Classifying the Heritage Elements Using Shape Grammar

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Abstract— **Traditional architecture style represents the evolutionary style and experienced characteristics of an urban environment that give a sense of place and identity. This style includes a mixture of technical and cognitive values that are difficult to conserve compared to other material resources. The process of organizing and classifying the architectural elements of these constructions in virtual digital manner is one of the means of preventive conservation for such elements and their values, which is essential in conservation operations of the built heritage.**

The study analyzes a number of international experiments that have employed shape grammar in studying and classifying the heritage elements in digital technique with specific rules. That because of the ability of these systems to examine the structure of the historic elements as it offers the possibility to combine their dimensional and morphological values, to classify them into a variety of categories with common characteristics in a specific style according to the local architectural language. The study seeks to determine the approaches of using the shape grammar as a mechanism of analyzing the structure of the elements of the Built heritage for classification. Next, to derive the rules and relationships that are used for the digital virtual reconstruction of the Built heritage according to the traditional architectural principles, and highlighting the digital applications and software that deals with the shape grammar in this field.

The methodology of this study adopted the analysis of a number of studies that employed the shape grammar in the built heritage domain in order to review the potential of this digital systems and applications, to be presented as a documentation procedure for information management of preventive conservation projects of the urban environment in ancient cities.

Keywords-component; Digitization, Built Heritage, Shape Grammar, Historic Buildings, Architectural Elements, Local Architecture.

I. INTRODUCTION

Shape grammar have achieved a great importance in architecture since its concept has been introduced by Stiny in the 1970s , and its potential application in architecture ,and its cognitive importance was embodied in the analysis of the composition structures in architecture, In addition to multiple applications, the shape of grammar is considered to be similar to language as a morphological language , and it is a tool for classifying, describing, generating and evaluating architecture, and its elements. These grammars have the ability to describe the morphological structures of architecture, and to reproduce them in the same language, in addition to evaluating the results and their extent participation in the same morphology, functional and special characteristics of the same architecture.

There are many levels of employing the shape grammar in architecture, according to the goal, classification mechanisms, and methodologies to formulate shape grammar. This research highlights these aspects, focusing on the aspect of employing these shape grammars in classifying architectural components according to certain criteria. Several research efforts have discussed the classification of heritage components, including the following:

1. Saleeb: The study discussed the development of a system of classification of heritage elements by comparing the current classification systems according to the type of elements, characteristics, timelines and analysis of suitability of the elements for reuse.

2. Lagomarsino: presented a topological classification related to damage of heritage elements in a historical building according to its classes, and classified components, after setting classification criteria according to the category of damages and behavior in disasters such as earthquakes, and suggesting appropriate restoration techniques for the heritage elements.

3. Sun: The research discussed the difficulties in classifying the World Heritage, and made recommendations to achieve effective classifications by identifying the heritage elements in the conservation process by analyzing the information and presenting it in a digital format includes various information can be accessed by specialists. An electronic portal aseCHNH has been established to manage the heritage element information.

DOI: http://doi.org/10.24086/aces2020/paper.240

4. Abulnour: The research discussed the classification of monuments according to criteria such as the degree of importance in heritage, the level of deterioration, and the state of preservation. the classification process includes antiques and heritage architectural elements.

5. Orenia: The study deals with the classification of heritage elements in documentation processes in the database, with a hierarchical structure begins with general elements, decorations, and details. Each category includes common information in the elements it contains.

6. Lempert: In this research, a classification system has been created and applied to heritage sites. The system includes classification criteria according to the construction status, type of elements such as deteriorated, preserved, and recovered elements.

In this study, a new concept will be presented to classify architectural elements using the shape grammar according to the level of classification in architecture, methodology, and morphological, functional, spatial, dimensional and typological characteristics.

II. STUDIES VIEW

In this part, the study will be presented, analyzed, define the classifying mechanism of the elements, and determine the methodology of application, as follows:

2.1. Kitsakis- 2017

This study dealt the application of the shape grammar in procedural methodology for modeling the traditional Greek housing in Zagori. the study focused on determining the degree of detail of the facade to formulate the digital shape grammar CGA in a standard form. The modeling process is done in two levels, the first is for facades, and the second is for masses.

2.2. Çağdaş – 1996

The research highlights the analysis of traditional Turkish houses by the parametric shape grammar to describe the structural aspects of this style. The research aims to present shape grammar that determine the morphological, spatial and structural properties that provide the foundation to formulate the grammar.

2.3. Stiny– 1978

This is one of the first studies that applied the shape grammar in architecture to study the characteristic Palladian villas style to generate plans in the same style in design. The research studied the structural and morphological (such as the hierarchy of the elements, the axis and other characteristics common) characteristic of plans to reformulate Palladian plan in a modern style.

2.4. Castro – 2016

The research focuses on the dimensional analysis of architectural elements in Florence region – Italy by the shape grammar to analyse the columns in a heritage building to convert them into digital models that can be easily formulate the grammar by computer .The results show that the shape grammar leads to create a three-dimensional model similar to reality by assemblage the components .

2.5. Ahmed – 2004

This study analyses a group of caravansaries in Central Asia by the shape grammar to determine the grammar for the complex style plans (which borrowed components from several architectural styles) and divided them into components that can be easily organized to create new plans in the same architectural language. This characteristic was analysed in terms of symmetry and hierarchy to determine common components in this style.

2.6. CALOGERO – 2006

In this study, the shape grammar was employed to digitally reconstruct the eastern wing of the Louvre Museum using procedural modeling techniques in City -Engine program.

2.7. Andaroodia – 2006

The research focuses on the characteristics of the spatial, functional and morphological organization of the caravansary .the research relied on the computing shape grammar by representing the buildings using Auto CAD, then classifying them according to the determined characteristics, then arrange its plan in a hierarchy according to the grammars to represent the heritage vocabulary in an interrelated relationship that describes these components by formulate two grammars :shape grammars and relationship grammars.

2.8. SASS – 2007

The study dealt the shape grammars to define the construction grammars for the prototypes production by three-dimensional printing. The grammars here is as a restriction in the printing process. The research took the Palladian Villa as a case study in the assembly and physical modeling according to the structure of the heritage elements by providing structural and spatial information about the elements.

2.9. De Godoi – 2006

The research employs the shape grammars to rehabilitate the historical areas that lost their original Characteristics due to non-correct renewal operations. The study focuses on Monte Alegre city in Brazil to develop principles for re-adapting the facades using the shape grammars digitally to make them compatible with the historical urban context by analyzing the facades structural, rhythm and its characteristics.

2.10. Lambe – 2017

The study deals the analysis of the traditional architectural style of Pol residences in Ahmedabad - India by formulating the shape grammars that serve as an analytical tool to meet the

DOI: http://doi.org/10.24086/aces2020/paper.240

contemporary needs to solve the incompatibility problem of modern buildings with the traditional context of the old area by studying the morphological, spatial and functional characteristics.

2.11. Said – 2008

The study focuses the structural analysis traditional Malay housing TMH in Malaysia using shape grammars. The research aims to provide effective approach to conserve the old buildings by defining the architectural style of TMH in a computing environment by determining the common characteristics. The study relied on the housing sections in the analysing process of spaces and formulating grammars

2.12. Müller – 2018

This paper focuses on reproductions parts of the traditional Roman urban in Pompeii by the shape grammar to analyse the structure of the city and formulate the traditional dwellings distribution grammar in a short time at low cost by importing elements from a pre-defined library that enables the user to keep pace with the processes of change In urban .

2.13. Al-Kazzaz – 2012

The study proposed a methodology for deriving hybrid designs using adaptation in the shape grammar from several designs, then use the shape grammar as an analytical, generation and evaluation tool for the resulting designs. The potential Hybridization using shape grammars done by deriving the hybrid design by original grammar, or by mixed grammar, or using the original and mixed grammar together. The study took the minarets as a case study to formulate the grammar to derive hybrid designs.

2.14. Trescak – 2012

The research focuses on synthesis problems to create a number of designs and determine the optimal design among them using the shape grammar by combining previous designs - for a specific architectural style - and devising common morphological characteristics by AI approaches in the process of creating designs.

2.15. Yavuz1– 2016

The research focuses on the structural analysis of the brick patterns arrangement by the shape grammar in the heritage buildings facades in Anatolia based on the consistency, symmetry and replacement concepts. The study analyses the traditional facades that employ brick units as decorative elements to determine the structural organizing of it and rebuild other facades in the same architectural language in three stages.

2.16. Filipe – 2012

The research deals the deriving shape grammar to create new shapes in the dimensional framework for a set of heritage columns provided by the description programs as follows:

2.17. Eilouti – 2012

The research focuses on analysing the structure of the traditional Damascene house by shape grammar at plans level. the research determined the plans vocabulary and its types, then re-built the plans according to them in the same architectural language. the parameters in the grammar determined the analysing of spaces to form restrictions on its organization in plans.

2.18. Ria -2016

The research aims to develop virtual models according to the local Mamminasata style using the shape grammar to formulate the guidelines for the contemporary future design in accordance with the traditional local language to conserve the local identity. this study relied on plans and facade analysing.

2.19. Olakanbi -2016

The research aims to provide special shape grammar for Suakin traditional housing in Sudan to analyse the structure of plans to understand the traditional architectural style by determining the functional, dimensional and typological characteristics to formalize and revive the traditional style according to a contemporary concept in two compounds: the first (meaning and context), the second (structure and form).

2.20. Krishnamurti -1995

The research analysis the morphology and structure of traditional Taiwanese houses by the shape grammar to determine the structural principles of these houses. The shape grammar provided an approach to understand the design and construction concept for these traditional architecture style that was classified according to the function, morphology and construction technology, to determine the common characteristics in the case study.

2.21. Tepavčević -2013

The research proposes a new approach to simulate the characteristics of a group of heritage churches in the Danube-France region that share similar and common characteristics and generate several shapes in the same architectural language based on the shape grammar.

2.22. Sayed -2015

The study focused on a mechanism of analysing the structure of Islamic motifs to generate them digitally using the shape grammar by the parameters PSG in 3D.

2.23. Eilouti -2007

The research paper aims to derive the shape grammar of the plans of educational buildings (schools) in Mamluk architecture by identifying the common aspects between them in two levels, the first: level of elements (vocabulary), the second: the level of relationships (typology). Morphological analysis of the case study revealed the existence of an architectural language represent this style.

2.24. Marzouk -2018

DOI: http://doi.org/10.24086/aces2020/paper.240

The study deals the challenges in establishing a classification system for heritage elements in Tosson Palace in Egypt, which contains elements from different historical periods, and with different styles. the research focuses on the classification systems problems of heritage elements with common characteristics:

2.25. Colakoglu -2000

This PhD thesis explores the applicability of computational design in analysing the structure of traditional architecture using shape grammar by algebraic operations. the study took Hayat traditional houses in Bosnia as a case study in two levels, the first is analytical to extract the basic structural principles of the dwelling, and the second the Synthesis proses to produce new design in the same architectural language.

2.26. Chiou -1996

This PhD thesis deals the analysis of heritage elements in Chinese architecture using the shape grammar in dimensional (mathematical) analysis in temple architecture to present a new analytical approach by exploring the roots of arithmetic in the structure of architecture. the study aims to define mathematical principles that can be extracted from arithmetic analysis by the shape grammar.

2.27. Benros -2018

The PhD thesis studies the methodologies of formulating the shape grammar for traditional architecture to prove the reliability of the choosing mechanism of the formulating methodology according to the architectural style. The study makes a comparison between three different approaches (Palladian villa, Prairie housing, and Malacquera residences). The research aims to refute the hypothesis that a specific methodology of shape grammar is for a specific architectural style.

2.28. Al-Jameel -2014

The study analyzed a sample of Islamic mosques using the shape grammar according to the topological characteristics. The research relied on the standard grammar to formulate the relationships between spaces with neutralization of parametric grammar.

2.29. ŞENER -2008

The research aims to develop an algorithm shape grammar to understand the structure of the Ottoman mosques in a digital system by the artificial intelligence approach to generate mosques in the 2D, 3D in a in the same architectural language. The research analyzed the topological relationships of the mosque's components with each other to determine the inclusion options for these components:

2.30. Al-Allaf-2014

The study aimed to determine the morphological characteristics and the structural typological of residential entrances in the old city of Mosul for classifying the entrances into groups to specify the Geno type of them. The result of this research discovered the diversity of structural, visual elements and the typological grammar.

2.31. Zhu -2015

The study proposed a methodology for automatic 3D modelling of urban facade by shape grammar sot this paper presented a 3D modelling method applied to virtual city design using City which integrate with ArcGIS.

2.32. Di Angelo -2012

The study provides virtual reconstruction of traditional Bali residences in Indonesia using the shape grammar by integration with modern techniques using City Engine tool that allows an effective generation of architectural models which depends on the procedural methodology to facilitate generating.

III. Studies Analysis

After presenting the studies, in this part, the studies will be classified and analyzed according to the scope of dealing with heritage architecture to determine the formulating methodologies, the techniques, characteristics and their strategies for deriving the grammar. The scopes of architecture are determined as one of the characteristics of classifying studies as they share a specific methodology as follows:

- The studies in the urban scope
- The studies in the masses scope
- The studies in the plan scope
- The studies in the facades scope
- The studies in the architectural elements scope
- The studies in the architectural sections scope
- The studies in the detail scope

3.1. The studies in the urban scope

3.1.1. Müller – 2018

- Classifying the urban components based on GIS data.
- Classifying the heritage sectors according to the density, coverage ratio, a functional map to describe land use (residential, agricultural, commercial, public), street network, and age map.
- Classifying the street network according to its planning characteristics and uses.
- Formulating the distribution grammar of areas and street network.
- Importing façades grammar from the digital heritage library using the City Engine program.

3.1.2. Zhu -2015

- Collecting Data and analysis it by Google Earth to provide facade image via photography.
- Importing facade data from Google Earth to ArcGIS to get geographic information.

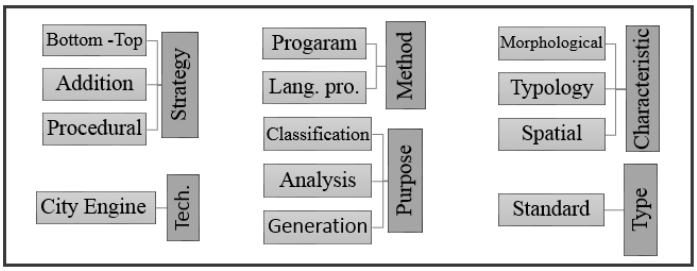
DOI: http://doi.org/10.24086/aces2020/paper.240

- Using the City Engine to create a 3D model of the building from 2D data that was taken by ArcGIS.
- Using the facade rule tool in City Engine to create the automatic grammar CGA format quickly.
- Using the grammar to generate the blocks facade and add materials and colours using City- Engine.

3.1.3. Di Angelo -2012

- Formulating grammar begins from urban level to the grammar of the building blocks distributions by determining the direction, intensity, organization, and function of distributed units.
- Formulating the grammar of individual buildings after determining their position in the urban by creating a floor plan.
- Arranging the wings of the traditional house according to the space hierarchy.
- Designing columns, according to their components, the crown, the body, proportions and its shape.
- Other details of the decoration that include stones, pillars, roof elements, etc.

From analysis the studies of the shape grammar in urban scope, the following aspects were determined:



3.2. The studies in the Masses scope

3.2.1. SASS – 2007

- Classifying the elements according to the spatial analysis to the walls, columns, windows, ceiling, frieze, additions, stairs, doors, details.
- Symbolizing the elements to determine the insertion points of the elements together.
- Formulating sharp grammar to determine the o components assembling in a three-dimensional space in two types, morphological for the element and relational between them.

3.2.2. Trescak – 2012

- The research applies two different types of algorithms, the first is the tree search algorithms (the shape grammar are stored in a branched tree structure form according to its characteristics), the second is the optimal detection algorithm for the style.
- The research provides an SGI tool for an automatic creation of designs in a similar style by the detection algorithms in the artificial intelligence that discovers sub-forms then evaluating them.

3.2.3. Tepavčević -2013

- Statistical analysing of the morphological characteristics of the buildings by the multiple comparison method to determine the most common characteristics, based on LSD TEST method.
- Determining the morphological characteristics to select the frequency of them based on the logic fuzzy theory that including: Tower, entrance, front door, side and front openings, and wall type.
- Representing the characteristics according to: Dimensions: (represented in metric units), Relationships:(placing elements together), and Categories (that cannot be represented numerically)
- Prioritizing the characteristics to prevent errors or conflict as follows: block, interface and details.
- Classifying of grammars into: morphological grammar and the typological grammar.
- Apply CGA numerical grammar in procedural methodology using City Engine.

3.2.4. ŞENER -2008

- Classifying the mosque components according to the spatial characteristics into: the structural system (domes and arcades), functional components (the chapel and interior spaces), the connecting components (corridors), another components (minaret).
- Determining the central dome which restrict relations with the other the elements.
- Mathematical analysis to determine proportional systems, which includes: the interior space, the structural system, the elements (the minaret, the dome), and the plan (length and width).
- Determining the Hierarchy of components to avoid mistakes in applying the grammar.
- Testing relational grammar: roof systems, mosque spaces and components relationships.

From analysis the studies of the shape grammar in the Masses scope, the following aspects were determined:

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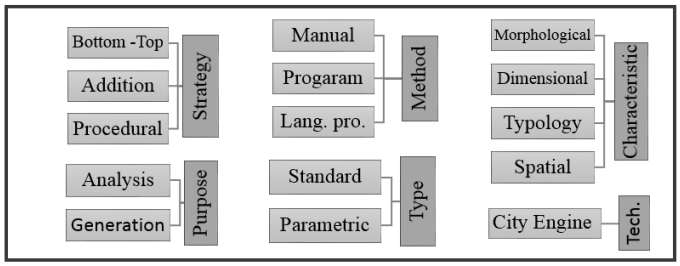

3.3. The studies in the plan scope

3.3.1. Çağdaş – 1996

- Determining the main spaces that include: Rooms, Stairs, and Halls.
- Classifying the dwellings according to the three components relationship with each to other: plan without a hall, plan with the external hall, plan with the internal hall, plan with the central hall.
- Classifying the plan according to morphological analysis to L, O, =, -, +, I, H, U.
- Typological analysis: the corner relations, the partial relations, and the integral relationships.
- Formulating the shape grammar in five stages, then applying them.

3.3.2. Stiny– 1978

- Determine the grid and the axis to define the units in specific dimensions (in the grammar of proportionality) and determine the axis to apply the concept of symmetry.
- Determine of the outer wall that restricted by the grid.
- Planning the inner spaces that depends on the grid in a rectangular or T or + shape.
- Reorganizing the internal rooms to achieve the principles of symmetry.
- Determine the main entrances: by its relationship with the axes and halls.
- Determine the column locations in the facade.
- Locating the openings that include windows and doors.

3.3.3. Ahmed – 2004

- Classifying the main components according to the morphological characteristics (symmetry, axes, orthogonal, central) and spatial elements into: the courtyard, the wall, the towers, the first fort, the secondary, the primary entrance, and the secondary,
- Classifying the plan according to the arrangement of the spatial components into: the simple plan (an open area Surrounded by a wall), the multi-cell plan (a courtyard surrounded by one floor), the complex plan (a courtyard surrounded by two floors).
- Typological analysis of the spatial elements to determine its relationships with each other.
- Defining the spatial constraints to limit irrational applications while allowing a wide range of the formation.
- Formulating the grammar: the boundaries, the cell, the fort, the entrance and the sites of the towers

3.3.4. Andaroodia – 2006

- Classifying the building style according to the determined characteristics and to the other its information such as the name, plans, location and time period, to include them in Protégé.
- Analysis of the morphological characteristic of the plans, which include orientation, axis (balance and symmetry), entrance (side, central), spatial organization of the main components that include, Yard, accessory units, Iwan, Stables, external wall towers.
- Classifying the process is according to four grammar: morphological grammars, spatial elements, dimensional parameters and functional grammars (the entrance, courtyard, and tower).
- Verification process includes: the courtyard, the iwan, the entrance, rooms adjacent to the courtyard, the room behind the iwan and the towers.
- Formulating the shape grammars. 66 grammars were formed in 21 formation processes.

3.3.5. Eilouti – 2012

- Classifying the main elements of traditional Damascene house according to the functional ,morphological and typological analysis into the courtyard (without a courtyard, owns courtyard , two, or three) , the Iwan and entrance (corner, middle, and side, and its relationship with the courtyard: directly, a broken entrance) , rooms (Organizing them around Patio: O, L, U, I), stairs.
- Organizing the plans according to the functional, and spatial characteristics.
- Dimensional analysis of the plan by parameters: dimensions, size, and proportions.
- Formulating the shape grammar according to the morphological, functional, dimensional and typological analysis from the bottom to top.
- Evaluating the grammars to derive new plans in the same traditional housing style.

3.3.6. Olakanbi -2016

- Classifying the traditional house elements according to functional and spatial characteristics into: Balcony, Circulation, Toilet, Kitchen, Room, Majlis, Stair Casr,

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Court Yard, Khazana, Moshrobiya, Darwa, Storw, Diwan, Dhlis, Kharjaia
- Representing the initial shape in the coordinate X, Y, then defining a reference point (0,0).
- Determining the parameters that enables the user to modify and derive new forms.
- Formulating the functional, spatial, and dimensional grammar of each element.
- Applying the grammar: Determining the dimensions of space by the parameters, Determining the shape of the space, Determining the entrance, and windows and finally inserting the details.

3.3.7. Eilouti -2007
- Determining the morphological characteristics that includes: symmetry, proportionality, geometrical, axes and transformation (rotation, reflection, scaling and displacement).
- Classifying of the main components according to the functional analysis: Iwan, shrine, minaret, courtyard, entrance, ablution area, and water container.
- Analyzing the structure of the plan to determine spatial relationships between spaces.
- Formulating the grammar: External Border, Interior Spaces - Distances - Iwan And Courtyards, Mihrab, Rooms - The Main Entrance - The Wall Thickness - Openings - Termination.

3.3.8. Colakoglu -2000
- Classifying the housing components according to morphological, spatial, functional, contextual, and dimensional characteristics and into: rooms, Hayat (main space) and the attached spaces.
- Generating new designs: transformation: (changing the shape), Euclidean transformation (rotation, scaling, and displacement), Parameters values and replacing elements in a model with another.
- Determine the spatial relationships between the main elements: the rooms - Hayat, the first floor - the stairs, Hayat - the stairs, the kiosk - the first floor, the ground floor - the courtyard.
- Formulating the grammar that represent three main styles of housing: Prt.A, Prt.B and Prt.C
- Appling the grammar in five stages.

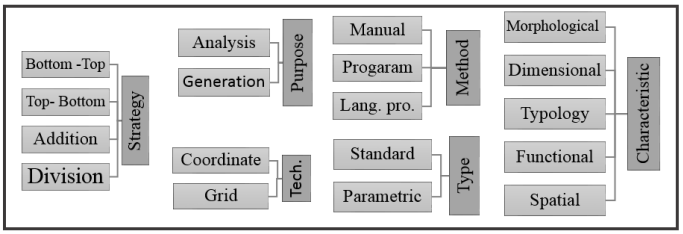
3.3.9. Chiou -1996
- Determining the mathematical systems in ancient Chinese architecture.
- Classifying the temples according to the morphological characteristics (entrances, axes, main buildings, their height, and dimensions) into: basic, longitudinal, central, and complex type.
- Determine the proportional relationships between the classified components.
- Formulating the grammar: determining the origin point 0, 0, by the label (∗), add the central room, the doors, the windows, the spaces surrounding the central rooms, the courtyard, the secondary buildings, the corridors, the roofs, the levels of openings, and termination.

3.3.10. Benros -2018
- Comparing the three shape grammar methodologies to form an effective methodology the to apply the grammar by the following operations: Addition - Union - Subtraction – Termination.
- Formulating the shape grammar of Palladian villa by top to bottom strategy by dividing the grid.
- Formulating the grammar of Malagueira residences by top to bottom strategy by adding the spaces.
- Formulating the shape grammar of Prairie housing by bottom to bottom strategy by determining the central space then adding another space.
- Apply the new methodology to produce a new design.

3.3.11. Al-Jameel -2014
- Analyzing the mosque styles according to: plane ceiling, divided plane ceiling, non-courtyard domes, courtyard with domes, domed with arcades, oblique arcades with courtyard.
- Classifying the common elements into: the outer borders, the chapel, the courtyard, the secondary spaces (arcades) and spatial elements.
- Analyzing the geometric and morphological characteristics according to: the mosque shape ،the chapel shape ،the courtyard, secondary spaces, spatial elements, and the side spaces shape.
- Topological analysis, which includes: the courtyard relationship to the mosque, the chapel relationship to the mosque, the secondary spaces relationship to the chapel, the spatial elements relationship to the chapel and secondary spaces.
- Formulating the grammar by this strategy: top -down, addition, and division.
- Generating the spaces: the outer limits, the chapel and secondary spaces, the termination

From analysis the studies of the shape grammar in the Plan scope, the following aspects were determined:

DOI: http://doi.org/10.24086/aces2020/paper.240



3.4. The studies in the facades scope

3.4.1. Kitsakis- 2017

- Classifying the traditional dwellings according to the morphological and dimensional characteristics (number of floors, ground floor level, proportions, balcony, arches, ceiling), into four types: Type A (ground floor, rectangular plan) ,Type B(two-floors, square plan) , Type C (two-floors, rectangular plan) and Type D (two floors, rectangular plan).
- Segmenting of the façade to determine the level of detail LOD to : LOD1(determine the mass of building and its proportions without detail) , LOD2, (determine the basic shape of the facade and its proportions as well as the architectural elements in Two-dimensional) and LOD3(add elements and details in 3 dimensionally from HBIM digital library).

3.4.2. CALOGERO – 2006

- Collecting and representing the data using the basic polygons to formulate the grammar.
- Analyzing the morphological characteristics of the museum facade elements.
- Applying the grammar by using City Engine after creating polygons in OBJ format.
- Creating the facade elements in 3D, which includes columns, entrances, windows and details.
- Exporting object models to build the new facade.

3.4.3. De Godoi – 2006

- Classifying the facade element according to the analysis into: entrances, windows, columns, cornice, frieze, details and other structural elements and analyzing them using the parameters.
- formulating the shape grammar from top to bottom, starting by inserting the initial shape (by width and height parameters), the cornice, the column, the openings, then inserting the details.

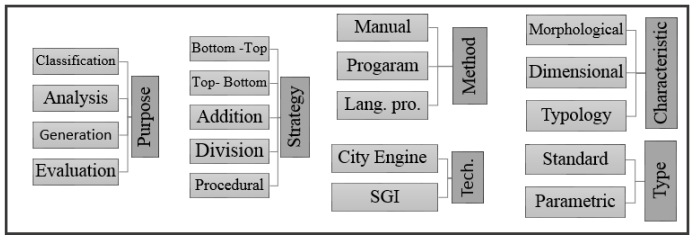
3.4.4. Lambe – 2017

- Analyzing the plans to classify them according to the spatial and functional spaces, into: courtyard, living, iwan, bedrooms, kitchen, services (bathroom, store, water tank), corridor.
- Determining the priority of applying the grammar: the central space courtyard (the initial shape), then the living space, balcony, kitchen, iwan, porch columns, arches, upper floors, and roof.

3.4.5. Ria -2016

- Classifying the houses according to originality, composition, and morphological characteristics.
- Determining the vocabulary which are two main types: common in all buildings (the high floor, the truss roof, the building block), and the secondary (found in some buildings: the balcony the courtyard, additions).
- Representing the vocabulary of facade and plans using Borland Delphi program.
- Applying the grammar with modifying the transformations such as repetition, the scale, or addition, whether in whole, partial or complex way.

From analysis the studies of the shape grammar in the Facades scope, the following aspects were determined:



3.5. The studies in the architectural elements scope

3.5.1. Castro – 2016

- Dividing the column into the main components: base, body, crown, materials, and details.
- Classifying columns into: Tuscan, Doric, Ionic, Corinthian, and Composite.
- Formulating the shape grammar of components according to stages, and sub-stage that represents the forming possibilities of the part by parameters according to the morphological analysis.
- Assembling the parts: draw a line then divide it into by points that represent the insertion of the parts, that include the inclusion the base, the body, the crown, the cornice, the arches, and the frieze
- Applying the grammar in the City Engine
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3.5.2. Al-Kazzaz – 2012

DOI: http://doi.org/10.24086/aces2020/paper.240

- Classifying process: according to the morphological, the minaret classified into 5 basic components: the base, body, balcony, lantern, head and joints between them (The functional and behavioral characteristics were neutralized).
- Determining the components of the element according to the arrangement way from bottom to top: the base, the body 1, the balcony 1, the body 2, the balcony 2, the lantern, the head.
- Formulating the original grammar, then the sub-grammar, and determining the labels of applying the grammar to represent the main components.
- dimensional analysis by determining the ratio of components by the parameters according to several numerical proportions.
- Applying and testing hybrid designs in the standards of innovation.

3.5.3. Filipe – 2012

- Determining the shape grammar for classified element.
- Create an identifying structure for shapes by parameters.
- Dimensional analysis of element to elicit mathematical equations of the element shape grammar.
- Applying the grammar and evaluating the results.

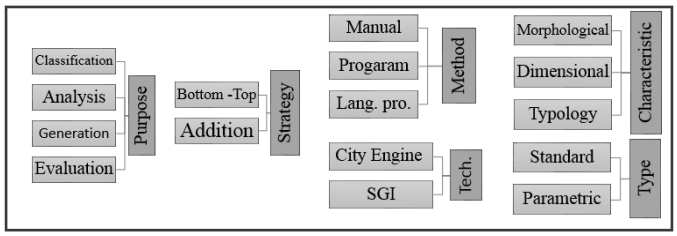
3.5.4. Marzouk -2018

- Developing the general concepts for classifying heritage elements according to the style, characteristics, proportions, state of the elements, technology, value, colour, texture and material.
- Creating a methodology that defines the functional, material, and structural characteristics.
- Classifying according to the structural behaviour of the elements: Structural elements: (vertical: columns and stairs, horizontal: bridges and lintel), and surfaces: domes, flat, and cellar) , Elements associated with structural elements(horizontal :secondary roofs, vertical :Supportive element and Handrail, and openings :doors, windows, and arches) and Stand-alone elements(horizontal :shelves and balcony, vertical :monument and statues and roofs :carved ceiling).

3.5.5. Al-Allaf-2014

- Classifying the design characteristics into primary (All entrance in a group are shared it), and secondary characteristics (which make a diversity between the entrances in the same group).
- Classifying design elements into: door step, column bases, column body, column crown, entrance lintel or arch, engraving over lintel, frieze or cornice and secondary elements.
- Classifying the entrance according to morphological characteristics and the components into: primary entrances with non-composite designs (the rectangular entrance, with a tapered Arch, and with a semicircular Arch), and composite entrances (with arche and frame, semicircular with gable, segment with gable, rectangular with side window and a wide rectangular entrance.

From analysis the studies of the shape grammar in the Elements scope, the following aspects were determined:



3.6. The studies in the architectural sections scope

3.6.1. Said – 2008

- Organizing the styles in hierarchy way from the simplest shape to the most complex ones by representing them in a simple geometrical form consisting of lines and shapes.
- Determining the central unit in these dwellings and the spaces attached to it.
- Classifying the elements according to the functional analysis to: guests' room, kitchen, bed room and services, then the components of it into: walls, columns, ceilings, floors, and openings.
- Classifying the style according to the spaces relationships to formulate the grammars.

3.6.2. Krishnamurti -1995

- Determining the initial shape, which is symbolized by a label (*), then define the axis of symmetry.
- Determining The composition of the room, by grammar: dimensions, axis, proportions, and area.
- Adding doors and windows to the central room by its parameters h, w, and u.
- Compositing the main building plan, which includes 7 grammars.
- Creating a courtyard by Determining the dimensions, width, depth, level, and corridors.
- Creating a plan for the secondary building by parameters of length, width, and depth, and Determining the spatial relationships between the two buildings, and ways to connect them.
- Determine the ceiling according to the shape of the roof, the number of layers, dimensional values, the number of

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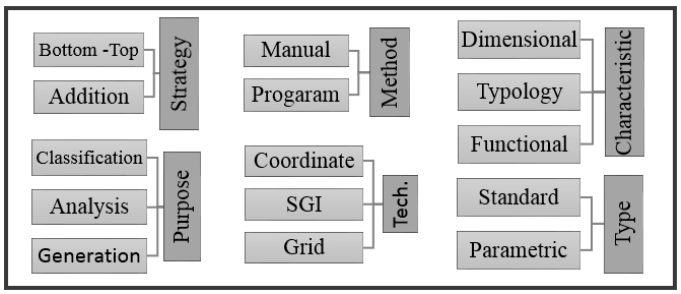
columns, the attached details, the inclination value of the roofs, the number of parts.

From analysis the studies of the shape grammar in Urban scope, the following aspects were determined:



3.7. The studies in the detail scope

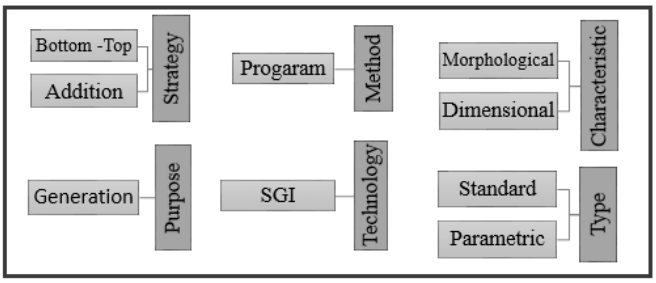
3.7.1. Yavuz1– 2016

- Classifying the facades that use bricks according to the shape, dimensions, transformation ratios and the characteristics of the brick units.
- Determining the basic parameters: brick laying method - brick dimensions - transformation ratio - material ratio - joints area.
- Classifying the patterns of arrangement of brick units: Horizontal Piling / Plain Facing (Horizontal bricks homogeneous units), Horizontal-Vertical Piling / V-Wave Facing (units in both the horizontal and vertical directions) and Oblique Piling / Spica Facing (arrangement of 45-degree brick units in both the horizontal and vertical directions).
- Applying the grammars to produce new patterns.

3.7.2. Sayed -2015

- selecting the initial shape which represented by polygons, then applying the transformation by the parameter that control the position and transformation operation of the shape including rotation, symmetry, distribution, and rhythm.
- The shape grammar was formulated in Autodesk Maya program using a Python programming language that includes a graphical user interface (GUI).

From analysis the studies of the shape grammar in the Detail scope, the following aspects were determined:



From the previous study, the vocabulary of the Shape Grammar in analyzing and classifying the heritage architecture are:

- Type of Shape Grammar
  - Standard shape grammar: This grammar applies parameters in rules to synthesis new ones.
  - Parametric shape grammar: This grammar depends on application of the rules to Initial shape.

- The Characteristics
  - Morphological Characteristics: Dealing with the external morphological properties
  - Dimensional Characteristics: Adopting mathematical analysis to determine the proportions.
  - Functional Characteristics: Acting as a restriction on the functional spaces.
  - Typological Characteristics: Determining the relationships between the elements.
  - Spatial Characteristics: Determining the location of an element in a system or a group

- The Purpose of employing Shape Grammar
  - Classifying: Grouping the element or styles that share the same characteristics from other.
  - Analyzing: Determining the Morphological and structural Characteristics of a particular style.
  - Evaluating: Determining the context of a particular element in an architectural language.
  - Generating: Creating many alternatives in the same architectural language.
- The Analyzing Methodology
  - Traditional (Manual): Representing the characteristics and rules in a drawing process.
  - Software (computer applications): Using applications in analyzing digitally.
  - Digital languages OWL, GDL, CITY GML, Python: Representing characteristics in an application.

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- The Strategy of Formulating the Shape Grammar
  - Top- Bottom Strategy: Defining external borders then adding or dividing the elements.
  - Bottom -Top Strategy: Defining a central element then adding other elements relationally.
  - Addition Strategy: Adding elements gradually according to priority to reach the final form.
  - Division Strategy: Dividing the total element into other elements to reach the final form.
  - Procedural Strategy: Modelling controlled by shape grammar in computer applications.

- The Technique of Applying the Shape Grammar
  - City Engine: A 3D modelling application for urban scale and facades as well.
  - SGI: Digital applications, based on shape grammar, for generation an architectural style.
  - Coordinate: The reference point coordinate for generating designs in a traditional method.
  - Grid: A grid-based a determined unit to apply specific shape grammar according its.

After defining the vocabulary of the shape grammar including: the methodology, technique and strategy for each scope of architecture, the optimal method for shape grammar will be determine by analyzing previous studies according to these vocabulary in Table 1.

DOI: http://doi.org/10.24086/aces2020/paper.240

Technology				Strategies					Methods			Purpose				Characteristic					Scope							Type		Title	
Grid	Coordinate	SGI	City Engine	Top- Bottom	Bottom -Top	Division	Addition	Procedural	Manual	Program	Pro. Language	Classification	Analysis	Evaluation	Generation	Dimensional	Morphological	Spatial	Typology	Functional	Urban	Mass	Planes	Facade	Elements	Section	Details	Standard	Parametric	Studies and Research	Sequence
			●		●			●		●		●			●		●	●			●	●						●		Kitsakis	1
	●			●			●		●			●			●			●		●			●					●	●	Çağdaş	2
●				●			●		●						●			●		●			●					●		Stiny	3
			●		●		●			●		●	●		●	●	●								●		●		●	Castro	4
				●			●		●			●	●			●	●		●	●			●					●	●	Ahmed	5
			●	●	●		●	●		●				●	●		●	●				●		●				●		Calogero	6
				●			●				●	●	●					●	●	●			●					●	●	Andaroodia	7
					●		●			●		●			●		●		●			●			●		●	●		SASS	8
				●			●		●			●	●	●	●		●	●						●	●			●	●	De Godoi	9
					●		●		●			●	●		●		●	●		●			●					●		Lambe	10
		●	●		●		●			●	●	●	●	●	●	●		●		●						●		●	●	Said	11
			●		●		●	●		●		●			●		●	●			●	●		●				●		Müller	12
					●		●		●				●	●	●		●								●			●	●	Al-Kazzaz	13
		●		●	●		●			●			●	●	●		●		●			●						●		Trescak	14
					●		●		●			●	●				●								●	●			●	●	Yavuz1	15
					●		●		●			●		●	●	●	●									●			●	●	Filipe	16
	●			●		●			●			●	●	●	●	●	●	●	●	●			●					●	●	Eilouti	17
					●		●			●		●			●		●	●				●	●					●		Ria	18
	●			●		●	●		●				●		●	●	●	●	●	●			●					●	●	Olakanbi	19
					●		●		●			●			●			●	●	●			●			●		●	●	Krishnamurti	20
			●		●		●	●		●	●	●	●		●	●	●	●	●			●		●	●			●	●	Tepavčević	21
		●			●		●			●	●				●	●	●										●	●	●	Sayed	22
	●			●			●		●			●			●		●	●		●			●					●	●	Eilouti	23
							●		●			●	●			●	●	●							●		●	●		Marzouk	24
					●		●		●			●	●		●	●		●	●	●			●					●	●	Colakoglu	25
	●				●		●		●			●	●		●	●		●		●			●			●		●	●	Chiou	26
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●	●			●		●			●			●			●			●	●	●			●					●		Al-Jameel	28

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							•		•			•	•				•								•			•		Al-Allaf	30
•			•		•	•	•	•		•					•		•		•		•		•				•		Zhu	31
			•		•		•			•		•			•		•	•			•	•		•	•			•		Di Angelo	32
4	7	4	8	14	16	5	27	5	18	12	5	25	17	9	27	12	23	21	13	15	4	10	15	8	11	3	4	32	19	Total	
																														Percentage	

Table No. 1, Aspects analysis of the shape grammar studies in architecture

Technology				Strategies					Methods			Purpose				Characteristic					Type		
Grid	Coordinate	SGI	City Engine	Addition	Division	Top- Bottom	Bottom -Top	Procedural	Manual	Program	Pro. Language	Classification	Analysis	Evaluation	Generation	Dimensional	Morphological	Spatial	Typology	Functional	Standard	Parametric	
0	0	0	50	75	0	25	75	75	0	99	0	75	50	0	99	0	99	66	25	0	99	0	**Urban**
0	0	30	60	90	0	10	90	50	0	99	20	70	20	30	99	20	99	70	50	10	99	20	**Mass**
20	46	6	0	87	27	53	47	0	87	13	13	80	53	20	86	40	50	93	60	80	99	73	**Planes**
13	0	13	50	99	0	13	87	50	25	75	25	75	37	37	87	25	99	75	37	13	99	50	**Facade**
9	0	9	27	99	0	9	91	18	55	45	18	90	55	36	73	45	99	45	27	0	99	63	**Element**
0	33	33	0	99	0	0	99	33	66	33	33	99	66	33	99	66	0	99	33	99	99	99	**Section**
0	0	25	0	99	0	25	75	0	25	75	25	75	50	0	75	75	99	25	25	0	99	50	**Details**

Table No. 2, the correlation results of architecture scope with the techniques and strategies, purpose, types and Characteristic of shape grammar

IV. Findings

From the analysis of previous studies, it appears that some concepts of shape grammar are associated with the type of studies in terms of the architecture scope, the techniques, and strategies that used in the analysis process. the percentage of correlation of the dependent variable (methodology, technique, strategy, purpose, type, and characteristics) with the independent variable (the scope of study: urban, mass, plans, facade, elements, details, and section) were calculated to determine the most suitable approach for each scope of architecture analyzing.

Below the conclusion of the correlation architecture scope with the techniques and strategies of shape grammar in the study cases analyzed:

4.1. Urban Scope:

1. Type of the shape grammar: This Studies relied on applying the standard grammar that depend on rules which include transformation operations on the initial shapes, and no type of parametric grammar applied in studies.
2. The Characteristics: Studies in this type focused on the morphological and structural characteristics of urban and in a lesser on spatial components and their distribution, without using the functional, dimensional, and relational characteristics.
3. The Purpose: Most studies, in the urban scope, focused on structural analysis to generate parts of urban district

DOI: http://doi.org/10.24086/aces2020/paper.240

in the same architectural language, in addition to categorizing urban components such as streets, squares, and nodes.
4. The Methodology: Urban studies used the programs and application
5. The strategy: Most studies relied on the procedural methodology in generating parts of urban district, while some studies relied on a Bottom-Top strategy by determining the place the components together and pedestrian streets adopted as the smallest component to assemble the elements according it.
6. The Technology: Most studies used the City Engine program in the application process.

4.2. Mass Scope:

1. Type of the shape grammar: Type of shape bases: This studied used the parametric in addition to the standard grammar to produce different shapes in the same style.
2. The Characteristics: This studies analysis the morphological, structural, spatial Characteristics to study the relational between the urban components, and some studies dealt with analyzing dimension to determine the proportions of the masses.
3. The Purpose: This study aims to classification and generation
4. The Methodology: This approach has relied on programs.
5. The strategy: There are two strategies in this scope, the first is procedural for the generation process, and the second is the Bottom-Top to assemble the components.
6. The Technology: Using the City Engine app to apply shape grammar by procedural method.

4.3 Plans Scope:

1. Type of the shape grammar: Standard shape grammar were applied in all studies which the applied rules on the initial shape, while parametric grammar was applied to generate an anew plan in the same language.
2. The Characteristics: this studied based on a functional analysis and spatial elements, in addition a number of studies that based on the dimensional characteristics by parameters to study the mathematical properties of the plan.
3. The Purpose: These studies seek to generate and classify plans according the analysis.
4. The Methodology: Most of these studies relied on manual analysis - drawing, while some used program languages to convert them into applications to classify them digitally.
5. The strategy: The plans adopted two types of strategies, the first Top-Bottom which the overall shape and external borders are determined, then the outer borders are divided, the second, Bottom -Top , which determine the position of a central element or space then the adding other spaces that surrounding it gradually, such as the courtyard or central hall in houses and the mosque.
6. The Technology: In the process of formulating the grammar, the X, Y coordinate axes are used to distribute the spaces by addition strategy, or the Grid by relying on the units.

4.4. Facade Scope:

1. Type of the shape grammar: In this level of facades analysis, the standard shape rules are used by applying rules on the shapes, and the parametric by parameters to Synthesis the facades.
2. The Characteristics: this study analyzed the morphological characteristics of the facade in addition to the spatial properties and relational analysis to study the positions of elements in the facade.
3. The Purpose: These studies directed towards generating the facades in the same language, in addition to classifying them according to the characteristics analyzed.
4. The Methodology: The representation of grammar was done by programs by programming language, while other studies adopted the manual method derivation of grammar.
5. The strategy: The addition strategy was adopted, that is that adding the elements according to its relationships , in two ways , the first is the Bottom-Top by adding a central element, then then the other , and the second is Top -Bottom which determine the external borders of the facade then adding the element gradually.
6. The Technology: most of the studies using the City Engine program, while some studies presented applications for generating facade after formulating the grammar.

4.5. Element Scope:

1. Type of the shape grammar: This study used the standard grammar, by analyzing the elements morphologically then grouping them. Some studies used the Parametric grammar to employ parameters to generate new elements in the same architectural language.
2. The Characteristics: Relied on Analyzing the Morphological Characteristics Mainly, Then the Dimensional Characteristics to Analyze the

DOI: http://doi.org/10.24086/aces2020/paper.240

Proportions, Then Relational Analysis to Determine the Relationships Between the Elements Component.

3. The Purpose: These studies mainly aim to classifying the architectural elements, then generating them elements and employed the grammar to evaluate the generation process.
4. The Methodology: The studies relied on manual analysis to formulate the grammar, in another study, some applications and programs were employed for that by representing the grammar digitally such as GDL \ OWL and others.
5. Strategy: The strategy: The study used Bottom-Top derivation strategy, by adding parts of the elements gradually according to the grammar.
6. The Technology: The City Engine program has been applied in a number of studies for generation of architectural elements.

4.6. Section Scope:

1. Type of the shape grammar: This study based on the parametric and standard grammar in the process of generation and analysis.
2. The Characteristics: Contained the analysis of functional and spatial characteristics, in addition the of dimensional values to determine the proportions of spaces.
3. The Purpose: The studies aim to classify and generate the designs.
4. The Methodology: The grammar in this study were formulated manually, and in some studies, many programs were used in the formulating process.
5. The strategy: All studies based on a Bottom- Top strategy by addition process.
6. The Technology: Relied on the coordinates to generate the sections of spaces because of The possibility of coordinates to deal with dimensional analysis.

4.7. Details Scope:

1. Type of the shape grammar: This scope of studying used standard and parametric grammar in formulating shape grammar.
2. The Characteristics: It depends mainly on the morphological and dimensional characteristics.
3. The Purpose: These studies aim to generate designs.
4. The Methodology: Depends on generation software.
5. The strategy: Depends on the Bottom-Top strategy by addition process.
6. The Technology: Some studies have employed a program for generation patterns
7.

V. Conclusions

In architectural theory and practice, the context plays an important role in proposing architectural vocabulary. Contextual structure theory refers to the relationship between new buildings and the current environment during the process of adding new buildings and the restoration processes of the old buildings to achieve harmony and communication between the past and the present , so the shape grammar is one of the important approach to achieve Contextual in built heritage by generating new designs based on the existing architectural style without restricting the designer. local or traditional architecture represents a cumulative knowledge foe heritage resulting from construction techniques and local materials that make a distinct architecture language. the conservation process required to defined the knowledge foundations n which it is based. So, several methodologies have been employed to represent knowledge of this architecture, Perhaps the most prominent of it is the shape grammar that analyses and classifies the architectural elements according its common characteristic in many scopes of architecture including the Urban, Mass, Facade, Plan, Sections, Element, and Details.

The importance of shape grammar in analyzing architecture structure is attributed to the ability of it to combine morphological and dimensional analysis as an algorithm for analyzing the architecture structure into vocabulary according a various characteristic including functional, morphological, dimensional, spatial and typological characteristics. This feature enabled the shape grammar to analysis the existing architecture in general, and traditional, in particular, to determine its characteristics in order to restore the virtual reconstruction of the architecture without changing its language. According to this, many international experiences have employed the shape of grammar in conservation and representation the characteristics heritage element by several methodologies such as computer applications and programming languages according to the purpose of the studying that includes: generation, evaluating, classifying the heritage elements. The results of the research showed the importance of shape grammar as a supportive approach in conservation and restoration architecture.

VI. Recommendations:

1. Providing a database for specialists which adopts the shape grammar for local architecture.
2. Digitization the shape grammar in a computerized application to facilitate the deal with it to encourage architects and to design in the local architecture style.
3. Studying the methodologies of formulating grammar and determine the optimal ones for each scope of architecture.

DOI: http://doi.org/10.24086/aces2020/paper.240

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