The Elucidation of Terraced Housing in Iranian Vernacular Architecture through Fractal Models: In Case of Masouleh and Abyaneh Settlements

Ehsan Reza

Submitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
in
Architecture

Eastern Mediterranean University
July 2016
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

Prof. Dr. Cem Tanova
Acting Director

I certify that this thesis satisfies the requirements as a thesis for the degree of Doctor of Philosophy in Architecture.

Prof. Dr. Özgür Dinçyürek
Chair, Department of Architecture

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Doctor of Philosophy in Architecture.

Prof. Dr. Özgür Dinçyürek
Supervisor

Examining Committee

1. Prof. Dr. Özgür Dinçyürek
2. Prof. Dr. Kokan Grchev
3. Prof. Dr. Nuran Kara Pilehvarian
4. Assoc. Prof. Dr. Kağan Günçe
5. Assoc. Prof. Dr. Özlem Olgaç Türker

ABSTRACT

The Latin term “Vernaculus” which means ‘native’ generates the terminology of vernacular architecture. It represents the architecture of people that defining the built environment. Accordingly, this terminology makes reference to the sense of place attachments to the designated context by the inhabitants, wherein they are rooted in the specific origin points that refer to their distinct race and homeland.

This research is based on identifying the vernacular architecture of Iran; specifically by focusing on steepy land context so-called terraced housing. Aimed to drive fruitful design principles qualified to be applicable to contemporary architecture, are investigated. It should be noticed that Iranian terraced housing precedence have been remained literally unique in accordance with their local entity and heterogeneity among their topography; in comparison with various form of terraced housing all around the world.

The identification of these settlements was evaluated according to the topography, climate, urban pattern and spatial organization of Iranian terraced settlements. As an outcome, the analysis of case studies and data processing will enable decision makers, planners, architects and designers to become more aware of the existing architectural ritual. The contemporary housing design problems can be solved by employing an appropriate method of design and building construction with reference to the present vernacular housing stock.

In the second half of Twentieth Century, many different methods were used in order to study formation and development of traditional settlements. One of these is fractal

geometry that is based on mathematical algorithm. Fractal geometry is particularly focusing on organic patterns, which have been developed and diversified in vernacular architecture. There are many useful thoughts that can be learnt from the organic patterns and from searching for the randomness and self-similarity of a vernacular settlement.

This study is going to investigate some critical points of the application of box-counting method to the evaluation of fractal dimension of some chosen vernacular settlements. The relationships amongst the topography, elevation and urban pattern are analyzed in two selected Iranian terraced settlements; Masouleh and Abyaneh.

The investigation will be accomplished through fractal analysis of two different villages in different geography of Iran. By referring to the fractal dimension calculated with box-counting method, different type of information will be collected about mentioned vernacular settlements. The new housing pattern will be proposed according to the cellular automata theory.

Keywords: Terraced house type, Vernacular architecture, Fractal Dimension, Box-Counting Method, Iran.

ÖZ

Yöresel mimarlık, Latince ‘vernaculus’ kelimesinden türeyip, ‘yerli’ anlamındadır. Yapı çevresini tanımlaya yerel insanların mimarisini temsil etmektedir. Bu terminoloji, insanların bölgeye olan aidiyeti, nereden oldukları, kendi orijinal ırkı veya memleketinin temsili anlamına gelir.

Teras evleri (basamak/merdiven konut) adı ile bilinen, İran’da eğimli arazide gelişen yöresel mimarinin, yararlı tasarım prensiplerini analiz ederek çağdaş mimariye uygulamak, bu çalışmanın temelini oluşturmaktadır. Tüm dünyada birçok örneği bulunmakla birlikte, İran teras evleri bu coğrafyadaki yöresel zenginliği ve farklılıkları ile eşsizdir. Bu köylerin belirlenmesi İran teraslı yerleşkelerinin, iklim, kentsel doku ve mekansal organizasyonuna göre değerlendirilmiştir. Sonuç olarak, örnek çalışmalar ve oluşturulacak veri tabanı sayesinde planlamacılar, mimarlar ve tasarımcılar, mevcut mimari doku hakkinda daha çok bilgi sahibi olacaklardır. Çağdaş konut tasarım sorunları; uygun tasarım yöntemleri ve yapım teknikleri kullanılarak ve mevcut geleneksel konut stokunu referans alarak çözülebilir.

Yirminci yüzyılın ikinci yarısında, geleneksel yerleşim oluşumunu ve gelişimini incelemek amacıyla birçok farklı yöntemler kullanılmıştır. Bunlardan birisi matematiksel algoritmaya dayanan fraktal geometridir. Fraktal geometride, özellikle gelişmiş ve yöresel mimaride çeşitlenmiş organik desenler üzerinde durulmaktadır.

Bir yerel yerleşim biçimi; organik kalıplarından, rastgelelik arayışından ve kendine benzerlik gibi birçok yararlı düşüncelerden öğrenilebilir.

Bu çalışma, bazı seçilmiş yerel yerleşim birimlerinin fraktal boyutunun değerlendirilmesi ve kutu sayma yönteminin uygulanmasındaki bazı kritik noktaları araştırmaktadır. Topografya, görünüş/cephe ve kent dokusu arasındaki ilişkilerden dolayı seçilen iki İran teraslı yerleşim yeri, Masouleh ve Abyaneh, analiz edilmektedir

Araştırma, İran'ın iki farklı coğrafi bölgesinde bulunan köylerin fraktal analizi yoluyla gerçekleştirilecektir. Kutu - sayma yöntemi ile hesaplanan fraktal boyuta atıfta bulunarak, ilgili yöresel yerleşim yerleri hakkında farklı bilgi türleri elde edilecektir. Hücresel otomata teorisine göre yeni konut örüntüsü önerilecektir.

Anahtar Kelimeler: Teras ev tipi, Geleneksel mimari, Fraktal Boyut, Kutu- Sayma Yöntemi, İran

To My Family

ACKNOWLEDGMENT

First of all, I would like to fully extend my respect to my invaluable supervisor, Prof. Dr. Özgür Dinçyürek; and my gratitude for his academic guidance, which always encouraged me more in the process of completing this study. There is no doubt that without his precise supervisions and constructive comments this research would not have been successfully done.

I would like also to appreciate the members of scientific committee, Assoc. Prof. Dr. Asu Tozan and Assoc. Prof. Dr. Özlem Olgaç Türker; who have deliberatively contributed all the time to the progress, and the process of assessment for this dissertation.

I would like to express all my appreciation to Prof. Dr. Prof. Dr. Yonca Hürol for all her academic efforts aiming to provide a ground for doing such a study.

Moreover, it should be stated that the study would not have been possible without kindnesses and also precious motivations given by Assoc. Prof. Dr. Sadiye Müjdem Vural, and my friend Kamiar Yazdani. Also, I would like to extend my appreciation to Assist. Prof. Dr. Öznem Şahali for her valuable support in this process.

And finally, I am always deeply grateful for having the important roles and unconditional supports of my lovely family in all aspects of my life, specifically in accomplishment of this and broadly, in all levels of my education.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

1.1 Problem Statement

Architecture and human needs are in direct relation in first step. Indeed, interfacing of mentioned concepts are always impacted by several parameters including; culture, economy, politics, society, religion and beliefs, which generate local identity together with formal approaches in built settings as the result.

Disregarding the know-how and mislaid of local identity from prior descendant in architectural discipline, began to emerge in the period of the industrial revolution and vested afterwards. A thoughtful problem in identity and arrangement of the built environment has been caused by detachments of human beings from nature and ignorance to the admiration of the existing environmental settlements.

As a result, the contemporary decision makers and emerged a kind of “identity crisis” in architecture, are evident of disappearance of some major factors including contextual design, environment friendly concerns in building design and regards to the cultural patterns.

Vernacular architecture is an organic architecture, which is usually formed according to many different factors such as environment and culture. Therefore, understanding these geometries of its urban pattern and building form is not easy and usually it is

very complicated. Formal architectural approaches have used mostly Euclidean geometry that represents pure volumes that can be defined by regular forms. Organic geometries do not have certain shape and organization like natural objects such as mountains.

Vernacular architecture has this organic geometry of natural objects whereas contemporary settlements are mostly forming a totally different geometry than the natural environment. In this context, in the light of vernacular architecture, nature friendly design approaches, which are generally lost in contemporary cities, can be achieved. By understanding the necessities of vernacular architecture, it is highly important to revive the traditional techniques in today's architecture. There is a vital need to think about and examine a few areas as contextual investigations; find their possibilities, put the consequence of studies all together, exhibit them by order, and finally as a result, introducing them as applicable model in contemporary architecture.

1.2 Aim and Objective

In the dissertation, it is aimed to prove the necessity of the systematic development of the vernacular architecture by proposing new methodology for the further studies of new housing developments in contemporary architecture.

The literature reviews are mostly based on the general description of the vernacular architecture, fractal geometry and cellular automata. Finding a solid relationship in between vernacular architecture and fractal geometry to help reviving vernacular architecture by then to achieve an standard applicable contemporary housing is the main aim of this study. As it is mentioned before, fractal geometry will be used as a

main tool, therefore, understanding the importance of the usage of it, in contemporary design and architecture will be explained. Moreover, it should be mentioned that fractal geometry is based on the density ratio of pattern. Therefore by focusing on the term pattern, the fractal geometry and fractal dimension will be explained.

According to this ideology the general description of fractal theory and geometry will be clarified from many different points of view of scholars; therefore, simulation of these villages will be done by the help of analysis of some specific villages, in contemporary architecture.

1.3 Research Limitation

This study will be the result of four different professions; physics, mathematics, computer software and architecture. By considering the multi-dimensional essence of this research, the limitation should be appropriately characterized to accomplish the accurate result. In this sense, topographical constrain, significantly generates the initial limitation of the research. Amid this study, only the urban vernacular settlements, which are placed on steep topography, will be sought. Terraced houses are an architectural solution for steep topography. Without any doubt, Iran is a country surrounded by various mountains. Accordingly, by considering the existence of the variations in topography, geographical and climatic issues related, hence there are many thoughtful lessons that can be learnt in the light of vernacular architecture of the region. Moreover, the dense housing in urban vernacular settlements can be enlightening the contemporary dense housing.

For such topography Iran is selected with its two vernacular architecture cases; Masouleh and Abyaneh settlements. The Terraced houses in these two settlements

have certain patterns. With the help of fractal geometry, mentioned patterns within the local building culture would be found. For finding the fractal geometry and regenerating the pattern, fractal dimension has to be calculated. There are many different methods for finding fractal dimension such as walking-divider, box counting, prism counting, epsilon-blanket, perimeter-area relationship, hybrid, power spectrum, fractional Brownian motion, variogram, isarithm, etc. in many different fields. By comparing different mentioned methodology, it could be concluded that, box-counting method, in architecture, is the most reliable and practical methodology. For this reason, box-counting method will be used for finding the fractal dimension in this study. Also there are many software and programmes, which are available for simulation of those rural settlements, but Fractal Analysis System for Windows, fractal3 by Hiroyuki Sasaki is the programme (based on box counting algorithm) that will be used in this study. Finally cellular automata methodology will be used for proposing new settlements.

1.4 Research Methodology

According to the diverse interpretation of researchers from different disciplines in term of architects, mathematicians, urban planners, decision makers, computer software developers, etc., numerous approaches can be followed in the following studies.

The framework of this dissertation was shaped towards qualitative and quantitative approaches, therefore for this purpose; there are two types of engagement to the subject mentioned below;

- **Literature review:** It will be the initial level of contributions through finding obtainable publications in the research areas, in the field of vernacular

architecture, contemporary housing, settlement pattern, fractal geometry, fractal dimension and investigating the references relative with formal and functional approaches to the vernacular architecture.

- **Data collection:** To investigate collected data of housing based on vernacular architecture literature, it will be fruitful to declare a domestic investigation in its distinctive vernacular architecture. This will be applied by getting aid of:
  - Photography Documentations
  - Sketches of cases on the site
  - Data analysis of the plans and elevations.
  - Finding the proportions and ratios of these organic settlements according to the fractal geometries, by box counting (graphical and mathematical).
  - Collecting data, analysing and decoding them manually according to fractal geometries (finding fractal dimensions) and computerizing them by "fractal3" software for reviving the vernacular architecture in contemporary architecture.
  - Cellular automata (CA) for the concept of growth will be used to form new housing proposals.

Therefore, dissertation begins with introduction to presents vernacular architecture, profound agents that take role in configuration of the rural patterns and recognition of vernacular architecture, which are based on geographical values. In previous studies the vernacular architecture was discussed in general. As vernacular architecture doesn't belong to any "style" and because of the variation of this type of architecture and settlements, different classification should be analysed.

The study continues by deep description of fractal theories, and definition of fractal dimension is given. As it is very wide topic and it is not just summarized in architectural borders so clarification of this subject is one of the most initial study in this investigation. Also the hypothesis of the study and the method used are explained in detail and applied on the case studies.

Simulation of the process is done by “Cellular automata” computational method which can simulate the contemporary housing proposal due to the simple rules of growth which are based on Conway’s game of life theory.

Parallel to the mentioned descriptions, hypothesis was tested on the mentioned case studies. Masouleh and Abyaneh settlements are examined via urban pattern, elevation and environmental organization and the fractal dimension of both villages were going to calculate.

Finally, a methodology is developed to propose a new housing in metropolitan cities. The result of this proposal is the intersection or junction of the vernacular architecture and contemporary architecture, which can prove the meaning of sustainability in many different dimensions.

1.5 Background of the Study

The research is formulated to explore Iranian vernacular architecture by focusing on staircase houses in the case of Masouleh and Abyaneh. The introduction of the study is begun to explain description, aim, limitation, methodology and finally the evolution of terraced housing.

More currently, on one hand, Iranian rural settlements have been affected by internal migration of inhabitants to the urban contexts. On the other hand, with regard to challenging condition of living, which is rooted in the degree of excellence of building techniques and expensive maintain coasts, the inhabitants have been uprooted to transfer from their own vernacular origin points to the cities.

Besides, the existing problems of urban settlements can be sought through outstanding features of vernacular architecture (Oliver, 1997). Consequently, data collection of mentioned principles, are worthy to be discovered in order to utilize in architectural discipline.

Hence, basing on two varied zones of Iran, the research is aimed to inspect the local terraced dwellings in those specific zones. In general, it is intended to introduce the vernacular architecture and more importantly, to extract applicable principles toward the problems of current housing developments.

Terraced housing is the high-density arrangement and organization of settlements, which is locating on the steep lands and topographical regions, which has the strong hierarchy in between the units. The most important point of this type of housing is unity and hierarchy. These units cannot perform alone and they are working as a system.

Chapter 2

GENERAL OVERVIEW ON VERNACULAR SETTLEMENTS

2.1 The General Characteristics of Vernacular Architecture

"Vernacular Architecture as derived from the Latin word "Vernaculus" means native", which has good reason to be recalled as "the architecture of the people" (Oliver, 1997, p. xxi).

The word "Vernacular" have a broad definition, which becomes a significant notion, by interfacing of various parameters such as; indigenous, folk, primitive, widespread, and spontaneous.

Moreover, Rudofsky defined vernacular architecture as: "Architecture without architect and non-pedigreed architecture"(Rudofsky, 1964, p. 1).

But then, inspired by one of the most vital references in this research, Oliver (1997) points out in the Encyclopaedia of vernacular architecture of the world, also referred in Reza (2011), seeking for a simple description of vernacular architecture cannot be a reliable point of view because of its sub-varieties. However, he identifies vernacular architecture as dwellings and all other building typologies included, that are simply have been built by locals. Indeed, inhabitants, by considering their own environmental and contextual understanding of local material and their experiences, have shaped the built environments. Furthermore, he additionally states, the built

environment is formed to rectify the needs and the lifestyle of inhabitants (Reza, 2011).

In addition, Oliver (2003), in his book named 'Dwellings', determines that: "It is contended that popular architecture designed by professional architects or commercial builders for popular use, does not come within the compass of the vernacular." Likewise, Oliver proposes the simple definition of vernacular architecture as "the architecture of the people, and by the people, but not for the people" (Oliver, 2003).

According to that, as Dincyurek quote from Sancar (1991); "Vernacular is the architecture of the common, ordinary people not upper class or avant-garde, and cuts across all scales with repeated patterns or ideal types with variations, which can be found at the artifact, building and settlement scale" (Dincyurek, 2002, p. 16).

As Oktay (2006), remarked in her unpublished master thesis (2006), "Definition of 'vernacular architecture' covers cultural attributes, environmental factors and economic circumstances. In this manner, climate topography/site, available resource, existing technology, time, locality, culture, way of life can be classified as the predominantly used key words while explaining the term" (Oktay, 2006).

Brunskil defined vernacular architecture as: "Sort of building which is deliberately permanent rather than contemporary, which is traditional rather than academic in its inspiration which provides for the simple activities or ordinary people, their farm and their simple industrial enterprises, which is strongly related to place, specially through the use of local building material, but which represents design and building

with thought and feeling rather than in base or strictly utilitarian manner" (Lawrence, 1987, pp. 16-17).

Correspondingly, the building techniques of vernacular architecture are learned through experiences and by master-apprentice relationship throughout the history. There is no main manuscript defining the specific style, distinct calculation and drawings for building techniques of vernacular architecture. Moreover, builders are the subjects in these regions, who have adequate knowledge about environmental factors, cultural context, lifestyle and needs of inhabitants. In other concept, vernacular buildings are accomplished as the substantive response to the daily-based needs of the inhabitants (Reza, 2011).

For clarification of the term, "vernacular architecture" there is a compulsory need to define the place of vernacular architecture in the built environment and then the identification of vernacular architecture should deeply analyze.

Classification of vernacular of built environment can be done in various ordering. Though, Rapoport recommended a threefold division of the built environments. (Rapoport, 1969).

- Primitive- Very few building types, a model with few individual variations, built by all. (Tribal Culture).
- Preindustrial Vernacular- Those of peasants and preindustrial cultures- a greater, though still limited, number of building types, a more individual variation of the model, built by tradesmen.

- High styles or grand design- (Of which modern architecture is a special case) – Many signified building typologies in which buildings is an authentic entity (however it may be changing), designed and constructed by groups of professionals.

As a consequence, vernacular terminology addresses to belonging of inhabitants to the specific regions whereby, they are grown up and the places, which represent their origin points. In such a case, the concepts of identity, scene of belonging and the heritages correlate with the words nationality and hometown (Reza, 2011, p. 10).

As the result, investigation of vernacular architecture was done by various research methodologies. In addition, in the process of asserting this kind of categorization, might introduce a degree of limitation that permit scholars to concentrate on their own research aims more precisely.

Instead, Oliver categorizes the vernacular architecture as; Aesthetic, anthropological, archaeological, architectural, behavioural, cognitive, conservationist, developmental, diffusionist, ecological, ethnological, evolutionary, folkloristic, geographical, historical, museological, phenomenological, recording and documentation, spatial, structuralist, and generative-transformational (Oliver, 1997; Reza, 2011, p. 14).

Moreover, many scholars such as; Paul Oliver, Henry Glassie, Amos Rapoport, Roderick Lawrence, Nabeel Hamdi, Ozgur Dincyurek and etc.; highlighted the particular importance of the locality in vernacular architecture as: "Physical expressions of the cultural thought and everyday experiences of the inhabitants. Additionally, the vernacular tradition is the direct and unselfconscious translation

into the physical form of culture, its needs and value – as well as the creative, desires, dreams, and passions of a people" (Cavalcanti, 1996).

To be able to understand the issue of tradition precisely, the actual concept of tradition requires some evaluation. In this respect, it has been argued amongst many scholars in the fields of anthropology, geography, history and archaeology and taken into consideration in vernacular architecture. The concept of tradition, in respect of the view of vernacular architectural knowledge, can be described as the representation of a dynamic past for contemporary people to interpret, integrate transmit and adapt to present and future building construction (Vellinga & Asquith, 2006; Heath, 2009).

To get benefit of traditional method in architecture today, there is an vitality to investigate and focus on particular districts, in order to discover their potential, to then organize the results of these studies and to present them in a categorized way, with a view to, subsequently, putting them forward as principles to be applied in the future proposals of new settlements (Reza, 2011).

Therefore, as aforementioned, the building techniques of vernacular architecture are visually and experimentally transferred from generation to generation. Regard to this, building techniques is not depended on any particular methodology and inherited composed structural calculations or technical drawings. Therefore, the craftsmen of these regions have adequate information in respect of the environmental factors, cultural issues, lifestyles and their needs. In order to understand the design method of vernacular architecture, therefore, it is necessary to understand how architectural forms are generated by tradition (Dincyurek & Turker, 2007; Hubka T. , 1979).

Nazar Alsayad commented on the study of regional architecture as follows: “Traditions are also ever changing but they somehow do not die easily. However, I have argued elsewhere that the built environments of the new global order exhibit a sense of placelessness resulting possibly from the fact that tradition and the practices of the vernacular are increasingly becoming less place rooted and more informational based” (Heath, 2009).

As it is mentioned in previous studies; According to this concept, house could be describe as a place for identifying the personal, getting engaged together, the spatial hierarchy, daily-based events. In addition, the house formation does not come into being only as the outcome of physical forces or any causal factors; however, it is the results of entire variables of socio-cultural parameters emerged in their broadest meanings. Climatic condition, building techniques, local material and socio-cultural factors, shaped the geometries of houses. Therefore, the dwellings as representative of each cultural setting are, then, broadly being affected by all mentioned factors. The linkage between behavior and form has been emerged in two aspects. Firstly, to comprehend the behavioral patterns in the concept of desires, motivations and feelings, is fundamental to discover the built form; since the built form is affected by physical embodiment of mentioned patterns. Secondly, the built forms influence the lifestyle and behavior. Ruining the built environments of local settlements including traditional dwellings is implying also devastation of the culture itself (Rapoport, 1969).

2.2 Global Approaches that Shaping the Pattern of Vernacular Architecture of the World (Organic Architecture)

Vernacular Architecture has multi diverse classification due to the aim of different disciplines such as nonprofessional (informal) and professional architects (formal), Sociologists, Anthropologists, Geographers, Psychologists, Geologist and others.

According to mention fields, there are various approaches and terminologies due to their demands, which in some the possibilities of sharing criteria's are high.

Different scholars proposed many different categorizations and classifications of mentioned approaches. This dissertation mainly focused on Lawrence's study (1987), which was one of the pioneers. It should be mentioned that following terminology still is using in recent researches. Ozgur Dincyurek used same methodology in his dissertation in 2002.

- The aesthetic/formalist interpretation;
- The typological approach;
- Evolutionary theory;
- Diffusionism: social and geographical;
- Physical explanations: building technology, material, site and climate;
- Social explanation: defense, economy, and household structure;
- Socio-cultural factors: religious practices and collective spatial images.

As it was mentioned the interpretation has been categorized into seven different disciplines. On the other hand, classification of "Encyclopedia of Vernacular Architecture of the World's Classifications" was defined in subsequent section.

- Aesthetic
- Anthropological
- Archaeological
- Architectural
- Behavioral
- Cognitive
- Conservationist
- Developmental
- Diffusions
- Ecological
- Ethnographical
- Evolutionary
- Folkloristic
- Geographical
- Historical
- Museological
- Phenomenological
- Recording and Documentation
- Spatial
- Structuralist

It should be mentioned that, interpretation of all given approaches need deep discussion, which is not in the aim this dissertation. Therefore, some of terminologies, which are going to be examined, will be justify.

As Oliver, describe the “architectural studies terminology” as a tool to uncover the technological and organizational principles and bring defined methodologies of analysis to vernacular buildings (Oliver, 1997, pp. 1-2).

Architectural studies on vernacular architecture in terms of the sharing of knowledge, "know-how," or "technology" was transferred in between different generations.

Also as Pavlides, claimed; diversity and quantity of architectural practice due to the manifest of vernacular architecture were increased in past decade. Distinctive interpretation of architecture extract from mention statements which called as; iconic architecture, picturesque evocation of symbolic identity; architecture as determined by climate, material or function; and architecture as embodiment of experiential, emotional, spiritual and sensory qualities (Pavlides, 1997, pp. 12-15; Dincyurek, 2002, p. 26).

Geography is another approach which in dissertation mainly focused and it is in direct relation with the pattern of settlements, environmental topographical, spatioeconomic locational scales ranging from the regional to the continental which highlight the complex interactions between habitat and physical environment (Oliver, 1997, pp. 1-2).

“Spatial concept” which was one of the most significant subjects among scholars such as Bruskill, Leroy and Presciozi is going to be used in this research. Mentioned approach mainly emphasizing the organization and articulation of spaces and volume in different scale.

Due to Cuisenier, spatial approaches to vernacular architecture were classified in three tasks. First, there is the ethnographical and phenomenological tasks, that could be, perceive from the daily life of inhabitant of the specific region. Second is the sociological and ethological task, which is more based on the interaction of inhabitant’s social life, such as; economy, language, religion and beliefs and etc. Final tasks were termed as architectural and anthropological, which is representing the interpretation of the types and style of buildings, constructors and users (Cuisenier, 1997, p. 60).

From another point of view spatial approach to vernacular architecture could be categorize and achieve in two extensive methods. The first one was observation of building and examination of inhabitant interaction in building construction and usage. Second methodology was based on living experience of built spaces and from that to obtained and perceived how the buildings were considered and construct. Also, it should be mentioned that in followings research, both methodology would be use (Cuisenier, 1997, p. 60).

As explained, various indicators such as geographic algebra, economy and culture are forming the organization of spaces in settlements. Hence, the mentioned indicators take the main role in order to form the settlements as well as they essentially act to be interrelated to each other (Reza, 2011).

Instead, majority of the designer, who are interested in geographic studies, attempt to emphasize the climate impacts as the principal excuses of establishing the rural contexts. Several scholars claimed that, the local materials, and in parallel, some other ones remark defensive reasons are the general formation of the settlements. Also others point out the formation of rural settlements is deeply affected by economical indicators. It has to be stated that the religious and cultural values are importantly taking role, for which researchers can concentrate on (Ghobadian, 2009; Reza, 2011).

Furthermore, as Zargar (1999) states; none of these factors (geography, economy, culture, community) can work independently and they have strong correlation in between each other (Zargar, 1999; Reza, 2011) (Fig 1).

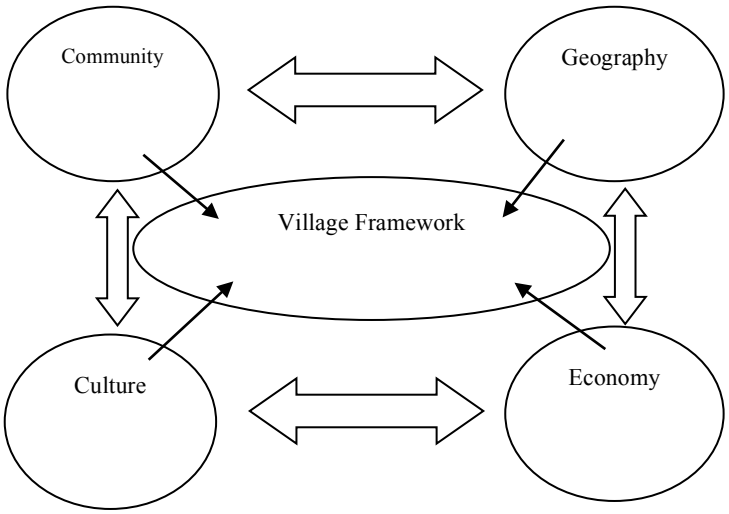


Figure 1: Effective Factors in Shaping Villages (Zargar, 1999, p: 30)

As Oliver motioned, “Only by identification and labelling can classes and categories be identified that make reference possible to unseen or recollected phenomena. While vernacular architecture is as susceptible to classification as is any other kind of human artefact is, however, a complex a complex problem in itself” (Oliver, 1997).

Effective parameter that shaping the pattern of the villages is going to be investigates from macro to micro scale. First scale, is defined the establishment scale and it is highlighting the location of the villages. Second scale is mainly investigating on spatial organization of the villages, where through the placement of built environment, fields and farms, rout and roads, bridges and etc.

Third scale is specifically, focusing on the built environment of the villages by examination of the passages, density, plot sizes, shape and organization of plots, the place of social activities, chamber, and etc.

Fourth scale, is relating with analysis of the building units accordingly to shape and internal organization of the houses, quality of spaces, composition of spaces and etc.

Final range, are reflecting the micro scale analysis of building components and construction details such as doors, windows, roof, faced and etc. It should be mentioned in all scales of mentioned investigation, the impact of external effect should be considered.

Geography is a significant aspect, which is commanding the shape of vernacular villages. Mentioned terminology will be categorized in two disciplines, which called as artificial and natural geography. This categorization is clarifying the geographical interpretation.

In this study artificial geography is examined with an emphasis on the location of the villages to the cities, roads, streets and etc. Adjacency of vernacular settlements with cities, are effecting on the social and economical structure of the villages. Despite,

natural geography mainly, identifying with environmental factors such as; water, wind, rain, snow, temperature, humidity, sun saturation, topography and etc.

The overview indicates that there is a strong relationship between the geographical aspects and formation of vernacular settlements that is going to be specifically examined in the following part of this dissertation.

More specifically, as Dincyurek mentioned; “For understanding the vernacular architecture in the world, divers classifications can be used. Geography, cultural landscape, population density, and climate are the major determinants of the classifications in the world in order to identify the place within the context. Among the mentioned classifications, the climatic classification is the most striking approach to understand the divergences and penetrations of the vernacular architecture in the world” (Dincyurek, 2002, p. 40).

Also, Oliver emphasize that; “Climate is the most determine environmental factor in the development of human –life” (Oliver, 1997).

In addition, “Climate is integration in time of the physical state of the atmospheric environmental characteristic of a certain geographical location” (Shaterian, 2011).

Therefore, due to the versatility of climatic factors in the world, dissimilar architectural approaches emerged. Subsequently, classification of those different climates in the world is significant to attain accurately the design solutions.

Jeffrey Cook, in the vernacular architecture of the world encyclopaedia, categorized the climatic zones of the world, in nine distinctive regions as; Arctic and sub-Arctic, Continental, Desert, Maritime, Mediterranean, Monsoon, Montane, Subtropical, Tropical (Cook, 1997).

2.3 Identification of Iranian Vernacular Architecture in Terms of Geographical Values

Iran is a mountainous country. In view of the fact that there are many variations in the general topography of the mountainous regions of the country in respect of both the climate and the geography much, can be explored in precedents of vernacular architecture. For this reason, this research is aimed to indicate and analyze the Iranian vernacular architecture (Reza, 2011). The characteristics of Iranian vernacular architecture will be argued by regarding to the geographical, topographical and climatic factors.

2.3.1 Geographical Value of Iranian Vernacular Architecture

Iran as a vast country, placed in the Middle East is occupied 1,648,000 km2 of square area. The country shares its boundaries by neighbouring countries including Turkmenistan, Azerbaijan and Armenia in the north side. Also, Afghanistan and Pakistan are lying to the east boundary of country and Turkey and Iraq to the West one.

Iran has a long coastline of Persian Gulf and the Oman Sea in southern border. The total land border of Iran is 51,700 kilometres in length and the total coastal border is 2,510 kilometres in the north and the south sides. As it mentioned Iran has coastline of Caspian Sea-which is one of the largest lakes of the word-, and also coastal line of Persian Gulf in south. Iran is geopolitically is intersecting bridge in between the East

and the West by considering to the spiritual, cultural and political factors (Shaterian, 2011).

2.3.2 Location and Topographical Factors in Iranian Vernacular Architecture

The topographical aspects are classified with regards to the physical appearance of the regions. In the consequence, Oliver, categorized the topography as, below-ground, coastal, desertic, and forest, grassland, lacustrine, lowland, marine, riparian, slope, upland and valley. Moreover, the inhabited zones are classified distinguishably, according to their organizations including; cluster, compact, compound, dispread, grid, linear, nodal, organic and peripheral are the different type of villages' organization (Oliver, 1997). Subsequently this research is focus on the linear typology of rural settlements.

By investigating the Iranian rural contexts, the vast range of their varieties is evidently noticeable. In mountainous regions, the settlements demonstrate the complicated urban pattern of houses that are projected from the steep side of mountain ranges such as Masouleh in the north and Abyaneh in the centre of Iran. In parallel with, some of the other built environments set into recessed and cause of the complexity of dwellings' interaction, recognition of settlements are difficulty communicating. In such a case, Kandovan village in Azerbaijan and Meymand village in Kerman can be exemplified (Figure 2). In addition, rural settlements tend to resemble as fortified citadel, with the dwellings interlocked with each other. Such rural settlements can be found in central part of Iran and also, in the plains region (Zargar, 1999).

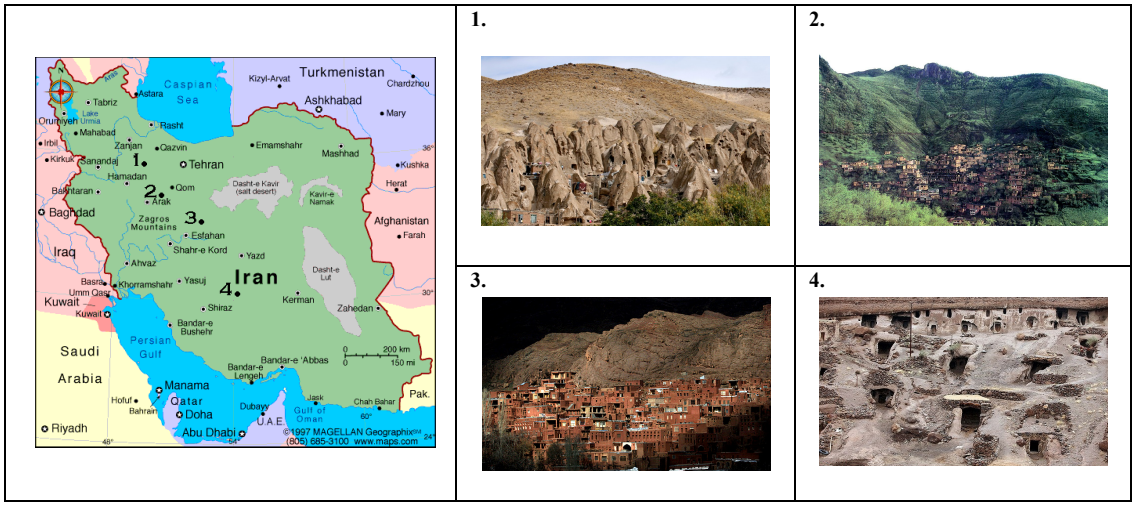


Figure 2: Map of Iran with the Location of Villages (left), Kandovan (1), Masouleh (2), Abyaneh (3), Maymand (4) [1][2][3][4]

Iranians vernacular architecture has altered classification, due to the geographical, cultural and climatic factors. In respect to this, the research is focused on Iranian rural settlements with extroverted orientation, which are located in the zones that have steep topographical characteristics.

Therefore, the focus will be on the villages of Masouleh and Abyaneh, which have a similar steep topography. Then, the climatic factors on the one hand and the topographical issues on the other hand, will be the distinctive variables. Masouleh, as the first villages, is located in the northern part of Iran. This village is 1,050 meters above sea level in the Alborz mountain range, near the southern coast of the Caspian Sea.

The second village, Abyaneh, is located in central Iran, on the northwestern slope of the Karkas Mountains and it is 2,500 meters above sea level (Figure 3).

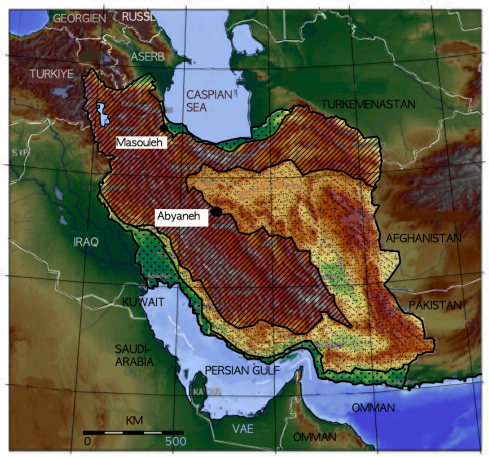


Figure 3: Map of Iran, Location of Masouleh and Abyaneh [5]

"Moreover, half of Iran is mountainous area and the other half is semi-desert and fertile agriculture planes prone. The general mountains of Iran consist of two huge arches, which stretched out from Azerbaijan to Afghanistan and encompass all the southern part of Caspian Sea. The other arches starting from Azerbaijan and continues to the west and south. These two arches surrounded the tree side of Iran (South, East and West) and not allow atmospheric phenomenon gets inside to Iran and the only open side is eastern side which has access to the Turkestan plains and central Asia" (Reza, 2011).

To sum up, this research is focused on the vernacular architecture with projected form from the terrains, in steep topography.

Masouleh and Abyaneh villages have been built on the mountainsides but at various elevations. They have compacted housing morphology caused by the use of the natural environmental factors. Consequently, dwellings are situated in the steep slope and running parallel to the main pathway of the village. To conclude, all dwellings in mentioned villages have been built in parallel with existing topography lines. In addition, the resulting differences in levels mean that the roofs of the dwellings can

also act as pathways in both villages. This approach creates a distinct elevation of differing angles for these villages. Masouleh's settlements are positioned at a 47-degree angle approximately and those of Abyaneh at around a 29-degree angle (Figure 4). As a result, Masouleh housing developments are denser in comparison to the housing developments in Abyaneh. Therefore, the combination and integration of public and private space, in respect of the use of the roofs as pedestrian paths is more visible in the case of Masouleh village.

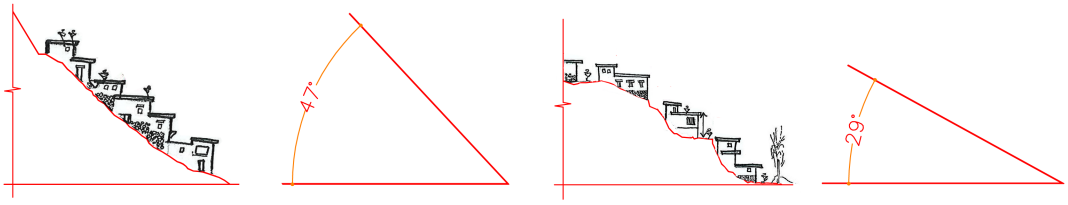


Figure 4: Section and Angle of Masouleh Village (left) and Abyaneh Village (right), (by author)

In both villages, the interconnection amongst the mountains, the village and the river creates an integrated unity between the nature and the built environment. In accordance with this, agricultural fields are located to the west and east orientation of the valley and orchards are located in south side of these villages.

2.3.3 Climatic Factors in Iranian Vernacular Architecture

With reference to the construction of vernacular houses, climatic conditions are of primary concern worldwide. Throughout the generations, human beings have designed and constructed their dwellings according to the climatic conditions, aiming to meet the most convenient life style (Reza & Dincyurek, 2017).

Different scholars classified the climatic zones in Iran by many different categorizations. For instance, Riazee introduced 9 different climates in Iran, which

include six winters and five summers. By using Olgyay's method, Riazee has done his research by regarding to perspectives based on the building construction and human comfort conditions. In parallel with, Ganji generally recommended four divided climates zone in Iran, which are temperate and humid climate (southern side of Caspian Sea), cool climate (Western Mountain), hot and dry climate (central plateau), hot and humid climate- northern shores of Persian Gulf (Reza, 2011).

The climatic zoning of this study is based on the findings of Ghobadian (Ghobadian, 2009). As he stated, Iran is generalized in the category of dry countries. In fact, by considering its climatic diversity, it can be introduced into four main climatic regions:

- The Northern Coastal Region Temperate climate.
- The Central Plateau Region Hot and Dry Climate.
- The Mountainous and High Plateau Region-Cold Climate.
- The Southern Coastal Region Hot and Humid Climate (Ghobadian, 2006) (Figure 5).

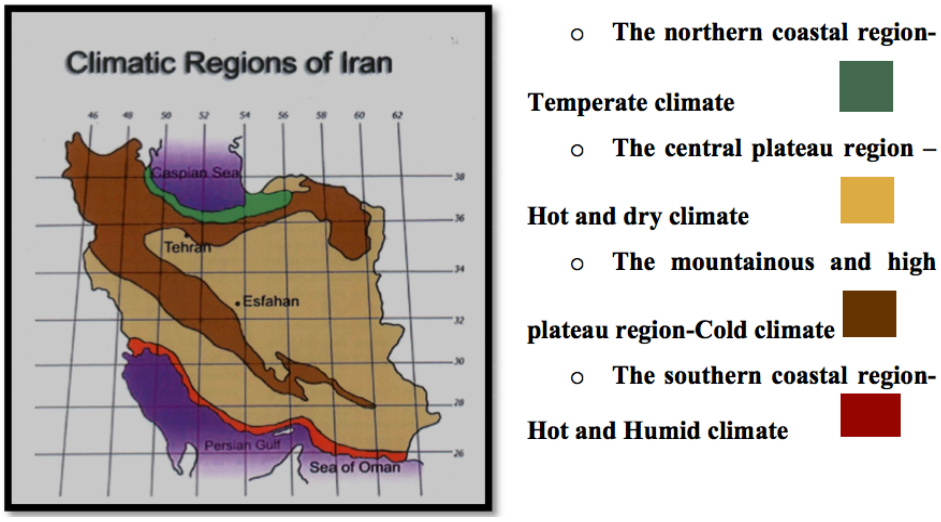


Figure 5: Climatic map of Iran (Ghobadian, 2006, p:25)

By regarding to Ghobadian's classification, the selected case studies are located in first, second and third region, therefore the climate characteristics of fourth region is not going to be explaining in this study (Reza & Dincyurek, 2017).

Therefore, these diverse climatic conditions affect the construction style of the houses in each climatic region. In the temperate climate of region one, houses have been faced to the outside with the help of locating the opening on the external walls aimed to increase cross ventilation amongst the hot seasons of the year in the central plateau region, which dominantly have various hot and dry climate during summer and cold in winter.

In the second region, the interior spaces of the dwellings are designed aimed to protect the spaces from the frequent sand storms in the region, which is hot and dry. These dwellings are, consequently introverted, which illustrates that all openings are faced to one courtyard at least, except the entrance door. In this region, the houses are designed to be houses for all seasons. The reason is the northern wing of those houses, are able to receive natural light directly and with regard to this, the spaces behind can be used during the cold months of the year. While, the southern wing of such houses is in shape permanently and those can be used during the summer. In such a house formation, Wind towers are mostly constructed on the summer wing. Moreover, as the third region, is defined by in the mountainous characteristics in the high plateau region, it has, therefore, cold climate condition. Respectively, Alborz and Zagros mountains are spread toward the north and the west of the country as the high mountain ranges. In this regard, the region has cold climate in the winter, mild and dry in the hot season (Ghobadian, 2009; Mohammadabadi & Ghoreshi, 2011; Keshtkaran, 2011; Reza & Dincyurek, 2017).

By considering the cold climate conditions in the villages standing on mountainous regions, the buildings' openings are mostly faced to the south aiming to absorb natural light. Also, other three exterior walls of the house are adjacent to the soil and the neighbour house for avoiding the heat loss. The dwelling typologies for this specific climate zone are given below (Figure 6).

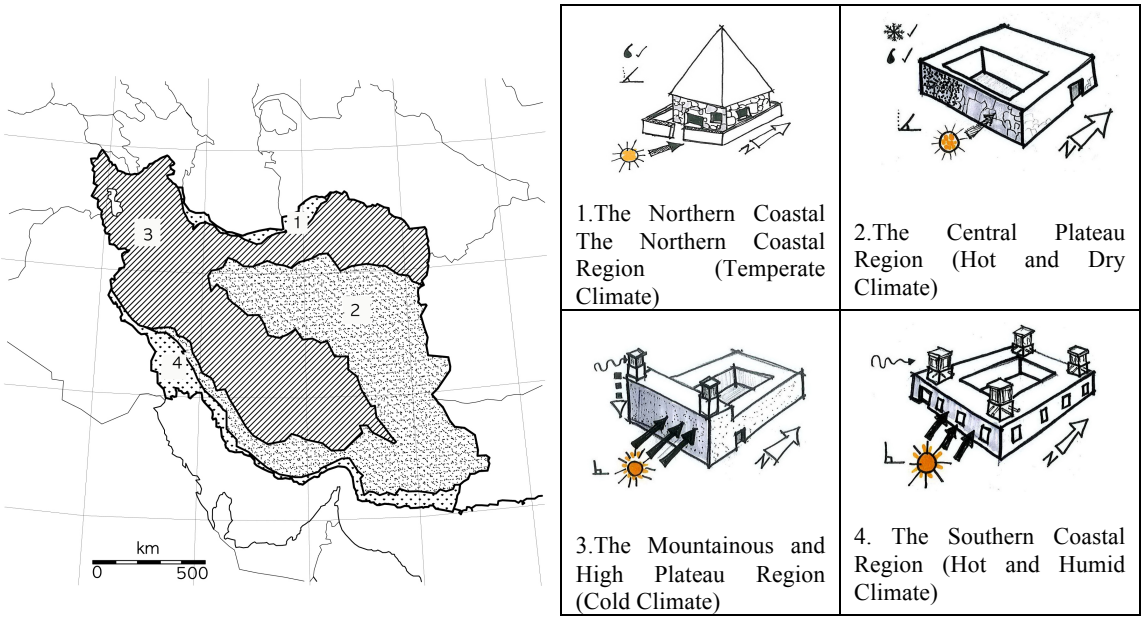


Figure 6: Climatic Map of Iran and Building Typologies (by author)

2.4 Terraced Housing Formation in Vernacular Iranian Settlements: Masouleh and Abyaneh Villages

Available natural resources has shaped the settlements, and as water is an essential requirement for life, villages are established close to water sources such as rivers, aqua ducts, oases and springs.

"Masouleh Rood Khan" is the river, which flows Masouleh village, but its source is located 200 kilometres from this village (Golboo, 2009).

Moreover, Abyaneh Village is feed for water by “Do Abi” spring, which flows constantly during a year (Memarian, 1997).

The abounded old pattern of Masouleh -old Masouleh or Kohneh Masouleh in local dialect-, was founded roughly 1006 AD, which located nowadays below in the new pattern towards the northwest. The inhabitant has been replaced from the old pattern of Masouleh to the current one, due to the possible attacks from neighboring villages and the risk of infectious diseases.

Various thoughts indicate on the history of Abyaneh village by referring to the civilization of Sialk (archaeological site near Kashan) is declared with 6,000 years old. It is supposed that Abyaneh village could have been emerged from one of those communities. This village has a square area of approximately 70,000 metres (Ghorbanizadeh & Abyaneh, 2008).

2.4.1 Topography of Masouleh and Abyaneh Villages

Masouleh and Abyaneh villages have been built on the mountainsides but at different elevations. They have high-density housing developments due to the use of the natural environmental factors. Consequently, housing units, which are placed on rectangular-shaped steep slope facing in parallel to the main pathway of the village. In the other words, it can be stated that all housing units in designated villages are constructed paralleled to the topography. Also the resulting differences in levels mean that the roofs of the dwellings can also act as pathways in both villages. This approach creates a unique elevation of differing angles for these villages. Masouleh’s settlements are positioned at a 47-degree angle approximately and those of Abyaneh at around a 29-degree angle. As a result, Masouleh housing developments are denser in comparison to the housing developments in Abyaneh.

Therefore, the combination and integration of public and private space, in respect of the use of the roofs as pedestrian paths is more visible in the case of Masouleh village.

In both villages the interconnection between the mountains, the village and the river creates an integrated unity between nature and the built environment. In accordance with, agricultural fields are arranged to the outer east and west sides of the rural settlements and in addition, orchards are situated in the southern position.

There are two concerning facts which should be consider in respect to developments on the skirts of mountain ranges. The first natural disaster is the de facto avalanches. As a result of their experience the local people have not carried out any construction work on avalanche routes. Secondly, if construction work did take place on the hillside for some special reason, the villagers were always careful about the possibility of falling rocks and avalanches and took some safety precautions. For example, in order to afford themselves some protection against possible avalanches and falling rubble, they harvest and forage the plans, which grow on the slopes because of the presence of this flora increases the temperature of the soil and as a result of the increased temperature the snow masses tend to lateral movement and to create avalanches.

But then, the probability of falling rubble is another natural disaster can be happened in the region of Masouleh. There is plenty of rock pieces embedded in the sloppy side of the hill at the pick point of this rural settlement. To this regards, this natural disaster has created difficulties for the inhabitants during 1990 earthquake occurred;

the movement of these rocks destroyed many houses and caused many fatalities (Zargar, 1999).

In addition, Ghaleeh Kooh mountain skirts serve as the settlement location of Abyaneh village. The village rounds parallel to the valley and perpendicular to the main route between Kashan city and Natanz (Figure 7).

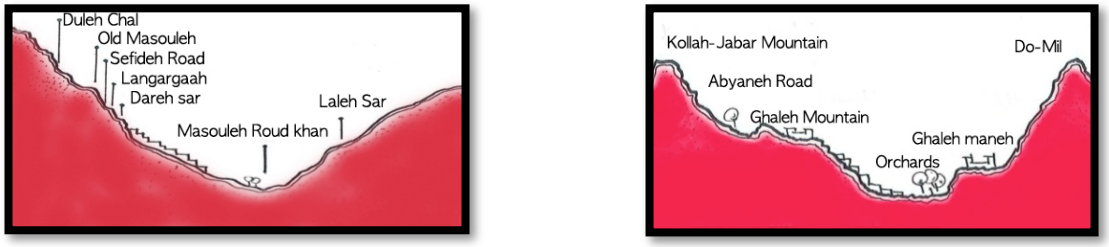


Figure 7: Location of Masouleh (left) and Abyaneh (right) Villages (by author)

As mentioned, both of these villages have high dens housing morphology caused by the natural environmental factors. Hence, dwellings are situated in the rectangular-shaped steep slope, and parallel with the main pathway of the village.

2.4.2 Climatic Factors of Masouleh and Abyaneh Villages

There is a strong integration in between Masouleh and Abyaneh villages and gentle sloping surroundings, which has a constrained space and interconnection between mountain, villages and stream constrained nearby individuals to move their agribusiness fields, a long way from their settlements.

Rural settlements of Masouleh are placed amongst the sharp slopes of Alborz Mountain ranges, wherein; the climate is cooler and drier than the humid climate of the Caspian Sea on the other hand. Together with, the rural settlements of Abyaneh village are located in the border of central plateau region, which has a hot and dry

climate, and the mountainous and high plateau region, which has a cold climate. Therefore, these villages have a multi climatic character (Figure 8).

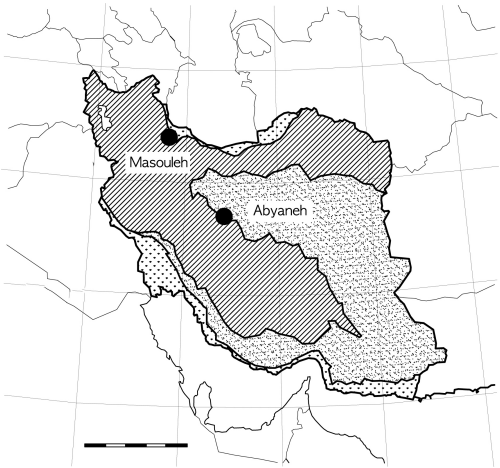


Figure 8: Location of Masouleh and Abyaneh on the Border of Different Climatic Regions (by author)

As mentioned, the mountainous regions have low winter temperatures especially at night times. Subsequently, a warm and convenient environment for variety of human events was the main challenge for the local builders in such a high lands. In view of the fact that the colder temperatures infiltrate the lower part of the valley at night the residential units were not located there. The valley is also sometimes subject to flooding. The shadow, cold and windy side is placed in the north. So that, southern and the central regions of the foothills are the optimum location for any residential development. As a result of these factors, all the houses in both villages are oriented in southerly and easterly directions with their windows and entrances facing south.

Moreover, the form and spatial arrangements of the units in Masouleh, were mostly settled according to the two principal climatic factors of high rainfall and high humidity. An externally orientated form for maximising the usage of wind flow and ventilation is one of the best solutions in humid and moderate regions (Rameazaanpour, 2010).

However, this outward-oriented design of buildings is also present in Iran's western mountains and the central plateau where it is not so humid as e.g. with Abyaneh village.

2.4.3 Urban Patterns and Spatial Relations of Masouleh and Abyaneh Villages

In Masouleh and Abyaneh villages, dwellings have been built standing on ground level, which give opportunity to be opened on two to four orientations. Balconies act as type of space to transit in between the built and the natural environment, thus mentioned transitional spaces integrate internal and external spaces in the settlements. Therefore, local residents also installed large windows on the main elevation. According to Memarian, the urban context of these villages, has created a kind of symbiosis between that of the green space of the natural environment and the architecture as a built environment, this example, therefore, demonstrate the representation of essential principles of the 'nature friendly design' terminology (Memarian, 1997).

As the aftereffect of these findings account of morphology, this village portrays exceptionally unmistakable components, which are welcoming people, and it bears a run of the mill character in context.

Masouleh village has four main districts, which are; Khaneh-bar, Masjed-bar, Keshe-sar and Asad. There are also a further six subsidiary districts. A special mosque dominates each district. There is a natural channel, which influences how the passages are formed and located. Consequently very few of the roads run parallel in this village. Accordingly, therefore, bearing this in mind, 'perpendicular' passages with a gentle slope or stairs connect the different levels.

Abyaneh village has three main sub-districts, which are: Heradah, Pal and Yosmoon. Also, the houses in Abyaneh are made from a red-clay, which, interestingly, often creates an effect like dancing flames on the grey slopes of the mountain (Ghorbanizadeh & Abyaneh, 2008). The main pathway has an organic shape paralleled to the main topographical attitude of the terrain in this village. Also, some of passages are called as cul-the-sacs in native dialect, which means dead-end. Those long passages have been connected with each other by perpendicular shorter passages. Therefore, staircases are often used in their construction. The plan, section and perspective of each village are given in Figure 9.

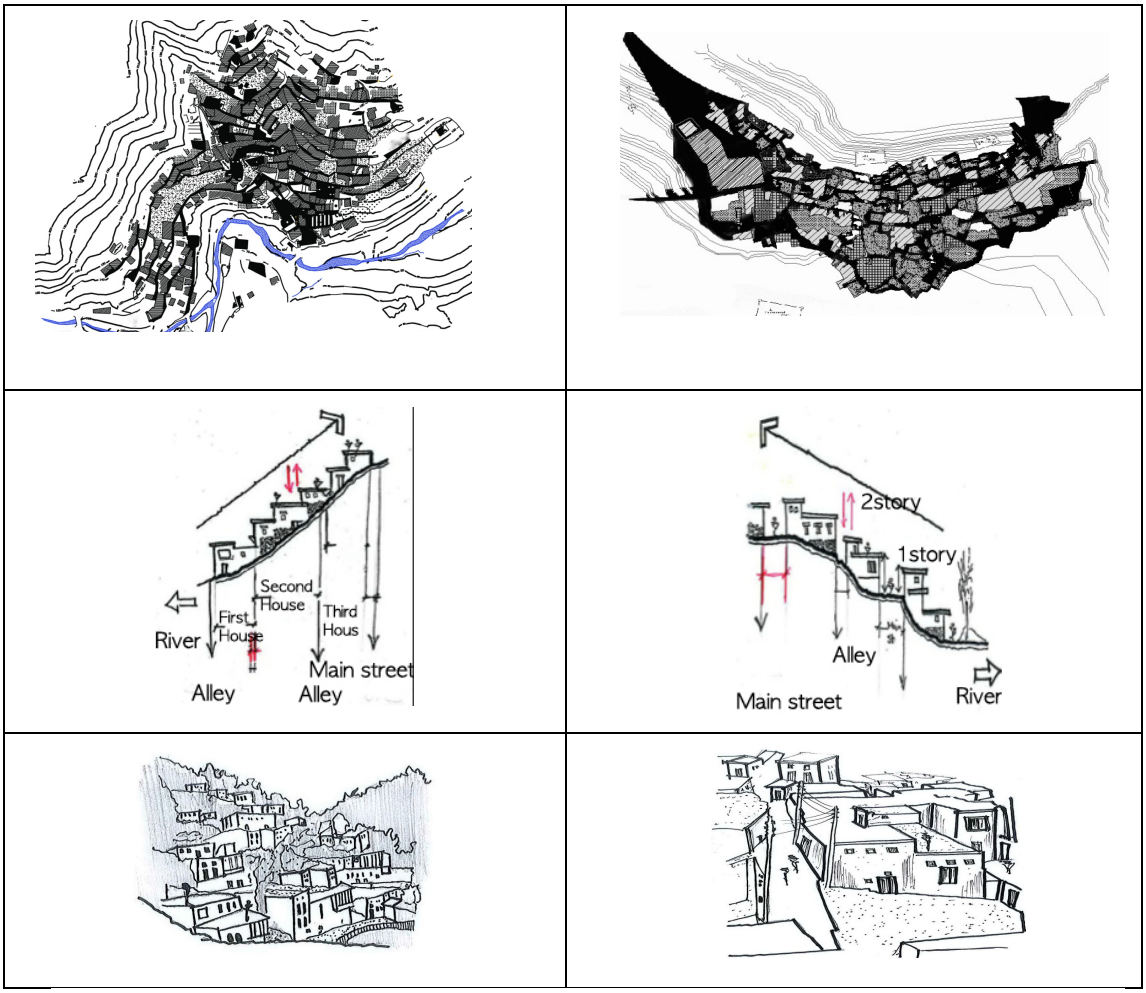


Figure 9: Situation Map, Combination of Private and Public Spaces and the Urban Fabric of Masouleh (left) and Abyaneh (right) (Memarian, 1997)

Chapter 3

THOROUGH INVESTIGATIONS OF FRACTAL AND CELLULAR AUTOMATA THEORIES

3.1 Chaos Theory, Complexity and Emergence Concepts

Complexity Science is a methodology, which presents elective models rather than conventional investigative techniques as an efficient and fathomable structure for complex frameworks. Newtonian physics details the deliberate structure obviously; along these lines setting up its utilization in all examination regions of science, building, connected science, business administration, etc.(Reza & Dincyurek, 2015).

As Jenks (1997) mention, “Four Jumps to Consciousness. Each of the four worlds emerged unpredictably from a small part of its predecessor, and our own world is the first to reflect back on the underlying causes and laws. One part of these laws, the Cosmic Code which scientists are slowly decoding, created the initial inflation badly named the 'Big Bang'. Because new, holistic worlds really do emerge with their own internal laws and being, the reductivist programme of modern science will only produce partial truths.” (Figure 10).

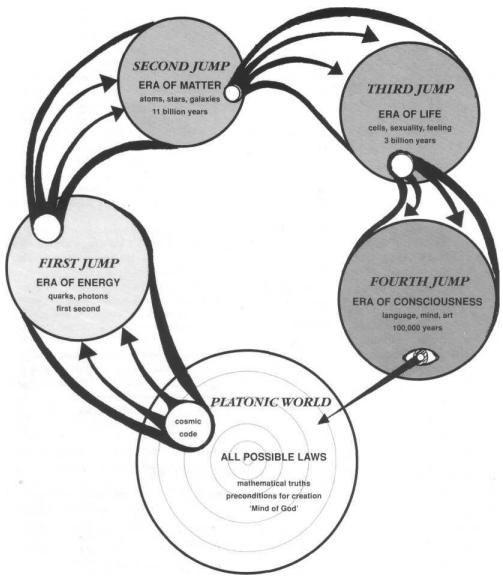


Figure 10: Four Jumps to Consciousness (Jenks, 1997)

“Standard science and historical theology are being transformed here in a way that could be called Post-Christian and Post-Modern because it grows out of Christianity and Modernism alike. Modernism itself was a Post-Christian movement, but it was based on a mechanistic science and a view that the universe developed gradually and deterministically. By contrast, the post-modern 'sciences of complexity' explain a more creative world, a picture filled out by many emergent sciences such as ‘fractals’, ‘Chaos Theory’, ‘nonlinear dynamics’ and ‘Complexity Theory’ itself. Taken together they paint an entity that is more like a dynamic organism than a dead machine and one which, like the Christian world-view, has a certain purpose.” (Jencks, 1997) (Figure 11).

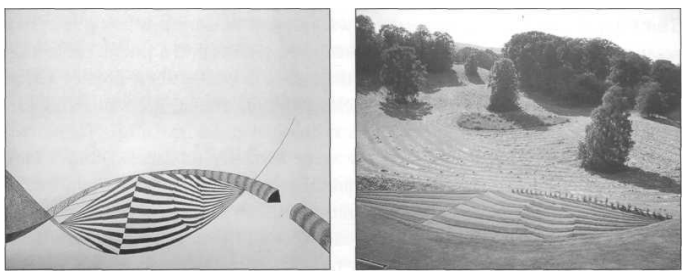


Figure 11: Symmetry Break Terrace, Scotland, 1995 (Jencks, 1997)

“During the 20th century the revolution of non-linear and quantum physics and the theories of relativity, based on a time and space assumption, resulted in the emergence of the chaos theory, which opening up non-linear systems. When scoping onto the global environment, it is clear that natural phenomenon are highly interconnected, interdependent and non-linear and, therefore, can be referred to as complex systems, thus shaping and defining the border between traditional and modern science. Traditional science attempts to eliminate complexities by studying the individual components of a system within an isolated environment” (Reza & Dincyurek, 2015).

Being a standout amongst the most imperative attributes of non-linear frameworks, self-similarities frameworks saw its advancement from regular and organic frameworks before it broadened into the distinctive fields of software engineering, economy and etc.; (Complexity Learning Lab, n.d.). Nevertheless, before proceeding to the explanation of the self-organization characteristics, the concept of “system” is defined as follows:

According to the Oxford Dictionary, “a system is a set of things working together as parts of a mechanism; a complex whole.” Therefore the result could be the part of mechanism or an interconnecting network.

The purpose behind the development of all globally coherent frameworks that prompt the local cooperation between various small-scale frameworks is characterized as the normal principle for self-organization. This methodology depends on the limit for adjustment which complex system get from non-linear cooperations, which their components create when acting, and responding with each

other's conduct. This adjusts to the second Newtonian law which expresses that every action has an opposite and equal reaction (Reza & Dincyurek, 2015).

Accordingly, this study will predominantly concentrate on the conduct of complex system when connected in design and architecture. The key thought behind the complexity hypothesis is that after various iterations utilizing small, basic parts, which are duplicated, consolidated or changed, through basic standards, a differing framework, whose future state is not effortlessly unsurprising, emerges. The new data, which the framework gives back, gives chances to an analogical extrapolation specifically from different procedures in design, which results in a spatial form and configuration pattern. This is exceptionally useful to planners as they consistently take a gander at living life forms that get their mind boggling shapes and behavioural examples, through their communications in space, here and there over drawn out stretches of time (Reza & Dincyurek, 2015).

'COMPLEXITY' is a term that has been broadly used to mean whatever that is not simple, but it does have various discipline and particular descriptions. This study is going to emphasis on the performance of complex system when applied to architecture. Accordingly, this study will mainly focus on the behaviour of complex systems when applied in architecture. The key idea behind the complexity theory is that after a number of iterations using small, simple parts, which are replicated, combined or changed, through simple rules, a diverse system, whose future state is not easily predictable, arises. The new information, which the system gives back, provides opportunities for an analogical extrapolation directly from other processes in architecture, which results in a spatial form and configuration pattern. This is very helpful to architects as they regularly look at living organisms that acquire their

complex forms and behavioral patterns, through their interactions in space, sometimes over long periods of time (Reza & Dincyurek, 2015, p. 62).

In the province of architecture, complexity is not only a mathematical thought procured from science and the characteristic world, which is then connected in outline. It is a natural quality in the realm of construction development, clear in the example of development and advancements of settlements. Just the patterns characterize as old, while the mathematical methodology then again is later. It is required to notice that in city making, the cosmological, hierarchical and geometrical movement in context permits the engagement with the city, starting from the earliest stage because of the discrete granular strengths, which it unfurls. Then again, since the nineteenth century, and even at times, the pioneer arranging urban plans areas from top-down (Reza & Dincyurek, 2015, p. 63).

As Batty & Longley (1994) observed, "The concern for more micro issues, for thinking of cities in terms of the actions of individuals, came from another area entirely: ideas about disaggregation and heterogeneity. Batty uses these ideas in city simulation, studying emergence through cells" (Batty & Longley, 1994).

He also argues for the existence of the fractal cities. "Hallmarked by self-similarity and order on all scales, and links city growth explicitly to sensitivity to initial conditions, to bifurcations and chaos theory. This is qualified, however, by the observation that the rates of growth are generally too low to exhibit the dramatic manifestations of chaotic behavior that might be seen in other system. The point is that the system's mathematics and the speed of digital computation have provided a new power with which to simulate the complex evolution of settlement pattern, even

in the multifarious modern city. Such an approach has both analytical and generative potential. What does a similar focus and process means, in terms of aesthetics, materiality and responsiveness, at the scale of the individual architectural project" (Burry & Burry , 2010, p. 53).

On the other hand as Jencks (1997) claimed; "As we have seen the inadequacy of Modern architecture, and the necessity for creating an architecture of organizational depth, but that still leaves important questions open. Is there one language of architecture, which is more suited to the contemporary situation than another? Is there an answer to the perennial question - asked since the early nineteenth century - 'in which style shall we build?' Before taking on this recurrent query I will examine several of the emergent languages, which are inspired by, or revealing of, Complexity and Chaos theories. Therefore, I will touch on nine or so identifiable departures of the last several years, starting with the analogies, which have become so familiar with the emergence of Chaos Theory" (Jencks, 1997).

3.2 Definitions and History of Fractal Concept

Before explaining the fractal theory, it is important to understand the root of the word fractal. The term fractal comes from the Latin word 'fractus,' which means 'broken' or 'irregular' or 'unsmooth'(Reza & Dincyurek, 2015).

"Fractal theory is based on geometry and dimension theories. Fractals are mathematical sets with a high degree of geometrical complexity, which can model many classes of time series data as well as images. The fractal dimension is an important characteristic of fractals because it contains information about the geometric structure. It has become an effective tool to study complex sets. There are

many definitions for the fractal dimensions of a fractal set" (Tang, Tao, & Lam, 2002).

As Bovill (1996) mentioned: "There is symmetry in nature, but on closer observation there is also a complex diversity. Not all humans are the same size and shape. This was the self-similarity, which can be perceived from nature from macro scale. As he mentioned: oak trees are not identical. There is however, a newly developed concept to size. It has self-similarity, in which small parts of an object are similar to larger parts of the object". This self-similarity can be seen in Figure 12 as the formation of the Sierpinski gasket (McGuire, 1990).

Additionally, Mandelbrot (1989): Comprehensively, mathematical and natural fractals are shapes whose roughness and fragmentation neither have a tendency to vanish or vacillate here and there, yet remain basically unaltered as one zooms in and examination is refined. Subsequently the structure of each piece holds the way to the entire structure.

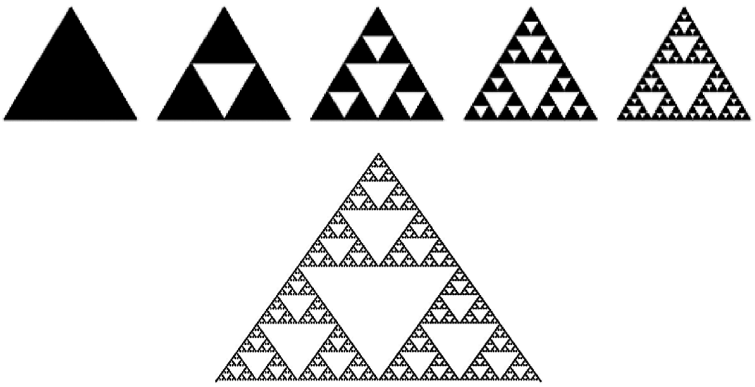


Figure 12: The Formation of the Sierpinski Gasket (McGuire, 1990)

As Jacob (2008) pointed out in his dissertation; “Randomness can be introduced into this formation. In ‘An Eye for Fractals’, Michael McGuire illustrates this by randomly picking a point on sides of the triangle instead of the mid-point as observed above. After only eight iterations, a mountainside with rugged rock outcrops can be observed” (Figure 13).

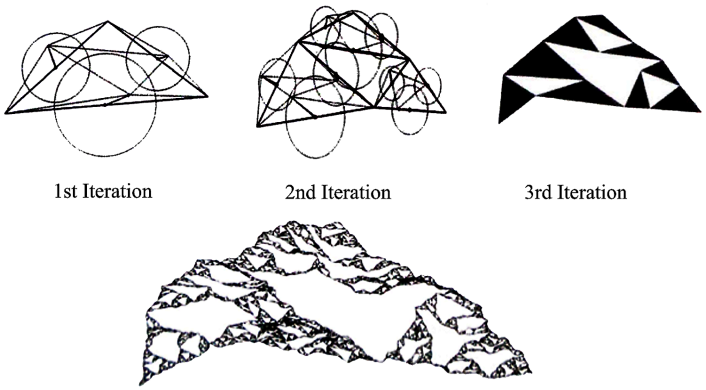


Figure 13: Introducing Randomness (McGuire, 1990)

Also, as Bovill (1996); referred to Michael Barnsley, in his book ‘Fractal Everywhere’, provides this warning in his introduction:

“Fractal Geometry will make you see everything differently. There is a danger in reading further. You risk the loss of your childhood vision of clouds, forests, galaxies, leaves, feathers, flowers, rocks, mountains, torrents of water, carpet, bricks, and much else besides. Never again will your interpretation of these things be quite the same.”

It should be mentioned that, due to the limitation of this research, psychological aspects are not the main focuses of this research, and the main target is to find the

randomness and self-similarity of a vernacular settlement, which is going to be discussed in following chapters.

3.2.1 Fractal Theory

According to Burry & Burry (2010), in ‘The new mathematics of architecture’: “Intuitive meaning. That has a form, either exceedingly irregular, or exceedingly fractured or fragmented, and continues to be so whatever the scale it is examined at. That contains distinguishing elements whose scales are highly varied and cover a very broad range” (Burry & Burry , 2010).

Apart from mentioned spontaneous meaning of fractal, configuration of fractal set or object should be clarified. “The word fractal does not distinguish, intentionally, between mathematical sets (theory) and natural objects (reality): it is used in those cases in which its generality and the resulting intentional ambiguity are either desired, made clear by the context, or do not entail associated drawbacks” (Burry & Burry , 2010).

Between uncontrolled chaos absolute disorder and Euclidean order, for characterizing the "segment of fractal order", the mathematician Benoit Mandelbrot, characterized the clarification of the topographical structure's relief in the mid-sixties by some basic inquiry:

“How can we explain the form of topographic relief, the geometry of fractures and their distribution, the morphology of the fluvial system with classical geometry? How can we justify in the future present the existence of sealed compartments in science? The question is answered by proclaiming the need to resort to fractal geometry in order to present a series of experiences that encompass from patterns of

natural process to abstract numerical simulations obtained using computational techniques" (Mandelbrot & Frame, 2003).

In fact, "Fractal geometry has had a revolutionary impact upon the theories of physics, especially in the construction of mathematical model of phenomena that appeared to be governed by a casual or unpredictable order. Not only turbulence phenomena (as in the expansion of a gas in the air), but also natural patterns have been characterized by irregularity (the profile of a shoreline, the shape of the tree, land reliefs, etc.) and dynamical structures of temporal-spatial development (clusters, multitudes, deployments, etc.) The characteristics of fractal permit, in effect, a definition of elastic pattern of evolutionary topologies that characterize such phenomena. Also, fractal objects do not have a dimension that is measurable by a whole number. Their dimensionality is found precisely along the boundary between lines, planes and volumes. They are more efficient at occupying space than their real counterparts. They are more dense than lines, but without arriving at massifying on plane, like a spongy ball of yarn" (Burry & Burry , 2010, p. 474).

Beside this, one of the results of the vast point of interest of a fractal object is that, they basically don't have any conclusive absolute size, and such scalar uncertainty presents globalist in locality and, most importantly, allows 'local' transferences of the part to the entire: what is called 'scalar jump' (Jencks, 1997).

Moreover, fractal geometry would not summarize only in micro scale. As Batty & Longley mentioned; "If it weren't for the profound idea that complex entities such as cities can be understood in the very simple terms that make them up. Cities demonstrate enormous variety, but there is order in this variety, and this order is

clearly constructed by very simple elements. The new digital geometry and the expansion of CAD enable us, more than ever, to interpret such developments. If fractal geometry is the way to joining form and function, the coming decade should see the emergence of a new theory that demonstrates how form and function coevolve spontaneously through new dynamic design" (Batty & Longley, 1994).

3.2.2 Comparison of Euclidean Geometry and Fractal Geometry

In order to clarify the essence of fractal geometry, this study will use the comparison of Euclidean Geometry with fractal geometry, by referring to different characteristics, which was presented by Jacob (2008) in Table 1 given below.

As it is mentioned in previous studies; the fundamental assumption behind fractal geometry was specifically influenced by the planners and decision makers and opened new skylines for them in the field of contemporary art and architecture approaches. As aforementioned stated, fractal geometry depends on scientific calculations and non-direct material science. Truly, it's mandatory to locate a special ratio, which is known as the fractal dimension. In the accompanying segment, this study will concentrate on depicting the significance of the fractal measurement. Besides, the most valuable strategy for finding the fractal measurement will likewise be clarified (Reza & Dincyurek, 2015, p. 64).

In addition, "Architecture has traditionally used Euclidean Geometry that represents pure volumes that can be defined by equations; it enables us to describe smooth surfaces and regular forms. However, natural objects such as mountains have irregular, fragmented characteristics. Also, natural models can be described realistically by using methods of fractal geometry. A fractal object has two basic characteristics: infinities detail in each point and a degree of self-similarity between

parts of the object and its overall characteristics process rather than equations. This process which represent the object is viewed from different distances, with the same degree of detail and analyses and represent things in the course of time." (Burry & Burry , 2010)

On the other hand, by explaining the characteristic of Euclidean geometry, and by defining the differentiation of mentioned geometry with fractal geometry, the necessity of fractal geometries will be clear more.

"Euclidean shapes do not display a cascade of textural depth. On closer observation, Euclidean shapes remain straight lines and smooth curves. The Koch curve is an example of a fractal. It is created in a recursive way, mapping itself at smaller and smaller scales. It displays a cascade of self-similar structure." (Bovill, 1996)

Euclidean geometry and fractal geometry are not conflicting but complementing. (Table 1). Fractal geometry was able to clear several confusing theories that Euclidean geometry could not; thereby filling the gaps in it (Haggard, Cooper, & Gyovai, 2006).

Table 1: The comparison of Euclidean geometry with fractal geometry (Haggard, Cooper, & Gyovai, 2006; Jacob, 2008, p. 15; Reza & Dincyurek, 2015, p. 65)

ABOUT	Basic assumptions behind Euclidean geometry (200 years old)	Basic assumptions behind fractal geometry (20 years old)
1. Description	The main concern is the description of –man-made objects. Natural objects are assumed to be difficult to describe or are indescribable in geometric terms.	There is holistic reality, infinitely complex but geometrically describe-able which we call nature.
2. Form	Simple rules give simple forms. Complex forms require complex rules; therefore simplicity is a virtue.	Infinitely complex forms are easy to generate by simple means. Complexity is an accessible to us. Simplicity can be a virtue, but can also be simplistic. Complexity is our biological heritage.
3. Form generation	Formulae are the generator of form.	Iteration and feedback is the generator of form.
4. Randomness	Randomness has no place in geometry.	Randomness can be part of the form generating process.
5. Dimension	There are three whole numbered dimensions.	There are an infinite number of dimensions that can fill the gaps between one, two and three dimensions
6. Infinity	Infinity is not dealt with in geometry	Infinity is an everyday quality and part of geometry.
7. Length	Length is fixed and measurable	Length is often infinite.
8. Scale	Scale is the relative size of objects to ourselves, other objects, or systems ofmeasurement	Scale is where we choose to focus our attention on an infinite choice of scales

9. Order	Order is predictable and desirable. Disorder is unpredictable and undesirable	Order can be very complex; order and perceived disorder are not discrete things but often aspects of the same thing.
10. Reality	Reality is dualistic with order and disorder in opposition to each other.	Reality is complex, diverse and holistic. Duality between order and disorder is sometimes a useful tool, often an illusion and sometimes a delusion.
11. Harmony	Harmony can be achieved by simplification.	Harmony can be achieved by complexity.
12. Order & dynamics	Control is an essential part of aesthetics.	Dancing with chaos is an essential part of aesthetics.
13. Symmetry	Symmetry and asymmetry are important aesthetic devices.	Self –Similarity and affined similarity are also important aesthetic devices.
14. Form expression	Geometrical solids are the basic building blocks of aesthetics because they deal with differentiation.	Fluidity is an essential part of aesthetics because it deals with connectivity and process.

Also, as Benoit Mandelbrot, defines Euclidean geometry in the Fractal Geometry of Nature; "Why is geometry often called cold and dry? One reason lies in its inability to describe the shape of a cloud, a mountain, a coastline, or a tree. Clouds are not spheres, mountains are not cones, a coastline are not circles, and bark are not smooth, nor does lightning travel in straight line" (Mandelbrot, 1982, pp. 34-74).

According to this definition Bovill mentioned; " Mandelbort's fractal geometry has the capacity of describing the cascade of detail observed in these natural forms. The relationship between nature fractal geometry is often introduced through the example of the length of a coastline. As the length of the instrument one uses to measure a coastline gets smaller, the measured length of the coastline gets longer as smaller and smaller bays and inlets are included in the measurement. A natural rocky coastline displays a progression of detail similar to the Koch curve, except that it's meandering is random. Moreover, "Architecture composition is concerned with the progression of interesting forms from the distant view of the elevation to the intimate details. This progression is necessary to maintain interest. As one approach and enters a building, there should always be another smaller-scale, interesting detail that express the overall intent of the composition. This is a fractal concept. Fractal Geometry is the formal study of this progression of self-similarities detail from large to small scale" (Bovill, 1996).

3.2.3 Definition of Fractal Dimension

Scholars and scientists describe the fractal dimension as a special ratio, which is used for evaluating density and visual compactness. As shown in Table 2 below, there are many different ways to find the fractal dimension. Discussion and explanation of methods for fractal dimension was not a tangible topic between architects and designers until it becomes a practical method and tool for them.

Table 2: The description of fractal dimension methods (Annadhason, 2012; Blackledge, Evans, & Turner, 2002; Jansson, 2006; Klinkenber., 1994; Turner, Blackledge, & Andrews, 1998)

Method	Description	Usage
Walking-divider method	The initial and final step must be carefully chosen. The initial step (staring value) is described as half of the average between the points.	Finding linear fractal curved. (1D)
Box counting method	The fractal surface is covered with a grid of (n) dimensional boxes or hyper-cubes with side length, δ and counting the number of boxes that contains a part of the fractal N (δ). For signals, the grid consists of squares and for images, the grid consists of cubes. The fractal surface is covered with boxes of recursively different sizes.	Finding the surfaces (2D) and linear objects (1D) by rectangular grid shapes.
Prism counting method	The most inaccurate as it does not yield similar fractal dimension values. Based on four triangles defined by the corner points. Algorithms are similar to the box counting method. The triangles define a prism based on the elevated corners and a central point computed in terms of the average of the four corners.	Finding the surfaces (2D) and linear objects (1D) by triangular grid shapes. It is slower due to the number of multiplications implied by the calculation of the areas.
Epsilon-Blanket method	Fractal dimension of curves/surfaces are computed using the area/volume measured at different scales. It is a high fractal dimension and it gives a less accurate result.	Finding the surfaces (2D) and linear objects (1D) and also it can be used for finding the depth (3D) images.
Perimeter-Area Relationship method	To estimate the perimeter's fractal dimension of self similar shapes which are embedded into 2D Euclidian spaces. Proposed by Mandelbrot for closed fractal curves as follows from the fractal dimension.	Closed curve, Circle (2D) Euclidian shapes.
Hybrid method	Calculate the fractal dimension of 2D surfaces using 1D methods. This approach is based on the relationship that exists between the fractal dimensions of a surface's contours (1D fractal curves) and the fractal dimension of the surface.	Any algorithm used to compute from D1 to D2.

Power spectrum method	Advanced evaluation method for estimating fractal properties in Nonlinear-Physic, Chemistry, Medicine and etc.
Fractional Brownian Motion method	
Variogram	
Isarithm	

As Vaughan and Vaughan, (2008) mentioned fractal geometry might be utilized to portray irregular or complex lines, planes and volumes that exist between entire number integer dimensions. This infers, rather than having a dimension, or D, of 1, 2, or 3, fractals might have a D of 1.51, 1.93 or 2.74. This idea can be promptly comprehended by considering an idea test. From a distance, it might appear to be a perfect two-dimensional surface (D = 2). But, if a person rubbed their hands across the surface they would feel that the surface has some texture and this implies that the table surface is more than two-dimensional. However, the surface is not really three-dimensional either. Mandelbrot suggests that, fundamentally, if the sentiment surface is exceptionally inconspicuous then the real dimension of the table may be just marginally higher than D = 2; perhaps D = 2.1. However, if the surface was scarred and heavily marked with the grain of its underlying material, it might have a D = 2.3. (Vaughan & Vaughan , 2008; Reza & Dincyurek, 2015)

According to the ideologies of many different scholars; “Using the box-counting method, Bovill’s analysis showed that the elevation of the Robie house had a much higher fractal dimension than the elevation of the Villa Savoye; the difference was in the order of 10%. The comparison of the results confirms the intuitive interpretation, that architects have historically offered, that Wright’s design, with its elaborate windows, modelling and raked rooflines, has greater and more consistent visual

complexity than Le Corbusier's white, geometric elevation. While Bovill's results were never meant to imply anything further about the architects' works, other researchers have subsequently interpreted them as implying a fundamental difference between Modernist and Organic architecture. At the same time, Bovill's box-counting method has also been described and extrapolated by a number of researchers and it has been used to determine the fractal dimension of selected views of ancient as well as modern architecture" (Bovill, 1996, p. 119). Due to his interpretation, the box-counting dimension is considered by calculating the number of boxes that include lines from the internal illustration. As the result there will be more infill boxes that include lines in them by considering the reduction of grid sizes. Table 3 and 4; indicate the number of boxes that have lines in them to the total number of boxes of the grid, which indicates the grid size.

Table 3: Box Counting For the Robie House Elevation (Bovill, 1996)

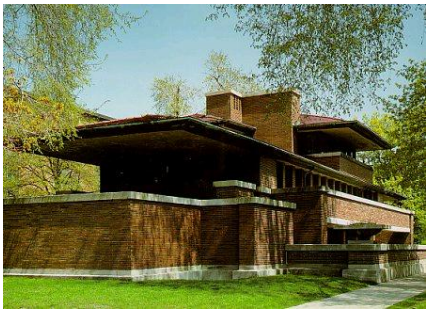
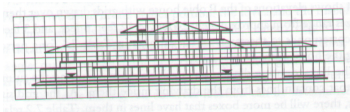
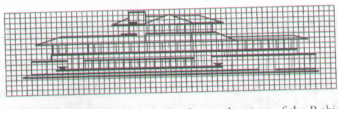
Box Count	Grid Size	Grid Dimension	
16	8	24 feet	
50	16	12 feet	
140	32	6 feet	
380	64	3 feet	

Table 4: Box-Counting grids over elevations of the Robie house (Bovill, 1996)

Box Count	Grid Size	Box -Counting
16	8	
50	16	
140	32	
380	64	

Due to the description of fractal and box counting method, the equation was used for finding fractal dimension shown as below;

$$D\ (\text{Box-Counting}) = \frac{\log n+1\ (\text{Solid box}) - \log n\ (\text{Solid box})}{\log n+1\ (\text{Total box}) - \log n\ (\text{Total box})}$$

Due to Robie House elevation, there will be three different fractal dimension is going to calculate. The first fractal dimension is ascertaining by allocating 16 boxes which each one is 24 feet.

D (box, 24'-12') = [log (50)-log (16)] / [log (16) - log (8)] = 1.645

The next iteration will be done by exploring of those boxes that are 12 feet across with boxes that are 6 feet across;

D (box, 12'-6') = [log (140)-log (50)] / [log (32) - log (16)] = 1.485

The final range which the boxes will be compressed, by 3 feet size locating on the elevation;

D (box, 6'-3') = [log (380)-log (140)] / [log (64) - log (32)] = 1.441

As the result of these calculations, the last two results are in closer arrangement than the first calculation. This means that, fractal dimension in mentioned iteration are much closer to each other (Figure 14).

Also as Bovill claimed; Boxes are left out of the account for two reasons: One, the profile of the building is described with greater accuracy, and two blank or undetailed areas of the elevation are indicated. Thus, the counted boxes represent the area of the elevation where there is something to look at and by referring to the Sierpinski gasket, found a distant relationship with progressed shape (Bovill, 1996).

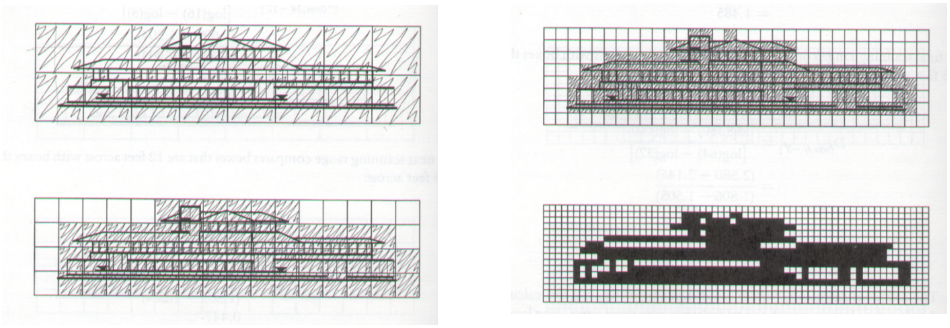


Figure 14: The Counted Boxes from the Box-Counting Analysis of the Robie House Elevation (Bovill, 1996)

It should be mentioned, Box Counting is one of the methods for calculating the fractal dimension, and calculating the fractal dimension is not the target of dissertation. This expansion will be mentioned just for describing the logic of fractal geometry, which will be used in parametric design disciplines.

Moreover, in the ancient period, the relationship between inhabitants and nature was not that much unfamiliar and unrelated, in comparison with contemporary era. According to this, their architecture and construction were following nature's orders. As they grew in nature, this chase unconsciously took place it was reflected to their productions as well. On the other hand, it can be mentioned that their unconsciousness of the human being were grown by fractal orders of nature.

This achievement is visible in the rural settlements and patterns clearly, and as it mentioned before, the aim of this dissertation is finding these natural orders, and transferring them to contemporary architecture by new definitions. One of these definitions that can be useful for this bio mimicking is called parametric design, which will not be the target of this dissertation.

3.2.4 Usage of Fractal Dimensions

Fractal dimension has various dimensions in different disciplines such as physics, chemistry, geography, psychology and etc.; this brief explanation is giving general perspective as an introduction to usages of fractal dimension.

According to Salingaros; "Human beings are apparently tuned to prefer an environment that has the self-similar properties of a fractal. Furthermore, as different types of fractals are characterized by what is known as their "fractal dimension" D, we respond best to "mid-range" fractals where D is between 1.3 and 1.5. In such fractal environments, our body automatically dampens its response to stress induced by intensive tasks and reaction to external forces. This implies that particular fractal environments are healing, or at least buffer us from life's stresses. The remarkable fact is that this response is independent of what the fractal designs around us actually look like: they can be either representational or abstract" (Salingaros , 2012).

He also claimed that; “The results from a 1986 study carried out by NASA (Wise, Rosenberg 1986) strongly indicated that persons respond positively to natural scenes (either real scenes, or visual images of them), whereas they respond negatively to non-fractal abstract shapes. Subjects had to perform three types of challenging mental tasks: arithmetic, logical problem solving, and creative thinking while exposed to four different 1m x 2m images. Ordinarily, such tasks induce a degree of physiological stress, so that it was possible to measure the effect of the image on the body state while performing these tasks” (Salingaros , 2012).

On the other hand, “The results are as follows: the abstract non-fractal artwork increased the stress by 13% as compared to the control situation, whereas the two natural scenes decreased the stress by 3% and 44% as compared to the control” (Taylor, 2006).

As Joye commented; “Only this assumption explains why we respond in a positive manner to artificial fractals and, coincidentally, why humankind has produced fractal designs on artefacts and buildings for millennia” (Joye, 2007).

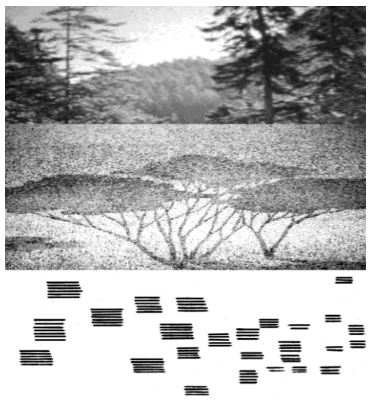


Figure 15: A photograph of a Forest (top), an artistic rendition of a landscape (middle), painted lines (bottom). © Richard P. Taylor, used with permission. (Salingaros , 2012)

Moreover, as an altered benchmark, we can list the expanding stress conditions caused by the diverse exploratory situations. I will utilize the control circumstance (plain white board) as simply one more of the components, giving it equal importance (Figure 15) (Salingaros , 2012).

On the other hand, Zexin, Bo, & Zhi (2013), classifying the stress variety as;

1. Savannah landscape: minimal environmental stress
2. Dense forest scene: slight increase of environmental stress
3. Minimalist colourless environment: significant increase of stress
4. Abstract non-fractal design: further increase of stress.

Ordering the experimental environments in this way demonstrates clearly that minimalist design is neither preferred, nor particularly good for us as far as dampening our physiological response to stress. It increases stress over our innate baseline fractal preference. When we abandon minimalism in design and create complex but non-fractal artificial environments, we actually increase our stress ever further. I'm aware that this is a disconcerting statement to designers, artists, and architects, yet it is supported by incontrovertible experimental data" (Zexin, Bo, & Zhi, 2013).

In addition Salingaros, also discussed about fractal dimension's effect on physiological aspects as; "Allow me to provide some background on what the fractal dimension D represents. A smooth line (either straight or curved) has D = 1, whereas an area fills in a two-dimensional region and has D = 2. However, an infinitely crinkled, meandering, and convoluted line will fill a little into its adjoining area and will have D somewhere between 1 and 2. An example of this type of fractal line is

the von Koch Snowflake, with D = 1.26 (which is amply documented on the World-Wide Web). A mathematical object that has dimension approximately halfway between a line and an area, i.e. that has fractal dimension around 1.5 is called a "mid-range" fractal. The more convoluted and meandering a fractal line, the closer its fractal dimension will approach 2, at which point it ceases to be a line because it fills in all the area. We can also arrive at a "mid-range" fractal in quite a different manner. Starting from a filled in plane with D = 2 we begin to punch holes into it, perforating it with smaller and smaller holes. If we do this in a regular hierarchical manner, we are reducing its dimension and eventually create a "mid-range" fractal with D somewhere between 1 and 2" (Salingaros , 2012).

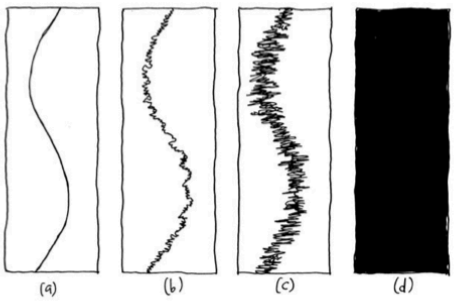


Figure 16: Fractal Lines of Increasing Dimension, Until They Become an Area: (a) D = 1 (not fractal), (b) D = 1.2, (c) D = 1.7, (d) D = 2 (not fractal, (Salingaros , 2012)

He also commented on fractal architecture of natural environment as; "The forest scene (Figure 17, Left), which turned out to have a mildly positive effect, has dominant lines with fractal dimension D = 1.6, whereas the savannah landscape scene (Figure 17, Right), with a strongly positive effect, has lines with fractal dimension D = 1.4. According to this and other experiments, human beings do have an enhanced response to fractal images characterized by lines with fractal dimension nearer a preferred value of D = 1.4. Therefore, it should be no surprise that the

subjects in the above experiment responded better to the savannah landscape scene" (Salingaros, 2012).

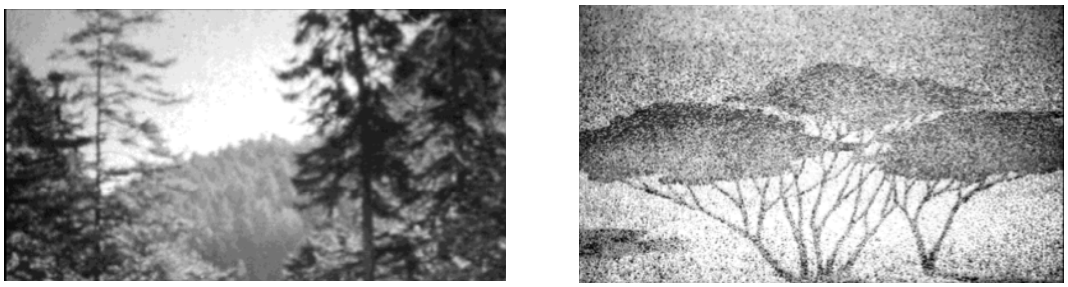


Figure 17: A Photograph of a Forest (Left), an artistic rendition of a landscape (Right), (Salingaros , 2012)

Moreover due to a square gasket and the relaxing effects of needlework; "Further distinct experiments by Taylor and his associates reveal a preferred value for the fractal dimension of edge lines with D = 1.3" (Hagerhall, 2008).

As Joye, mentioned; "Goldberger, Salingaros, Taylor, Wise agree on one fundamental point: there appears to be a certain resonance between our cognitive apparatus and environments that possess fractal properties. Furthermore, not all fractals elicit the same degree of positive emotion leading to psychological stress reduction, but specifically mid- range fractals with fractal dimension around D = 1.4"(Joye, 2007).

As a matter of the fact, utilization of late investigative results as it was examined, reported here to drastically upgrade the new spaces, for example, learning and workplaces with considering well-being and long-term issues.

As it was pointed out before, current investigation mainly focused on the fractal usage. Therefore, following chapter presents the emergence and interpretation of fractal architecture.

3.2.5 Fractal Geometry in Architecture

Usage of organic shapes by inspiration from nature, facilitate new architectural approaches and construction techniques, representing the harmony between man-made and natural build environments.

Numerous architects and designers from past to present, were deciphering natural methodologies of architecture in their activities.

Antonio Gaudi (1825-1926), who was Spanish Catalan architect was one of the well-known architect, artist and decision makers that most of his projects locations is in Barcelona.

As he claimed on, the reasons about 'Inspiration of nature'; "Those who look for the laws of Nature as a support for their new works collaborate with the Creator."

'Sagrada Familia', Roman Catholic Church in Barcelona, was designed and constructed by Antoni Gaudi, which was one of the pioneers of mentioned style in architecture.

According to Jacob, "Sangrada Familia is said to perfectly combine Gaudi's penchant for Gothic and Catalan architecture, and curvilinear Art Nouveau shapes. Symbolism reflects in every aspect of the building. If allowed two phrases to describe Gaudi's work, it would be 'art nouveau' and 'organic'. From Barcelona to

the cathedral to the spires to the entrance to the evangelists; the detail is striking (Figure 18) (Jacob, 2008).

Figure 18: Different views of Sagrada Familia (Jacob, 2008)

By looking back to history, number of mentioned architectural approach could be found in the history such as Kandariya Mahadeo Temple in Khajuraho (Figure 19).

Figure 19: Kendariya Mahadeo Temple

This religious monument is the continuation of mountains skirt and the place for worship with embarrassing the sky. Also, the elevation creates vibrating replication almost like geological layers, proper with the Hindu mythology. Correspondingly, the temple design includes the classic image of a cosmic person. This building, symmetrically filling the gridded space of the floor plan, includes the prototype of the interstellar mountain. And according to Jacob (2008) the fractal dimension was calculated as 1.762.

As Jackson (2014) indicating, “Thus a structure such as the Kandariya Mahadeva temple in Khajuraho visually conveys a recursive sensibility. It is a whole of self-similar peaks clustered and rising; forming a consistent coherent totality the rising slopes of a cosmic mountain. The rising and falling lines lead up to one supreme point of transcendence, symbolic of the ultimate unity which is of supreme importance in many great Hindu traditions. All the features are parts of the ultimate oneness, and so they share the same style, though on various levels and scales of significance and attainment.” (Figure 20).

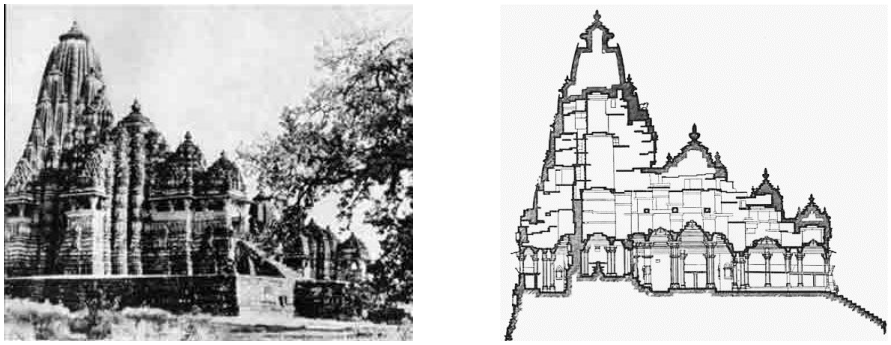


Figure 20: The Rising, Fractal-like Shikharas of Kandariya Temple in Khajuraho. Stella Kramrisch's book, The Hindu Temple (Jackson, 2014)

As a matter of the fact, both mentioned scholar Jacob and Jackson concluded that; the subdivisions make the user feel more comfortable and relaxed and with three basic principles (harmony, proportion and scale), aesthetics will be more meaningful.

According to them; “Harmony is achieved through compositional balance. The form may be symmetric or asymmetric. It is coupled with high degree of complexity. Also, proportion, is the harmonious relation of parts to each other and a perceived whole. Contrary to the notion that ‘beauty lies in the eyes of the beholder’. Moreover, scale would mean the relative size of buildings. This may be with a

particular measuring system or relative size of parts to the whole." (Jacob, 2008; Jackson, 2014)

Usage of fractal is not only summarized in building definition scale. This terminology could be expanded in macro scales such as urban scale. In addition it can be the topic of the natural pattern, which doesn't have any defend, and Euclidian shapes, such as hilly cities.

According to Zexin & Zhi (2013); "The hilly city is different from plain city and is also different from the mountainous city, it is somewhere between these two types of urban space, with more varied landscape than plain city and more delicate and pleasant city space than mountain city. The topography is the objective condition for the development of urban spatial structure. Hilly areas have diverse topographic relief, with mountainous and rivers surrounded. Hills have the following characteristics: Firstly, with the characteristics of topographic relief, hills are combination of slopes made up of all kinds of rocks. The slops are generally moderate and desultorily cut, without certain direction. Secondly, the altitude is less than 500 m and the relative height is no more than 200 m."

In addition, they classified hilly lands in two categories according to the space types. First one is punctiform hills space, with fragmental space and no directionality. The other is linear hilly space, mainly consist of intervals, the space has obviously directionality and intervals are usually accompanied by a river. It should be mentioned that hilly topography has the characteristic of complexity and self-similarity as well. It is found that, in fact real topography had not only strict fractal part, but also non-fractal part of linear trend and scale-related. These scale-related

parts are easily observed in the actual topography. Also as they stated in the fractal characteristics of hilly city spatial structure; “In the discussion of city spatial structure, city geometry relation is an important feature of special structure and the point, line and plane in space is an important factor of structure”. (Zexin, Bo, & Zhi, 2013)

Moreover “The city spatial structure also has fractal structure characteristics; it is reflected in various aspect of city space, such as boundary system, traffic system, functional structure etc. the self-similarity of city topography at different scales and that of natural topography and plane shape of mountain city at different scales, can be summarized as the self-nested structure of non-linear fractal structure.” (Long & Meie, 2007).

As Yue & Ran-ran (2010) metions; “Draw the fractal characteristics of the city space shape. In fractal figure, the structural units exist in the form of groups; each group has a closed boundary and the function is relatively independent. It described the space structure changes of community in the city scale. For example, there are residential districts, commercial district, and city secondary main roads system in residential districts. Hilly city boundaries at different scales, form city boundary to group boundary, till the boundary of every land, have similar characteristics of irregularity; the characteristics of freestyle traffic system also penetrate from the main road system to bypass system.”Moreover they were discussing about three conditions for the existence of fractal structure of the city as;

1. The hierarchical structure.

2. The basic unit.

3. Self-similarity.

In addition, as the claimed; hilly cities exist as double fractal structure;

1. The fractal structure of natural topography.

2. The fractal structure of city space (Zexin, Bo, & Zhi, 2013).

Also, they were looking for finding fractal dimension value of hilly city shape. As they mentioned, the hilly urban space fractal characteristics, one need to use a mathematical model for the quantitative description of the extent of the fractal and different fractal dimension measurement method represent different connotation. At present, the measurement methods of fractal dimension of city space include boundary fractal dimension. When use the boundary fractal dimension, one can calculate the fractal dimension of different kinds of land. Its value means the fragmental degree of land boundary, or the land area of different space and they categorized it as:

"A) The grid dimension means to divide different city land into grids and then calculate the boundary fractal dimension of grid, in order to reveal the evolution of city shape and land use structure.

B) The radius dimension method reflects the centripetal aggregation degree and spatial distribution pattern of city land and can be used as the quantitative basis for judging the efficiency of city centre." (Huang, Wang, Wang, Li, & Zhang, 2007)

In fact, for the measurements of fractal dimension of urban identity, it contains mostly ordinary or flat cities at present and there are less elevated and hilly cities included. Due to mentioned case study, however, the measurements and correlation of fractal dimension values of cities at home and abroad, one draw conclusion that the suitable fractal dimension esteem city space is about 1.7 (Huang, Wang, Wang, Li, & Zhang, 2007)

3.3 Cellular Automata (CA) Theory

This study will be continued by focusing on the specific methodology, which is known as 'Cellular Automation' for the regeneration of the extracted pattern in order to operate contemporary housing proposal.

"Cellular automata is the computational method which can simulate the process of growth by describing a complex system by simple individual following simple rules. This concept of simulating growth was introduced by John von Neumann and further developed by Ulam in the area of simulating multi-state machines. The concept gained greater popularity when Martin Gardner described John Conway's "Life", a game that generated two-dimensional patterns. Stephen Wolfram began researching the concept to represent physical phenomena and has recently reintroduced the discussion in a New Kind of Science." (Krawczyk, 2002)

As Dinçer, Çağdaş and Tong mentioned; "Currently this approach is moving forward to an integrated architectural design process by the influence of developing technologies. The idea that design, practice or materializing processes in architecture are complementary and are implemented interactively has come to light as a result of this approach. The concept of mass customization supported by digital production

instead of mass production and standardization has also gained importance. In other words, a new paradigm based upon rich and creative possibilities of electronics instead of mechanics refuses simplification efforts of modernism. Also it has been put forwarded as a result of the idea that genuineness is as easy and economical as repetition" (Dinçer, Tong, & Çağdaş, 2014)

New computer sciences, such as; cellular automata, shape grammar, genetic algorithms have been beneficial outcome on growing new design approaches. Among specified techniques, cellular automata was much more distinctive and more unmistakable than the others. Fundamental contrasts is possibility of visualization of the information and yield and presenting them, which is standout amongst architect's prerequisites. Developing the model beside managing complex structure by considering the neighbors and dispersing in entire world is another positive approach of mentioned terminology.

Due to importance of cellular automata it should be mentioned that; "The connection to architecture is the ability of cellular automata to generate patterns, from organized patterns we might be able to suggest architectural forms. Cellular automata, viewed as a mathematical approach, differ from traditional deterministic methods in that current results are the basis for the next set of results. This recursive replacement method continues until some state is achieved. Fractals and strange attractors are also created in a similar manner. Many digital methods in architecture are parametrically driven, Krawczyk, an initial set of parameters is used to generate one result. If an alternative is desired, the parameters need to be modified and the generation is repeated anew. The difference between these two methods is that in parametric methods the results can be easily anticipated, while in recursive methods the outcome

usually cannot. This offers an interesting and rich platform from which to develop possible architectural patterns." (Krawczyk, 2002)

According to Krawczyk, cellular automata, particularly, classified in three different dimensions as;

1. Wolfram, one- dimensional,
2. Conway, two-dimensional
3. Ulam, three-dimensional (Figure 21 and 22).

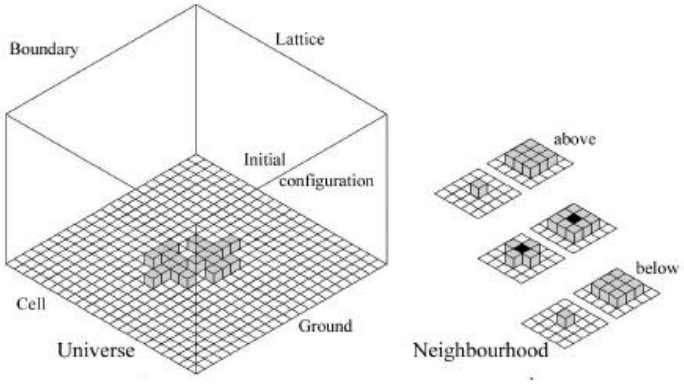


Figure 21: Basic Cellular Automata Terminology

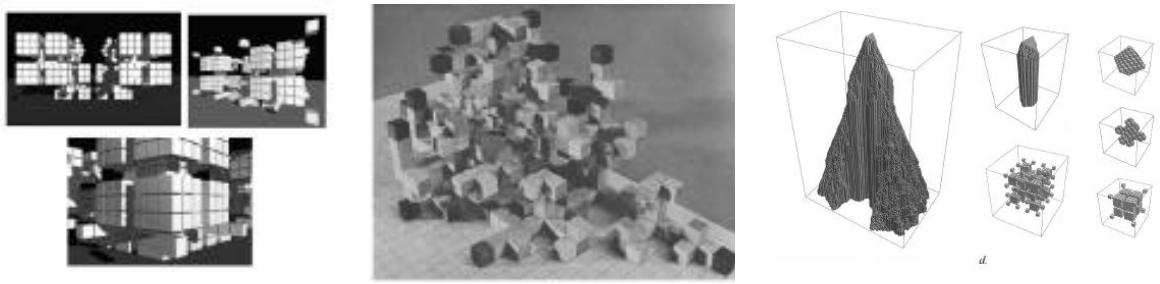


Figure 22: Three-dimensional Cellular Automata

3.3.1 Basic Definition of Cellular Automata

The three-dimensional universe, Figure (2a) of cellular automata comprises of a boundless cross section of cells. Every cell has a particular state, involved or vacant, spoke to by a marker recording its location. The transitional process begins with an underlying condition of involved cells advances by an arrangement of standards to each succeeding generation. The tenets figure out who survives, passes on, or is conceived in the next generation. The principles utilize a cell's neighborhood to define its future. The neighborhood can be determined in various ways.

Figure (2b) represents two basic techniques, for figuring out which contiguous cells to consider. The law developed by Conway is: check each possessed cells' neighborhood, survival happens if there are two or three neighbors, death happens if there are any other number of neighbors, and birth occurs in a void cell in the event that it is contiguous just three neighbors. As each generation advances, one of four cases can happen over some timeframe. Either the cells find a steady form and show up not to change; or they become what is called a "blinker" and substitute between two stable states; or all or a cluster of the cells become a "glider", a gathering of cells that begins to transverse the universe forever, or all the cells die, elimination. An assortment of guidelines has been offered, with Conway's being the conventional beginning stage (Krawczyk, 2002).

3.3.2 Architectural Interpretation of Cellular Automata

"The pure mathematical translation of cellular automata into architectural form includes number issues that do not consider built reality. For example, Figure 3 displays an initial configuration, 3a., and its raw results at the 8th generation, 3b. The interpretation or translation to a possible built form can be dealt with after the form

has evolved or it can be considered from the very beginning. Deciding to follow a combination of both approaches, as shown in Figure 23, a boundary is placed on the lattice to represent a site, along with a ground plane, and an orientation of growth that is vertical and to the sides, but not below. The cells are stacked over each other to create a vertical connection without a vertical displacement between layers of cells" (Krawczyk, 2002).

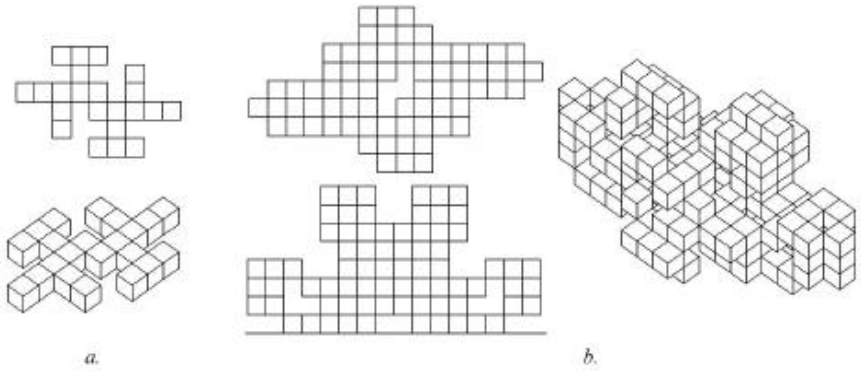


Figure 23: Sample Generation (Krawczyk, 2002)

"Cellular automata comprise cells which represent specific number of the defined states and function as a set of rules with a specific grid order in a certain period of time (Terzidis, 2006). Cellular automata include basic components such as cellular spaces, local value space, neighbourhood, limitation conditions, transition rules and repetitions (Hoekstra et al., 2010). Lack of external control (autonomous), heterogeneity, universal order (emergence from local relations), self-maintenance (repair and production metabolisms), harmony (functionality/ following external changes) and hierarchy (nested self-organizing processes) are the fundamental concepts of this tool. This tool, which was originally developed to define self-organizing systems, can also be used for interpreting problems of architecture and urban designing that include a broad content from social interactions to spatial relations and behaviour of material thanks to structural and behavioural features.

Conway's "Game of Life" is one of the most known examples of cellular automata and has become a prototype for complex systems with its simple and comprehensive properties (Hoekstra et al., 2010). It is a study, which exemplifies a complex behaviour as a consequence of very simple local rules. Basically it is operated by transition rules, which comprise four different logical states and affect each cell separately (Figure 1). Rules of the Game of Life are based on set of logical and arithmetic processors using terms like "and", "or" and "not". These rules are applied to an initial configuration which includes living and dead cells within a lattice of NxM grids and new patterns start to emerge over time. In the proposed model, rules of Conway's "Game of Life" in Figure 1 have been interpreted logically and evaluated directly in architectural spatial relationships." (Dinçer, Tong & Çağdaş, 2014).

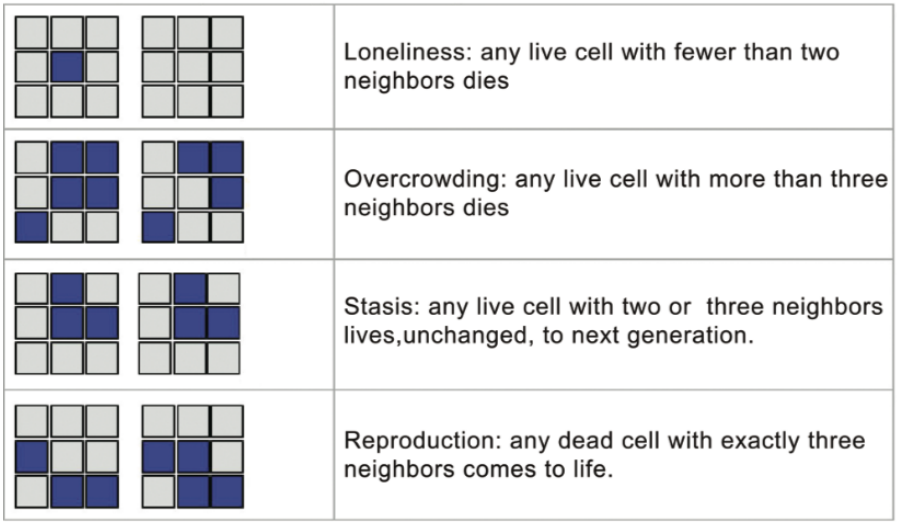


Figure 24: Transition Rules of the Game of Life (Devetakovic et. al, 2009)

"The first experiences about using cellular automata in architecture are Price's "Generator" and Frazer's "Universal Constructor" applications (Herr and Kvan, 2007). Price's study is the first architectural project combining a general understanding of useful space and elements of micro controller support structure.

This study is based on the functionalist approach that spaces in structures are organized according to user needs rather than aesthetic. On the other hand, Frazer aimed at determining an architectural approach as logical cases both in time and space with his study "Universal Constructor". Then, Coates and his team (1996) carried out some studies in architectural design studio in order to develop a specialized cellular automata as a tool of decision-support having features such as shaping and extensive state variables in digital environment. This study inspired by Conway's "Game of Life" investigated three stages; firstly defining the rules and increasing neighbourhood of cells and associating it with architecture; secondly behaviours of cells affected by environmental factors; thirdly potential shapes which can create three dimensional configurations affected by cellular relations. Krawczyk (2002), in his studies, also addressed that cellular automata have the potential of cells to produce spaces and the development of their structural features. The generations include defining the growth space of cells and identifying their growth directions; determining the problems about establishing vertical and horizontal relations; carrying out processes such as combination or overlapping of cells and supporting these processes by structural elements; trying out varieties by changing shapes of cellular elements and eventually reaching to conceptual models (Figure 24).

Krawczyk (2003) explained the differences in generation processes in another work; hence he obtained new alternatives, which may have regular and irregular architectural structures in each generation process by changing formal features of cells. Clark and Anzalone (2003) examined two and three-dimensional cellular automata in terms of both their structural properties and potentials of creating architectural forms. They have investigated the potentials of forms consisting of appropriate geometrical and space-truss systems by matching rules of cellular

automata with concepts such as discrete elements, algorithmic relations, patterns, scalability and external control. Every behaviour of the new forms has been organized with certain rules (angle, location, distance, connection etc.) and they all engendered an integrated structure, which can turn into different shapes with other elements.

Finally, Herr (2008) suggested in his dissertation that cellular automata could be used more effectively by adapting it to architecture instead of using classical cellular automata applications (such as Conway's Game of Life). It was proven by the approach of Schön's "Reflection in Action" that architectural problems could be solved by developing cellular automata which define special architectural relationships types and by giving feedbacks. Moreover, with the idea that the graphical elements representing cellular automata may limit architectural variety, some solution offers have been used as alternatives to the elements, which are proven to be unproductive and are not restrictive to creativity."

"Cellular automata cannot be used effectively because of its some negative features in spite of its contributions to the design process in architectural field. These negative features are the formation related to function, lack of ability to interfere in the process, redirecting to certain form patterns, lack of ability to manage spatial relationships as the content of the project expands. When cellular automata is assessed for well-defined design problem and interpreted in parallel with basic architectural approaches, its negative impacts can be reduced and, by the way, its contributions to design can be increased." (Dinçer, Tong & Çağdaş, 2014)

- **Disadvantages**

"In other words, it is a suitable solution to adapt cellular automata to the conditions of the context without depending on the classical cellular automata and to evaluate it with designer's interventions in a problem context gathering different user types, containing different functions and requiring open ended opinions." (Dinçer, Tong & Çağdaş, 2014)

There are very close similarities between cellular automata and mass housing designs, which are gaining importance in big cities and which must appeal to different type of users, in terms of their contents and aims. Accordingly, as a decision- support tool, evaluating the model developed by cellular automata can be useful for such design problems. For, the necessity to design these types of housing as innovative and unique examples meeting the demands is constantly gaining importance. Also, cellular automata supports the process, which is appropriate for the needs of renewal depending on the time and changing users as well as opening new opportunities for innovative formation, with its structural properties which operate as bottom-up and relate to the neighbourhoods and in which function leads the form." (Krawczyk, 2002)

Chapter 4

INTERROGATIVE DESCRIPTION OF ORGANIC PATTERN FOR PROPOSING NEW HOUSING

4.1 Understanding and Identification of Pattern Language in General

Due to Oxford dictionary classification the word ‘Pattern’ is defined as, a repeated decorative design or a model or design used as a guide in needlework and other crafts.

Also, as it mentioned before, ‘complexity’ and ‘pattern’ definition are supplement of each other. Pattern language is a tool for equipping the complex system sorts by the help of computer science to be able to represent as built environments. Or in another word, it can be claimed that; complex system is created by dissimilar ‘pattern’, which is systematically governing different regions of the system.

This part of the study is going to describe how existing pattern languages, developed and how they grow.

According to Christopher Alexander; “We observe the world around us and learn its structure by abstracting cause and effect, and by documenting recurring solutions obtained under different conditions. Such empirical rules, representing regularities of behaviour, are called "patterns". Visual patterns are the simplest expression of the

pattern concept. Also, the ability to observe patterns gives us the human advantage of both adapting to, and changing our environment" (Salingaros, 2000)

As Lynn Arthur Steen mentioned; "The language of a group of patterns, forms the groundwork for any discipline. Learned pattern languages is not intrinsic to the human mind, were carefully preserved in the past. Many patterns of human relations are codified into religions, myths, and literary epics. A collective intelligence develops from pooling discoveries accumulated over generations. This process is entirely general. The sciences rely on mathematics for the ability to organize data and explain phenomena by means of regularities, or logical patterns." (Steen, 1988)

Distinguishing the pattern language is not a formal process. Complication is the core and main characteristics of complex system, and as it was mentioned before each complex system is built by different patterns. Due to this, many scholars and practitioners were challenging to cast the structure of pattern languages in different disciplines such as time, space and human dimensions.

One the other hand, "Pattern language description is introduced into architecture more than twenty years ago and it was appreciated by few practitioners. Patterns are a powerful tool for controlling complex processes, but because of misunderstandings, they have not played a wide role in architectural design. Instead, patterns have found unexpected success in computer science." (Alexander, Ishikawa, & Silverstein, 1977)

As it argued, among few scholars and practitioners in the field of architecture and urban planning, Christofer Alexander's ideology and classification of pattern

language is the most practical one. Therefore, next chapter specifically will focus on his terminologies about pattern language in architecture and urban planning.

4.2 Pattern Language and Spatial Relationship in Architecture and Urban Planning

As Alexander mentioned; the pattern language extends from the scale of surface detail, to the scale of a large city, and covers 's ideas on how to best implement a more human built environment.

“Some of the urban patterns flatly contradict land speculation and the erection of mega towers, while the building patterns make obvious the need for more structural quality than today's contractors are used to providing. Both of these points threaten a profit source in the construction industry. While it is not yet clear how to reconcile those differences, Alexander's critics find in this, an excuse, to dismiss all of the Pattern Language as impractical and unrealistic”. (Dovey, 1990)

Therefore, according to the definition of urban cities by Alexander; living cities are define with boundaries and include many different districts, which has specific function. Whether these functions take place in micro or macro scale, urban boundary should be well defined. In other words boundaries are the most fundamental principles that are defining the patterns.

For better perception of urban cities’ pattern, he classified the description as mathematic and practice definition.

“In mathematical terms, it is accurate to call such a line a "fractal," since it is neither continuous, nor perfectly smooth. The needed information for this already exists in

several Alexandrine patterns, which combine to give a definite urban geometry very different from that found in contemporary cities." (Salingaros, 2000)

On the other hand, "In practice, it is very cumbersome to work from a complete catalogue of discovered patterns to create a product. A simplified connective list can drastically improve the utility of any pattern language. A procedure for generating such a map is based on the conceptual "chunking" of information." (Miller, 1955)

Moreover, "The shape of the traditional city has faded into a multiple landscape. The process, which is happening on world scale, is one in which the city has stopped being an enclosed area and has come to manifest itself as a combination of multiple and fragmented remnants. Like a patchwork on the land, the crystalline shape of the primitive city erupts in a heterogeneous spread of splashes and hollow. A patchwork of linked realities; of conflicts and tensions and loveliness-attractions-fostered precisely by the potential for mobility, interchange and displacement. A patchwork therefore-or perhaps more like a plankton-converted into a collection of individual fragments without apparent cohesion, without referential figuration and whose only principle of continuity is based no longer upon the shape of the edifice, but rather upon the networks that articulate them and the "back ground" that surround them. No longer as a residue, but rather a component; in this visual succession of faced (space in negative) and reticulated meshes." (Salingaros, 2000)

In contrast, "Today, patterns are open matrices, rather than closed templates. No longer 'samplers' reproduce to (re) produce models, but rather logics of basic information. By extension, patterns are evolutionary grids, at once normed and flexible." (Gausa et al., 2003, p. 474)

4.3 Organic Pattern and Spatial Relationship in Vernacular Architecture

In addition, due to the target of this study, this chapter is going to explain the organic pattern. But before that, it is essential to describe the definition of organic architecture. According to Frank Lloyd Wright, " the ideal of an organic architecture. is a sentient, rational building that would owe its 'style' to the integrity with which it was individually fashioned to serve its particular purpose a 'thinking' as well as 'feeling' process." (Wright & Gutheim, 1975)

According to this, the common line in between vernacular architecture and organic architecture will be defined as individuality. In other words, the concept of organic architecture could be described as; dissimilar effects to different architects and manifested itself in a variety of methods. Moreover, "Organic Architecture is not a style of imitation, but rather, a reinterpretation of Nature's principles to build forms more natural than nature itself. Engineers, designers and architects often look to nature for inspiration. The research on "natural constructions" is aiming at innovation and the improvement of architectural quality. The introduction of life sciences terminology in the context of architecture delivers new perspectives towards innovation in architecture and design. The investigation is focused on the analogies between nature and architecture. From the time immemorial, human beings have been accompanied with the nature and natural organisms. These interactions sometimes lead to different and contradictory paradigms but the natural organisms have always been the inspiring sources for humans. Mother Nature devotes its countless gifts and resources generously to human beings, to be able to develop their civilizations all over the world" (Mirzaei, 2013).

Different architects and decision makers, have different approaches on organic architecture. Aforementioned approaches were defined by different parameters. Some of the parameter of Wright's organic architecture may be categorized as; building and site, materials, shelter, space, proportion and scales, nature, repose, grammar, ornament, human values, simplicity, mechanical systems and furnishings and etc.;

According to Mirzaei, "A house should look part of the hill, not perched on it and comes from nature, and belongs to that the hill and the house live together and happiness of each one depends on the existence of the other. Organic architecture can be defined in nine phrases: Nature, Organic, The function performance, Delicateness, Tradition, Decorating, Spirit, The third dimension and Space." (Mirzaei, 2013)

In organic architecture three principles are being discussed as follows:

1. "Building is like a natural element and it is one complete component of environment which has been grown up from and all warm and colourful spectrums which have harmony with environment being utilized." (Gössel, 2007)

2. "Building is like a particular element in a purpose that each architecture and construction in its location and individual and in connection with psychological needs of its owner and user has a unique situation and all these aspects should be considered in designing of building." (Field, 2007)

3. "The building should be considering like a traditional element. Each building has its own special personality and not only has been built for him by a house plan or

individual personality but the connection with traditions of country which has in there the building being built. Finally we can say that organic architecture tend to natural order." (Mirzaei, 2013)

Parallel to mentioned classification; organic pattern, is going to be explained briefly.

"Till now, numerous researches have been conducted in order to describe the principles and specialties governing native architecture and reasons of these being valuable and constant. Naturalistic specialties of organic architecture make it evident that this architecture has also been perceived as organism and as such all the construction that emphasizes these specialties can be named as organic architecture" (Peter, 1996).

Also, "Organisms notwithstanding variety, complexity, elegance, richness and beauty have formed and come into being on the basis of real survival and proclivity to continue life and thus structural form and perfection in the nature is the vigilant reaction for survival. In this architecture, human attention merely is in their natural aspects and human being have perceived partially from natural ingredients and architecture are being shaped higher in grade from other animal and that are proportional to their environmental perfection. Today, large part of world's architectures confronting to organic flow are ultra-organic but in most of these architectures, the systematic natural principles have been ignored with the claim of absence of nature. By this way, this architecture can be named as infra organic rather ultra-organic. Exploitation of nature in most of the architectural writings today merely is in segregating process. By this way, global architectural arena can be classified into following three layers:

1. Infra-Organic: Emphasis on overpowering nature and ignoring their principle (machine and mechanized architectures).

2. Organic: Emphasis on naturalistic and attention to natural principles.

3. Ultra-Organic: With naturalistic preservation and attention to natural principles, restoring ultra-natural layers in the human existence" (Ourjafar, Mahmoudinejad, & Hadian , 2011).

More specifically, according to Charles Jencks, "In nature's organisms, every part is provided by nature and is being used in another shape after consumption and imitation. Nothing disappears in nature nor comes in to existence, but is always changing in shape and form" (Jenkes, 2002).

"Use of vernacular materials in architecture highlight this point however; the most contemporary architectural styles destroy nature by applying non-recyclable materials, and reparation of parts. It means that the organism starts to amend the part and the whole system continues its way to the preconceived goal, in collaboration with the other parts" (Ourjafar, Mahmoudinejad, & Hadian , 2011).

Chapter 5

USAGE OF FRACTAL GEOMETRY AS A TOOL FOR SIMULATION OF STEEPLY DENSE HOUSING; IN THE LIGHT OF TWO VERNACULAR CASE STUDIES

5.1 Analysis of Masouleh and Abyaneh Settlements with Box-Counting Method

As it mentioned before, in earlier times, the relationship between human beings and natural environment was not so unfamiliar and unrelated, as compared to contemporary times. Accordingly, their building edifices followed natural orders. As inhabitants grew in nature, this chase unconsciously was reflected to their architectural productions as well. Rural settlements and organic patterns are the most tangible examples of mentioned architectural production. (Reza & Dincyurek, 2015)

The main aim of this study is to determine a solid relationship between vernacular architecture and fractal geometry, which will allow for reviving of vernacular architecture in order to achieve a adoptive dense housing. As mentioned previously, there is a critical need to understand fractal geometry due to the importance of its usage, in the context of contemporary design and architecture. It is also notable that fractal geometry is based on the density ratio of patterns. Therefore, focusing on the term “pattern”, “fractal geometry” and “fractal dimensions” can be explained. Therefore, in order to determine the fractal geometry and the regenerating patterns, the fractal dimensions have to be calculated.

As it was explained in chapter two, for such topography in Iran, vernacular terraced housing will be selected as case study. The terraced houses in some of the villages have organic pattern. Through the aid of fractal geometry it will be able to determine the mentioned patterns within the local building culture. Masouleh and Abyaneh villages are two distinctive case studies of mentioned urban fabrics and rural regions.

Fractal theory will be used in the investigation of vernacular architecture characteristics in Masouleh and Abyaneh villages and in the definition of fractal dimensions in order to proceed with this study. As mentioned previously, the theory has a wide area of investigation from different points of view with the clarification of this subject in the field of architecture as one of the initial studies conducted. The parallel analysis of the Masouleh and Abyaneh villages will be done in accordance with the fractal theory test. Finally the general conclusion and recommendations in respect of what research may be carried out on the subject in the futures, included. The result of the study will be the meeting point between the vernacular architecture and contemporary architecture, which may, in fact, provide a particular meaning by referring to sustainability on several different planes.

It should be mentioned that prior to this study, different scholars have only carried out a fractal analysis on the vernacular settlements of Amasya, Turkey. As the result of this study, all the four groups of scholars claim that an Amasya settlement has a high fractal dimension. Also, the settlements' box-counting dimensions were tested by the author (Table 5).

Table 5: The fractal dimension of Amasya, Turkey

Result	D (elevation)	D (urban)
Bovill (1996), (as cited in Vaughan & Ostwald, 2010)	1.717	1.432
Lorenz (2003), (as cited in Vaughan & Ostwald, 2010)	1.546	1.485
Vaughan & Ostwald (2010)	1.505	1.585
Bourchtein (2014)	1.770	1.640
Reza & Dincyurek (2015)	1.659	1.760

Moreover, Bourchtein (2014) with his scholars analysed Amasya case and carried out a fractal analysis on two historical Brazilian cities, Ouro Preto and Pelotas. (Bourchtein , & Naoumova , 2014)

As a conclusion, the most important reason of re-testing Amasya settlements fractal dimension in this research, was to check the accuracy of the result and findings of box counting method, which was used in this research. As the result by comparing the result it could be concluded that outcomes of this test are very close to the others. Therefore, this study conducting by same methodology on focuses cases.

5.1.1 The Fractal Dimensions of The Masouleh's and Abyaneh's Elevations

The elevation formation of vernacular house forms generally provides valuable information about the physical, social and cultural characteristics of the context.

Moreover, as Oliver (1997) mentioned: the categorization of the typology of an elevation should commence from the shape of the buildings. On the other hand, shapes are affected by the volume of the building and such as the form of the walls and roofs. Therefore, the shapes of buildings adjacent to each other represent a recognizable image, which can then further identify the built environment. (Oliver, 1997)

Furthermore according to Alberto Saldarriaga Roa: “Ornament should not be taken as a significant element in elevation typologies” (as cited in Oliver, 1997). However, in some cases such as Masouleh and Abyaneh villages, ornamental elements such as doors and windows become a part of the elevation images in respect of their shapes and composition.

As it is mentioned above, the fractal analysis of Masouleh and Abyaneh villages will be achieved firstly by finding the fractal dimensions on elevations and then fractal dimensions in urban pattern will be calculated.

With the help of the Box-counting method, this study will first test the fractal dimensions ratio of selected Masouleh and Abyaneh houses’ elevations. As it mentioned before houses of chosen settlements have self-similar characteristics, which is going to prove by testing arbitrary selected elevations in each settlements. According to this, one silouhet of five different fractal dimensions for each village are going to be calculated in this elevation. The first one is calculated by allocating 16 boxes, which each one is 3.65 meters long. In second iteration, the number of boxes increases to 64 boxes and accordingly the third and fourth and fifth iteration continue with 256 and 1024 and 4096 boxes respectively. (Table 6)

Figures below (Figure 25, 26, 27 and 28) show the counted boxes as shaded with pencil for clarification of this box counting. As Bovill (1996) stated: “Boxes are left out of the account for two reasons: One, the profile of the building is described with greater accuracy, and two blank or undetailed areas of the elevation are indicated. Thus, the counted boxes represent the area of the elevation where there is something to look at.” (Bovill, 1996)

The prolific ornamentation of the openings in the Masouleh and Abyaneh houses prevented the box counting analysis to perceive them as openings. Therefore, such detailed ornamentation on doors and windows, count as empty boxes to achieve more accurate results in this study.

According to the formula shown below, box-counting dimensions will be tested in different iterations.

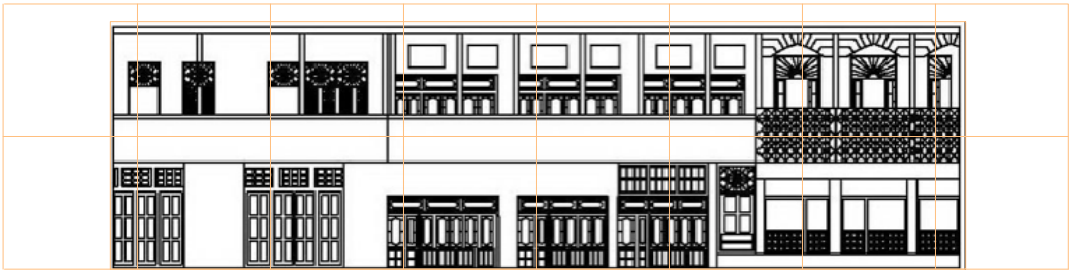


Figure 25: First Iteration of Masouleh elevation (by author)

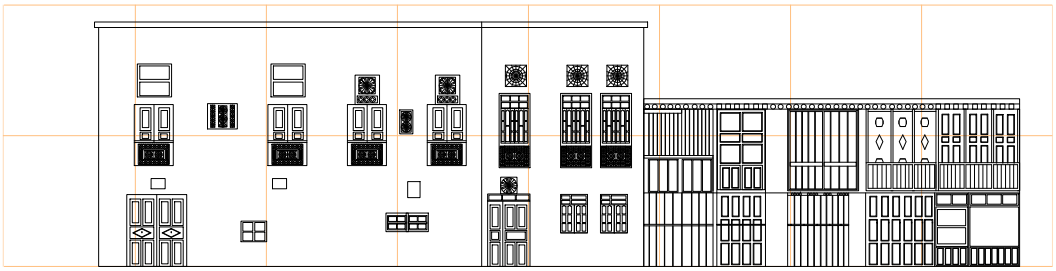


Figure 26: First Iteration of Abyaneh elevation (by author)

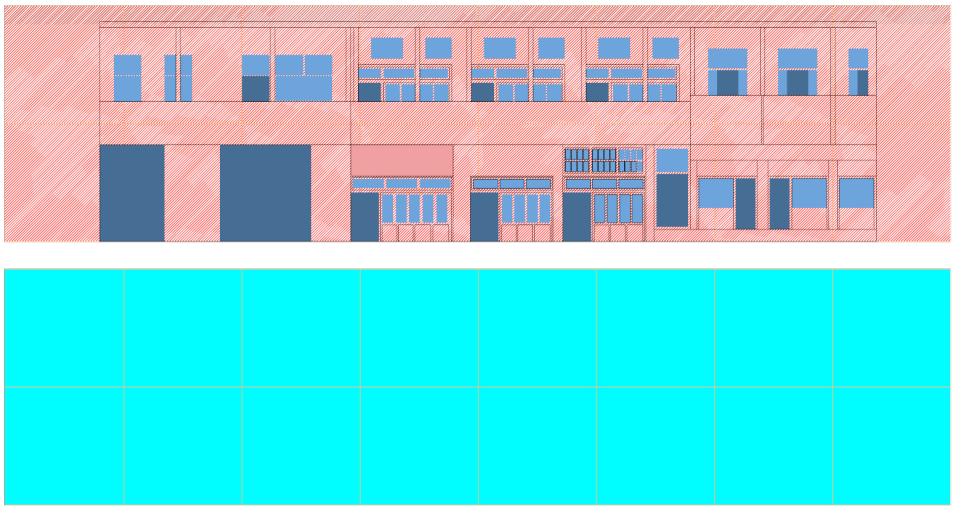


Figure 27: Box-counting; First iteration of Masouleh elevation (by author)

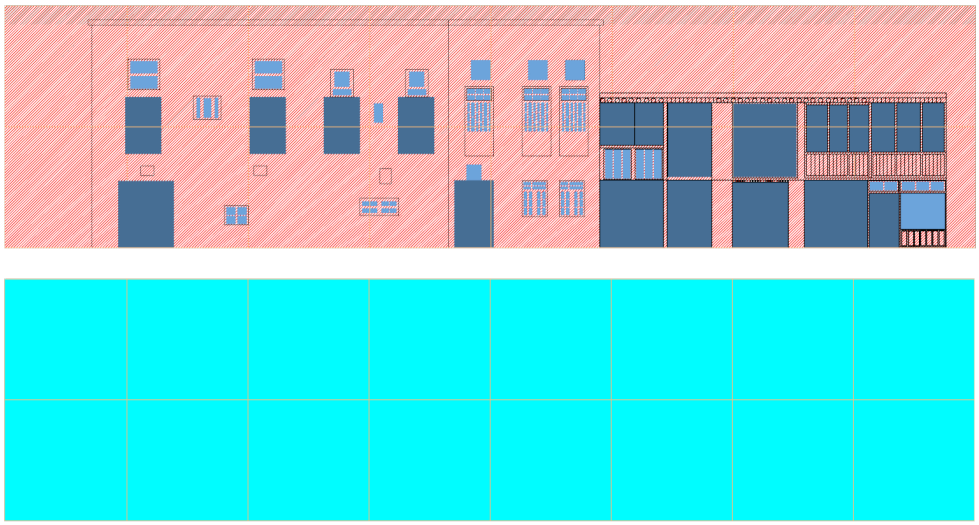


Figure 28: Box-counting; First iteration of Abyaneh elevation (by author)

The next step will be done by explosion of those boxes that are 3.65 metres across with boxes that are 1.82 metres across as seen in Figure 29 and 30 and the formulas; and following step is given in Figure 31 and 32 with formulas.

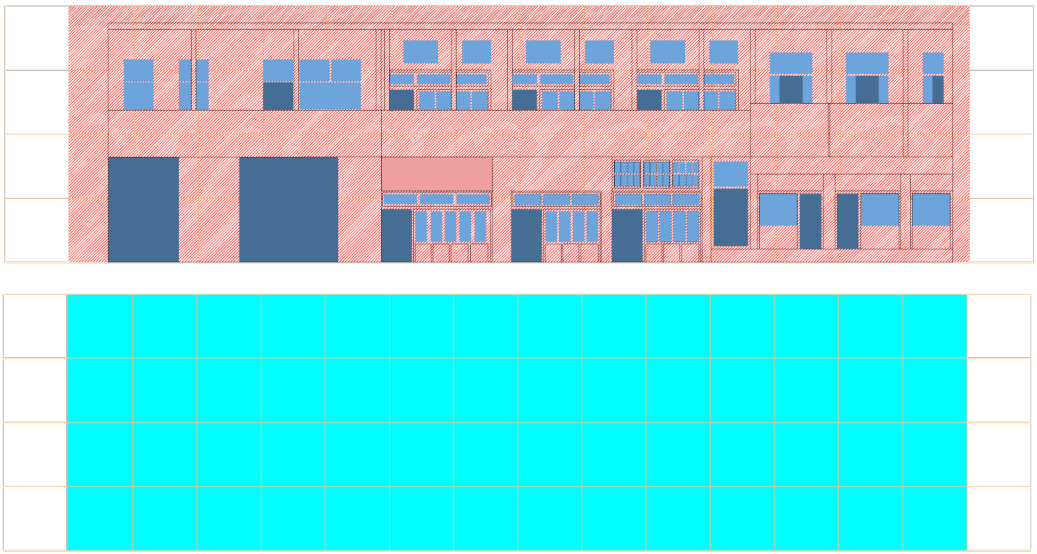


Figure 29: Box-counting; Second Iteration of Masouleh elevation (by author)

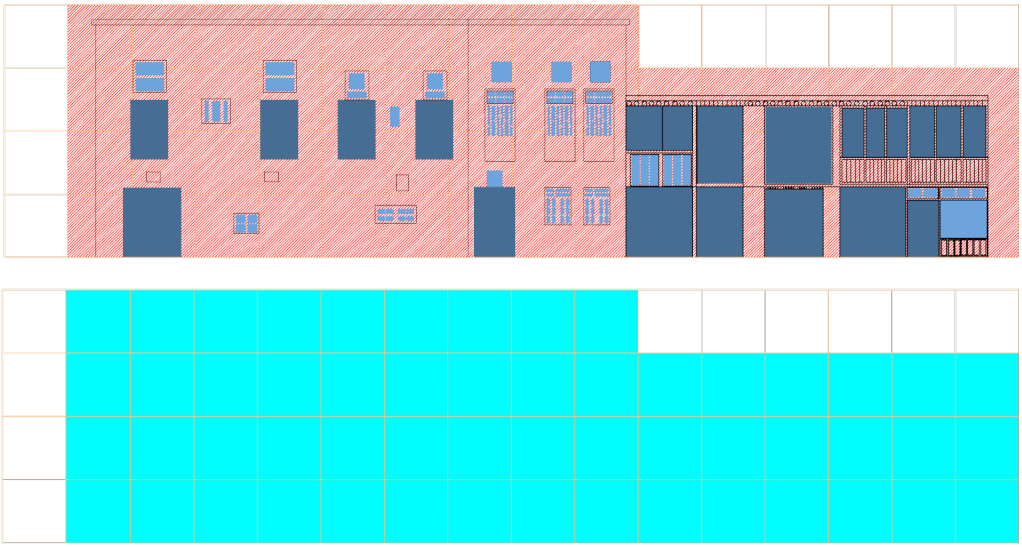


Figure 30: Second iteration of Masouleh (left) and Abyaneh (right) elevation (by author)

$$D_{Masouleh}\left(Box 3.6-1.8\right)=\frac{\left[\left(\log 56\right)-\left(\log 16\right)\right]}{\left[\left(\log 16\right)-\left(\log 8\right)\right]}=\frac{1.748-1.204}{1.204-0.903}=\frac{0.544}{0.301}=1.807$$

$$D_{Abyaneh}\left(Box,3.6-1.8\right)=\frac{\left[\log\left(54\right)-\log\left(16\right)\right]}{\left[\log\left(16\right)-\log\left(8\right)\right]}=\frac{1.732-1.204}{1.204-0.903}=\frac{0.829}{0.301}=1.754$$

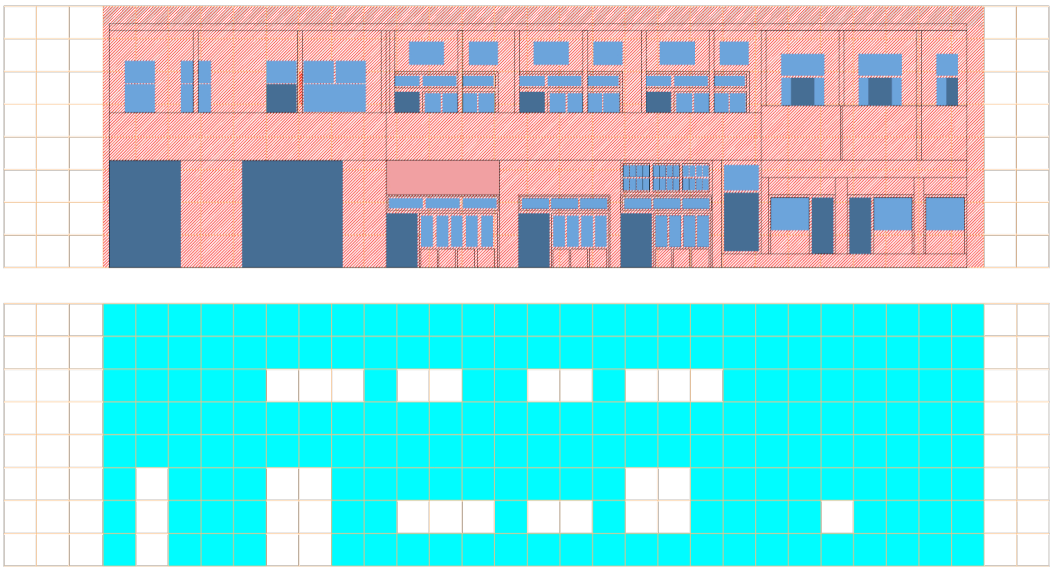


Figure 31:Box-counting; Third iteration of Masouleh elevation (by author)

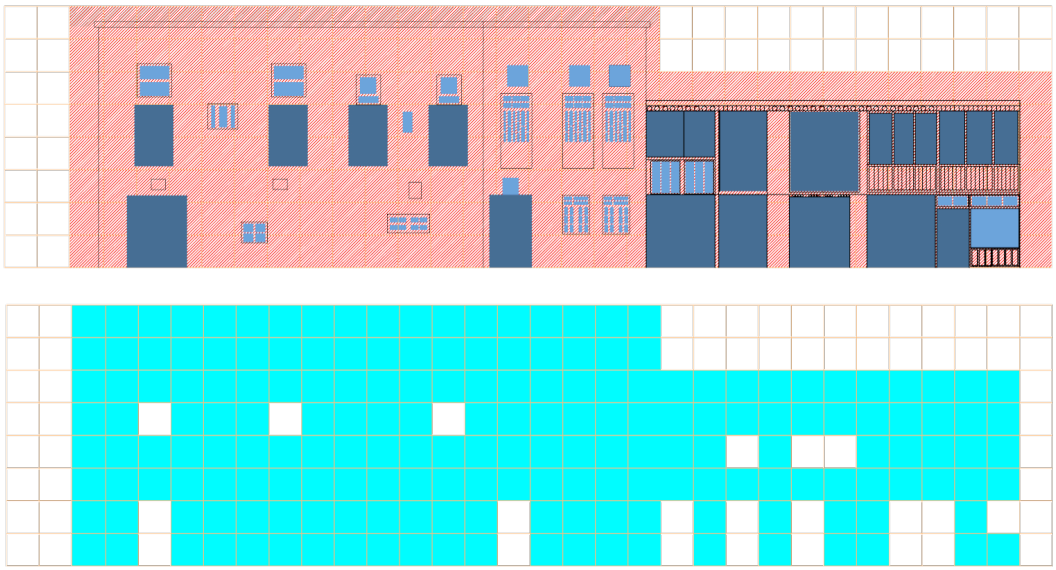


Figure 32: Box-counting; Third iteration of Abyaneh elevation (by author)

$$D_{Masouleh}\left(Box1.8-0.9\right)=\frac{\left[\left(\log 183\right)-\left(\log 56\right)\right]}{\left[\left(\log 32\right)-\left(\log 16\right)\right]}=\frac{2.262-1.748}{1.505-1.204}=\frac{0.514}{0.301}=1.707$$

$$D_{Abyaneh}\left(Box,1.8-0.9\right)=\frac{\left[\log\left(189\right)-\log\left(54\right)\right]}{\left[\log\left(32\right)-\log\left(16\right)\right]}=\frac{2.276-1.732}{1.505-1.204}=\frac{0.544}{0.301}=1.807$$

The next range, which the boxes will be compressed, by 0.9 and 0.4 metres locating on the elevation as seen in Figure 33 and 34 and the formulas;

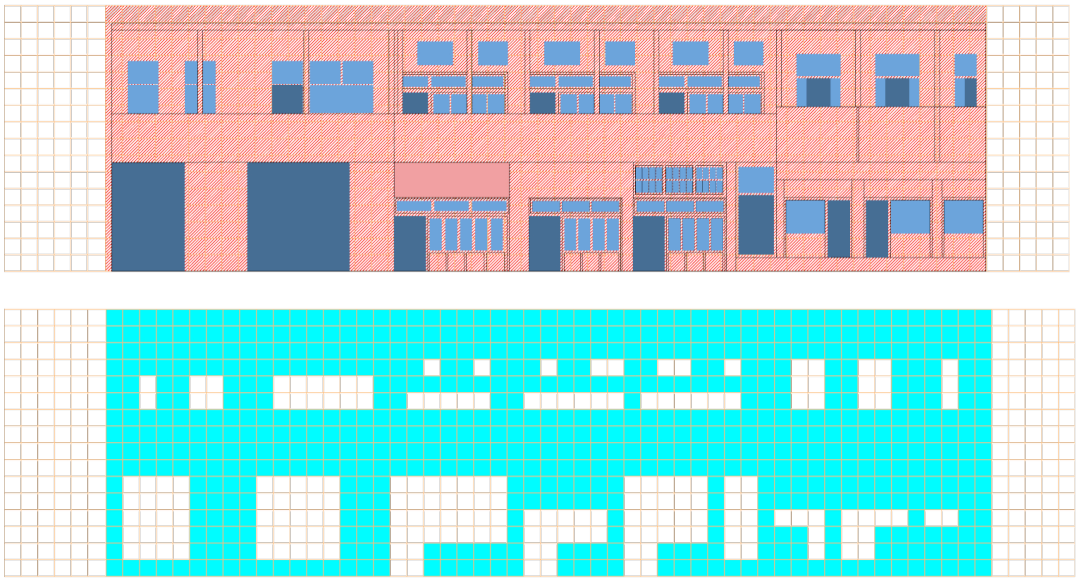


Figure 33: Box-counting; Fourth iteration of Masouleh elevation (by author)

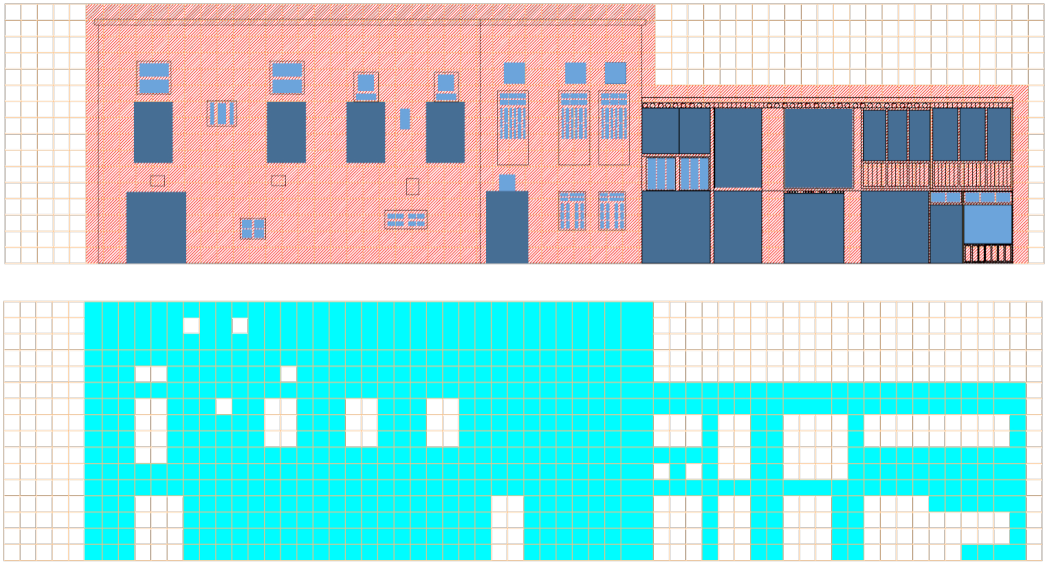


Figure 34: Box-counting; Fourth iteration of Abyaneh elevation (by author)

$$D_{Masouleh}\left(Box0.9-0.4\right)=\frac{\left[\left(\log 632\right)-\left(\log 183\right)\right]}{\left[\left(\log 64\right)-\left(\log 32\right)\right]}=\frac{2.8-2.262}{1.800-1.505}=\frac{0.538}{0.301}=1.787$$

$$D_{Abyaneh}\left(Box,0.9-0.4\right)=\frac{\left[\log\left(651\right)-\log\left(189\right)\right]}{\left[\log\left(64\right)-\log\left(32\right)\right]}=\frac{2.813-2.276}{1.806-1.505}=\frac{0.537}{0.301}=1.784$$

The last step, which the boxes will be compressed, by 0.4 and 0.4 metres locating on the elevation as seen in Figure 35 and 36 and the formulas;

Figure 35: Box-counting; Fifth Iteration of Masouleh elevation (by author)

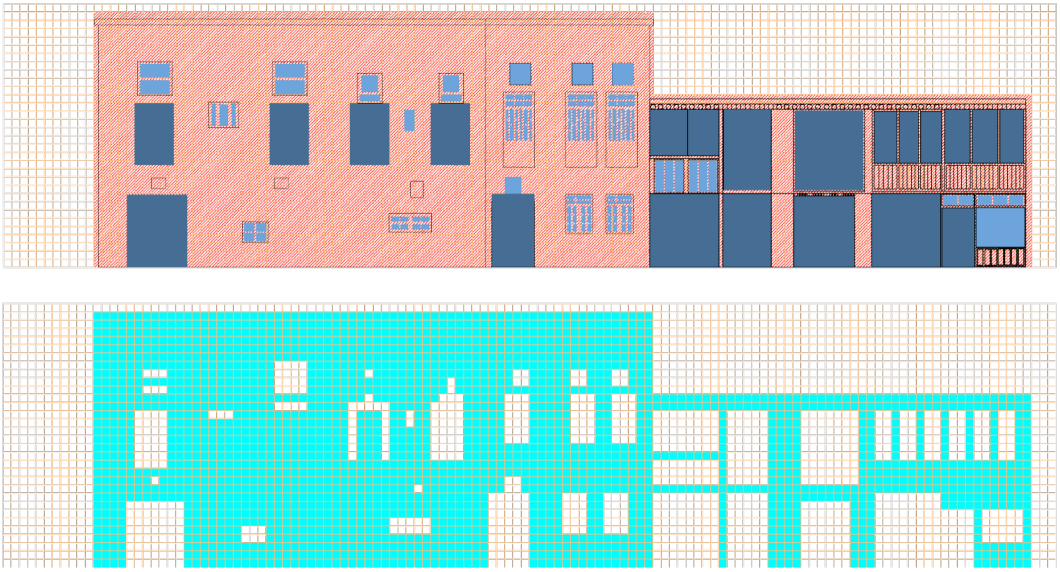


Figure 36: Box-counting; Fifth Iteration of Abyaneh elevation (by author)

$$D_{Masouleh}\left(Box, 0.4-0.2\right)=\frac{\left[\log\left(2193\right)-\log\left(632\right)\right]}{\left[\log\left(128\right)-\log\left(64\right)\right]}=\frac{3.341-2.8}{2.107-1.806}=\frac{0.541}{0.301}=1.797$$

$$D_{Abyaneh}\left(Box, 0.4-0.2\right)=\frac{\left[\log\left(2154\right)-\log\left(651\right)\right]}{\left[\log\left(128\right)-\log\left(64\right)\right]}=\frac{3.333-2.813}{2.107-1.806}=\frac{0.52}{0.301}=1.727$$

Table 6: The box-counting of Masouleh and Abyaneh' s Elevation

Grid size	Box Number	Grid Dimension	Box –Counting	
			Masouleh	Abyaneh
8	16	12 Feet = 3.657 Metres	16	16
16	64	6 Feet = 1.828 Metres	56	54
32	256	3 Feet = 0.914 Metres	183	189
64	1024	1.5 Feet =0.457 Metres	632	651
128	4096	0.75 Feet=0.228 Metres	2193	2154

It can, therefore, be concluded from the analysis that the fractal dimension range of elevations of the specifically mentioned house in Masouleh village is located between 1.707 <D< 1.807 and Abyaneh's mentioned house is 1.727 <D< 1.807. The results show that, Abyaneh's house elevation has higher fractal dimension. A high fractal dimension, therefore, proves the high amount of self-similarities in the mentioned analysis.

5.1.2 The Fractal Dimensions of The Masouleh's and Abyaneh's Urban Patterns

In the next step, this study will find fractal dimensions in urban patterns of Masouleh and Abyaneh villages, using the same method. Therefore, this study will specifically, test the fractal dimensions ratio of Masouleh's and Abyaneh's urban patterns. Four different fractal dimensions will be calculated. The first one is calculated by allocating 16 boxes of which each one is 7.32 metres long. In the second iteration the number of boxes increase to 64 boxes and accordingly the third, fourth and fifth iteration continue with 256, 1024 and 4096 boxes. Table 7 shows the number and size of the boxes, which are going to be used in different iterations. Figure 37 to 46

and the formulas shows the first, second, third, fourth and fifth iterations of Masouleh's and Abyaneh's urban pattern.

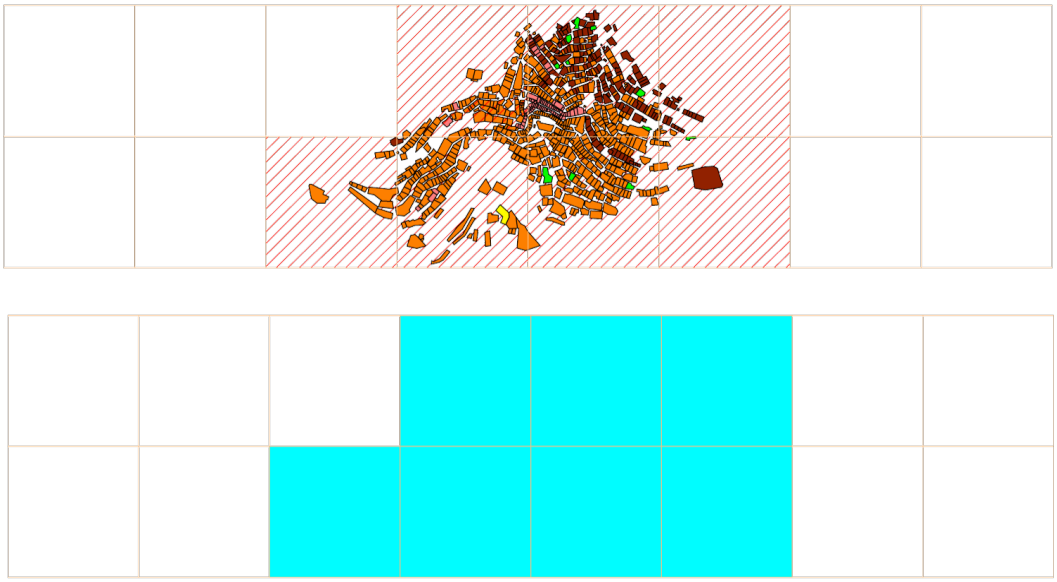


Figure 37: Box-counting; First Iteration of Masouleh urban pattern (by author)

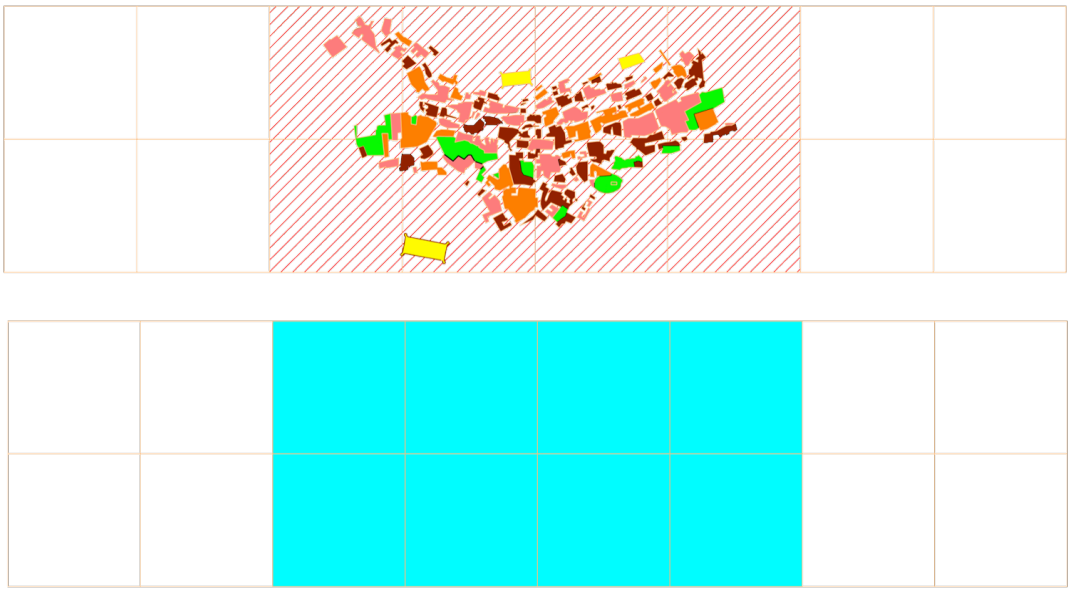


Figure 38: Box-counting; First Iteration of Abyaneh urban pattern (by author)

$$D_{Masouleh}\left(Box 7.3-3.6\right)=\frac{\left[\left(\log 21\right)-\left(\log 7\right)\right]}{\left[\left(\log 16\right)-\left(\log 8\right)\right]}=\frac{1.322-0.845}{1.204-0.903}=\frac{0.497}{0.301}=1.585$$

$$D_{Abyaneh}\left(Box, 7.3-3.6\right)=\frac{\left[\log\left(22\right)-\log\left(8\right)\right]}{\left[\log\left(16\right)-\log\left(8\right)\right]}=\frac{1.342-0.903}{1.204-0.903}=\frac{0.439}{0.301}=1.458$$

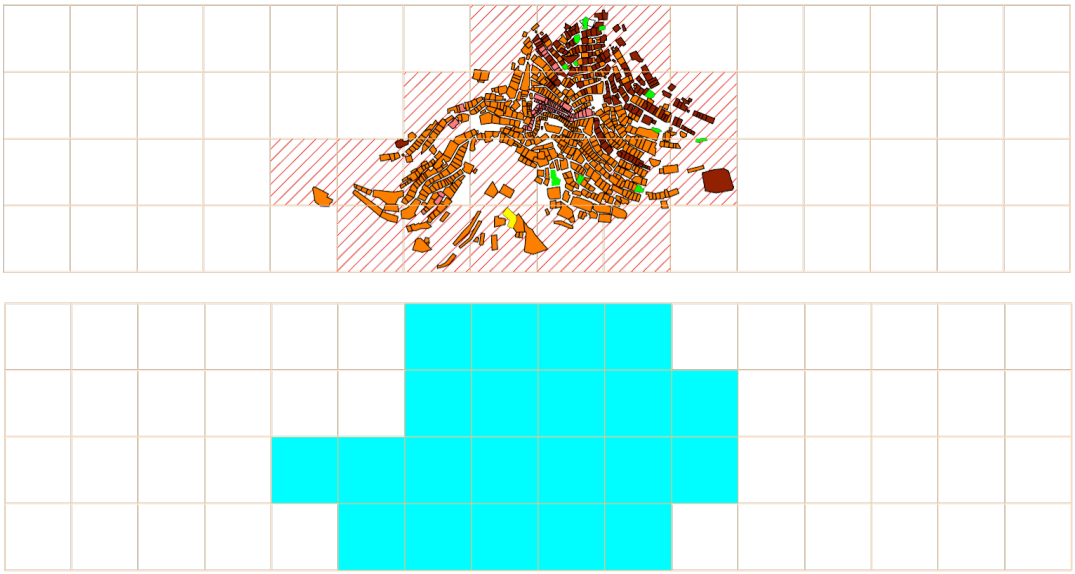


Figure 39: Box-counting; Second Iteration of Masouleh urban pattern (by author)

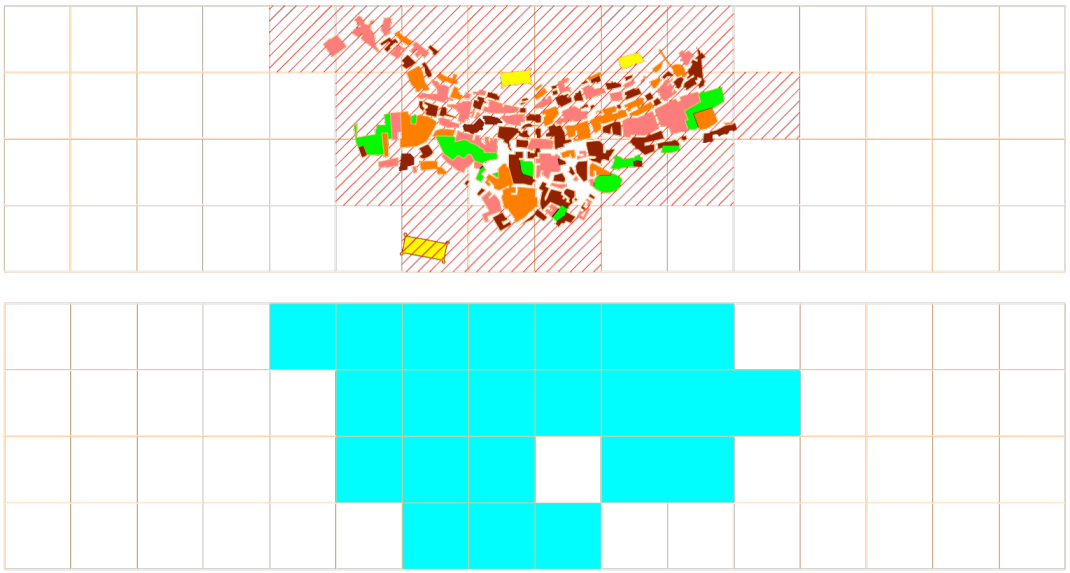


Figure 40: Box-counting; Second Iteration of Abyaneh urban pattern (by author)

$$D_{Masouleh}\left(Box3.6-1.8\right)=\frac{\left[\left(\log 64\right)-\left(\log 21\right)\right]}{\left[\left(\log 32\right)-\left(\log 16\right)\right]}=\frac{1.806-1.322}{1.505-1.204}=\frac{0.484}{0.301}=1.607$$

$$D_{Abyaneh}\left(Box,3.6-1.8\right)=\frac{\left[\log\left(63\right)-\log\left(22\right)\right]}{\left[\log\left(32\right)-\log\left(16\right)\right]}=\frac{1.799-1.342}{1.505-1.204}=\frac{0.457}{0.301}=1.519$$

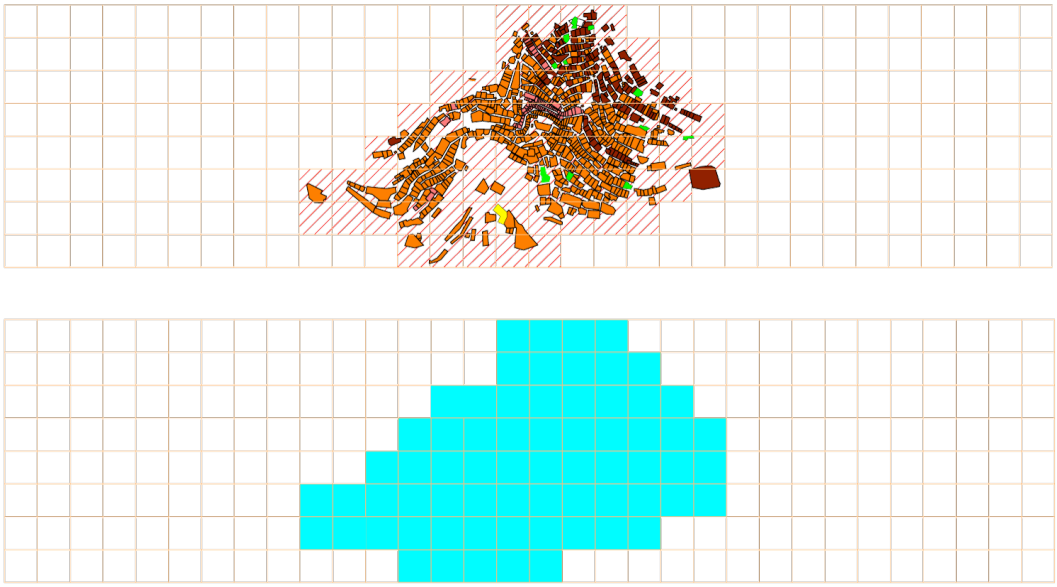


Figure 41: Box-counting; Third Iteration of Masouleh) urban pattern (by author)

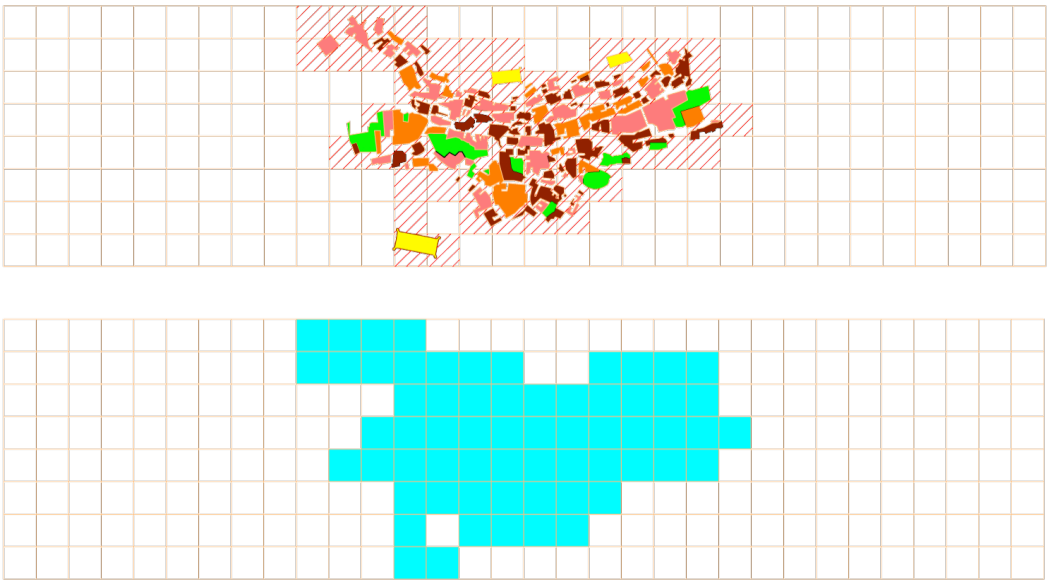


Figure 42: Box-counting; Third Iteration of Abyaneh urban pattern (by author)

$$D_{Masouleh}\left(Box1.8-0.9\right)=\frac{\left[\left(\log 206\right)-\left(\log 64\right)\right]}{\left[\left(\log 64\right)-\left(\log 32\right)\right]}=\frac{2.313-1.806}{1.806-1.505}=\frac{0.507}{0.301}=1.684$$

$$D_{Abyaneh}\left(Box,1.8-0.9\right)=\frac{\left[\log\left(192\right)-\log\left(63\right)\right]}{\left[\log\left(64\right)-\log\left(32\right)\right]}=\frac{2.283-1.799}{1.806-1.505}=\frac{0.484}{0.301}=1.607$$

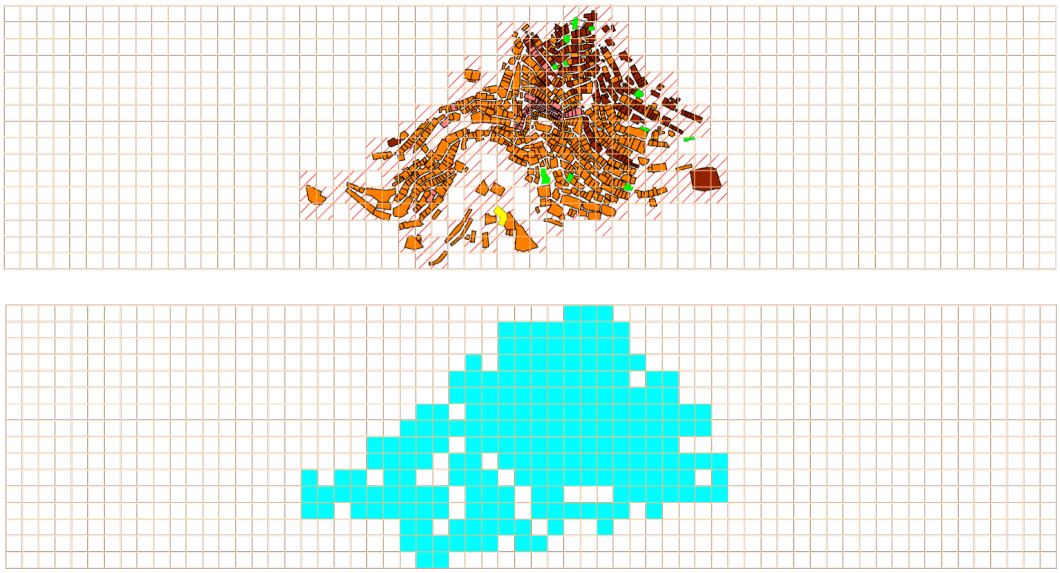


Figure 43: Box-counting; Fourth Iteration of Masouleh urban pattern (by author)

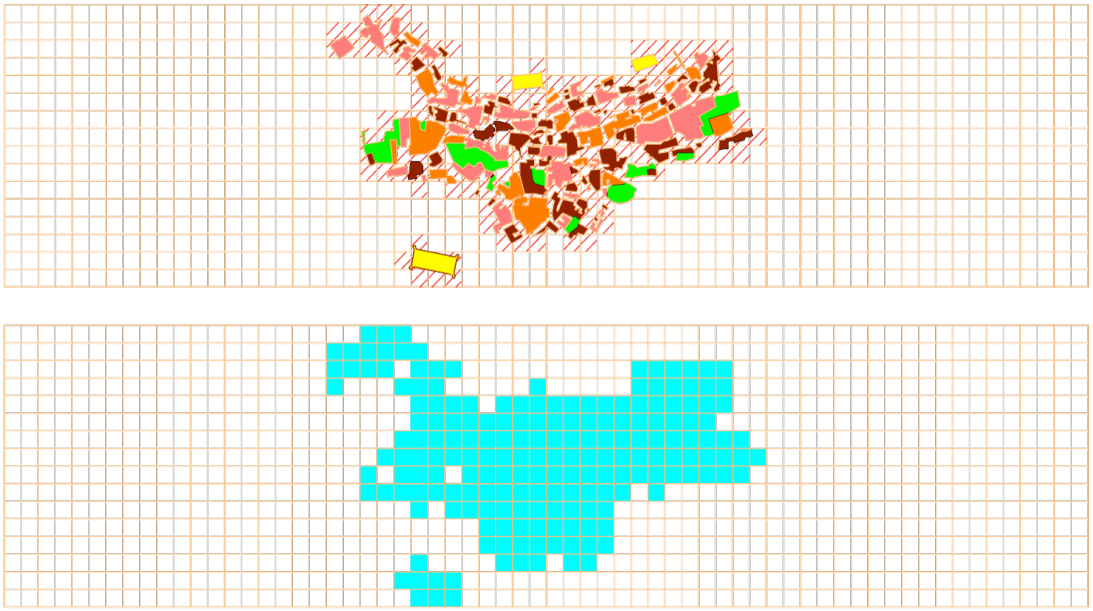


Figure 44: Box-counting; Fourth Iteration of Abyaneh urban pattern (by author)

$$D_{Masouleh}\left(Box0.9-0.4\right)=\frac{\left[\left(\log 664\right)-\left(\log 206\right)\right]}{\left[\left(\log 128\right)-\left(\log 64\right)\right]}=\frac{2.822-2.313}{2.107-1.806}=\frac{0.509}{0.301}=1.691$$

$$D_{Abyaneh}\left(Box,0.9-0.4\right)=\frac{\left[\log\left(583\right)-\log\left(192\right)\right]}{\left[\log\left(128\right)-\log\left(64\right)\right]}=\frac{2.765-2.283}{2.107-1.806}=\frac{0.482}{0.301}=1.601$$

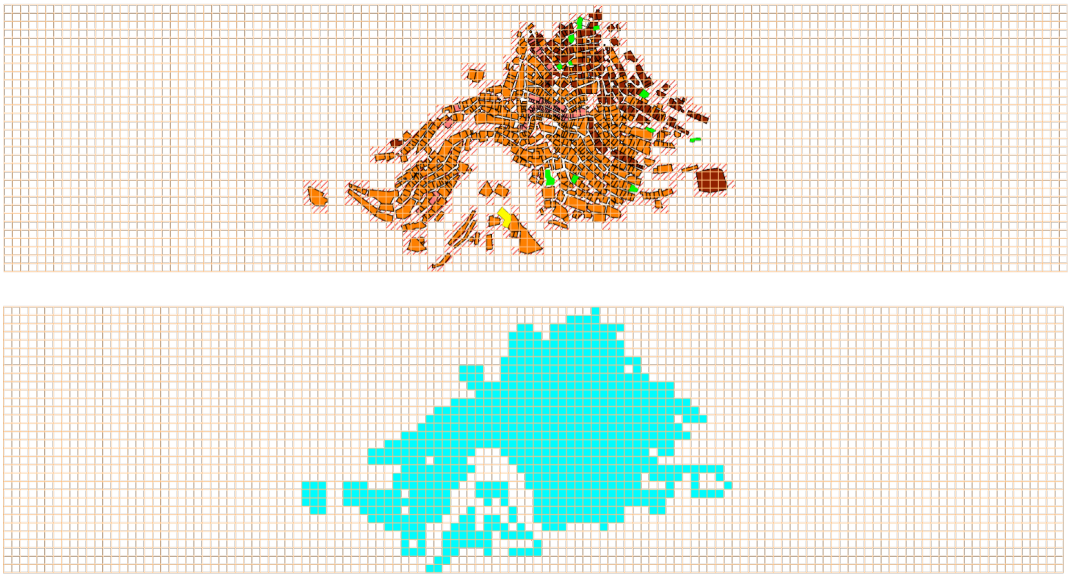


Figure 45: Box-counting; Fifth Iteration of Masouleh urban pattern (by author)

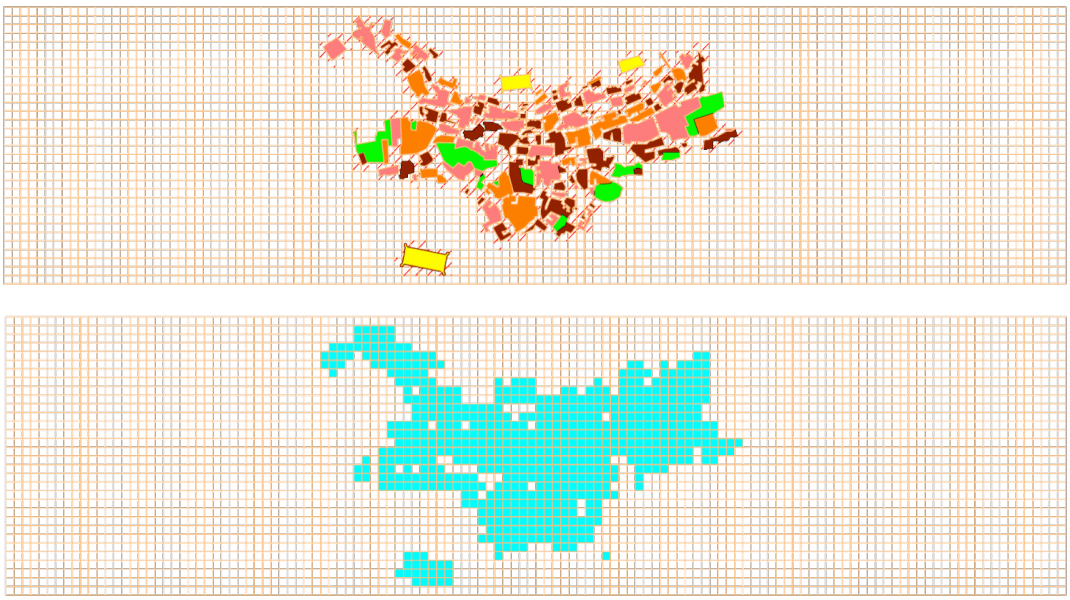


Figure 46: Box-counting; Fifth Iteration of Abyaneh urban pattern (by author)

Table 7: The box-counting of Masouleh and Abyaneh Urban Patterns (by author)

Grid size	Box Number	Grid Dimension	Box –Counting	
			Masouleh	Abyaneh
8	16	24 Feet = 7.3152 Metres	7	8
16	64	12 Feet = 3.6576 Metres	21	22
32	256	6 Feet = 1.8288 Metres	64	63
64	1024	3 Feet = 0.914 Metres	206	192
128	4096	1.5 Feet =0.457 Metres	644	583

It can, therefore, be concluded from the analysis, that the fractal dimension range of the aforementioned urban pattern in Masouleh village is located between 1.585 <D< 1.691 and, Abyaneh village is 1.458 <D< 1.607 which shows the fractal dimension in urban pattern of Masouleh village is higher then Abyaneh village. According to the result, self-similarities in the Masouleh village urban pattern are more than Abyaneh village.

According to the result, self-similarities in the elevation are higher than urban pattern in both villages. Since self-similarities in nature occur in the high range therefore, adoption of elevation is more than plan organization in mentioned case.

Growing and regeneration of the pattern, which were extracted from the elevation and urban pattern of Masouleh and Abyaneh villages by using the box counting method, will be the initial configuration concept of future housing proposals.

In breif, by comparing the fractal dimension of Masouleh and Abyaneh Villages with Amasya, it could be concluded that the elevation of Abyaneh village has a higher fractal dimension than that of Amasya and Masouleh village. On the other hand, the urban plan organization of Masouleh and Abyaneh village has a lower fractal dimension when comparing the results obtained from analyzing Amasya village,

which was done in this study. Although, this dimension is still in the higher range in comparison with the previous investigation, which was discussed.

5.1.3 Fractal Dimension of Masouleh's and Abyaneh's Environment

As it is mentioned before, "Mandelbrot has introduced the term 'fractal' specifically for temporal or spatial phenomena that are continuous but not differentiable, and that exhibit partial correlations over many scales. The term fractal strictly defined refers to a series in which the Hausdorf–Besicovitch dimension exceeds the topological dimension. A continuous series, such as a polynomial, is differentiable because it can be split up into an infinite number of absolutely smooth straight lines. A non-differentiable continuous series cannot be so resolved. Every attempt to split it up into smaller parts results in the resolution of still more structure or roughness. For a linear fractal function, the Hausdorf–Besicovitch dimension D may vary between 1 (completely differentiate) and 2 (so rough and irregular that it effectively takes up the whole of a two-dimensional topological space). For surfaces, the corresponding range for D lies between 2 (absolutely smooth) and 3 (infinitely crumpled). Because the degree of roughness of spatial data is important when trying to make interpolations from point data such as by least-squares fitting or kriging, it is worth examining them beforehand to see if the data contain evidence of variation over different scales, and how important these scales might be. Mandelbrot's work suggests that the fractal dimensions of coastlines and other linear natural phenomena are of the order of D = 1.2–1.3, implying that long range effects dominate." (Burrough, 1981)

For finding the fractal dimension of natural pattern to find a relation in between built environments and the natural environments, following methodology will be considered.

It should be declared that, finding the fractal dimension of natural pattern with box-counting method is a complicated approach. Accordingly particular scholars in different disciplines such as agriculture, architecture, landscape design and etc; were trying to find specific solution. By the help of computer science, various computer software was developed for mentioned purpose.

Among these softwares, Fractal3 (Fractal analysis system for Window) that was developed by 'Hiroyuki Sasaki' in National Institute of Livestock and Grassland Science was tested, and compared with the Amasya's fractal dimension, which was calculated by various scholars. The result of comparison confirmed the trustworthy of mentioned software as it is shown in below chart.

Table 8: Comparison of Fractal Dimenssions calculated for Amasya, (by author)

RESULTS	D(ELEVATION)	D(HILL)	D(URBAN)	D(RANGE)
Bovill (1996), (as cited in Vaughan & Ostwald, 2010)	1.171	1.566	1.432	0.285
Lorenz (2003), (as cited in Vaughan & Ostwald, 2010)	1.546	1.357	1.485	0.189
J.Vaughan & Ostwald,2010)	1.505	1.495	1.585	0.080
Bourchtein (2014)	1.770	----------	1.640	----------
Reza by Fractal3 software (2015)	1.659	1.742	1.760	0.035

Therefore, the result of findings in case of Masoule and Abyaneh natural pattern is going to be categorized as Table 9 and 10;

Table 9: Masouleh village Environmental Fractal Analysis, (by author)

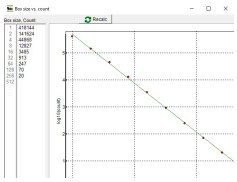
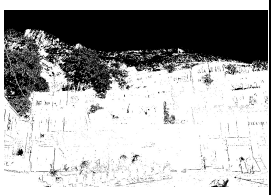
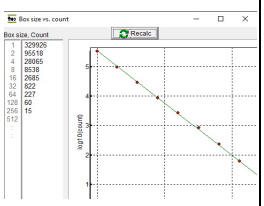
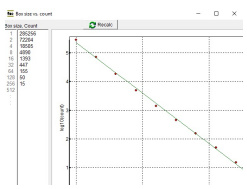
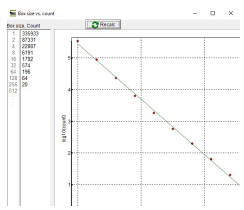
Masouleh Image	Image Processing	Fractal Graph	Fractal Dimension
			Results Cange size or Width, height 1182, 791 Cover or BrightDiff 44.7 R (n) -0.9996 (9) Fractal dimension 1.8196
			Results Width, height 1181, 747 Cover or BrightDiff 37.4 R (n) -0.9996 (9) Fractal dimension 1.7814

Table 10 Abyaneh village Environmental Fractal Analysis, (by author)

Abyaneh Image	Image Processing	Fractal Graph	Fractal Dimension
			Results Width, height 1181, 751 Cover or BrightDiff 32.2 R (n) -0.9989 (9) Fractal dimension 1.7600
			Results Width, height 1181, 791 Cover or BrightDiff 36.0 R (n) -0.9991 (9) Fractal dimension 1.7425

* It should be mentioned, due to the contract, which was signed in between author of this study and Fractal3's software developer (Hiroyuki Sasaki), all the results are only allowed to be used in dissertation and are not allowed to be used in any other publication.

It can, therefore, be concluded from the analysis, that the fractal dimension range of the aforementioned environment pattern in Masouleh village is located between 1.78 <D< 1.81 and, Abyaneh village is 1.74 <D< 1.76 which shows the fractal dimension in environment pattern of Masouleh village is higher than Abyaneh village. According to the result, self-similarities in the Masouleh village environment pattern are more than Abyaneh village.

5.2 Cellular Automata for Proposing New Housing Pattern

As it is mentioned before, Conway's "Game of Life" is one of the most known terminologies of cellular automata and has become a model for complex systems with its simple and inclusive properties. Also, rules of the Game of Life are based on a set of logical processing approaches and using terms like "yes" or "No", "And" or and "Not".

Therefore, in this study, the main aim is to simulate the new housing proposal in the light of the findings through fractal analysis of case studies.

Only by the help of computer software, proposing this new housing system will be possible. Therefore, all the data and parameters of current investigation need to translate to computer-based language. (Coding)

According to that, in first attempt, four different rules of Conway's "Game of Life" were written with Q-Basic language and all the rights were reserved by author.

```
{ public static cellState GetnewState(Cellstate CurrentState, int liveNeighbors)

    switch (currentState)

        case Cellstate.Alive:

            if (liveNeighbors  < 2 II liveNeighbors  >  3)

                return CellState. Dead;

            break;

        case CellState.Dead:

             if (liveNeighbors  ==  3)

                 return CellState. Alive;

            break;

                return currentState;  }
```

After testing the program, by using the last iteration plan of Masouleh and Abyaneh villages, the growth simulation are done. As it was stated before, last iteration, which was applied on Masouleh and Abyaneh village, is done with a matrix of [128, 32] (Figure 47 and 48).

It should be mentioned that there are some short names for the rules in the program, which is shown as below, and it is applied to each cell, and in each iteration all the possibilities are checked and new iteration are produced.

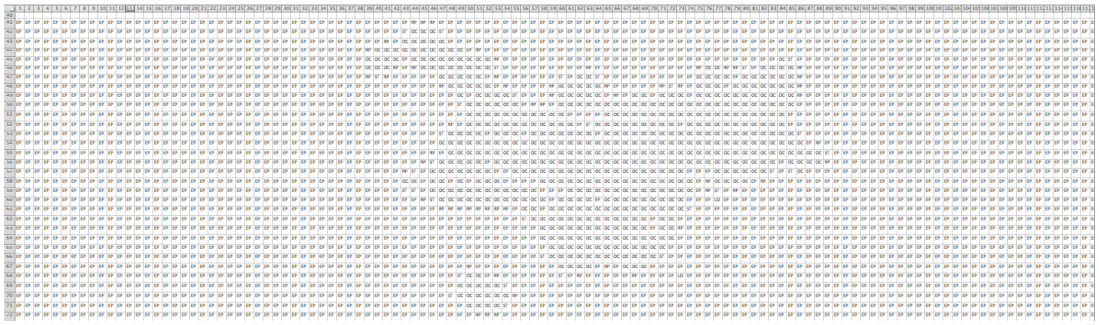


Figure 47: Generation of Matrix [128, 32], Ep = Empty, Lo = Loneliness, Oc = Overcrowded,Rp = Reproduction, (by author)

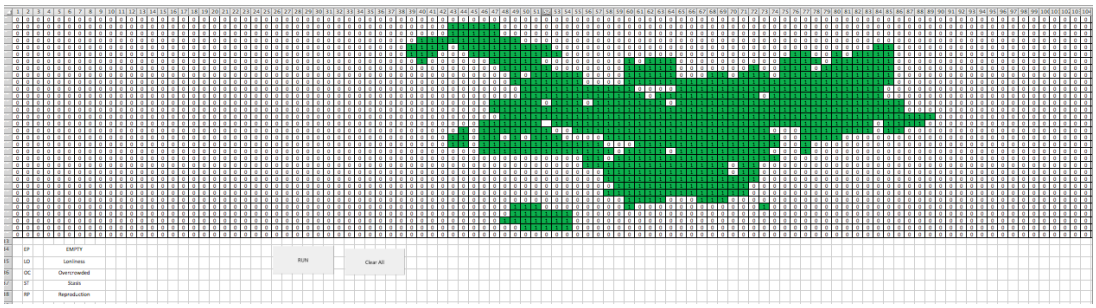


Figure 48: Generation of Matrix 2 (by author)

Therefore, five iterations were proceeding on each village as it will show in following part in Figure 49 till Figure 60.

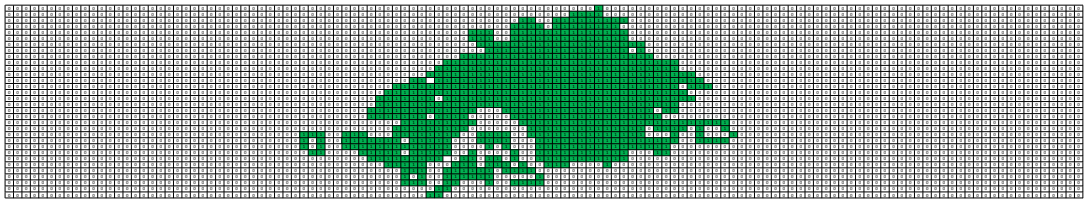


Figure 49: Masouleh Iteration 0 , Cellular Automata, (by author)

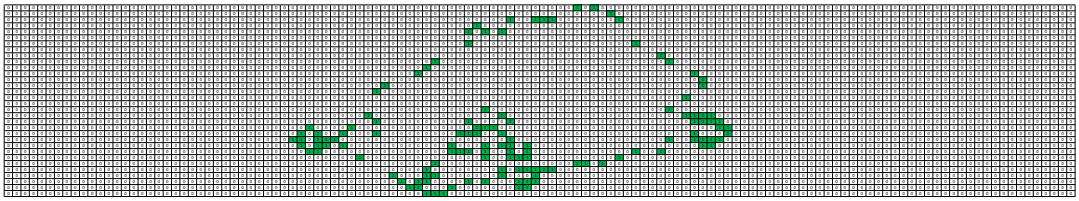


Figure 50: Masouleh Iteration 1 , Cellular Automata, (by author)

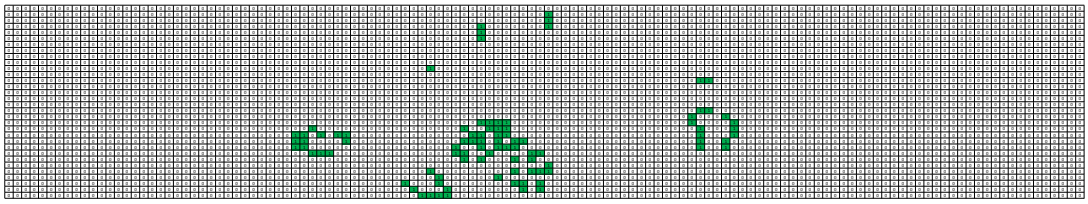


Figure 51: Masouleh Iteration 2 , Cellular Automata, (by author)

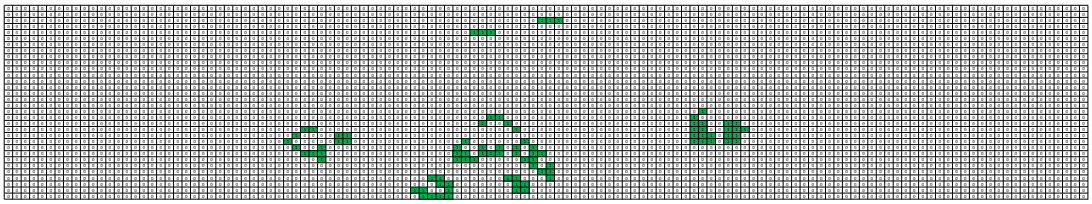


Figure 52: Masouleh Iteration 3 , Cellular Automata, (by author)

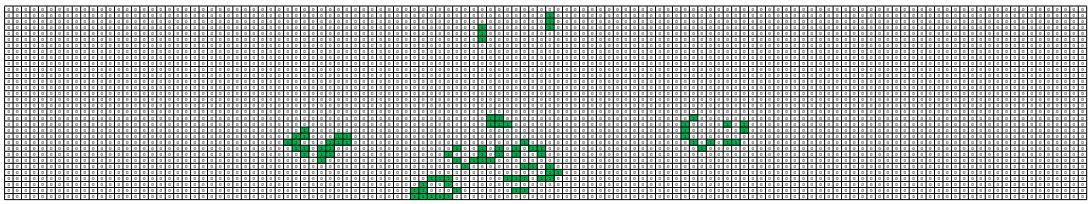


Figure 53: Masouleh Iteration 4 , Cellular Automata, (by author)

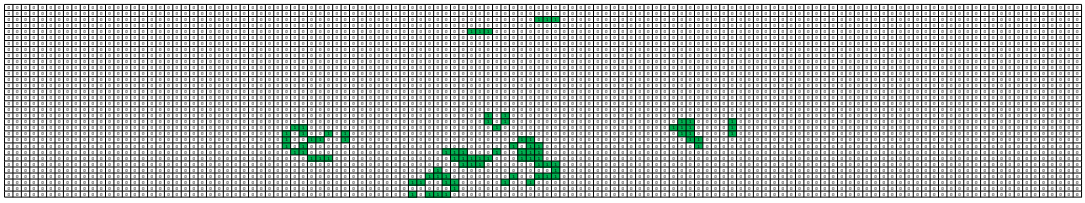


Figure 54: Masouleh Iteration 5 , Cellular Automata, (by author)

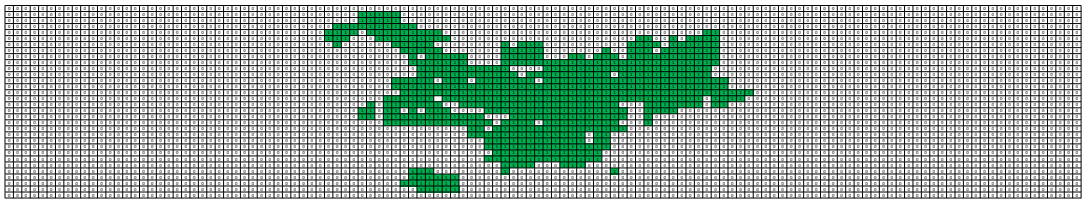


Figure 55: Abyaneh Iteration 0 , Cellular Automata, (by author)

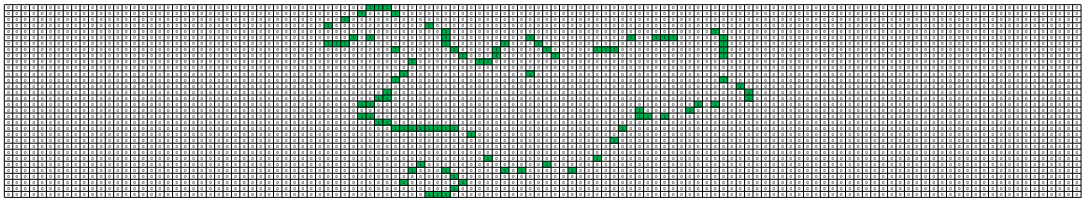


Figure 56: Abyaneh Iteration 1 , Cellular Automata, (by author)

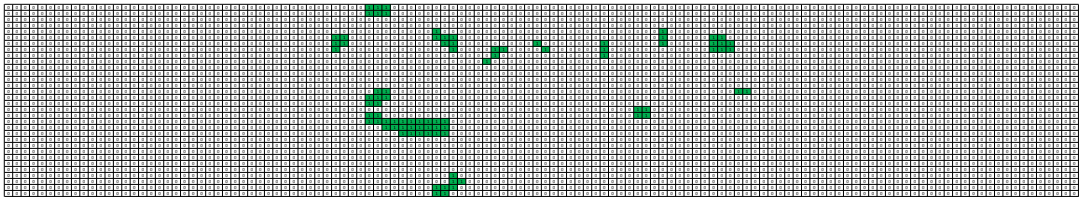


Figure 57: Abyaneh Iteration 2 , Cellular Automata, (by author)

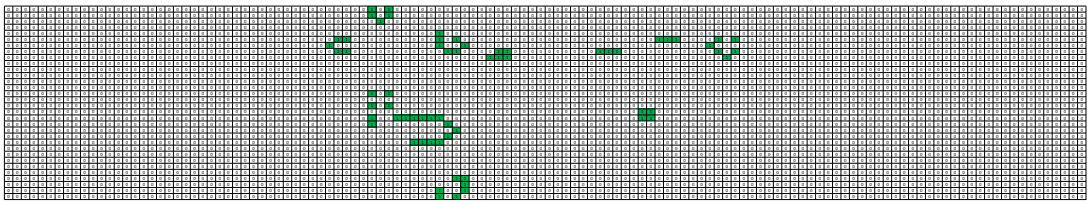


Figure 58: Abyaneh Iteration 3 , Cellular Automata, (by author)

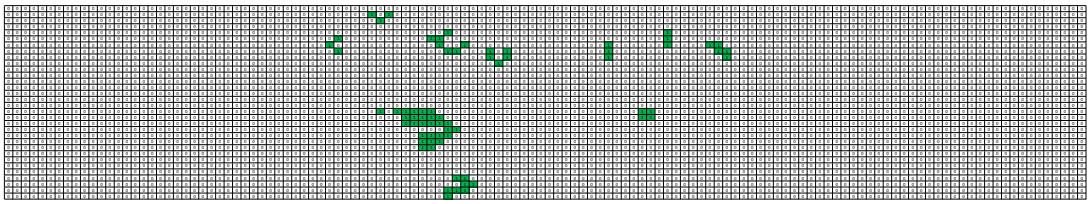


Figure 59: Abyaneh Iteration 4 , Cellular Automata, (by author)

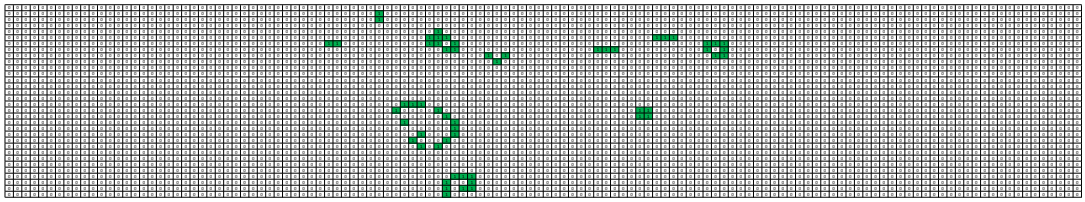


Figure 60: Abyaneh Iteration 5 , Cellular Automata, (by author)

Therefore, by allocating these 5 different iterations on top of another, new housing proposal would be emerged which is obeying the rules of Conway's "Game of Life" and representing the natural growth, in the light of vernacular architecture. Figures below show the new pattern organization (Figure 61 and 62).

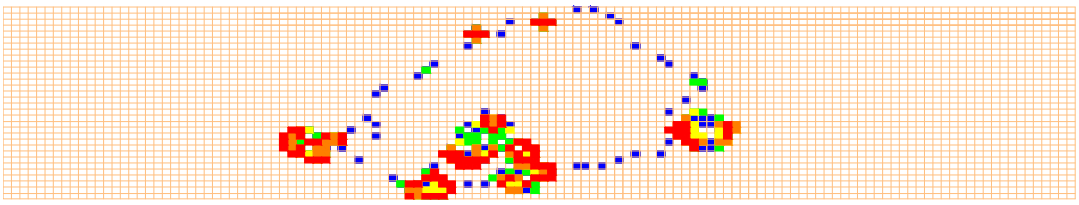


Figure 61: Combination of Iterations, Masouleh , Cellular Automata, (by author)

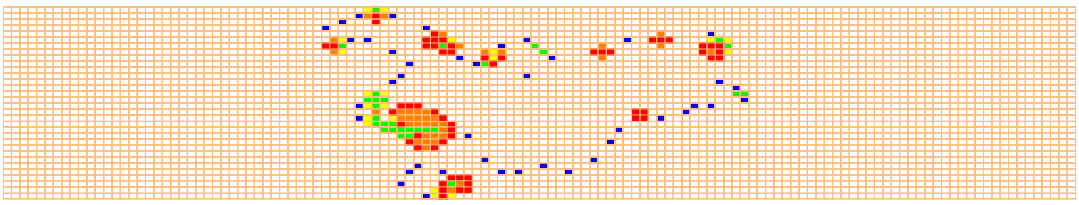


Figure 62: Combination of Iterations, Abyaneh , Cellular Automata, (by author)

Therefore, by the help of "Rhinoceros 5" software, (version SR12 64-bit) modelling of extracted pattern, were modelled and represented in Figure 63 to Figure 68.

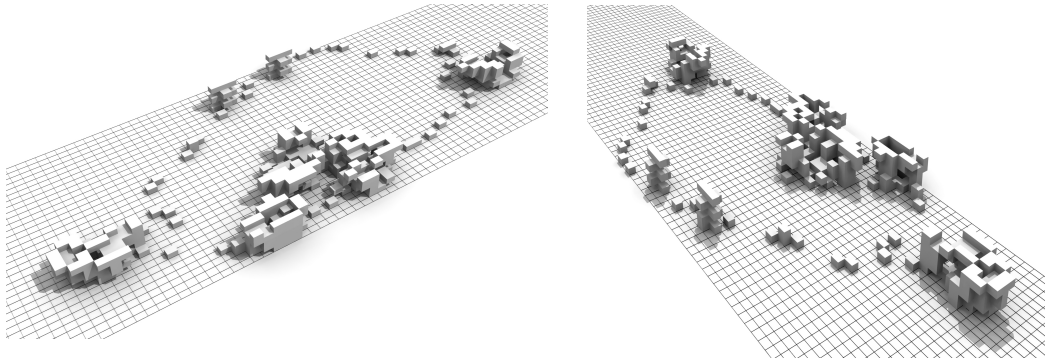


Figure 63: Masouleh, Isometric View Simulation of CA Results, (by author)

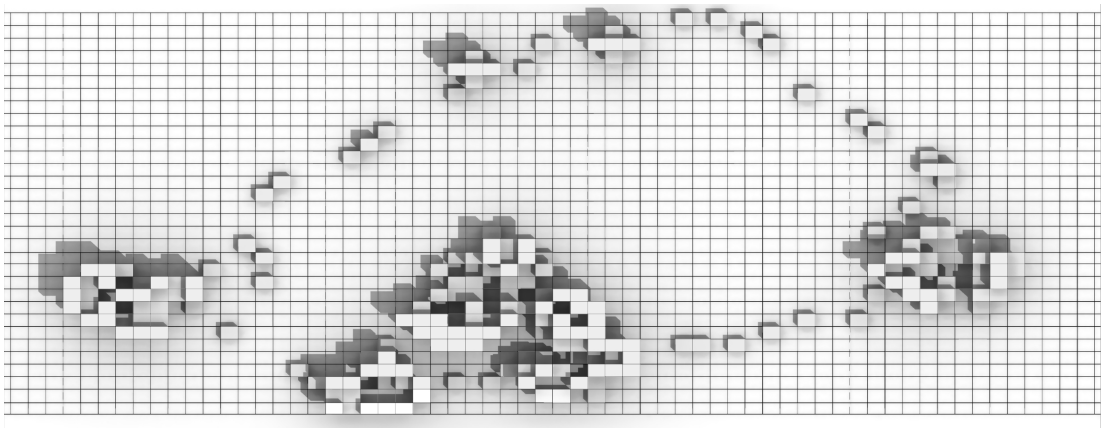


Figure 64: Masouleh, Urban Pattern's Simulation of CA Results, (by author)

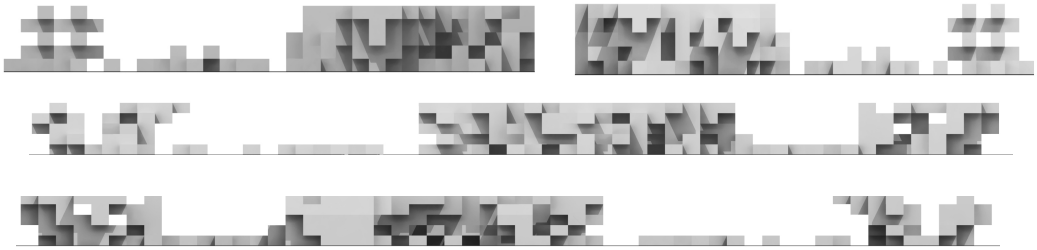


Figure 65: Masouleh, Elevation's Simulation of CA Results

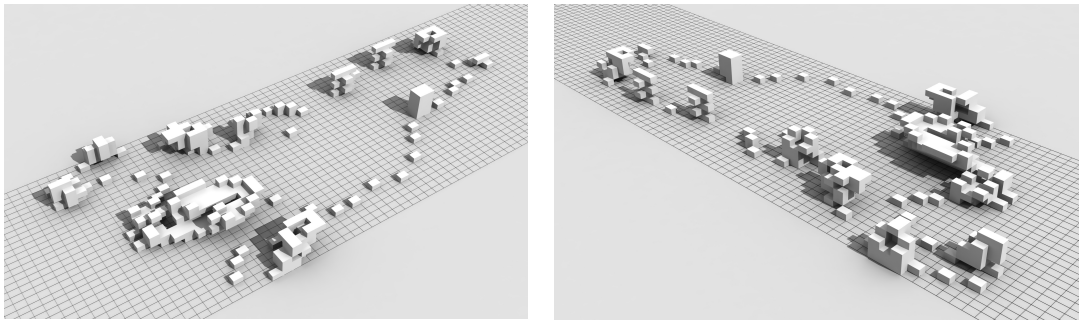


Figure 66: Abyaneh, Isometric View Simulation of CA Results, (by author)

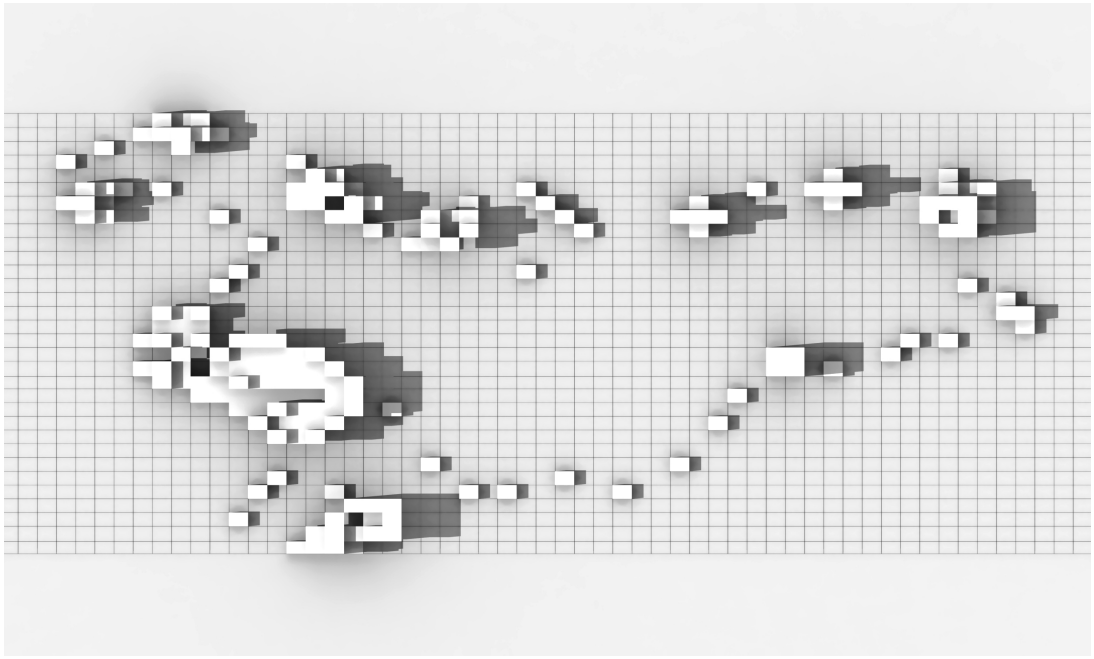


Figure 67: Abyaneh, Urban Pattern's Simulation of CA Results, (by author)

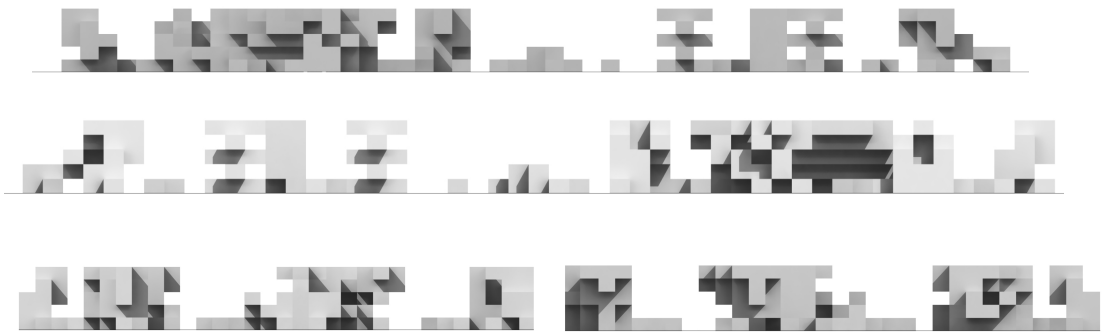


Figure 68: Abyaneh, Elevation's Simulation of CA Results, (by author)

As it is mention before, the fractal dimension of urban pattern in Masouleh settlements was higher than Abyaneh village, therefore, by comparing the outcome

of cellular automation and existing pattern, it can be concluded that the similarity of extracted pattern from Masouleh was more than Abyaneh settlements. Moreover, the result declares that, the natural growth of Masouleh village was concentrated more closely to the river and orchards, which in existing pattern of Masouleh settlement, was approximately out of built environments. In other words, the centre of new proposal is locating in southern part of river. Linear organization of building's units with respect to the counter lines still can be seen in outcomes. In addition, the new pattern is restricted towards north direction because of high mountainous level. Introverted housing typology still is visible in new housing organization and existence of hybrid spaces in between units is distinctive, which can be perceived in urban pattern and silhouette's outcomes (Figure 69).

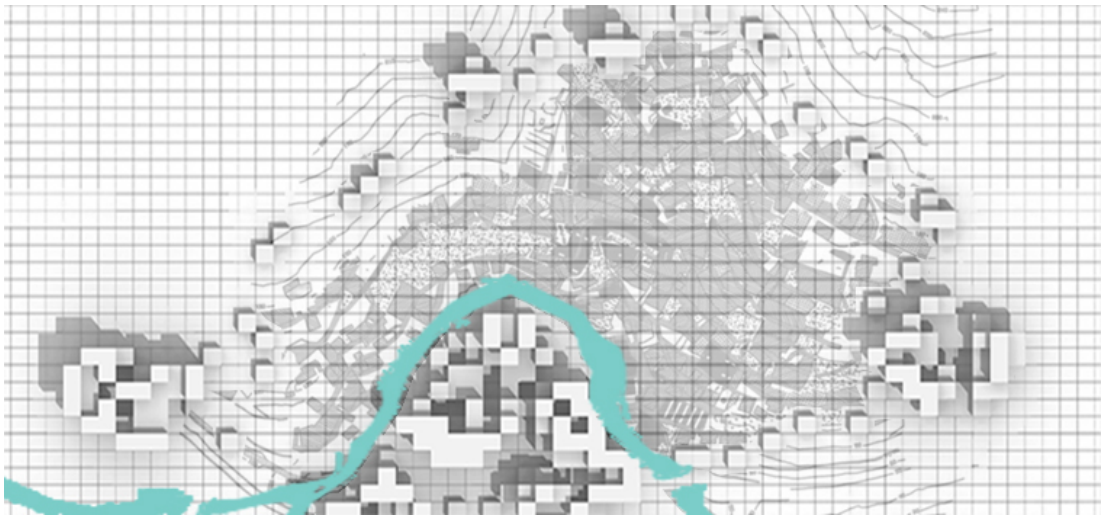


Figure 69: Cohesion of New Proposal to the Existing Context of Masouleh , (by author)

On the other hand, Abyaneh settlement, had totally different approach. Accordingly, the result proved that the natural growth of settlement was towards west and northwest direction. It should be mentioned that, most of important and historical buildings were located in east side of Abyaneh settlement. Therefore, densities of

buildings in center and east side of village were more than west side. In other words, it is possible to distinguish the new development of Abyaneh settlements in the west, from old pattern of mentioned built environment in the east. Afterwards, new vehicular access serves to permeability of the new proposal developed for Abyaneh settlements resulted from cellular automation process (Figure 70).

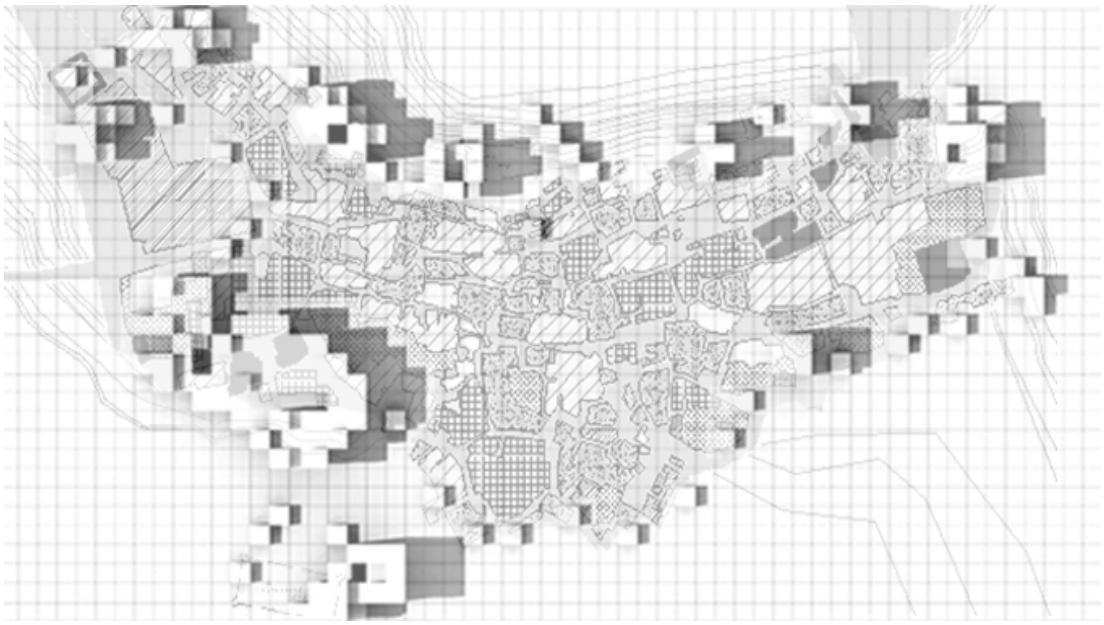


Figure 70: Cohesion of New Proposal to the Existing Context of Abyaneh , (by author)

Chapter 6

CONCLUSION

It can be concluded that, finding the fractal dimension of the vernacular settlements using the box counting method, will be the accurate tool for evaluation and for proposing new models of housing in contemporary architecture. Fractal dimension, is acting as an appropriate tool to establish the relation between the natural environment and the built environment, particularly in developing countries, which are expanding their mass housing towards the mountainous regions.

Also as the interpretation of aforementioned case study, it can be stated that the utilization of the topographical features will generate the level differences required in creating the design of terraced houses. The fractal dimension of the topography will be the same for the design of terrace houses. Generating hybrid spaces by utilizing the characteristics of terraced houses will create extroverted developments. These hybrid spaces will perform as a multifunction space where people join together for many different activities and will fulfill their social needs as human beings. One of the main problems of contemporary housing development is the gap created by neglecting the social needs of people and creating solitude for people. Terraced housing with its hybrid spaces will connect users together in harmony and will encourages a proper socio-cultural relation.

Lifestyle of human beings is chancing as fast as processing with high technology of the present century. In this manner, conventional construction techniques are not be using in many new developments. Even though, the construction technology of buildings is broadly chancing, the existing fabric of cities should be considered in the new housing proposals.

Dense housing units of terraced houses will provide social sustainability and when considered, will provide environmental sustainability as well.

In this perspective, as the vernacular terraced houses will attribute to the future housing developments in their perspective of society's cultural values and environmental characteristics of this region.

The relationship between the visual complexities of built and natural settings is analyzed in two vernacular Iranian settlements. The geometric complexity was measured by the fractal dimension of building's silhouettes and urban pattern.

The optimized algorithm was employed and in the aforementioned case study, strong connection between the natural environment and vernacular settlement was enhanced. It can be concluded, therefore, that result of finding from fractal dimensions of the vernacular settlements using the box counting method, will be the accurate tool for evaluation and for proposing new models of housing in contemporary architecture. Fractal dimension is acting as a convenient and an accurate tool to establish the relation between the natural environment and the built environment.

Also as the interpretation of aforementioned case study, it can be stated that the utilization of the topographical features will create the level differences required in forming the design of terraced houses. The fractal dimension of the topography will be the same for the design of terraced houses. Creating spaces similar in two dimensions such as urban pattern and in the third dimension such as elevation with the help of fractal dimensions will assist revitalization of the vernacular architecture that has been functioning for their users in time.

In this perspective, as the vernacular terraced housing considering the cultural attributes of the societies developed houses and environmental characteristics of this region, without any doubt, learning from these terraced houses are valuable for future housing development.

Geometric complexity was measured by the fractal dimension of buildings silhouettes and urban pattern.

The optimized algorithm was employed and in the aforementioned case studies, strong connection between the natural environment and vernacular settlement was enhanced. It can be concluded, therefore, that result of finding from fractal dimensions of the vernacular settlements using the box counting method, will be the accurate tool for evaluation and for proposing new models of housing in contemporary architecture. Fractal dimension is acting as a convenient and an accurate tool to establish the relation between the natural environment and the built environment.

REFERENCES

Alexander, C., Ishikawa, S., & Silverstein, M. (1977). *A pattern languag: towns, buildings, construction.* Berkeley, New york: Oxford University Press.

Annadhason, A. (2012). Methods of fractal dimension computation. *IRACST-International Journal of Computer Science and Information Technology & Security*, ISSN: 2249-9555, 2:1, 166-167.

Batty, M., & Longley, P. (1994). *Fractal cities: a geometry of form and function.* London: Academic Press Limited.

Blackledge, J.M., Evans, A.K., & Turner, M.J. (2002). *Fractal geometry-mathematical methods, algorithms, applications*. ISBN: 978-1-904275-00-8, Chichester, England: Horwood Publishing Limited.

Bourchtein, A., Bourchtein, L., & Naoumova, N. (2014). On the visual complexity of built and natural landscapes. *Fractal, 22* (4).

Bovill, C. (1996). *Fractal geometry in architecture and design.* Boston: Birkhauser. doi: 10.1007/978-1-4612-0843-3

Burrough, P. A. (1981). Fractal dimensions of landscapes and other environmental data. *Nature,* 294, 240-242.

Burry, J., & Burry, M. (2010). *The new mathematics of architecture.* London, United Kingdom: Thames & Hudson.

Cavalcanti, M. (1996). Aesthetics and the use of local materials in the folk built environment of inland pernambuco' In: Vestbro, D.U.,. *IAPS*, *14*, (pp. 82-95). Stokholm.

Complexity LearningLab. (n.d.) *Complexity theory: introduction*. Retrieved from http://complexitylearning.io/course/complexity-theory-introduction/

Cook, J. (1997). Climate. In P. Oliver, *Encyclopedia of Vernacular Architecture of the World* (Vol. 1) (pp. 127-139). Cambridge: Cambridge University Press.

Cuisenier, J. (1997). Spatial In P. Oliver, *Encyclopedia of Vernacular Architecture of the World* (Vol. 1) (pp. 60-62). Cambridge: Cambridge University Press.

Devetakovic M, Petrusevski T, & Mitrovic, B. (2009) An exploration in architectural design using cellular automata. *Generative Art Conference*, Milano, Italy.

Dinçer , A. E., Tong, H., & Çağdaş , G. (2014). A computational model for mass customized housing design by using cellular automata. *ITU AZ,* 11 (2), 351-368.

Dincyurek, O. (2002). *The rural vernacular architecture of Cyprus (Northern).*(Unpublished PhD Thesis). Eastern Mediterranean University, Institute of Graduate Studies, Famagusta, North Cyprus.

Dincyurek, O., & Olgac Turker, O. (2007). Learning from traditional built environment of Cyprus: Re-interpretation of the contextual values. *Building and Environment,* 42(9), 3384-3392. doi: 10.1016/j.buildenv.2006.08.007

Dovey, K. (1990). The pattern language and its enemies. *Design Studies, 11*(1), 3-9.

Field, D. M. (2007). *The world's greatest architecture: past and present.* Chartwell Books.

Gausa, M., Guallart, V., Müller, W., Soriano, F., Porras, F., & Morales, J. (2003). *The metapolis dictionary of advanced architecture.* Barcelona: Actar.

Ghobadian, V. (2006). *Climate analysis of the Iranian traditional building.* Tehran: Tehran University Press.

Ghobadian, V. (2009). *Sustainable traditional building of Iran.* Tehran: Dubai University.

Ghorbanizadeh, M, Abyaneh, SL. Abyaneh. (2008).Translated by Naser Namvar. *Iran: Harpark Abyaneh*. Tehran.

Glassie, H. (2000). *Vernacular architecture.* Philadelphia, U.S.A: Indiana University.

Golboo, F. (2009). *Looking toward Masouleh.* Tehran: Iranshenasi.

Gössel, P. (2007). *The A-Z of modern architecture.* Taschen, ED.

Hagerhall, C. M. (2008). Investigations of human EEG response to viewing fractal patterns. *Perception,* 37(10), 1488-1494.

Haggard, K., Cooper, P., & Gyovai, C. (2006). *Fractal architecture, design for sustainability*. Santa Margarita, California: Sustainability Group.

Heath, K. (2009). *Vernacular architecture and regional design.* Oxford: Elsevier Ltd.

Huang, Y., Wang, C., Wang, N.-a., Li, G., & Zhang, C. (2007). Study on urban spatial morphology with RS & fractal. *Geoscience and Remote Sensing Symposium*. IEEE International .

Hubka, T. (1979). Just folk designing: Vernacular designers and the generation of form. *Journal of Architecture and Education,* 32 (3), 27-29. doi: 10.1080/10464883.1979.107586609

Jackson, W. J. (2014). *Hindu temple fractals*. (D. o. Studies, Producer) Retrieved from http://liberalarts.iupui.edu/~wijackso/tempfrac/index.html

Jacob, S. (2008). *Sustainability through fractal architecture.* Retrieved May 23, 2013, fromhttps://www.academia.edu/409904/FRACTAL_DESIGNSustainability_through_Fractal_Architecture

Jansson, S. (2006). *Evaluation of methods for estimating fractal properties of intensity images*. (Unpublished Master's Thesis) Umea University, Department of Computing Science, Sweden.

Jencks, C. (1997). *The architecture of the jumping universe.* Great Britain: John Wiley&Sons.

Jenkes, C. (2002). Gradual movement from Hi-tech to organitech. (T. i. Ashraf, Ed.) *Abadi Journal* (42).

Joye, Y. (2007). Fractal architecture could be good for you. *Nexus Network , 9* (2).

Keshtkaran, P. (2011). Harmonization between climate and architecture in vernacular heritage: a case study in Yazd, Iran. *Procedia Engineering*, 21, 428-438.

Klinkenberg, B. (1994). A review of methods used to determine the fractal dimension of linear features. *Mathematical Geology*, 26:1, 23-46.

Krawczyk, R. J. (2002). *Architectural interpretation of cellular automata*. Retrieved from http://www.generativeart.com/

Lawrence, R. J. (1987). *Housing, dwellings and homes.* Great Britain: John Wiley&Sons.

Long, M., & Meie, O. (2007). On characteristics of fractal aesthetics in mountanious cities. *Mountain Sci,* 3, 148-152.

Mandelbrot, B., & Frame, M. (2003). *Encyclopedia of physical science and technology*. (3), 185–207, Yale University, Academic Press. doi:10.1016/B0-12-227410-5/00259-3

Mandelbrot, B. (1989). Fractal geometry: what is it and what does it do? *Proceedings of the Royal Society.*

Mandelbrot, B. (1982). *The fractal geometry of nature.* San Francisco: H B Fenn and Company.

McGuire, M. (1990). *An eye for fractals : a graphic & photographic essay.* Redwood City, CA: Addison-Wesley.

Memarian, G. H. (1997). *Memari maskoony Irani: gouneh shenasi borungara*. Tehran: Elm va sanaat university.

Miller, G. A. (1955). The magical number seven plus or minus two: some limits on our capacity for processing information. *The Psychological Review ,* 101(2), 343-352.

Mirzaei, R. (2013). Organic Architecture Means for Sustainability Goals. *Architecture and Modern Information Technologies ,* 2 (23).

Mohammadabadi, MA. & Ghoreshi, S. (2011). Green architecture in clinical centres with an approach to Iranian sustainable vernacular architecture (Kashan City). *Procedia Engineering*, 21: 580-590.

Oktay, M. (2006). *Learning from Karpaz vernacular: Conceptualization of the Karpaz vernacular architecture.* (Unpublished Master's Thesis). Eastern Mediterranean University, Institute of Graduate Studies, Famagusta, North Cyprus.

Oliver, P. (1997). *Encyclopedia of vernacular architecture of the world.* United Kingdom: Cambridge University Press.

Oliver, P. (2003). *Dwellings.* London: Phaidon Press.

Ourjafar, M. P., Mahmoudinejad, H., & Hadian , O. (2011). Design with nature in bio - architecture with emphasis on the hidden rules of natural organism. *International Journal of Applied Science and Technology,* 1(4), 73-84.

Pavlides, E. (1997). *'Architectural'* In P. Oliver, *Encyclopedia of Vernacular Architecture of the World* (Vol. 1) (pp. 12-15). Cambridge: Cambridge University Press.

Peter, C. (1996). *Diverse Aspiration in the Modern Architecture, Trans.* Qatreh Publication.

Ramezaanpour, B. (2010). *Introduction to Masouleh village*. Rasht.

Rapoport, A. (1969). *House form and culture.* Englewood, Englewood Cliffs: N.J.

Reza, E. (2011). *Identification of staircase house type in rural architecture of Iran: Masouleh and Abyaneh settlements.* (Unpublished Master's Thesis). Eastern Mediterranean University, Institute of Graduate Studies, Famagusta, North Cyprus.

Reza, E., & Dincyurek, O. (2015). The interpretation of vernacular architecture through fractal models: in the case of Iran, Masouleh village. In G. Amoruso (Ed), *Handbook of research on visual computing and emerging geometrical design tools* (Vol. 2, pp. 55-77). IGI Global E-Editorial Discovery System.

Reza, E., & Dincyurek, O. (2017, in print). The versatility of terraced housing in vernacular architecture. case study: steep regions of Iran. *Open House International*, 42 (2), in print.

Rudofsky, B. (1964). *Architecture withouth architect.* Albuquerque: University of New Mexico Press.

Salingaros , N. A. (2012). Fractal art and architecture reduce physiological stress. *Journal of Biourbanism ,* 2.

Salingaros, N. A. (2000). The structure of pattern languages. *Architectural Research Quarterly* , 4(02), 149-161. doi:10.1017/S1359135500002591

Shaterian, R. (2011). *Climate and architecture.* Tehran, Iran: Simayeh Daanesh.

Steen, L. A. (1988). The science of patterns. *Science,* 240, 611-616.

Tang, Y. Y., Tao, Y., & Lam, E. C. (2002). New method for featured extraction based on fractal behaviour. *Pattern Recognition ,* 35 (5), 1071–1081.

Taylor, R. P. (2006). Reduction of physiological stress using fractal art and architecture . *Leonardo ,* 39 (3), 245-251 .

Turner, M.J., Blackledge, J.M., & Andrews, P.R. (1998). *Fractal geometry in digital imaging*. California: Academic Press.

Wright, F. L., & Gutheim, F. (1975). In the cause of architecture. *Architectural Record* .

Vaughan , J., & Ostwald, M. J. (2010). Using fractal analysis to compare the characteristic complexity of nature and architecture: Re-examining the evidence. *Architectural Science Review*, 53(3), 323-332. Doi:10.3763/asre.2010.0024.

Vaughan, M. O., & Vaughan , J. (2008). Determining the fractal dimension of the architecture of Eileen Gray. (p. 1). Newcastle: University of Newcastle

Vellinga, M., & Asquith, L. (2006). *Vernacular architecture in the 21st century.* USA and Canada: Taylor & Francis.

Yue, W., & Ran-ran, W. (2010). Fractal and city planning. *Modern Urban Research* , 4, 53-57.

Zargar, A. (1999). *Daraamadi bar shenaakht memari rustaie Iran* [*An introduction to the Iranian rural architecture]* . Tehran: School of Architecture and Urban Planning, Shahid Beheshti University.

Zexin, L., Bo, L., & Zhi, L. (2013). Spatial fractal characteristics of hilly City. *Applied Sciences , 13* (7).

[1] Kandovan Images. (2015, January 20). Retrieved from http://www.loadtr.com/385355-iran_haritasi_.htm

[2] Abyaneh Images. (2015, January 25). Retrieved from http://goctinnhanh.com/tin-nhanh/ky-la-thanh-pho-khong-ai-mac-quan-ao

[3] Maymand Images. Retrieved from (2015 January20).http://perierga.gr/2013/11/%CE%AD%CE%BD%CE%B1-%CF%87%CF%89%CF%81%CE%B9%CF%8C-%C2%AB%CF%83%CE%BA%CE%B1%CE%BB%CE%B9%CF%83%CE%BC%CE%AD%CE%BD%CE%BF%C2%BB-%CF%83%CF%84%CE%BF-%CE%B2%CE%BF%CF%85%CE%BD%CF%8C/

[4]Maymand Images. Retrieved from (2015, January 5) http://www.anobanini.com/forum/viewtopic.php?f=10&t=42

[5] Map of Iran. (2015 January 17). Retrieved from http://en.wikipedia.org/wiki/Geography_of_Iran.