A Shape Grammar Based Expert System to Generate Traditional Turkish House Plan Layouts

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The traditional Turkish Houses have a long history, which has gone through many stages of development in Anatolia and Rumeli in the last five centuries. The purpose of this study is to experience the formal and syntactic information underlying the plan layouts of traditional Turkish Houses having a certain design language through an interactive and highly visual expert system. In the study, the shape grammar was applied as the method. Shape grammar enables the analysis of design languages of algorithmic structure and the production of new designs. By referring to the shape grammar, an algorithm is developed to generate plan layouts. Developed algorithm is interpreted to computer by using “Processing” coding interface. The input data is derived from Cagdas’s study named as “A Shape Grammar: The Language of Traditional Turkish Houses”. The generation process is executed by users, due to the interactive structure of the expert system by the help of keyboard. The shape grammar interpreter in this study helps users to understand the formal compositions and plan layouts of traditional Turkish houses. System also record numerous plan layout alternatives generated by users.

1. Introduction

1.1 Aim and Methodology

The purpose of this study is to show the formal and syntactic information within the plan layouts of Traditional Turkish Houses. The plan layouts are the most important characteristic features of Traditional Turkish Houses. This certain characteristics can be defined as design language and shown through an interactive and visual expert system. In this study, shape grammar was chosen as a method, which can be used in analyzing design languages and producing new designs.

The syntactic information about Traditional Turkish Houses is obtained from Cagdas’s study named as “A Shape Grammar: The Language of Traditional Turkish Houses [1]. The plan layout generation algorithm is interpreted to computer by using Processing interface. Design components, shape rules and restrictions are also defined to computer by coding. The present study generates the plan layouts of traditional Turkish Houses analyzed in Cagdas’s study.

1.2 Design Languages and Shape Grammars

People use natural languages to maintain daily relationships. Languages may change or develop but in a long time. Language is an abstract definition to show and explain the reality. On the other hand, artificial languages are special communication tools invented by the people. As an example, music notes are a part of a special language used by musicians. Moreover, Fortran and Pascal are computer based artificial languages [2].

Language consists of arrangements of the words in its own vocabulary. Likewise, design is an organization of design components. New designs are produced with new arrangements of shapes [3].

Many researches emphasize that there is a strong relationship between the structure of language and architectural design. Languages have a grammar that defines the combining rules of words. As mentioned on languages features, a similar approach for combining design shapes is possible.

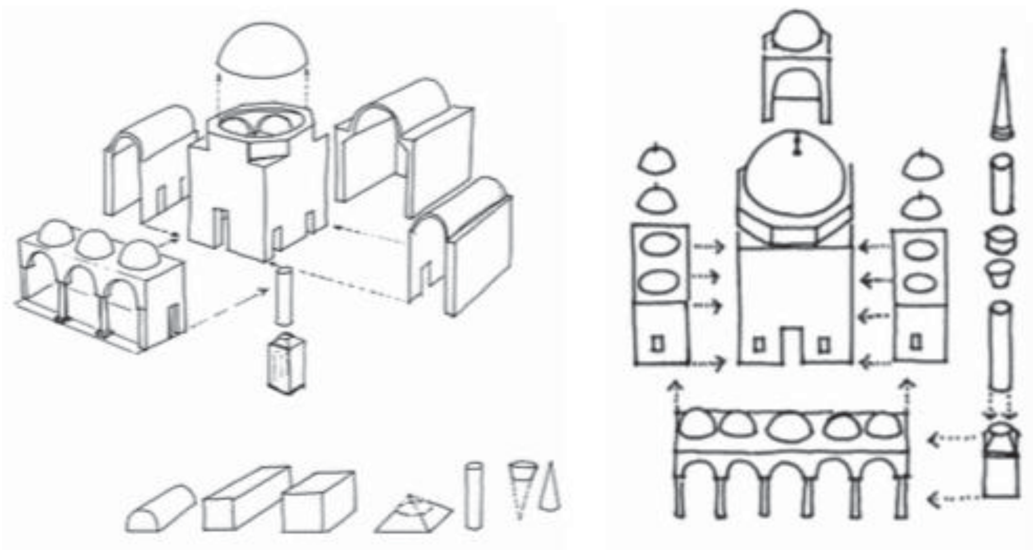

Image 1. Components of Classical Ottoman Mosque [5]

In the 1980's the researchers focused on the architectural designs, which are belonging to an era, an architect or a region. Each of these architectural languages that belong to a certain era or an architect has its own compositional principles. These architectural principles are defined with the set of rules and these made up to the grammar of that language [4].

In architectural design with using a limited number of components, the number of created combinations is numerous. However, it cannot be said all combinations are meaningful. In this point, shape grammar includes the rule set to provide the appropriate relationships between these components.

Shape grammar is a method introduced by Stiny and Gips in 1970s, enabling the analysis of design languages of algorithmic structure and the production of new designs in the same language.

Shape Grammar can be defined as a rule set which is deployed to form a design language. As linguistics does not invent a new language, shape grammar does not invent a new architectural language.

Shape grammar consists of generative rules used to produce shapes. Repeated application of shape rules to an initial shape lead the generation process of new shapes. A sequence of derivation often generates shapes that are unexpected [6].

First studies on shape grammars aim to criticize and analyze design languages with working on shape rules. By analyzing these rules, the original language is realized and new forms produced by using language. Each shape grammar is unique and expected to produce different designs. As, there is not an official language for all societies, there is not a common or finalized form of shape grammar.

Vernacular architecture language is evolved in a long term with additive and repetitive process. The language of vernacular architecture is complex but the whole keep architectural orders and information. This architectural information underlying vernacular architecture language can be defined through an algorithm. It is possible to analyze and decompose the vernacular architecture language. Decomposition is made by exploring the components and the rules of combining rules for these components. The components and the rules formalize the grammar of the language.

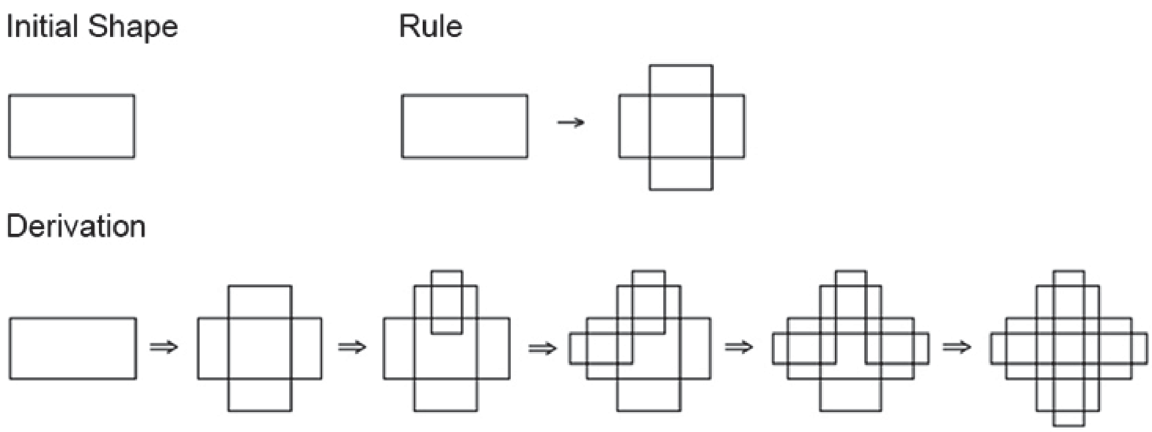

Image 2. Applying the rule on an initial shape [7]

2. Traditional Turkish Houses in the Context of Shape Grammars

2.1 Main Features of Traditional Turkish Houses

The building process of Traditional Turkish Houses started in Anatolia in 15th and 16th centuries. These houses expanded to other regions within the borders of Ottoman Empire. Traditional Turkish Houses have many developments in the architectural context during five centuries [1].


Image 3. Different types of Traditional Turkish Houses [8]

Various types of Traditional Turkish Houses were evolved under different geographic features, climates and traditions. In spite of all this diversity, some features of the Traditional Turkish Houses are remained unchanged in many regions. As Eldem [9] stated, all Traditional Turkish Houses have certain characteristics in common. The plan layouts of the houses are the most important characteristic.

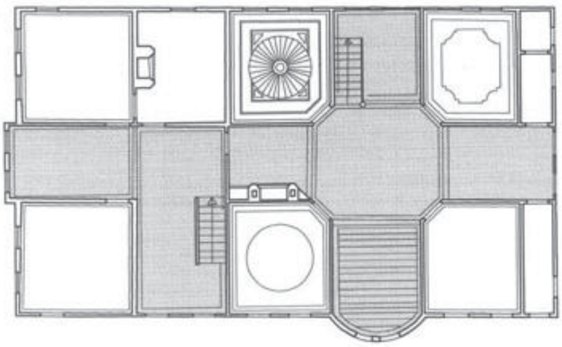


Image 4. Plan layout of main living floor and facade of a Turkish House [10]

The Traditional Turkish Houses usually have one floor. Over time, houses floor quantity has increased. Even the number floor is increased; the main living floor is generally located at the highest level. The plan layouts of main living are presenting the common language that belongs to Traditional Turkish Houses.

The architectural language of Traditional Turkish Houses consists of the organization of rooms, halls, eyvans and bays. The organization of these plan elements is a main issue. For this reason, certain details of house plans are ignored in the scope of this study.

2.2 Elements in the Traditional Turkish Houses Plan Layout

In this section, the elements that composing the Turkish Houses plan layouts are examined. These elements are rooms, halls, eyvans and bays.

Room can be described as the most important plan component. Number and the location of rooms directly affect the plan types. Aligning the rooms in one or more axes creates the hall. The hall is a corridor that connects the rooms. The plan types are named by the relationship of between rooms and hall.

According to the location of halls plan layouts are classified as without a hall, with an outer hall, with an inner hall and with a central hall. Graphical representation of hall types can be seen in Image 5.

Rooms on a single row can divided with a space called eyvan. Eyvan is an additional hall to get sunlight into the hall and to reach the courtyard from hall.

The bays are generally added to enlarge the interior volume of the house. Another purpose to add bays is to get sunlight and gravitate to view. Bays are generally located on the outer border of rooms but in some plan types bays are used as an extension of hall.

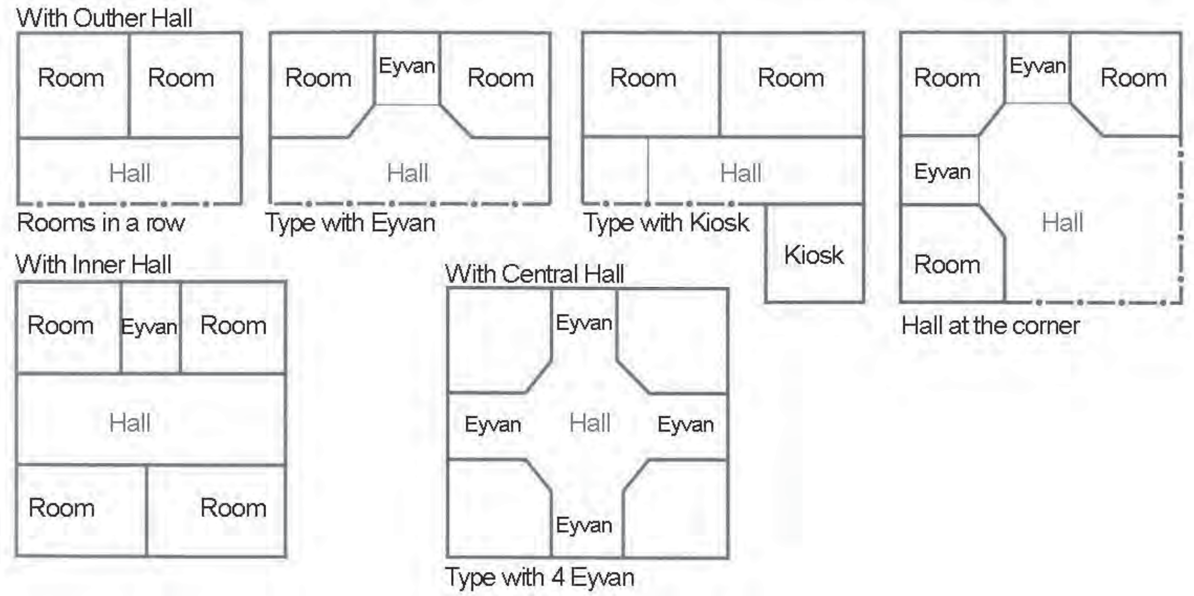

Image 5. Plan types and plan components of Traditional Turkish Houses [8]

2.3 Shape Rules to Generate Traditional Turkish Houses Plan Layouts

A parametric shape grammar to generate the Traditional Turkish House plan layouts is developed by Cagdas [1]. For guiding the generation process of the plan layouts an imaginary grid is used. Straight lines are used to create shapes. Definition of the spatial relations between the plan elements is made through shape rules sets. In the rule set vocabulary elements are represented with polygons. Polygons are placed in a grid to determine the alternative locations of the plan elements.

In Cagdas's work, the main vocabulary elements of Traditional Turkish houses are rooms, halls with their extensions. Two dimensional shape grammars are usable to create plan alternatives. The dimensions of plan elements may vary in different plan layout. To avoid that, blocks size parameters are standardized to make the modifications easily [1]. To create the expert system, the scope is limited only with rule sets belong to the plan types with inner hall. The rules that will be used in program are explained. In the rule set, RI code states the rule set for houses with inner halls. For example, RI31 code means the first shape rule of the third rule set.

In Cagdas study, the rule RI1 replace the initial shape with a hall labeled with letter "H". This rule application creates the core of the plan. This case means that every house should have a hall. RI2 rule set is used to locate rooms around the hall. RI21, RI22 and RI23 rules are used to add rooms. These shape rules are applied to generate plan types with more than one room. During this process the hall length is increased as seen in rules in Image 6. In other words the hall length is equal to the room length in those rules. Rooms are labelled with letter "R". The RI31 and RI32 and RI33 RI34 rules place the eyvan to the corner or between the rooms in a row. RI71, RI72, RI73, RI74, RI75 and RI76 rules add the bay to the outer border of a room [1].

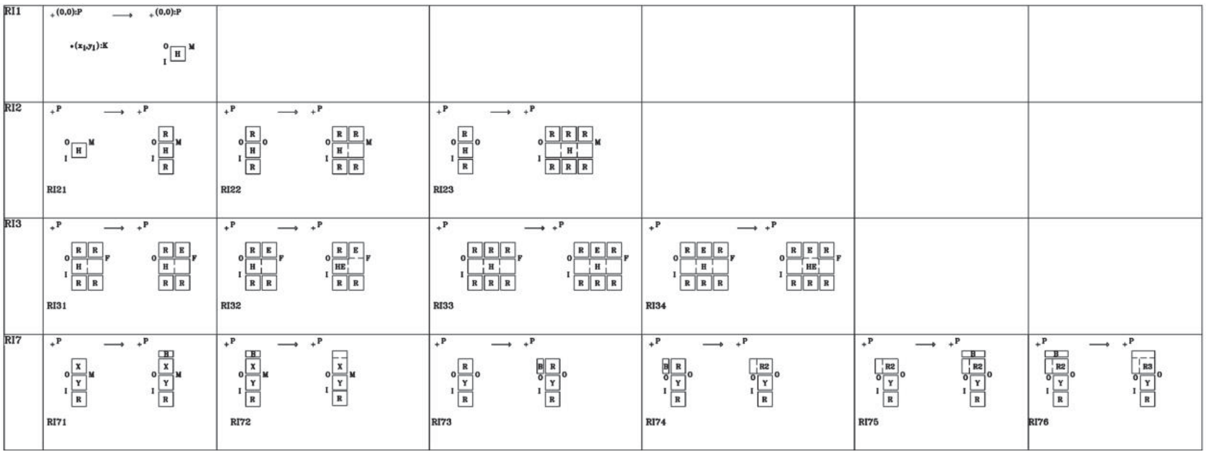
Image 6. Shape rules to generate plan layouts with inner hall [1]

3. Shape Grammar Based Expert System

3.1 Theoretical Background of the Expert System

Shape Grammar Interpreters are expert system that allows users to develop or generate designs. A Shape Grammar interpreter is a computer based system that can make operations. With using these systems development of these design alternatives can easily created in an interactive way [11].

Early shape grammar expert systems were implemented in Prolog by Krishnamurti [12]. Krishnamurti's approach is defending the need of algorithms for performing the shape rules. First visual shape grammar interpreter was done by Tapia [13]. Tapia developed a 2D shape grammar interpreter that is able to work on an entire shape with Euclidian transformations.

Jose Duarte developed a shape grammar for Alvaro Siza's houses at Malagueira. For the generation of houses, shape grammar proceeds recursively by locating rectangles. Duarte used the shape grammar to create an interactive computer system for the design of mass housing. Houses are created and rendered due to user preferences [14]. Such interactive systems enable user participation in design process.

3.2 Developing the Logic of the Expert System

Processing is a very flexible interface to create 2D geometric compositions. First, design components are defined on a 2D analytic plane by using coordinates. Shapes, sizes and the label are also specified. The components that will create the plan layouts are become unique with these specifications. The combination rules of components and restrictions are also defined. Processing interface is used to interpret all information about components.

Generation process of plan layouts is specified with a verbal algorithm and flowchart. Instructions about generation process are displayed to help the user while the code is running. Interface has coding screen, display screen and an interactive screen. Users have the chance to lead the process by the help of keyboard on interactive screen. Keyboard places the components into plan layouts due to the rules and restrictions.

The drawn plan components have different colors and labels. Overlapping between components and transforming components is restricted. The reason of these restrictions is having finite plan schemas by grammar.

To use the generative feature of shape grammar an algorithm schema is developed to perform the generation process. Algorithm schema help users to avoid from making errors and create design step by step.

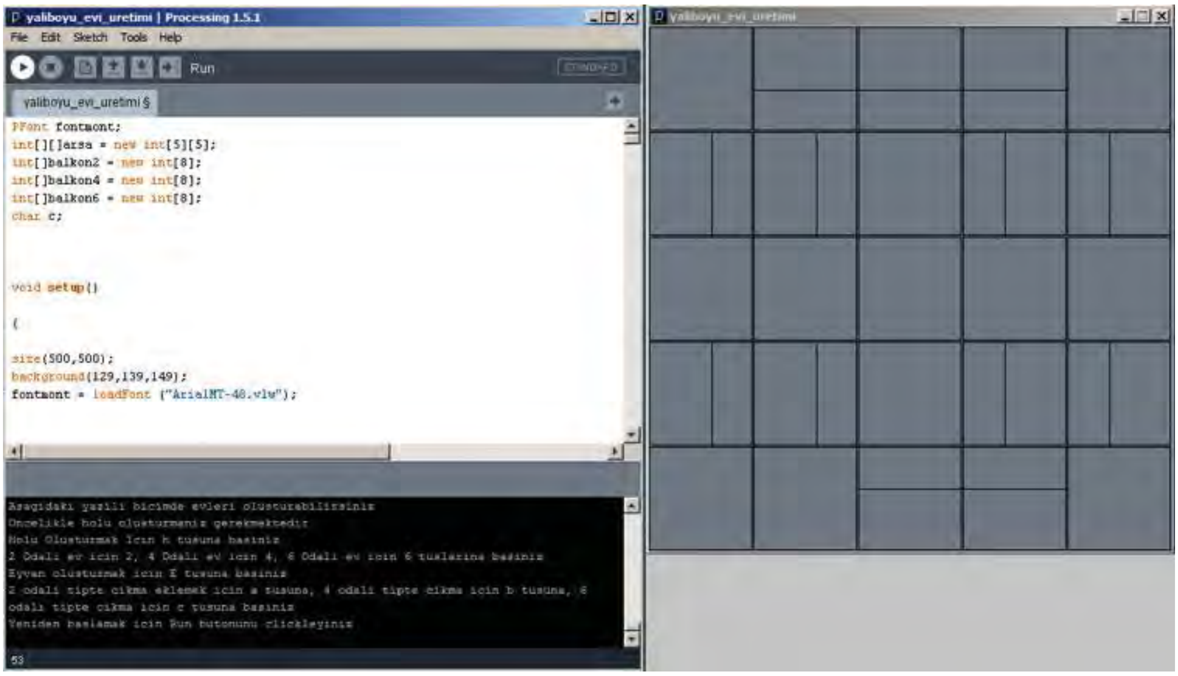

Image 7. Interactive interface of Processing

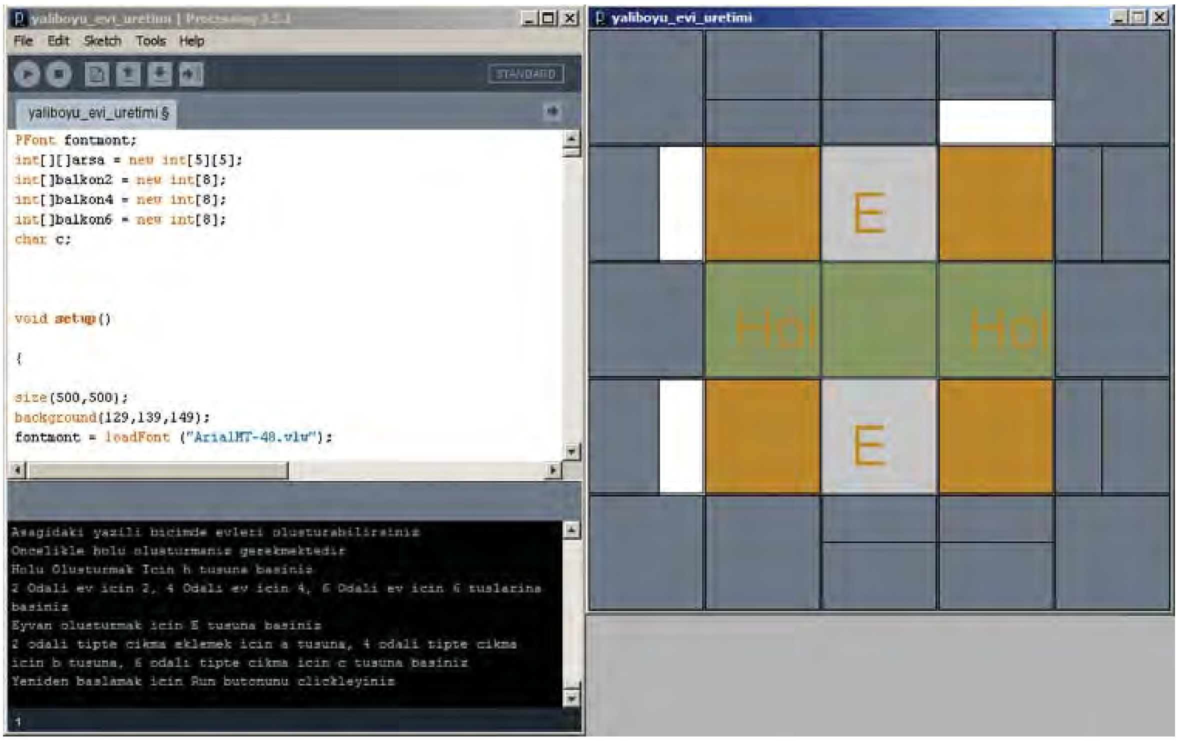

Image 8. Coding screen, display screen and interactive screen

3.3 Algorithm Schema of the Expert System

After mentioning how the Processing code operates, it is essential to give the working process of algorithm schema. The algorithm schema is generating plan layouts based on Cagdas's shape grammar study. Users are managing the generation process of layouts by communicating with code interactively by using keyboard. As shown in Image 9, process begins by drawing the layout, hall, room, eyvan ends with the addition of bays.

Algorithm schema is leading the user to define the size of layout in coding screen. After defining the size of layout the code is run. First, user is expected to create hall, which is the main element of Traditional Turkish House's plan layouts. In the next step, the rooms are located around the hall. The number of the rooms can be 2,4 or 6 based on grammars. Operation of adding rooms is reversible. It means layout with a 4 rooms can transformed into type with 2 rooms by deleting 2 rooms. Another plan element eyvan can be added to plan layouts. Eyvans can only added to plan layouts with 4 or 6 rooms. In other circumstances, the code does not respond to inputs. Before lasting the generation process, user can create bays. The bays are added randomly to plan layout on every pushing to the button. Adding bays is not a necessity.

After completing the code, the expert system based on an algorithm is run and the bugs are fixed. New steps and new components are added based on grammar developed by Cagdas [1].

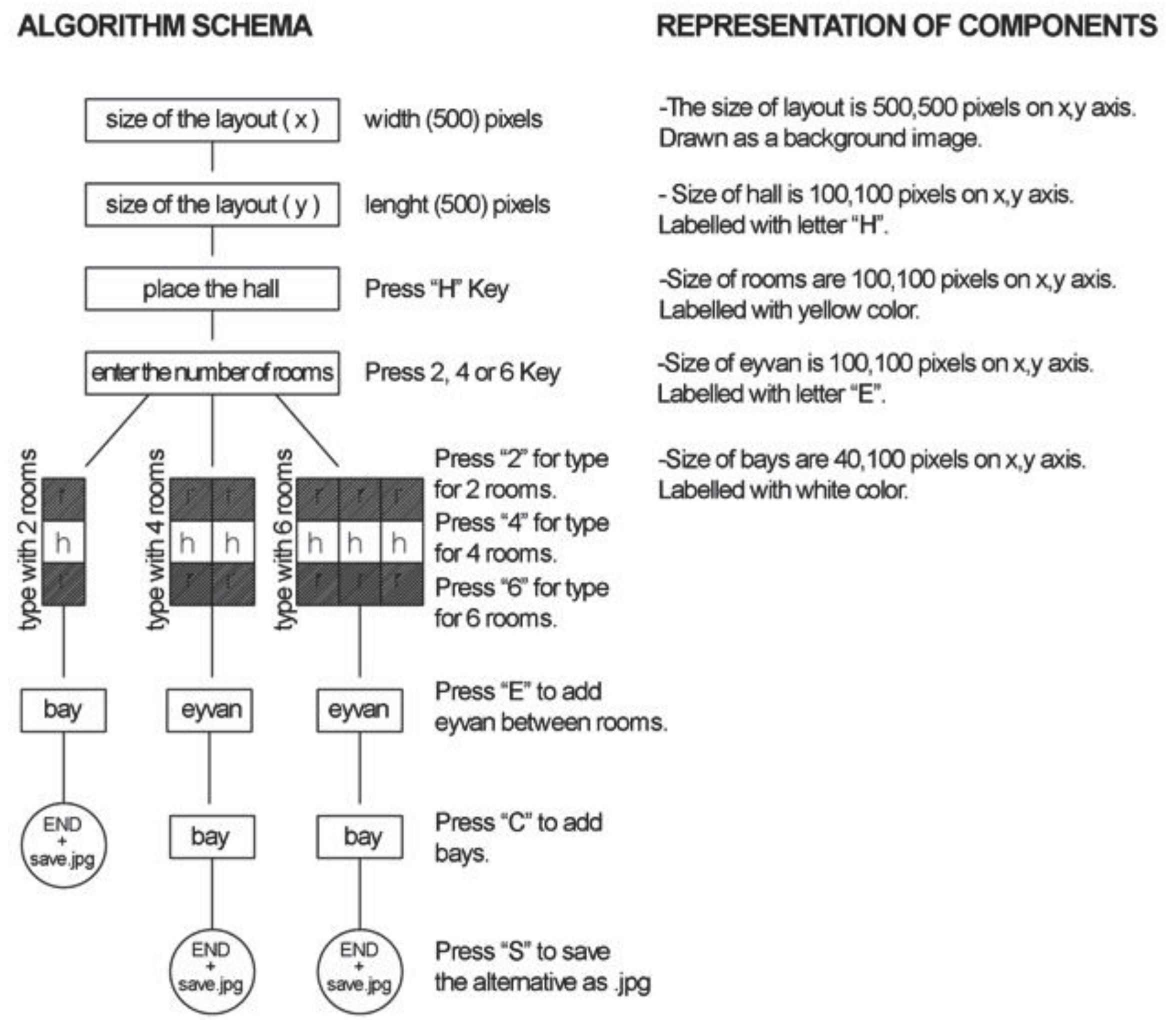

Image 9. Algorithm scheme and representation of design components

3.4 Rules and Restrictions on Creation Process

The system is running on an order, which is defined on algorithm scheme. The generation process is explained step by step below.

The layout (field) is the area where the design alternatives created on. Before running the Processing code the size of the layout has to be defined by the user in coding interface. Processing interface draw the layout once as a background. Changing the size of layout is not possible during the code is running. The user enters the width and length as parameters.

Every created plan layout based on a grammar has to include a hall. The distinction between inner or outer hall is not defined to the system. Expert system is able to produce only plan layouts with an inner hall. After running the code, the system automatically draws the background to place the plan components. Afterwards, system communicates with user from the instruction display screen.

Placing hall is the first step to generate a plan layout. “Push the letter H from keyboard to place the hall.” statement is written on instruction screen. By pushing to “H” button from keyboard, system places a hall at the middle of the layout. The hall size is 100,100 pixels on both axes.

The houses with inner hall may have 2, 4 or 6 rooms. System consults to user to choose one of these alternatives. User press the button “2” from keyboard to create 2 rooms, press “4” to create 4 rooms or press “6” to create 6 rooms. The rooms are located on the both side of hall on y-axes. Having 4 or 6 room create 2 rows this also enlarges the hall, which is a passage between rooms. Example can be seen in Image 10.

Houses with 4 or 6 rooms may have 1 or 2 eyvans. Users press “E” button to place one or two eyvan between rows of rooms. Adding eyvan is transforming rooms into eyvans. With this operation plan layouts with 3 and 5 rooms are created.

Bays can be located on outer edges, which is not neighbor with the hall. To locate bays user press button “A” for types with 2 rooms, press “B” for types with 4 rooms and “C” for types with 6 rooms. This operations start to create random bays on the edges which is not neighbor with halls. The restrictions within the process are listed in Image 10.

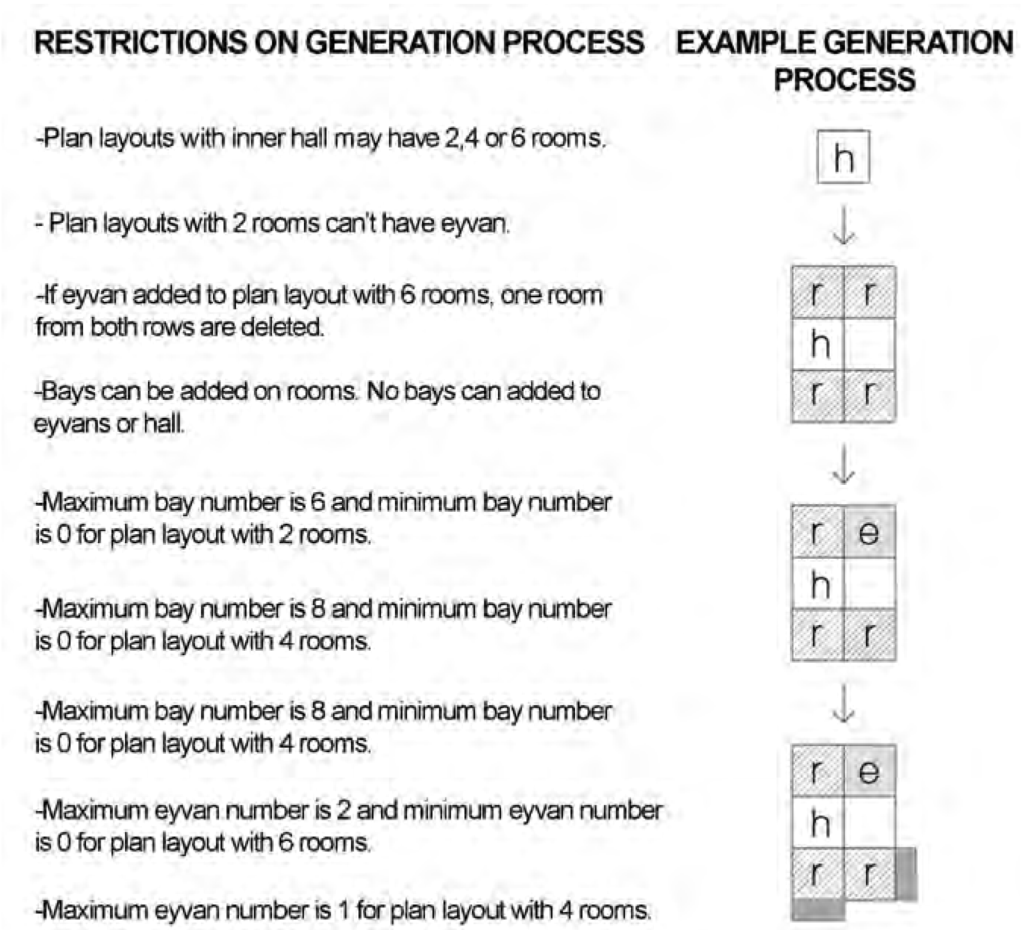

Image 10. Restrictions on generation process and example plan layout generation

3. Conclusion

This study presents an expert system that generates plan layouts in a closed shape grammar. In the scope of this study, an expert system is developed to generate fast and different design alternatives with using rendering, generating and saving abilities of computer. The expert systems code structure is changeable for any modification for further shape grammar studies.

Written code allows users to participate generation process interactively. Users also make inputs to the process. Expert system is explaining rules to combine design components. System also controls the process with specified restrictions. With the help of interactive display screen users generate plan layouts by following the process step by step.

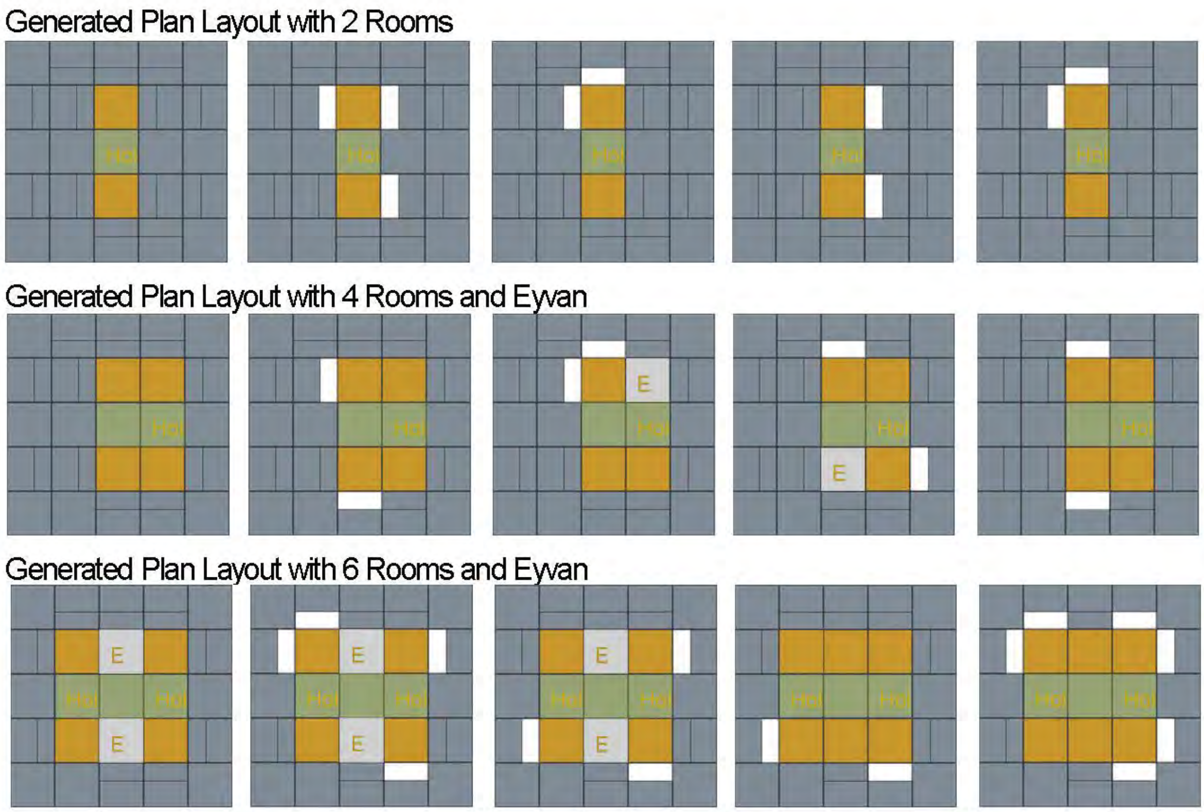

Image 11. Generated plan layout alternatives

Consequently, users learn the plan layout types, design components and the rules to combine these components. All these steps constitute the generation process, which are not separate processes. New plan layouts are generated based on a same shape grammar. Applying different rules for generation process end up with different plan layouts. The system is able to record these numerous plan layout alternatives.

The study is a trial where the artificial intelligence is dealt with in design training while regarding the use of shape grammar method. The shape grammar based expert system in this study helps users to understand the formal compositions and plan layouts of traditional Turkish houses.

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