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Explaining the Evolution of Iranian Traditional House Spaces Based on Distance Measurement Method of Plan Similarity Vector

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Abstract

Analyzing the evolution of architectural plans has long been an issue of interest to all researchers and designers worldwide, so how to create and develop traditional architectural spaces has been examined many times by researchers. However, most of these studies have limitations in the number of plans, algorithms, or data analysis methods. Now the question arises as to what method and tools can be used to create a process to provide a more comprehensive evolution and classification of traditional architectural plans. Therefore the ultimate goal of the research is to investigate and present a new classification based on simultaneous processing of available data in these plans.
Nevertheless, a distinct and combined research method has been used to achieve this goal, including quantitative, analytical, and historical methods. The research hypothesis is based on the fact that the purpose of the research can be achieved with the help of image processing algorithms and mathematical formulas and numerical data in the plan. Finally, the findings of this research show that it is possible to compare a large number of plans simultaneously by distance measurement method and using artificial intelligence and to extract a pattern from common and uncommon space dimensions.

Keywords: Similarities, Spatial relationships, Distance measurements, House plans.

1. Introduction

Architecture and urban planning require interdisciplinary and systematic thinking. Therefore, architecture must break the boundaries that it has drawn for itself and imprisoned itself in it, and respond to society's current and future needs like the past architects (Babakhani, 2018: 26). Peter Drucker states; We are on the verge of entering a "knowledge-based society" in which the main source of economy is not capital or natural resources and labor, but only knowledge is considered the only significant source in the world (Nonaka and Takuchi, 2005: 95). This is the alarm that Drucker mentioned two decades ago and states that the main source is knowledge, knowledge whose data volume is increasing many times more than the previous days, and on the other hand, its structure and foundations are more than ever being reduced to lower levels.
Therefore, according to Drucker, moving towards new knowledge will make the future of previous knowledge, and perhaps the secret of their permanence will be in the introduction of new knowledge. One of this knowledge is artificial intelligence, the increasing development of its algorithms in the world has provided a new platform for entering various industries such as banking, insurance, communications, etc., and sooner or later, the construction industry in its disciplines such as architecture, urban planning, civil engineering, and project management will enter this context.

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There have been various debates about what parts of the AI will affect the architecture, but everyone agrees on the introduction of artificial intelligence in architectural processes independent of pure software aspects. One of these important areas is discussing data and information analysis and performing the data mining process on traditional architectural data with modern methods. Traditional Iranian architecture as an ancient knowledge dating back several thousand years has a wealth of different data in various uses such as residential, religious, travel, and other buildings that should be categorized and clustered for extracting data related to architecture so that the movement of these spaces over time can be observed and their interaction with each other can be evaluated.
This evaluation can examine the way architectural knowledge interacts with today's society. For example, houses in the architecture of the world and Iran have the highest frequency in terms of quantitative and qualitative volume in the production of information and data; houses have been built or destroyed in large numbers in each historical period. The available data on the architecture of houses in each era reflects the different cultural, economic, social, political, and technological conditions of the time.
In traditional architecture, recognizing and understanding the needs of society has been done based on different criteria and based on these needs, very functional spaces have been created, one of which is the house and garden house (Khaneh bagh), but for weak reasons, less attention

has been paid to it in our architecture. Unfortunately, this topic has not been examined in architecture departments. The need for these spaces is very much felt at this time, and this need must be met by recognizing the past architecture and adapting it to the present-day's architecture (Pirnia 1992, 153). The design of architectural spaces deals with principles that have a decisive effect on replacing different units. These principles originate from people's habits, needs, and desires (Tavassoli, 1997, 13). One of these principles, which is formed from the people's demands over time, is the spatial dimensions, size, and relations.

To address this evolution in the architecture of traditional Iranian houses, a new classification is needed based on high frequency and fast processing on various data such as spatial relations, dimensions of spaces, building elements, openings, and other issues related to the traditional architecture of Iranian houses, in this research with the help of image processing algorithms and mathematical formulas, we discuss the evolution of traditional Iranian houses in the historical period of Qajar kingdom in order to extract the evolution in the dimensions of traditional house space.

The question of this research is based on the fact that what method and tool can be used to create a process to provide the evolution of spatial dimensions simultaneously, sizes and relationships of traditional Iranian house architecture with a high number and a new classification based on high frequency and fast and simultaneous processing of various data such as; spatial relationships, dimensions of spaces, constituent elements, openings and other issues related to the traditional architecture of Iranian houses, which in this research our hypothesis emphasizes that with the help of image processing algorithms and mathematical formulas and conversion of numerical data in architectural plans to recognizable vectors by algorithms can be brought to discuss the evolution of traditional Iranian houses in the Safavid to Qajar historical periods. The ultimate goal of the research is to provide a new classification of traditional house architecture plans based on the simultaneous processing of existing data (spatial relationships, dimensions of spaces, constituent elements, openings) in these plans.

2. Research Background

In 2017, Rodriguez and his colleagues at the University of Coimbra, Portugal, tested a similarity comparison process on a 70-plan database. This research is intended to perform artificial intelligence classification and clustering operations in the Java programming environment.

Rodriguez and his colleagues were looking for the best way to classify plans by artificial intelligence. The published results of this research indicate that the use of the network matrix distance method has higher accuracy in classifying and clustering architectural plans (Rodrigues and Sampayo et al. l, 2017). There is no extensive research in classifying plans and discovering their spatial relations with the help of artificial intelligence and image processing methods, but much research has been done traditionally. We do not desire to express previous research in traditional ways because of the current research approach.

Also, in a research in 2017, Martin Stacey Rawls, with the method of spoken grammar and creating various conditions, plans the generation and classification of the plan on the square and rectangle divisions, and to some extent, succeeds in producing limited samples (Stacey, 2017,2). In this method, architectural rules are converted into programming language commands. Then plan samples are entered into this process and based on the characteristics of the commands; they are placed in several categories, which, in this method, architectural rules are only the basis for categorizing, and the base plan does not exist for physical texture and form.

Also, in 2020, Feng Shi and his colleagues were able to provide appropriate divisions and classifications on the structure of rectangular lands by using the Monte Carlo tree search (Shia, 2020, 187). In this method, the classification is implemented based on the search for tree nodes. In fact, in this process, the nodes that have similarities in the command structure of the plans are placed in a category.

In 2019, Stanislas Chaillou at Harvard University researched new plans based on Gothic architectural patterns. In this research, with the help of GAN algorithms, he generates and categorizes plans with Gothic period components and indicators (Chaillou, 2019). Unlike previous research, Chaillou's research is based solely on the images of architectural plans, i.e., here the rules, dimensions, and sizes are weighed by a matrix method of scanned image pixels of architectural plans in an artificial neural network and then categorized based on the similarity of pixels of the architectural plans.

What can be deduced from the results and processes of previous researches, in all cases in which various algorithms such as network matrix, spoken grammar, conditions, tree search, and conflict generating networks have been used, the processes are one-way, i.e., in some cases, only dimensions and sizes are involved. In some cases, only the physical and apparent form of the plans is the basis of classification. However, in this research, the classification of plans and the recognition of their spatial relationships have been performed using artificial intelligence with different and combined processing methods, the Euclidean distance measurement formula, and numerical vectors.

3. Research Methodology

This research has been performed by quantitative, analytical, and historical methods and using Euclidean distance measuring formulas and 30 cases of traditional house plans of the Qajar period. These plans were selected based on random selection from the data of the Cultural Heritage Organization of Iran and converted into the database. Architectural plans are one of the most important architectural information with a very high and important information load. Architectural plans provide quantitative information, spatial relations, spaces, openings, and other available elements. However, this

type of research cannot evaluate architectural plans, which use new methods without changes and conversion into machine language, i.e., numerical vectors.
We must first train the main element in architectural plans, line, and point, to image processing algorithms to achieve this goal. Because the line and the dot are the main elements of the plan are transforming the data into metadata, i.e., labeling them and finally forming information, each line and point in the two-dimensional plane of the plan, which is displayed on the x and y-axis, is responsible for generating data. Nevertheless, the main point here is the language of computer learning, which is the language of numbers and vectors or matrices, meaning that mathematics is the only machine learning method that is understood in the form of numbers 1, 0, or RGB or BGR color codes.
Nevertheless, to achieve this goal and train architectural lines and points to the machine, the data must be prepared based on the numbers 0 and 1, and these concepts must be transferred to learn machine through vectors or matrices. To do this, each space is processed clockwise to codes 0 and 1 and then converted to a two-dimensional matrix.
That is, the first space in the plan will be the basis for starting the movement from the top left, in a clockwise direction, and then the next spaces will be converted one by one into a vector of dimensions of the spaces, spatial relations, and opening elements until they reach the starting point again. The length of the vector is based on the number of spaces in the architectural plans; that is, the more spaces there, the longer the vectors will be.

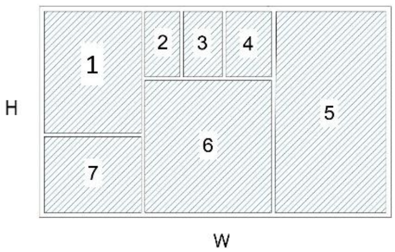
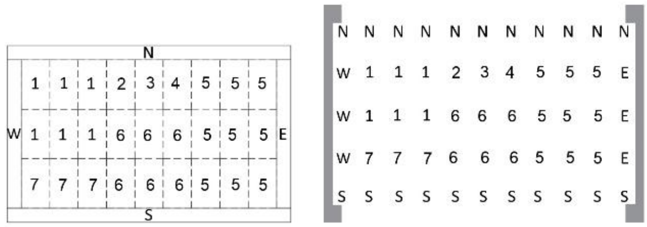


Fig. 1. Selecting spaces based on the clockwise direction to convert the plan into a spatial relations matrix.

After generating the required vectors, these vectors must be converted into a matrix of numbers. For example, in spatial relations, if space is connected to its adjacent space through a door opening, the number one must be placed in the matrix, and if it is unrelated, the number zero and if the space is interconnected, i.e., one space is nested from another space, it will be displayed with the number two. These numbers, which form the matrix in geographical directions, represent the condition of the plan from different perspectives.
For example, a matrix is made of elements that connect the spaces for spatial elements. This matrix indicates which space is adjacent to one space and by which element (door, window, porch, corridor, etc.) has been formed, and finally, if the differences in the matrices are made with the help of calculations, it is possible to extract the dissimilarity or similarity of the plans and provide a new classification.



Numerical string = [1,1,1,2,3,4,5,5,5,1,1,1,6,6,6,5,5,5,7,7,7,6,6,6,5,5,5]

Fig. 2. The manual method of converting a plan into a matrix for machine learning.

After converting the plans in the database into matrices, all of these matrices must now be subdivided into numerical feature vectors that the similarity cosine formula can calculate by a distance measurement at the cosine distance of two vectors.
The method of calculating the cosine similarity measure proposed by Collins is a measure of similarity between two non-zero vectors of an inner product space based on measuring the cosine of the angle between them. In this method, the cosine of 0 is one, which is less than 1 for any angles. It is thus a judgment of orientation and not magnitude: two vectors with the same orientation have a cosine similarity of 1, and two vectors opposed have a similarity of -1 (Farhadi and Jamzadeh, 2018, 21).
The cosine similarity is particularly used in positive space where the outcome is bounded in [0,1]. The cosine of two non-zero vectors can be derived using the Euclidean dot product formula: A.B = | (| A |) | | (| B |) | cos θ. When the cosine similarity is calculated using two data feature vectors using dot product, the formula in figure 3 will be the measurement criterion (Garcia, 2018, 9).

$$\text{similarity} = \cos(\theta) = \frac{A.B}{||A||\,||B||} = \frac{\sum_{i=1} A_i \times B_i}{\sqrt{\sum^{n}_{i=1}(A)^2} \times \sqrt{\sum^{n}_{i=1}(B)^2}}$$

Fig. 3.calculating the angle of cosine distance’s formula.

In the next step, the scanned images of the researched plans are converted by the scripts written in Python programming language into numerical data, and then a matrix of RGB or BGR numbers is made. Finally, this matrix is converted into a vector, and it has been evaluated with other samples using the Euclidean distance measurement formula. In fact, in this research, all computational and processing processes are coded through the Python programming language in special scripts.

4. Discussion

The case study of this research is based on the similarity in the evolution of house plans of the Qajar era based on figure 4. The number of these residential plans is 30. The method of selecting these plans is based on the historical period, climatic proximity, and close style in Qajar eras randomly expressed from samples with conditions (historical period, climatic proximity, and close style). These plans were taken by the Cultural Heritage

Organization and registered in the list of national monuments.

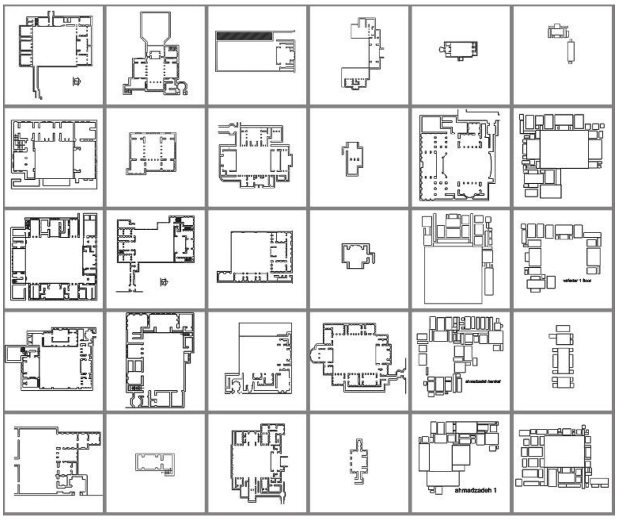


Fig.4.The sample plans that were reviewed.

5. Results and Discussion

Examining the evolution of traditional Iranian houses in the Qajar era shows that in these 30 buildings studied, there is a relationship between the minimum and maximum width and length of buildings, which these dimensions can be the initial basis for classification based on the dimensional structure of the spaces of each architectural plan. Also, the studied plans have several different spaces, which will be one of the effective indicators in plan classification. The spatial diversity of the plans is in the numerical average of 14 spaces, and several buildings have more spaces than this, which its factors can be discussed in another research. Figure 5 shows the minimum width of the plans in the studied samples starting from 7 meters and extending up to 40 meters and also their length starting from at least 10 meters to 60 meters.

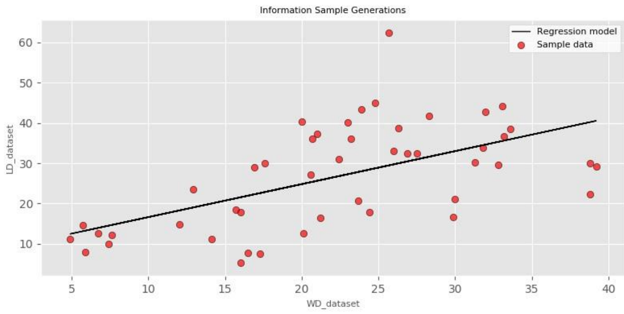


Fig. 5. Investigate the correlation between the width and length of the studied plans.

It should be noted that there is a positive correlation in the movement of the plans, and the space of the studied plans over time has increased in their frequency and dimensions so that in figure 6, high diversity of classifying 30 case studies can be observed Qajar era using the tree diagram. In this diagram, the classification of plants has been provided based on spatial dimensions and similarity in quantitative structures of plan spaces.

According to figure 6, this diagram aims to display the variety of scale and extent of the structure of dimensions and sizes in the architecture of traditional house plans under research, that is, in this diagram, there is a main category that can be called the category of traditional house plans space in Iran. It is blue and includes the main space and sub-space of 30 samples examined in this article. This category is divided into two other categories and is expressed in red colors. This division is based on the dimensions and size of the land and the dimensions of the spaces within the plans, and then the two open sub-categories are divided into two other sub-categories.

Eventually, each of the subcategories or secondary categories that are close in size and dimensions are subdivided into more detailed subsets, which indicates the fact that the 30 samples examined in this diagram each based on land area and the need for living spaces of individuals have a structure of different spatial divisions in terms of dimensions and sizes. In fact, in this period of Iranian house architecture, there is no standard or at least specific and defined dimensions for the space of traditional Iranian houses, and the dimensions of the spaces are created based on the needs of users as well as the design range (land area) and experience of traditional architects.

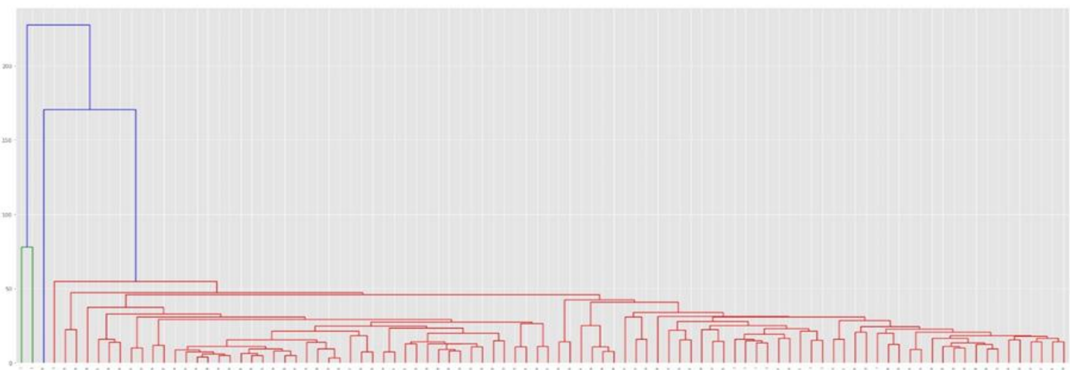


Fig. 6. Divide and classify the studied plans into a tree diagram.

According to figure 7, the frequency and final categories of the studied plans can be observed. In figure 7, the wide range of pigments represent the diversity of architectural plans, and the diversity of their color spectrum indicates the frequency range and different types of plans. The main colors represent the main categories of plans, and the combined colors represent the plans in these intervals, which are drawn in the x, y, z-axis of figure 7 as the coordinate axis.

Several categories can be seen in blue, red, green, orange, and yellow; for example, the most scattered or categorized blue color is in the range of 5 to 5, while red is in the range of zero to 5, but the yellow color is accumulated in the numerical range of 5 to 20, this composition and variety in the color spectrum of pigments, which represents the dimensions of the spaces of architectural plans, shows that how many categories are there and the numerical range of these spectra is in what range.

Fig. 7. Investigating the data structure of plans in three-dimensional space.

In the next stage, after examining the plan classification, a similarity process should now be performed on the plans selected from the database with the other corresponding plans. For this purpose, 30 plans have been selected, each of which has been compared with the other 30 plans as a feature vector, and then the percentage of their similarity has become a matrix of numbers, which is the percentage of similarity of each plan with other plans.

Figure 8 indicates a matrix of the percentage of similarity of the studied architectural plans, which shows the similarities above 70% in the numerical range of 70 to 100, and shows similarities less than that using the letter NaN. In figure 9, similarities are assigned to plans that have more than 80% similarity.

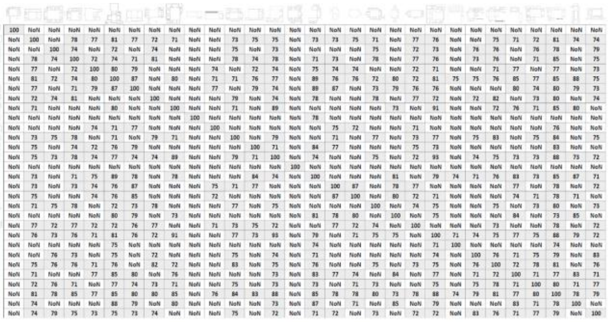


Fig.8.Similarity plans and similarity table more than 70%.

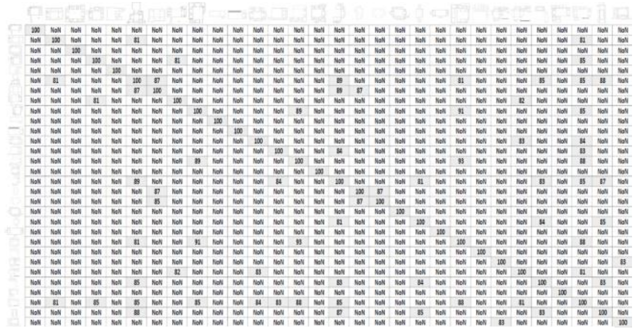


Fig.9.Similarity plans and similarity table more than 80%.

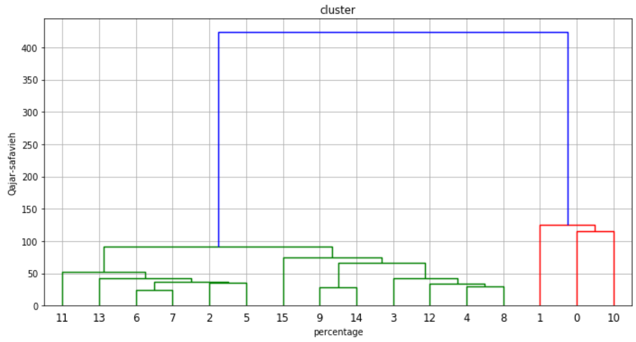


Fig. 10.Tree diagram from fifteen selected plans.

Fifteen plans were selected from the research samples and classified by the tree division method to validate the research. In figure 9, the X-axis indicates indices from 0 to 15, which are the plans examined in this tree diagram in which there are two main categories and four subcategories. For example, plans number 11, 13, 5, 6, 7, 2 are in the same category and have high similarity in their structure, and also other plans are classified in such a way that this percentage of similarities is derived from the similarity in the dimensions of the spaces that each plan has in its structure.

Finally, according to figure 11, all 15 case samples are de-noised; the big data is identified and placed in the classification process. For example, number 1 has two large samples that the first noise is in the range of 20 and the second is in the range of 40, i.e., the spaces of plan number 1 are out of the size of other spaces in 2 cases, which indicates the movement in the spaces of plans in two parts, the first part follows almost the same dimensions between 1 to 10 meters and the second part indicates dimensions between 10 and 40 meters as common spaces in the studied plans.

The 15 samples examined according to figure 11, which indicates the body part of the drawn boxplot, contain information about the spaces of the studied plans, which express the common dimensions, and these dimensions are between 4 to 8 meters. The boxplot categories indicates the dimensions of the spaces in the plan that follow the common mode but in higher or lower dimensions than the higher frequency in the plans. Finally, the upper part of the boxplots, which are in the form of dots, express a number between 10 and 40 meters which the plans studied are in spaces more than 10 meters and up to 40 meters, and also the number of these points at the top of the boxplots indicates the number of samples outside the common dimensions among the spaces of architectural plans.

Finally, it should be said that data analysis indicates that the evolution in these 30 samples and the 15 final selected samples in terms of spatial dimensions have two parts, the first part of this evolution is in the range of common dimensions and the second part in a non-common and varied range.

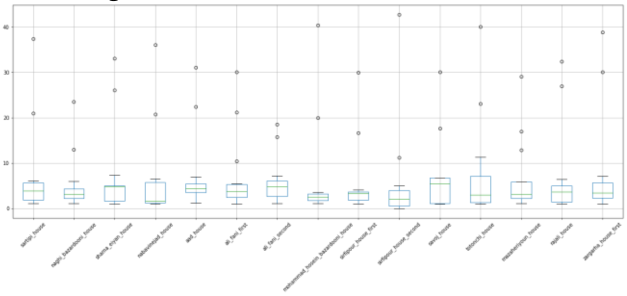


Fig. 11.review of noise data selected from the final fifteen plans.

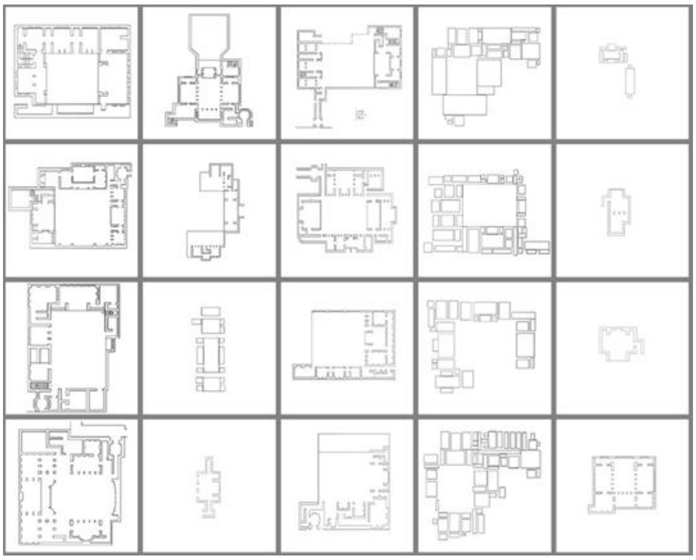


Fig. 12. Plans that are most similar in terms of form and spatial relationship with each other.

In fact, in figure 12, each column shows that these four plans are similar in form and spatial elements and are in the same category. According to Cullens's similarity and Euclidean distance measurement criteria, the form and spatial data of the examined plans have more than 80% similarity.

6. Conclusion

The results of this research indicate that in examining the evolution of the plan, 30 case studies from the Qajar historical period in 20 cases, there is more than 80% similarity in dimensions of spaces in the plans, and also all plans are in two main categories, each of which has special features and create other sub-categories, which are based on the percentage of similarity in the dimensions of the plan spaces. Also, the dimensions of spaces have two general structures; the initial structure indicates the common dimensions of spaces in the range of 4 to 8 meters, and the next range indicates the dimensions of non-common spaces in a number between 10 to 40 meters, which suggests the evolution of plans in this historical era, an evolution that occurred in the dimensions of spaces and all spaces have become two basic categories that it is suggested in another research, the effect of space dimensions on spatial relations as well as the dimensions of openings in residential plans must be considered.

Based on the data analysis process, out of 30 samples examined, 20 samples are in 4 general categories, which shows 80% similarity in terms of similarity criteria. There is also a positive correlation in the movement of plans, and the space of plans has been added over time on their frequency and dimensions. Thus, we can witness the evolution that has occurred in the dimensions of spaces, and all spaces have become two basic categories that can be examined in another research the effect of spatial dimensions in spatial relationships and the dimensions of openings of residential plans.

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