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Research Article

Computational Approaches in 21st Century Architectural Design: Defining Digital Representation Methods*

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ABSTRACT

The studies on design and design methods increased towards the end of the twentieth century in industrialized societies, however, the act of design started to be carried out with different auxiliary tools. The digital and algorithmic structure behind the computer has begun to provide the designer with different possibilities outside of the traditional drawing environment. After this period, the queries and discussions on the content of the design, its components, the intellectual process of the designer, and similar issues gradually increased. Within this scope, new theories and methods have emerged. In today's design, especially with digital technologies, transformations in theory and practice in the design process have brought new methods with them. Architects and designers have now become design tool developers rather than using use of the design tool. Based on this, the assistive tools that determine the current architectural design style is aimed to be explored in this paper. The study contributes to the field by (i) exploring these tools and their latent features, (ii) assessing the pros and cons of these tools, and (iii) last, implementing these design tools on the case studies.

Keywords: *Computational design, Design process, Digital technologies, Form, Representation*

21. Yüzyıl Mimari Tasarımında Hesaplamalı Yaklaşımlar: Sayısal Temsil Yöntemlerinin Tanımlanması

ÖZ

Yirminci yüzyılın sonlarına doğru sanayileşmiş toplumlarda tasarım ve tasarım yöntemleri ile ilgili çalışmalardaki artış, yardımcı araçlarla tasarım yapma yönündeki eğilimi artırmıştır. Dijital ve matematiksel yapısı sayesinde bilgisayar ortamının tasarımcıya geleneksel yöntemlere göre çeşitli kolaylıklar sunmasının yanında ilham verici farklı olanaklar da ortaya koyabilmesi, bu eğilimi daha cazip hale getirmiştir. Bununla birlikte tasarımcının düşünsel süreci, tasarım ve tasarımın bileşenleri konularındaki sorgulamalar giderek artmış, bu kapsamda yeni teoriler ve yaklaşımlar ortaya çıkmıştır. Günümüz tasarlaması tasarım süreçleri bağlamında, özellikle dijital teknolojilerle birlikte, teori ve pratikteki dönüşümler, beraberinde yeni yöntemler ve açılımlar getirmiştir. Mimarlar ve tasarımcılar, tasarım araçlarını kullanmaktan ziyade tasarım aracı geliştirmek konusunda kendilerini geliştirmektedir. Bundan yola çıkarak makalede, mevcut mimari tasarım stilini belirleyen yardımcı araçların incelenmesi amaçlanmaktadır. Çalışma, (i) bu araçları ve bunların tam olarak netleşmemiş ya da fark edilmemiş özelliklerini keşfederek, (ii) araçların olumlu ya da olumsuz yanlarının değerlendirilmesi ve (iii) son olarak bu tasarım araçlarının vaka çalışmalarında uygulanarak alana katkıda bulunması amacıyla bir ön çalışma olmayı hedeflemektedir.

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Anahtar Kelimeler: *Biçim, Dijital teknolojiler, Hesaplamalı tasarım, Tasarım süreci, Temsil*

I. INTRODUCTION

Digital technologies, depending on their development processes, have been effective in bringing different application environments to the agenda in architecture and architectural design education. This development process transforms from product representation that can be created in the digital environment to one that supports creativity and decision-making, an activity specific to data, information and information processing, and human mental processes. With these developments and transformations, the focus of architecture has turned not only to the final product but also to the design process. Design and scientific research in different disciplines are the result of digital thinking skills. Digital thinking is an algorithmic way of thinking and a problem-solving process based on mathematical and logical calculations to reach the product. Using different abstraction methods to comprehend and solve problems; formulates problem and solution successfully. This information processing way can be realized by using the knowledge and experience of the expert, as well as with the opportunities provided by the digital environment. The product, which comes out mentally during design, is developed by following certain patterns of implicit design information. The realization of the whole or certain stages of the act of designing with the calculations performed by digital media makes it necessary to analyse the implicit information in the mental world of the designer. Design problems are taken to further levels by the computational processes of digital environments that are described and abstracted by algorithms and the design process is developed. The use of digital tools in the architectural design phases should not be reduced to the digitization of traditional methods or just the form search, therefore the use of digital tools should be perceived and applied as a search for the integrity of form, space, structure, and material, avoiding traditional restrictions. Digital technologies can bring different solutions to different problems by combining structured rational components, the intuitive process of the designer, and the advantages of computational methods. In other words, algorithmic and computational design approaches enable the use of the digital environment and the design possibilities of the designer together.

Significant developments have occurred regarding the transformation of design, process, and representation relations in the disciplines involved in the design. These changes in theory and practice have occurred because of the changing and transforming design environment rather than the result of an ideology, aesthetic concern, or a new understanding. Digital technologies are at the center of this situation. Architectural design, which has developed with a certain accumulation of knowledge over hundreds of years, brings along a traditional process. However, the introduction of new design possibilities by digital technologies has led to the questioning of some acceptances from traditional processes and the emergence of new concepts and discussions. This change and transformation in architectural practice has been described as a great revolution by researchers.

As it is known, the design is the reasoning process that the designer puts forward with the information coming from his background. Although it has been discussed for years whether a scientific explanation can be brought to the architectural design process, how factors such as creative thinking, intelligence, and talent are effective in the design process, the method the designer follows in the design process can take various forms. These processes will be examined in detail under the title of digital design approaches in architecture. The traditional architectural design process can be described as a visual-based process in which the design is developed and shaped in a representational environment with expression techniques such as sketch, technical drawing, and model.

Pioneer architectural designers have stated that representational forms are an indispensable assistant of the designer, and especially the sketch provides the dialogue with the designer by embodying the thoughts formed in the mind. Sketching as a representation method improves the design by allowing reinterpretation, originating in a blurry environment. That is, the representation medium for the designer is a feedback tool. The increasing use of digital technologies as a tool and aid in architectural design processes has included many new design methods in architectural practice. The designer can use the computer as a design development tool on the way to the result he envisioned, as well as

provide the emergence of a form that he did not think of, through the computer environment, through the network of relationships he predicted.

In this article, the theoretical studies, methods, and techniques used at the center of digital design approaches are explained and their aspects reflected in design practice are evaluated through examples.

II. DESIGN AND REPRESENTATION

Design is explained by design researchers in various ways; such as decision making in uncertainty [1], leaping from the realities of the present to the possibilities of the future [2], problem-solving process [3], cognitive action [4], knowledge-based activity [5]. In this context, design can be interpreted as a preparation and decision-making process for the solution of a defined problem. Architectural design, on the other hand, is aimed at solutions related to space, form and program. Explanations and definitions for design, design processes and design action can be increased. Lawson mentioned that to understand design, it is necessary to explain how different disciplines perceive the design and design process. He says that designing is action versus production and that there are significant differences in the end products produced by designers in different fields. For example, the software produced by a computer engineer against a problem is an act of design. However, the process that brings the engineer to a conclusion and the other one that a shoe designer goes through while designing is quite different from each other. In both cases, a solution to the current problem is produced. Here, the design of the software is carried out with a systematic, predictive and mathematical solution-based solution, while the production of the shoe designer is the result of a mental search that is ambiguous, implicit and spontaneous within the framework of problem definition. Designing deals with both definite and ambiguous ideas, both systematic and chaotic ways of thinking, both imagination and mathematical calculations [6].

It is clear that there are some visible changes and transformations in today's design world. The main reason for this situation seems to be the new design and representation environment brought by digital technologies. The designer has always resorted to representation in order to express his thoughts and ideas. In this context, the relationship of the designer with representation in the design process greatly affects the final product. In the 19th century, while the main tool used to carry out the design action was the model, until the paper became easily accessible, in the following times, the primary representation tool was paper. We can say that paper is dominant as a representation tool in traditional design processes. The place of the sketch is very important here. The blurry structure in which the sketch expresses thought and intuition helps us to give a potential meaning to each line drawn and makes the design open to different interpretations. As a result, we can say that the designer is fed by the sketch environment.

Nowadays, digital tools offer new representation environments and these mediums have quite different dynamics from traditional representation methods. While two-dimensional lines can be mentioned in the sketch environment, three-dimensional forms and spaces in the model, it becomes possible to talk about time and performance in the digital environment where computational methods are used. As a result, the interaction in the sketch and model environment and the interaction in digital environments will be quite different from each other.

As a result, within the present and future digital processes, there is no single design tool and representation medium. There are many methods. Interactions with alternative representation mediums lead the designer to different results. On the other hand, representation, which has been redefined with the development of printing and reproduction technologies, has been transformed again with the development of digital methods and has become meaningful by itself as well as being meaningful with the object it represents. That is, representation has become meaningful on its own. Another feature brought about by digital approaches is that irregular organic forms can be used as much as regular geometric forms.

III. DIGITAL APPROACHES IN ARCHITECTURAL DESIGN

Digital design is related to many disciplines such as geometry, mathematics, cognition science, psychology, biology, geography, philosophy, computer science. The digital design follows a multi-layered process starting from systems theory and cybernetics to morphogenesis [7]. Digital approaches define a process that is constructed in a holistic approach by covering the thoughtful, experiential and visual aspects of design. Digital design paradigms based on mathematical, mental and relational processes can be reflected in the creative design process and product with very different approaches. Although designing is a holistic decision-making process, the first research studies in the field of digital architecture were suggested as analysis, prediction and evaluation processes due to the limitations in digital technologies in the 1960s. These studies were defined by algorithms that generate mathematical solutions to well-structured problems and are based on information processing. These processes, which are used in different stages of architectural design, have turned into a holistic digital design approach with the possibilities of today's information and communication technologies and digital design theories.

Digital design methods consider the representation of the architectural product in the digital environment as geometric relations instead of geometric symbols. Therefore, representation of the design by parameters represents behavioral properties rather than geometric properties of the form. Visual modelling applications, which started with two and three-dimensional expressions, have become widely used with digital approaches. As a result of the development of computer software, the boundaries of basic geometric forms have been removed, resulting in the design and production of complex forms. Software that contains geometry-form information such as Building Information Modeling (BIM) and Computer Aided Design (CAD) technologies have been applied to architecture and have brought the construction representation to be constructible, rethinking design processes and reformulating as a digital system whole. However, in the design process, which is a very wide and comprehensive whole, the advantages of technology are taken advantage of by using digital systems focused on specific stages of the process.

According to Oxman, the forms of interaction transformed by the participation of digital technologies in the design processes take four different forms [8].

- Non-digital representation: Direct interaction of object-representation relationship with CAD tools such as sketch, model and drawing.
- Digital representation: Interaction withdrawing, model and sketching in the digital environment.
- Digital representation constructed by a mechanism: It is the interaction of the designer with the digital structure formed by the derivative mechanisms within the framework of defined rules and relationships.
- Interaction with the digital environment: The interaction of the designer with the mechanism that creates the digital design.

In architecture, digital technologies offer an approach through certain computational systems and their output. These approaches are systems that support the expert in the problem-solving process with design possibilities and facilitate the discovery of alternative solutions. Digital systems offer a new working method and the environment in design. These systems are based on identifying the unity between digital design principles and design elements with algorithms. They reinterpret traditional design languages and allows them to be used as data in future designs. Computational approaches in architectural design are used to solve problems of different scales in the context of different techniques and methods. These approaches are discussed under fractal structures, shape grammars, L-systems, evolutionary design, cellular automata, decision support systems, and performance-based design. It is an important issue that needs to be considered in which phase of the design digital approaches can be used effectively and how they can contribute. For what purpose and how to use digital methods in architecture is an important factor that will affect the final design.

A. FRACTAL STRUCTURES

Although the concept of fractal discovered with chaos theory has become a part of science literature after Benoit Mandelbrot, it is possible to find fractal fictions in much earlier local architectural examples in architectural design. When we look at examples of local architecture in primitive communities, fractal fictions can be found. The reason for this is that they reflect the fractal fictions that exist in nature to architectural design. After Benoit Mandelbrot published his book "The Fractal of Nature" (1982), the term used especially in the field of mathematics entered the world of architecture. As a result, it has provided researchers with the opportunity to examine architectural constructions at different scales. For example, when we examine the architectural texture in urban scale from macro to micro; It is possible to examine the occupancy-vacancy rates of the city, the spread of the urban transport network or the growth and development characteristics of the city. When we look at the architectural texture on a building scale; it allows us to examine the tectonic movements of the building, its plan grammar, occupancy and void proportions, door and window details, and even the texture of the material. As a result, when an architectural structure is examined in the context of its general fiction, if it contains similarities at different scales, it is possible to say that the architectural fiction shows a "fractal" formation, that is, a "similar to itself" formation [9].

Guzelci et al. (2020) similarly propose a computational model that automates the measurement of complexity of geometric patterns. They also explain the basic principles of the proposed model in the case of muqarnas 2-dimensional patterns of Sitte Melik Tomb (1228) in Sivas. The basic concepts that their model relies on are given in Figure 1 [10].

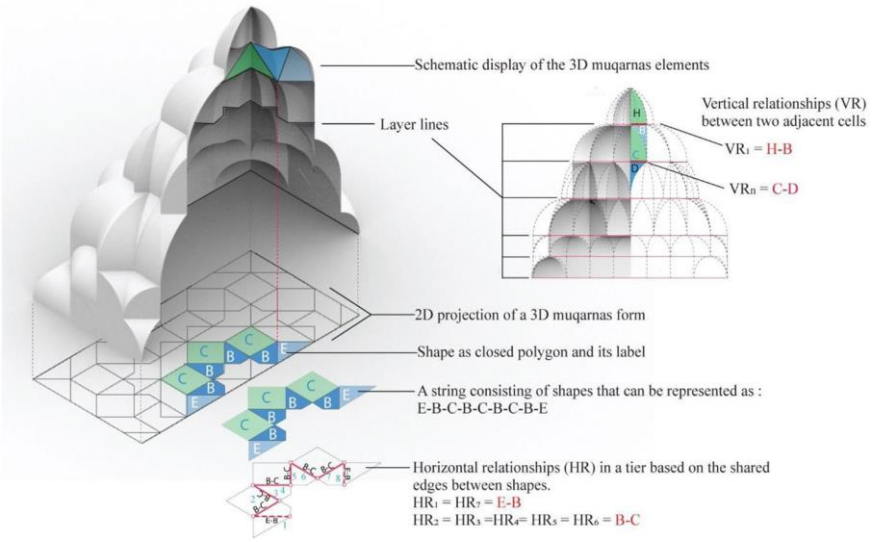

Figure 1. *Diagrammatic model of a muqarnas pattern and its related concepts [10].*

There are many examples of the links between fractal geometry and architectural design. There are hundreds of examples of architectural designs analyzed or designed through fractal geometry [11]. Many researchers, influenced by the mathematical and visual dimension of fractal geometry, interpreted fractal geometry in their unique way. Therefore, the fractal dimension has no common title in architectural design or criticism. In this context, it will be useful to divide such studies into two categories; what was completed before the fractal theory was formulated and what was completed later. The first category includes studies that show evidence of the underlying principles of fractal geometry with intuitive data. This section consists of the analysis and discussion of the urban scale textures in the local architecture or the textures at the building scale. The second category includes works that explicitly accept the architecture-fractal relationship. There are many different algorithmic connections in designs in this category, from inspiration to structure and even parts of the structure at different scales. Some of the architects who explicitly refer to complex patterns are involved in this

group; Steven Holl (USA), Peter Eisenman (USA), Jean Nouvel (France), Aldo van Eyck (Netherlands), Zaha Hadid (England), and Arata Isozaki (Japan) [11].

Architecture with a clear understanding of fractal geometry draws inspiration from it in a variety of ways, even if it does not use much of the mathematical or scientific understanding of the concept. For this reason, fractals in architecture are used as metaphors representing a theoretical connection. Both mathematical and theoretical approaches to fractal geometry can be realized through the architectural context. In contrast, fractal geometry in architecture is difficult to provide a fully consistent, meaningful, and holistic connection. It can be used as an aid in defining intuitive, intellectual or digital boundaries. In this context, there are various ways to benefit from fractal geometry in architecture (Figure 2).

It can be used as a design input in preliminary design processes, together with various factors that will guide the design. For example, fractals can be an input for generative systems where they can be used as the main factor guiding the design in the design process. In the criticism and analysis processes; it is the use of digital analysis is performed through design, designer or texture as data for criticism.

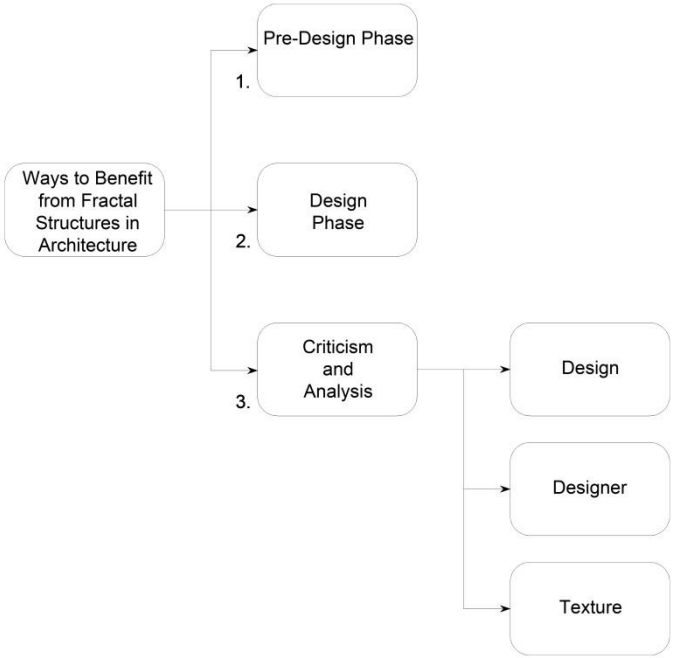

Figure 2. *Ways to benefit from fractal structures in architecture (illustration by the authors).*

As a result of these explanations, determining the boundaries of the relationship between fractal geometry and architecture will be able to prevent the problems that may occur. In this context, we can examine them in three stages. First, when working with fractal geometry, researchers must be clear about how to use it; as a structure, form, ornament or as inspiration. Second, fractal algorithms or generative systems are not enough to finalize a design. The designer cannot produce a complete building without some input during the design decision-making or development phase. Designs created with digital systems must be organized with some contextual data before they are available to the user. The last one is about how to measure architecture using fractal dimensions. As a result, the complexity behind each natural or artificial object can be measured or predicted with the aid of fractal dimension [12].

B. SHAPE GRAMMARS

Shape grammars were stated in the early 1970s by George Stiny and James Gips as an algorithmic structure, as a method of defining and creating design languages, one of the basic concepts of design and architecture [13]. Rollo (1995) defined morphology as a language tool used in coding the findings of a study on a design language [14]. The task of linguistics is to describe the derivative rules in the language by decomposing the language and revealing the grammatical rules for new formations. Just as linguistics does not invent a new language, grammar does not invent a new architectural language. The first studies on shape grammar are for analysis and critical purposes and aim to make visible the formal rules of a design language by analyzing [15]. Design languages with an algorithmic structure have repetitive properties and these properties can be defined as the rules of the language. By analyzing these rules, the original language is grasped and new forms can be produced using this language. In other words, shape grammar is the production of new forms depending on a set of rules. Each shape grammar is unique and is expected to produce different results.

Syntactically, architectural design can be defined as a combination of forms and relationships between forms. Derivation and development first start with the initial shape and continues by applying certain rules. Many forms and patterns can be produced from a basic shape grammar [16]. The combination of components in the design is possible by formulating certain principles. These rules can be expressed verbally or digitally [17].

Composition forms for Wright's country-style homes are derived from diagrams of shape grammars (Figure 3).

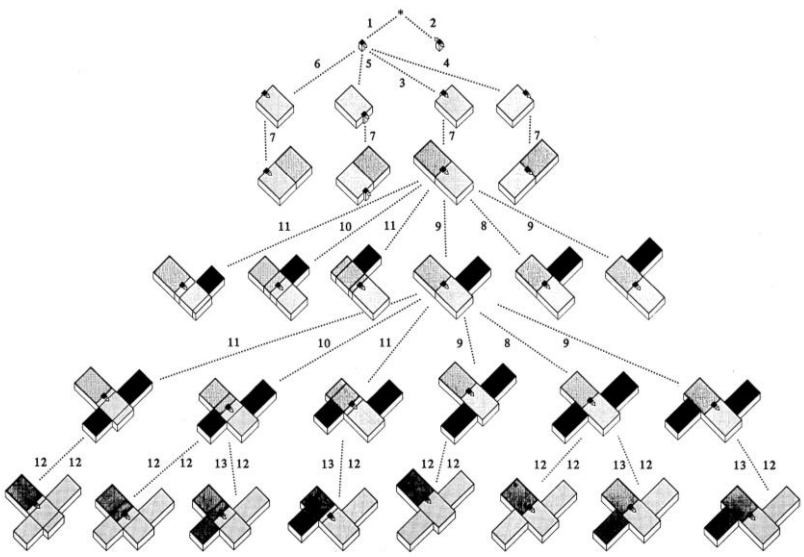

Figure 3. *Frank L. Wright's Prairie House Shape Grammar [18].*

The application of shape grammars as a design tool has expanded further in recent years. Shape grammar used for the analysis of architectural objects will also play an important role in previous and future research. The progress of digital technologies and the continuous development of their applied use in architectural studies provide a necessary basis for new approaches to be made in the future. The point is not to model buildings geometrically and historically, but to rely on an accurate model that describes the complex connections between architectural elements. In this sense, shape grammars can serve as a platform for studying architectural typology at complex levels that cannot be realized without the appropriate computational infrastructure.

In the 4th figure, a study by Duarte (2001) is the formal analysis of Alvaro Siza's Malagueira Houses and their reproduction in a computer environment with the help of an expert system [19].

Figure 4. *Malagueira Houses site plan [19].*

Computer-aided design and production systems offer and visualize home alternatives. After certain parameters are entered into the program interface, it can generate alternatives in the design language of Malagueira Houses. Proposals can be displayed with the help of 3D computer models or virtual reality tools. After examining the house typologies according to their functions and sizes, an architectural pattern language has been revealed. Siza's architectural approach and Malagueira Houses are analyzed in terms of shape grammars. This is because the architect's design language is inclined to shape grammars (Figure 5).

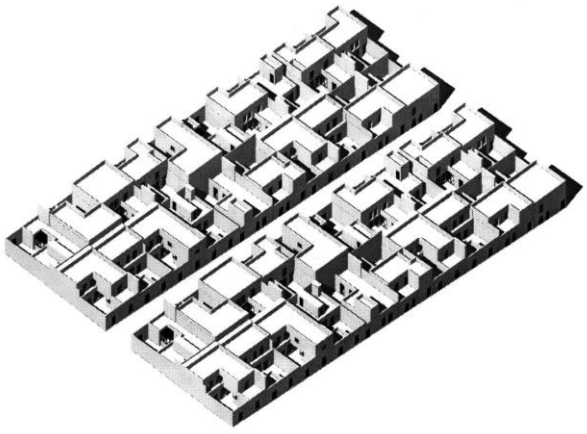

Figure 5. *Configuration of a city block [19].*

During the historical development of geometry, shape grammar developed by feeding on the last rings in this process. Along with the developments in the direction of geometry as empirical knowledge, shape grammars have also developed by feeding on the experience of seeing. The widespread expansion of such design approaches in a short period implies that development in the near future will greatly improve the usability of shape grammar in architectural design. Therefore, the presented analyzes and evaluation of the previously described architectural projects are crucial to understanding the future value of shape grammar logic.

C. L-SYSTEMS

Lindenmayer systems (L-systems) are a rewriting and visualization method developed by Aristid Lindenmayer in 1968 to simulate growth patterns of multicellular organisms and later used by many biologists and computer theorists [20]. L-systems, which are effective in simplifying complex systems, are currently used in the fields of architectural design, and the variability and diversity in their derivation can be achieved with different starting points. This approach, which is generally used in the production of organic forms and fractals such as plants and tissues, is also used in the production of transportation networks in the city and regional planning, although its areas of use in the design are limited.

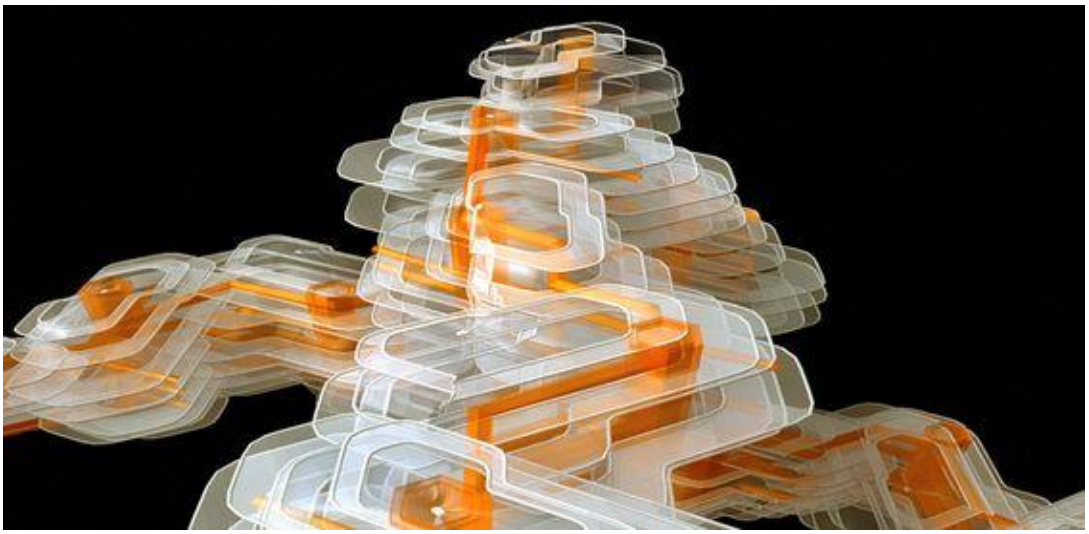

Figure 6. *A production designed using L-systems [21].*

In a study by Hansmeyer, volumes gathered around the central circulation were defined. The coordinates of the sequence created with the L-system codes defined in the Visual Basic programming language were visualized by transferring the codes to the Maya Program. The algorithm, which is branched and has 2 modules, consists of spaces positioned around the basic form, which is formed in the center and develops in the form of a ramp. The definition of the algorithm used can be made as follows:

1. The 2-dimensional path of the circulation area is created.

2. 2-dimensional profiles are combined with an angle of 45 degrees to obtain a 3-dimensional ramp path.

3. By creating the section profile of the ramp, it is applied along the road and the ramp module is created (1^{st} ruleset).

4. The chamber section is created and applied along the length to obtain volume (2^{nd} ruleset).

5. Rooms are placed around spiral-like circulation (3^{rd} ruleset)

6. Each rule sequence is applied in the specified number of cycles, the L-system sequence is obtained.

7. The sequence is visualized using the turtle graphic. Hansmeyer used modular growth with 3D L-systems in this work; increasing the number of cycles allows the mass to grow upwards with the added modules.

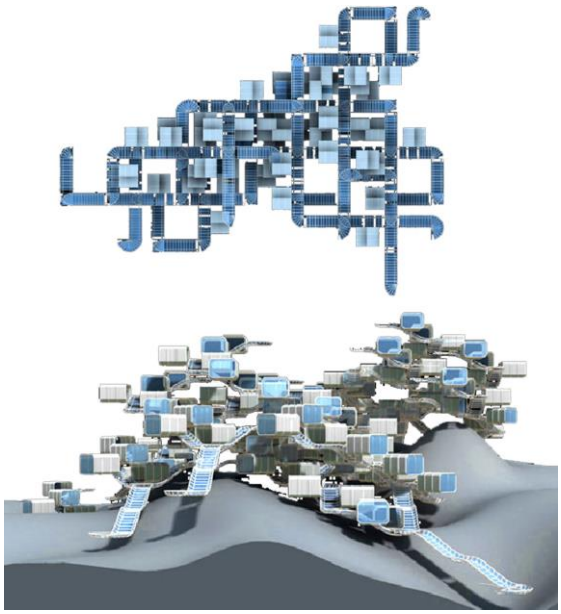

Figure 7. *Building form created with environment interactive L-system [22].*

D. EVOLUTIONARY DESIGNS

Examples in which evolutionary systems are modeled in the design are generally discussed under the main subject of algorithmic design. In the algorithmic design approach, the product or the family of possible products is formed automatically as a result of the established rules and relations system. Evolutionary systems based on this approach are concerned with the use of biological growth and formation concepts as a model for design in the architectural design process. Frazer describes this process in his book Evolutionary Architecture as follows: "Architectural concepts are defined as a set of production rules, the evolution and evolution of these concepts can be digitally encrypted. A set of fabrication rules can derive a large number of prototype formats. These products are evaluated according to their performance in a similar environment. The result is often unexpected" [23].

First, Holland used the evolutionary process for optimization problems within algorithms [24]. It is important to examine the various algorithmic processes obtained by analyzing genetic structures for experimental purposes and to reflect them on the design, to push the boundaries of architectural design. As a source of inspiration, the use of the effects of nature with computational sciences and the subject in many different branches of science such as engineering (artificial neural networks, genetic algorithms), science (complex systems, fuzzy logic, chaos, and fractals), medicine (robot prostheses, artificial organs). Taking place has increased interdisciplinary interactions. The reflection of evolutionary design in architecture has a wide range of applications from structural optimization methods to form generation methods and offers designers much potential.

Many new projects were signed for the 2008 Beijing Olympics. One of them is the Watercube National Swimming Center, which was built by the PTW architecture office, which won the competition opened in 2003, next to the National Stadium building, also known as the Bird's Nest, built by Herzog&de Meron for the Olympics. The Watercube National Swimming Center design can be taken as an evolutionary design model by establishing a structural layout derived from the soap bubble algorithm (Figure 8).

Figure 8. *Water Cube National Swimming Centre, Beijing, PTW Architects. In the design of the building, a structural order derived from the soap bubble geometric algorithm was created [25].*

It was designed with an organic and random approach, similar to a natural system. There is a system that repeats and reproduces each other. Based on the fact that the bubbles touch each other in a regular geometry, a structure with regular intersections, nodes, and perpendiculars is created (Figure 9).

Figure 9. *Soap bubble construction [25].*

E. CELLULAR AUTOMATA

Expressed as a new science by Stephen Wolfram, cellular automata emerged about 50 years ago by trying to solve the problem of complexity based on digital approaches [26]. The feature that makes this method important is that although it looks straightforward, it can easily produce complex structures. A cellular automata is an approach that simulates growth processes by defining a complex system with simple rules. The basic cellular automata terminology is illustrated by the authors in the Figure 10.

It consists of cells, each representing one of a certain number of defined states, depending on a set of rules that function in certain grid order and in a certain period according to the states of neighboring cells [27]. This approach, which was developed to define self-organization systems, is used in architectural and urban design problems that cover a wide spectrum from regional settlements, social interactions, and design processes to material behavior, as in various disciplines.

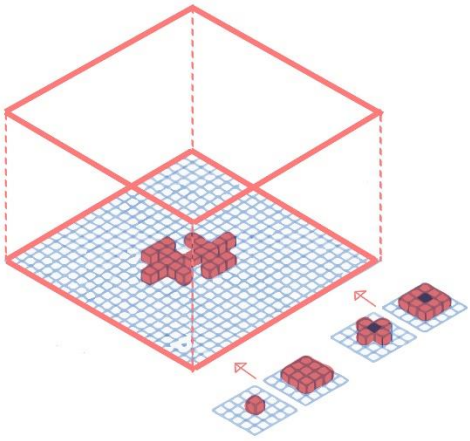

Figure 10. *Basic cellular automata terminology (illustration by the authors).*

It is possible to see fictions derived from cellular automaton both in terms of form and content, albeit with different approaches, in today's architecture, especially in large-scale building designs with complex functions and different user types. An example of these is the Nakagin Capsule Tower designed by Kurokawa, in the 11th figure [28].

Figure 11. *Nakagin Capsule Tower designed by Kurokawa [28].*

Nakagin Capsule Tower; is one of the practical examples of the “Metabolist” approach, which proposes an architectural understanding in which the concepts of the human, machine, and space form an organic structure together (Kruft, 1994). The structure consists of 144 modular capsules located around two main cores. Each of these capsules represents in itself hotel-style living units. The positions of these capsules have the ability to be renewed according to time and changing conditions. Because of these features, it is compatible with the structure of Cellular Automata both in terms of form and content.

F. DECISION SUPPORT SYSTEMS AND AI

Decision-making is defined as the decision-maker choosing one or several options that are most suitable for the purpose among all available options. Decision support systems are interactive computer systems that use data, documents, information, and communication technologies to identify and solve problems, complete the decision-making process and make decisions to assist decision-makers.

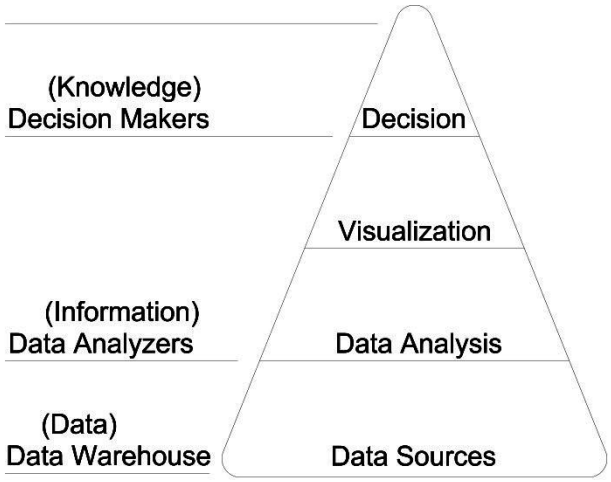

Figure 12 *Decision-making process (illustration by the authors).*

These systems, which are based on artificial intelligence studies, play an important role in solving complex, poorly structured, or multi-criteria problems, and the human expert assumes the role of a consultant in the decision-making process.

Considering the uncertainty of the solution method in the development of solution alternatives and the existence of subjective decisions, the importance of decision support systems in the selection of the solution is understood in architectural design problems.

G. PERFORMANCE-BASED DESIGN

Performance-based design techniques include design methods in which the architectural design process develops based on performance analysis. Building quality may be related to the performance of the building in terms of technical data such as climatic, structural, and acoustic data, as well as the various features that the designer expects from the space; additionally, various criteria like pedestrian-traffic flows, spatial relations, building program, economic parameters can be used in the performance evaluations.

Kolarevic mentions the "finite element method", which is a method of analyzing the geometric model in terms of structural, energy use, and fluid dynamics by dividing the geometric model into interrelated triangular units (mesh) for performance analysis in a computer environment [29]. Karadag and Serteser (2019) propose a meshless fluid dynamics algorithm to solve wind building interaction in the early design stage (Figure 13). Performance analysis of complex-shaped spaces can also be performed in a computer environment with such methods and developments in computer graphics facilitate the use of these techniques [30].

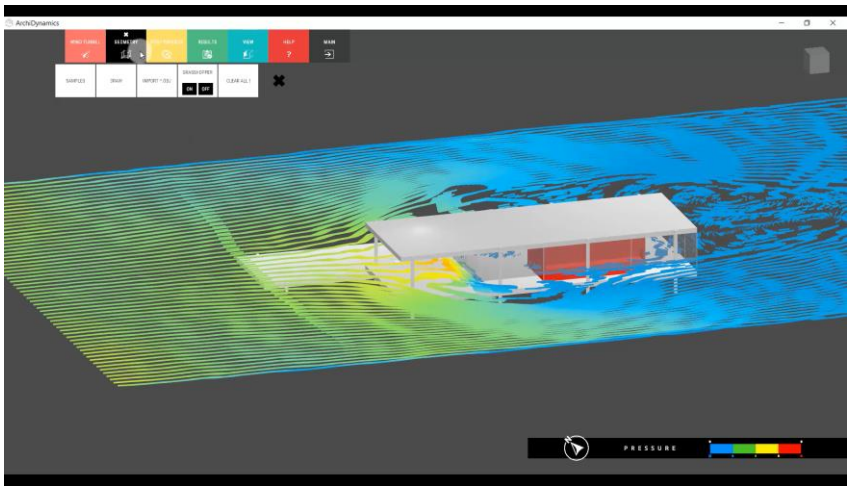

Figure 13 *A meshless fluid dynamics algorithm [25].*

Offices that use computer technologies as design tools use programs based on performance analysis not only for the revision of the design, but also for the development of a basic form produced in the early stages of the design, and the derivation of alternatives according to performance-based parameters.

There is several software to perform a set of spatial network analyses designed to understand social processes within the built environment. For instance, DepthmapX software works at a variety of scales from building through small urban to whole cities or states. At each scale, the aim of the software is to produce a map of open space elements, connect them via some relationship (for example, intervisibility or overlap), and then perform graph analysis of the resulting network. The objective of the analysis is to derive variables that may have social or experiential significance. The implementation of the step depth feature of the software on a case study is conducted by the authors (Figure 14).

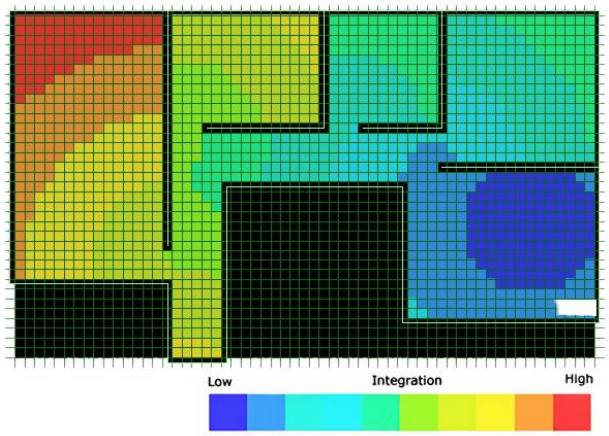

Figure 14 *Step depth analysis of a simple house (simulation conducted with DepthmapX software by the authors).*

IV. DISCUSSION AND CONCLUSION

The result obtained from the research on architectural design; is recorded as a combination of structures such as heuristic, algorithmic, personal, organizational, deductive, inductive, geometric, organic. It is thought that computer technologies and the digital representation environment respond and contribute to all these components of the design. This multi-alternative and transformative

representation environment have expanded the field of influence and research of design and architecture by bringing together new concepts, terminology, theories, methods and paradigm changes. Thanks to digital media and technologies, there is a virtual reality parallel to the reality we live in. Now to architectural terminology; Many new concepts such as emergent form, dynamic form, hypersurface, hybridization, topological geometry, generative design, parametric design, isomorphic architecture, performative architecture, animated architecture have been introduced. Many theories have been developed by taking these concepts into account. Here, it can be said that design is given a new role along with the digital one. The designer has also become a tool developer who develops his digital design tools and components. The sphere of influence of design and architecture has expanded and new areas of expertise have emerged, but at the same time, design disciplines have come closer to each other in terms of design and production processes.

Computational approaches provide representation of many overlapping, contradictory and related factors through algorithms and abstract conceptual, symbolic models; It expands the limits of the intuition by triggering the creative side of the designer. The digital approaches that have guided the change in design culture in recent years play an important role in contemporary design applications. The integration of computational approaches into the design process allows the development of new design solutions that are difficult or impossible to reach with other methods. The philosophy and principles of these approaches inspire alternative solutions in design. Architects or other designers are now tool developers rather than tool users. In the future, it is envisaged that a holistic system that includes different tools that support the automation of workflow and design decisions will be combined with digital design platforms for the integration of different design approaches. To use the rapidly developing digital design tools more effectively, it is becoming more and more important to develop computational thinking skills and to reflect this in the design process to education programs.

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