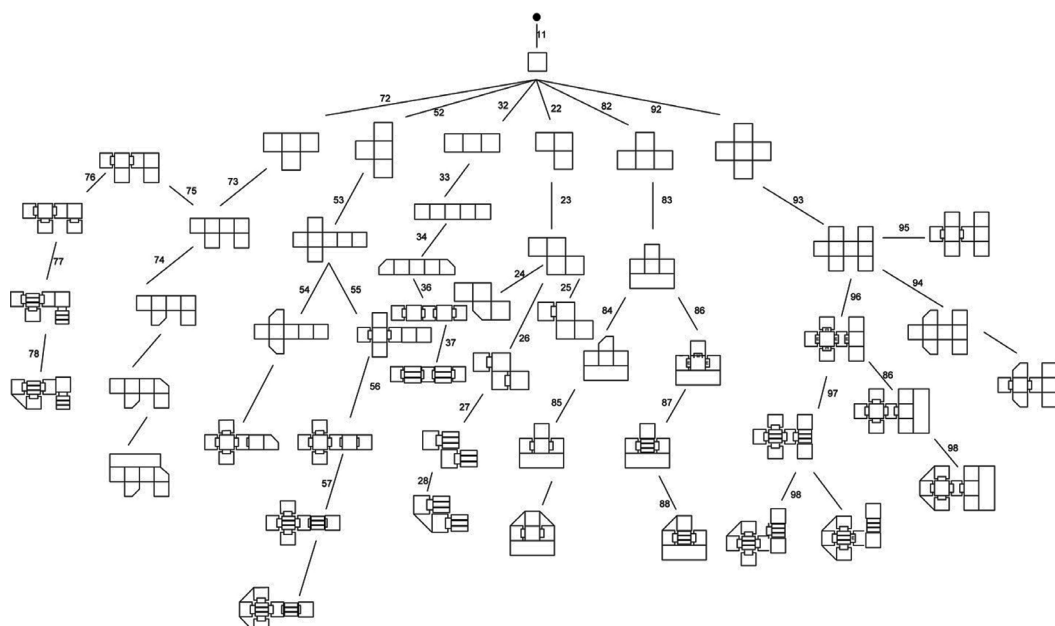


Diagram 2. Decision tree in double court houses. Source: authors.

Endnote

1. Kalen Golen
2. Located in Turkey.
3. Located in Turkey

Reference list

- Farrokhyar, H. (2013). *Sad khane sad plan [100 house, 100 plan]*. First edition. Kashan: Islamic azad university of kashan press.
- Gaznavian, Z. (2013). *Ensan shenasi fazaye khanegi az matloobiat ta vagheaat* [Interior space of urban anthropology: the utility to reality]. M. A thesis. Tehran: University of Tehran.
- Groat, L. & Wang, D. (2000). *Architectural Research Methods*. Translated to Persian by: Einifar, A. R. Tehran: University of Tehran.
- Gulen, C. (1996). *A Shape grammar: The Language Of Traditional Turkish Houses, Environment and Planning B: Planning and Design*.
- Haeri mazandarani, M. R. (2009). *Khane, farhang, tabiat* [House, Culture, Nature]. Tehran: Vezarat- e maskan va shahrsazi.
- Hariri, N. (2011). *Osoul va raveshhaye pajooheeshe keifi [Principles and methods of qualitative research]*. First edition. Tehran: Science and research branch of Islamic Azad University Press.
- Knight, T. (1999). *Application in Architectural Design and Education and Practice*. Report for the NSF/MIT Workshop on Shape Computation, Department of Architecture, School of Architecture and Planning. Cambridge, M. A: Massachusetts Institute of Technology.
- Knight, T. W. (1981). *The forty-one-steps. Environment and Planning B*, (8): 63-78.
- Kotsopoulos, S. (2007). *Concept formation in architecture: The Simmon's Hall Paradigm*. Boston Architectural College, MA 02115, USA.
- Ozkar, M. (2009). *Formal properties of grammars*. In Handbook of Mathematical Psychology, Vol. 2. NewYork: EDSDLUCE.
- Poordeihimi, SH. (2011). *Maskan va mohite roostae [housing and Rural environment]*. Farhang o maskan journal, (134): 32-40.
- Rapoport, A. (1997). *The meaning of the build environment: A Nonverbal Communication Approach*. Translated to Persian by Habib, F. Tehran: Pardazesh va barname rizi shahri press.
- Rapoport, A. (1977). *Human Aspects of Urban Form*. NewYork: Pergamon Press.
- Kasaei, R. (1984). *The Architecture of Iran Adobe Building*. Tehran: Mojarrad press.
- Sadek Hosny, S. (2012). *Shape Grammars: style Generators in Computer-Aided Architectural Design, Future University of Egypt, Department of Architectural Engineering*.
- Schulz, N. (2001). *Roohe makan: b sooye yek memari padidar shenasane [Towards a Phenomenology of Architecture]*. Translated to Persian by shirazi, M. Tehran: Rokh dad no.
- Stiny, G. (1976). Two exercise in formal composition. *Environment and Planning B*, (3): 35-56.
- Stiny, G. (1991). *The algebras of design. Research in Engineering Design 2*.
- Stiny, G. (2006). *Talking about seeing and doing*. Cambridge: Mass, MIT Press.
- Stiny, G. (1980). Introduction to shape and shape grammars. *Environment and Planning B*, (7): 67-75.
- Tepavcevic, B. & Stojakovic, V. (2012). *Shape grammar in contemporary architectural theory and design*. University of Novi Sad, Faculty of technical sciences, Department of Architecture and Urbanism. *Series: Architecture and Civil Engineering*, (10): 110-140.