An Informal Shape Grammars for Interpolations of Traditional Bosnian *Hayat* Houses in a Contemporary Context

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Abstract

This paper explores the use of an informal shape grammar method for *Hayat* house form interpolations. Interpolations are new house forms, which carry stylistic characteristics of an existing design language but are inserted into a context, which responds to a contemporary life style. The study is based on a corpus of eight *Hayat* houses designed in the classic Ottoman style in the 18th and 19th century in Sarajevo. The *hayat* is a large shaded gallery open to the garden. It occupies the most important place in the composition of the plan. In this study, a form-driven design strategy is applied. The emphasis is given to new house form generation. The generation of a new house form within the grammar proceeds in four steps: (1) Primitive *hayat* house generation, (2) sub-house generation, (3) House variations, (4) House development. The shape rules used in the process of *hayat* house interpolations are mostly informal and explain in general terms how certain parts of the form are modified.

Shape Grammars: Analytical, Original

Shape grammars can be divided into two categories: analytical and original. Analytical grammars are developed to describe and analyse historical styles. Original grammars are concerned with the creation of new and original designs. The use of grammars for creative design has not been explored as deeply as the use of grammars for analytical studies. In this paper the use of grammars for creative design is explored. Formal Shape grammars deals with an algorithmic process of design. It is a method by which the application of principles to design can be explored. A shape grammar consists of rules of the form $A \rightarrow B$, where A and B are shapes made up of solids, planes, lines, or points.[1] A rule specifies that whenever a shape A is found in the design, it can be replaced with shape B. Shape grammars explain how forms are constructed.

Creativity in rule-based design lies in the creation of the rules. Rules can be modified and expanded at every stage of a design process allowing the designer to make explicit his/her design knowledge in a structured framework. The designer controls form-generation by explicitly defining the criteria for new designs that fit a given context.
This study utilises computational processes in type-based design to generate *hayat* house interpolations. It is based on a larger study titled "Design By Grammar: Algorithmic Design in an Architectural Context.[2] " An informal shape grammar is used to generate primitive hayat houses that capture specific qualities of the *haya*t house type in Sarajevo. The grammar is not

merely analytical, aimed at describing a family of designs. And it is not original-grammar developed from scratch to generate entirely new designs. It spans between analytical and original grammars. The process can be summarised as follows. First a set of existing designs were used to infer the rules for primitive TYP. A *hayat* house generation. Three primitive *hayat* house types TYP. A1, A2, and A3 are generated. One of these, a house with a central *hayat* on both floors, TYP. A1 is selected for further elaboration. Than by applying the generative principles of shape grammar method sub-types of TYP. A1 are generated. And than variations of sub-TYP. A1 are created and developed with shape rules of addition and subtraction by introducing different constraints.

The rules are grouped based on their vocabulary and some based on the modification that they execute on the form. They are labelled in numeric order from 0 to 13. Some of the rules used in this study are self-explanatory and some are not. When necessary, detailed explanations of rules are given.

Hayat Houses

Eight *hayat* house designs from the 18th and 19th century found in Sarajevo, Bosnia and Herzegovina are the basis for this study. Two different sources of information (drawings and field trips) are used for the identification of the eight house designs.

Figure 1: Detached *Haya*t House

Figure 2: Semi-detached *Hayat* House

In its simplest geometric abstraction, the *hayat* house consists of two main elements, the rooms and the *hayat*. The *hayat* is a large shaded gallery open to the garden. It occupies the most important place in the composition of the plan. It is the backbone of the overall spatial configuration of the house. Its shape and size varies according to the geometry of the site and the size of the house. The house grew around this core, rooms and a hall, and the plan of the house continuously changed. The enlargement and development of the core pattern of the *hayat* house is based on the additive principle of design.3 The additional rooms around the *hayat* were build as the family expanded. Thus, it is difficult to determine an exact style of this domestic architecture. However the geometric simplicity of the basic schema of the *hayat* house allowed it to be modified according to each specific plot of land and also gave it great flexibility for future variations.

The *hayat* house is based on the dichotomy of semi-open and covered spaces. The main characteristics of the *hayat* house depend on its vertical and horizontal functional divisions. The horizontal plan of the house is divided into public and private spaces.

The vertical plan of the house is divided into two floors: the ground floor and the first floor. The ground floor whose geometry is often modified according to the demands of the site is semi- public and consists of a *hayat*, one or two rooms, a kitchen, and storage spaces. The first floor is used as private space and consists of a *hayat*, porch, and rooms.

Hayat houses named as TYP.A can be classified into three families of houses, depending the configuration and the elements of the ground floor. TYP.A1- a house with *hayat* at both levels, TYP.A2- a house with no *hayat* at ground floor level, and TYP.A3- a house without ground floor.

There are two types of urban *hayat* houses, detached and semi-detached. Although both have the same spatial configuration, the semi-detached *hayat* house integrates two (private and public) houses and two courtyards while the detached *hayat* house has only one courtyard. Figures 3, 4 and 5 illustrate the layout compositions of semidetached and detached *hayat* houses found in Sarajevo.

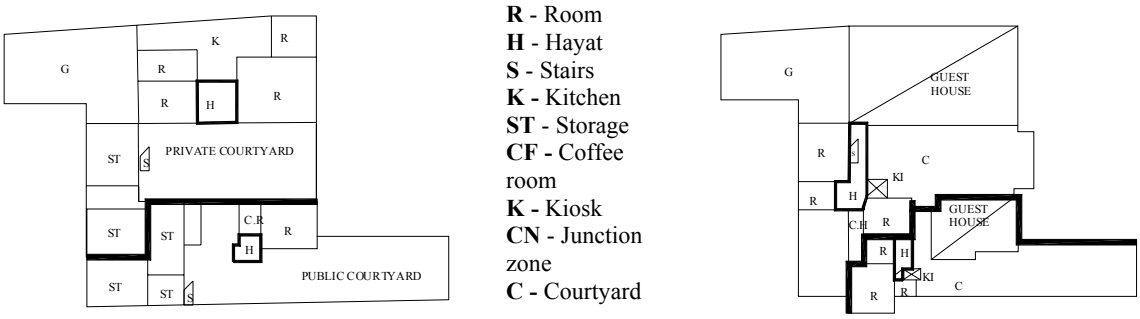

Figure 3: Svirzina, semi-detached house plan layout

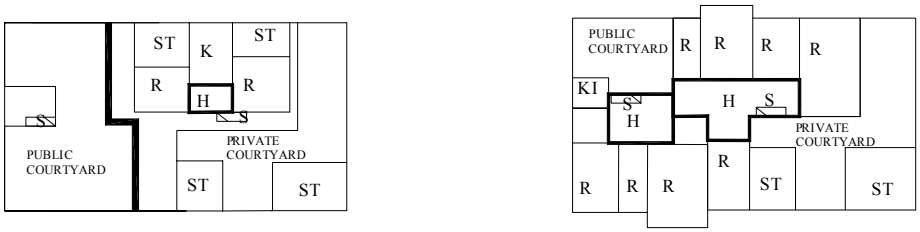

Figure 4: Dzenetica, semi-detached house plan layout

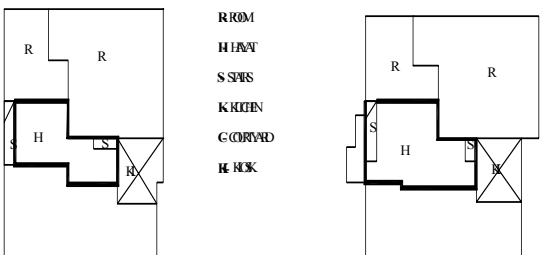

Figure 5: Saburina detached house plan layout

Design by Grammar

Novel interpretations of a *hayat* house are generated using a type-based design approach. Design types are constructed through the notion of generalisation. Here, design is considered as a process that begins with a primitive type and progresses to a specific design. Starting from a specific type to create a design emphasises certain relationships, over others that are treated secondary or are ignored as the design process progresses.

Four steps are used to generate interpolations of a *hayat* house:

1. Primitive *Hayat* house generations: generates three TYP. A1, A2, and A3 *hayat* houses.
2. Sub-house generation: generates sub-house types of TYP. A1.
3. House variations: generates variations of TYP. A1.1
4. House development: articulates TYP. A1.1 variations from 3.

1. Primitive *Hayat* House Generations

This first step illustrates the construction of primitive *hayat* houses. Here, the generic vocabulary, relationships between vocabulary elements and shape rule schemas that generate primitive *hayat* houses are extracted from the analysis of the *hayat* house precedents in the corpus. To define a shape grammar for primitive houses four phases are introduced:

Phase 1: definition of a vocabulary,
Phase 2: identification of the spatial relations between vocabulary elements,
Phase 3: creation of a family of spatial relations, and
Phase 4: definition of rules.

Phase 1
Phase 1 defines the vocabulary of the grammar as shown in figure 6. The vocabulary consists of five elements: the overall room space, shown as a U shape and labelled RS, can be used in both the ground and the first floor; the *hayat*, shown as a square and labelled GH for ground floor and FH for the first floor; the ground floor room space, shown as a rectangle and labelled GR; the wall, indicated by a line and labelled W, can be a part of a *hayat* or a ground floor room space; the stairs, shown as a rectangle with a diagonal line in it and labelled S.

To construct primitive houses, the ways that vocabulary elements can be combined with one another must be specified. The compositions of the vocabulary elements are given with spatial relations in phase 2.

Phase 2
Phase 2 defines spatial relations between vocabulary elements. Spatial relations are compositional ideas for making primitive *hayat* houses. Three of these spatial relations are illustrated in figure 7. They are defined in the following ways:

(1) Room / *hayat* compositions: a room (shown as a U shape) surrounds the *hayat*

(a square).
(2) Ground floor and stairs: defines placement of stairs on the ground floor. The stairs are in relation to the wall, labelled, W that can be a part of the *hayat* or ground floor room space.
(3) First floor *hayat* and stairs: describes the connection between the stairs and the first floor *hayat*.

In a spatial relation, the vocabulary elements can be arranged in many different ways. For the sake of simplicity, spatial relations with the same vocabulary elements, whether they are the same or different, are categorised in-groups and designated as family.

Phase 3
Phase 3 organises spatial relations with the same vocabulary elements but different configurations into family groups as shown in figure 8. Three family groups are illustrated. The first one illustrates two configurations: on the ground and the first floors, between the *hayat* and room space. The second family group illustrates the three different configurations between stairs and wall. Depending on the chosen house, the wall can be part of *hayat* or ground floor room space. For example, to generate TYP. A1 house rule 0.1 should be selected. This rule starts house generation with ground floor *hayat,* which has labelled wall on it. To generate TYP.A2 house rule 0.2 should be selected. This rule starts house generation with ground floor room space, which has labelled wall on it. In both, labelled walls indicate where the rules between stairs and wall can be applied.

The third family group illustrates five different configurations between the stairs and the first floor *hayat.* These spatial relations are the basis for the rules given in phase 4.

Phase 4
Phase 4 defines the initial shape and starting rules as shown in figure 9, and shape rules: group 1, 2, and 3 in terms of spatial relations as shown in figure 10. There are three different types of starting rules that define three different types of *hayat* houses extracted from the analysis: Rule 0.1 defines TYP.A1 (a house with a *hayat* at both the ground and first floor levels), rule 0.2, TYP.A2 (a house with no *hayat,* but only rooms, at the ground level), and rule 0.3, TYP.A3 (a house with no ground floor at all). In this study only TYP.A1 house derivation, and development is illustrated.

The shape rules specify the ways in which vocabulary elements of each type of house are put together. They are divided into three groups, corresponding to the three groups of spatial relations, as shown in figure 10:

Group 1 rules specify the location of the overall room space around the ground floor and first floor *hayat*.
Group 2 rules define placement of stairs on the ground floor.
Group 3 rules define the possible arrangements between the stairs and the first floor *hayat*.

Technically, group 3 rules operate on two different levels, the ground floor and the first floor. The left side of the rule determines the location of the stairs on the ground floor and the right side of the rule shows the location of the first floor *hayat* in relation to the stairs. The stairs belong to both levels and serve as a connecting element between the two. These rules determine the configuration of the first floor with respect to the ground floor.

1.1 The Application of the Rules to Designs

In this study only the derivation, and development of TYP.A1 (a house with a *hayat* at both the ground and first floor levels) is illustrated. The derivation of Typ.A1 house begins with a starting rule 0.1 shown in figure 9. The derivation is divided into two levels allowing the ground floor and first floor plans to be generated separately as shown in figure 11. The ground floor and the first floor plans are distinguished with different line thichnesses. Once the ground floor and the first floor plans are generated, then group 3 rules are used to connect the two floors with the location of the stairs. In order to articulate the space, a 3D representation of primitive TYP.A1 is shown as extruded plan.

2. Sub-House Generation

The second step for generating *hayat* houses consists of one stage. Here, by applying group 3 rules from step 1, five sub-types of TYP.A1 are generated as shown in figure 12. The location of the stairs plays an important role in sub-type generation.

3- House Variations

The third step for generating *hayat* houses consists of six stages. In each stage new shape rules are introduced. First, group 4 rules are used to transform sub-types of TYP.A1 for contemporary use. Than, group 5, 6, 7, 8 and 9 rules are used to generate variations of sub-types of TYP.A1. Each primitive house represents the beginning of a design alternative. Some groups have multiple rules while some have only one. The new shape rules are illustrated in figures 13 and 14.

The specifications for group 4 rules are as follows:

Group 4 rules modify sub-types of TYP.A1 for contemporary use, by transforming the first floor *hayat* into a central circulation hall as shown in figure 13. Group 4 rules operate on multiple levels. The left sides of the rules illustrate the composition of the *hayats* located on both the ground floor and the first floor. By applying these new rules of addition, the *hayats* on the first level are expanded, as illustrated on the right side of each rule. The elements of the different levels are distinguished by different line thicknesses. On the right side of the rules the new extension (*Ai*) is added to the front of the first floor *hayat,* so that it covers the ground floor *hayat,* and also extends beyond it a certain distance. This creates an overhang. Here the first floor *hayat* is transformed into a central hall by adding an extended *hayat,* which overlooks the garden and overhangs the ground floor *hayat.* Although the *haya*t loses its original function, the concept of it is carried on with extended *hayat* on the first floor. The extended *hayat* can be interpreted as private or semi-private space. The decision about its function and use depends on the designer's intention and on the program of the house.

Group 5, 6, 7, 8 and 9 rules generate elaborated variations of TYP.A1.

The specifications of these rules are as follows:

Group 5 rules mark emergent shapes as shown in figure 13. The left sides of the rules show the first floor as well as parts of the ground floor that are not covered by the first floor. The

right sides of the rules show emergent shapes indicated by label *Xi.* These emergent shapes are used to expand the first floor layouts in further stages of the design.

Group 6 has only one rule. This rule partitions the U shaped room space at the first floor level into five sections, a1, a2, b1, b2, and c as shown in figure 13. These partitions are used to generate variations of TYP.A1 in further stages of the design.

Group 7 rules add new spaces, labelled *Xi,* above the ground floor to the first floor layouts, thus expanding the total floor area. Depending on the designer's conception, a variety of addition rules can be extracted.

Groups 8 and 9 each have only one rule.

The group 8 rule subtracts the section a1, a2, b1, b2 or c, from the first floor plan, thereby generating variations of TYP.A1. However, in the graphic representation of the rule in figure 14, only subtraction of section b1 is illustrated to depict how the rule operates.

The group 9 rule erases room partitions and units the rooms in to one space. Both Group 8 and 9 rules are generic and can be applied to both floors. In figure 14 the graphic representation depict how the rule operates.

2.1 The Application of the Rules to Designs

Figure 15 illustrates derivation of TYP.A1.1 house variations in seven stages. In each stage of constructing primitive houses a specified group of rules applies. Figure 16 illustrates a partial set of TYP. A1 houses generated through above given rules. These houses are abstract forms. They are articulated by introducing new relationships and modifying existing ones in the following section.

4. House Development

The fourth step in the generation of *hayat* house interpolations illustrates the development of TYP.A1.1 variations in four stages. Four new groups of shape rules, group 10, 11, 12, and 13 are introduced for house development. The new shape rules are illustrated in figure 17.

The specifications of these rules are as follows:

Group 10 rules illustrated in figure 17 generate different layouts of U shaped room spaces by partitioning them. These rules apply on both the ground and the first floor. The rules 10.1 and 10.2 generate partial set of partitions as illustrated in figure 18. Then rule 10.3 replaces the *hayat* with a new *hayat* (with attached partition walls) from the set. The type of chosen partition is identified by a number (tp*i*) in the set. Group 10 rules generate rough room layouts for both the ground floor and the first floor. These layouts are used as templates for further articulation of inner spaces.

Group 11 rules modify the first floor *hayat* in accordance with a given condition (*w1 = w2)* as shown in figure 17. The *w* indicates the width of the spaces (circulation areas) around the stairs. This constraint, which requires all widths to be equal, derives from functional concerns. Two issues are taken into consideration: creating functional circulation areas around the first floor stairs, and providing an access to the extended *hayat* from the first floor *hayat*. The

default square shaped *hayats* are modified, depending on the location of stairs, and in accordance with the given constraint.

Group 12 rules modify the form of the house through another set of constraints as shown in figure 17. Here the emphasis is given to the configuration of the form and layout of the houses. The new rules, which modify the form and the layouts of the houses, are created on the bases of certain qualitative judgments, as explained below.

Rule 12.1 adjusts the uneven cantilevering portions of the first floor in relation to the ground floor as illustrated on the left side of the rule. The right side of the rule extends the ground floor with respect to the first floor under the constraint *l1 = l2*. The *l* here indicates the size of the cantilevering portion with respect to the ground floor. The rule generates even cantilevering portions on the first floor creating a visually balanced house form.

Rules 12.2 and 12.3 modify the corner of the room into an architecturally acceptable form. The left sides of the rules illustrate the adjacency relations between any two rooms on the first floor. On the right sides of the rules, the adjacency relations between the rooms are modified, creating clear-cut corners for each room.

Rule 12.4 elevates the extended *hayat* (A*i*) from the first floor level. This rule is a generalised version of several rules. Only one vertex of the extended *hayat* (A*i*) and the first floor *hayat* (FH) have assigned values (*xi, yi, zi*) to illustrate that the extended *hayat* is elevated from the first floor *hayat* under a given condition z2>z1. This rule is derived from the original *hayat* house designs in which some parts of the *hayat* have elevated floors. By applying this rule, the extended *hayat* is separated from the first floor, keeping its stylistic characteristics.

Group 13 rules transform the schematic house designs into architectural representations.
as shown in figure 17.

2.1 The Application of the Rules to Designs

In figures 19 and 20, TYP. A1.1 variations are articulated in four stages. In each stage of the development of the houses, a specified group of rules applies. Figure 21 illustrates a partial set of typologically related TYP. A1 *hayat* house interpolations.

Conclusion

In this study, a portfolio of typologically related *hayat* house interpolations is generated. An informal shape grammar is used to illustrate the practical applicability of a computational method for form generation.

This computational design method has two folds. First, it utilises the generation of standardised designs while respecting the existing stylistic characteristics in a given architectural context. Second, it provides an apparatus for continuing transformation of an existing type leading to a new type generation in language.

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