RESEARCH ARTICLE

THE ROLE OF ANATOMICAL AND ECOLOGICAL ANALOGIES IN ANIMAL ARCHITECURAL DESIGN METHOD (WHERE ANIMAL ARCHITECTURE STANDS)

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ARTICLE INFO	ABSTRACT
	As a branch of organic architecture or the architecture inspired with nature, animal architecture has been considered as one of the common architectural design methods. The main goal of this paper is to determine the position of this architectureamong architectural methods and the way these methods overlap. The research concludes that animal architecture has remarkable similarities with some design methods specifically the methods known as analogy, metaphor, biomorphic and organitech. Moreover, it may identify formal anatomical analogy between animals (bodies or habitats) and architectural projects. Furthermore, animals, as animate and motile natural phenomena, may also provide ecological analogies in architecturaldesign which produce more applicable and conceptual solutions. Those, therefore; function more than mere visual images in design thinking.

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INTRODUCTION

"Where does animal architecture stand among other architectural methods? What makes animal architecture unique? And, what are the commonalities between animal architecture and other architectural design methods?" are the main questions addressed in this paper. The main objective of this research, therefore; is to determine the position of animal architecture in comparison with other architectural design methods. Theorists like Geoffrey Broadbent (1969), Bryan Lawson (1980), Tim McGinty (1979), Charles Jencks (2002), and Kari Jormakka (2007) have classified design methods into different groups. In his book "*How Designers Think*", Bryan Lawson (2010) added up narrative or storytelling design technique to the methods proposed by Geoffrey Broadbent (1969) including pragmatic, iconic, analogical and canonic designs (Lawson, 2010, pp. 206-304). Apart from analogy or simile (looking at other phenomena) and metaphor (abstraction), Tim McGinty has mentioned the essence,

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programmatic and ideals methods as the five identified concepts of architecture (McGinty, 1979). Charles Jencks believes that contemporary architecture follows five new trends which show the creation of form, i.e.organi-tech, fractal, blobmeisters, enigmatic signifier, datascape, landform, cosmogenesis (Jencks, Charles Jencks, 2003). Kari Jormakka et al have categorized the seven designing methods in historical sequence. They believe design techniques have different resources, namely nature and geometry as authorities, music and mathematics as models, accident and unconscious as sources, rational approaches, precedent, responses to siteand finally generative processes (Jormakka & Schurer, 2007). Moreover, some other methods such as visual compositions, blurring, collage, diversity and plurality, field, flows, genetics of form, surface or skin and tornado in design have been recently put forth by related scholars (Gausa et al., 2003), (Knauer, 2007) (Rezaei, 2014 a) (Shields, 2014). Karl Von Frisch and Otto Von Frisch have posed the capability of using animal forms to create architectural projects by contemporary architects (1974).

The term animal architecture was coined in 1974 by Nobel Prize winner Karl Von Frisch (1886-1982) who demonstrated

the capacity of some not particularly complex animals to create sophisticated constructions with noteworthy degree of technological expertise (Bahamon & Perez, 2009, p. 5).

In addition to categorizing the routine, innovative and creative design, Mike Hansell takes architecture inspired by nature and animals into account (1984). Alejandro Bahamon and Patricia Perez regard the relationship between the building construction and biology as the theme of animal architecture (2009). They have studied the anatomical structure of animals (armor shell, hair, skin, snail, shell, scales), animal constructive structure (underground cavity, spider's web, beaver's dam, bird's nest), social animal constructive structure (anthills, beehive, coral reefs), and temporary animal structures (marsupial, pupae) on the belief that nature has taught them the patterns and techniques of construction while providing them with the construction material. Well-known architects such as Renzo Piano, Norman Foster, Frank Gehry, and Santiago Calatrava have used the anatomical structure of animals in their most recent works. In spite of the fact that animal architecture is significant and widely-used as a uniquemethod, some other design methods haveyet had similarities with animal architecture. In other words, animal architecture and some of the other methods significantly overlap. They overlap in some cases to the extent that animal architecture can be labeled as a subdivision of some methods.

Rezaei has proclaimed that all design methods could be considered as a sort of analogy varying from subjective/indirect to objective/direct relationships (Rezaei, 2012, 2014a, 2014b). This research, similarly, has arrived at the conclusion that animal architecture has in common features with not only analogical and metaphorical design process but also some architectural methods such as organitech and biomorphic designs. It demonstrates that animal architecture features a significant part of architecture inspired with nature. Nonetheless, it is important to figure out the unique components of animal architecture that is more than aesthetic aspect. Previous studies mostly do not take into account that animal architecture might be used beyond iconic or formal analogies. Animal architecture has been put forth by many experts in the field. However, none of them have elaborated on the details of the method and its evolution. It has not been seen in comparison with other methods. Through the fundamental methodology of animal architecture, we can properly use the design method in practice and for training purposes. A study of the common design methods shows that some of them overlap significantly, and at times using routine methods is not the solution while designing. An in-depth look into a certain design method may enable thinkers to complete and modifythe method or even create a new one.

The research has been formed with emphasis on the procedural views which are posed widely after the modern period and mainly concern the architectural and urban design fields. This might; however, be extended to other realms of design. The study has reviewed design methods in various categories in order to compare them with animal architecture. The study first explains the research methodology. It then briefly outlines the theoretical principles and concepts related to the architectural design and animal architecture. It goes on to review animal architecture through the theories which are related to the methods. The research will end with a conclusion.

MATERIALS AND METHODS

The data have been collected in a qualitative manner and based on the method of library and documentary studies. First, the architecture design methods[1] were studied and the nature of their relationship (commonalities and differences) with the concept of animal architecture was assessed. The research methodology is applied and descriptive. The data were collected through the literature relevant to design methodology. The data were analyzed using the descriptive and comparative method throughpurifying and providing quality data.

RESULTS

To determine the unique characteristics of animal architecture among the architectural design methods, this research has found the architectural method rather as a sort of 'analogy method' in which designers make visual similarities between either animal bodies or their habitats. Furthermore, the research has demonstrated that animal architecture, as a type of analogy, can be used beyond mere visual approaches. Designers may use animals' behavior and their life qualities in addition to their body or habitat shapes as the sources for their design analogies. Unlike previous design methodology studies, this is new to compare methods and find the originality, if any, of a method. It is true that some scholars (including Karl Von Frisch, OttoVon Friesch, Mike Hensel, Alejandro Bahamon and Patricia Perez) have put forth animal architecture and studied the method in the field. However, none has detected the way this method is unique compared to other design methods. The findings of this research show that animal architecture significantly overlaps with the analogical method categorized by Broadbent and Lawson, the analogical and metaphorical method by McGinty and the organi-tech method by Jencks and Jormakka's nature and geometry as authorities' method (Table 3).

Thus, the analogical method posed by Geoffrey Broadbent considers an analogy with phenomena on a general level, while animal architecture grants the analogy with animals on a smaller scale. McGinty's analogical and metaphorical method also puts forth analogy with natural and non-natural phenomena at a general level. In the direct analogical method as well as indirect and abstract metaphorical method, an analogy happens through a phenomenon. Therefore, animal architecture might be assumed as a subdivision of the method. The organi-tech method in Charles Jencks' categories in fact introduces a form of architecture which establishes a link between the structure and nature. Animal architecture also establishes a link between animals and designs which are part of nature and the structure indeed. In the end, the turning to nature and geometrical-biomorphic method in the category of Kari Jormakka et al, as it shows, is an analogy with nature and geometry. Meanwhile, animal architecture is also part of this method, i.e. turning to animals.

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[1]which fall under the process-oriented grouping

Table 1. Animal Architecture Classification by Bahamon and Perez- source: (Heidari, 2015, pp. 62-65)

	Category	Source example (Animal environment)	Target examples (Built environment)	
Animal architecture	Animal anatomical structures	armor shell, hair, skin, snail, shell, scales	Kiss the Frog MMW Architects/ Norway/ 2005/Skin	
	Animal constructive structures	underground cavity , spider's web, beaver's dam, bird's nest	Mur Island Acconci Studio /Austria/ 2003/ spider's web	
	Social animal constructive structures	anthills, beehive , coral	Izola Apartments OFIS Architects/ Slovenia/2006/Beehive	
	Temporary animal structures	marsupial, pupae	Plashet bridge Birds PortchmouthRussum Architects/ UK/ 2000/ pupae	

Table 2. Reviewing architectural methods inspired by nature (or science) - source: Authors

Natural Features (Heidari & Rezaei, 2015)	Approach (Rezaei, 2012, 014a,b)	Analogy (Steadman, 2008)	Sources			Examples
Inanimate (Objects) Living (Plants) Animate & motile (Animals)	Formal (objective)	Anatomical	Bodies	*Anatomical Structures*	*(Bahamon & Perez, 2009)*	*armor shell, hair, skin, snail, shell, scales*
			Habitats	*Temporary Animal Homes*		*marsupial, pupae*
				Individual Constructive Structure		*underground cavity , spider's web, beaver's dam, bird's nest*
				Social Constructive Structure		*anthills, beehives , coral reefs*
	Conceptual (subjective)	Ecological	Ecosystems Qualities			Sustainable Developments, Renewable Energy Use, Biodiversity, Waste Management, Using Animal Waste Within Projects, etc

Table 3. Commonalities between animal architecture and some other architectural methods- source: Authors

	Theorists	Methods	Commonalities between methods
Animal architecture	Geoffrey Broadbent	Analogical	Analogy with animals
	McGinty	Analogical and metaphorical	Analogy and metaphor from animals
	Charles Jencks	Organi-tech	Using of animal organs
	Kari Jormakka	Biomorphic	Turning to animals

It may identify formal anatomical analogy between animals (bodies or habitats) and architectural projects. Furthermore, animals, as animate and motile natural phenomena, may also provide ecological analogies in architectural design which produce more applicable and conceptual solutions.

Animal architecture, in all four shapes, adopts anatomical analogy in order to create architectural forms. Given the fact that animal architecture is directly linked to specific natural features including living and motile characteristics, a more detailed discussion of the method is recommended in order to identify design with nature. Concepts such as sustainability (including waste management, biodiversity, ecosystems and biological designs) might be researched as another type of analogy beyond visual approaches which is called ecological analogies in this article. We can, however, use it in a more efficient way for practical purposes. Men have destroyed the natural environment via unnatural construction activities. However, they can fulfill their role in preventing the destruction of the earth, environment and natural resources in the future by using environmentally-friendly methods such as animal architecture and by conducting relevant researches in the field.

DISCUSSION

Design methods

One of the greatest challenges in architecture and urban design fields has been built form creation or design methodology. It used to come up with a composition-synthesis process, which has proven to be controversial as far as the relevant literature review depicts.

Many believe that there is no specific method of designing in this profession at all. Moreover, in defining any process, following an assumed hierarchy is not guaranteed throughout the stages of that process. A large group of designers and critics have even claimed that, principally, there is no feasible definitive method of space design and that the methods in the books are only techniques to harness the human thoughts in specific stages of the path, and following it would not necessarily be effective. However, other paradigms make opposite claims and even try to define the empirical, intuitional and artistic aspects of design in the form of a defined process. If a space is designed, a method must have been used; a method which has found a solution for the problem of

designing. Some experts believe that the mentioned method can be fully put to research and turned into a process (Rezaei, 2014 a, p. 22).

As mentioned earlier, the present research is focused on contemporary design methods and highlighted process-oriented views. In the literature of design methodology, such figures as Geoffrey Broadbent (1969), Bryan Lawson (1980), McGinty (1979), Charles Jencks (2002) and Kari Jormakka (2007) have offered some classifications which will be addressed in the next sections of the research.

The classification of Geoffrey Broadbent (1969) and Bryan Lawson (1980)

Pragmatic design: Discussing on vernacular architecture emerged wisely in accordance with climatic conditions in different regions through the ages; Broadbent calls this way of construction a pragmatic method. In the pragmatic method, the designer normally finds the desired building form after combining various factors and choosing the construction material widely by trial and error (Broadbent, 1973, pp. 25-30), (Rezaei, 2014 a, p. 105). This method directly uses the existing facilities and building materials and does not call for innovation. This is essentially a traditional and conservative design method like painting the ready-made drawings in a drawing book. In fact, this is unlikely to yield great design or move design ideas forward positively (Lawson, 1980, pp. 203-204), (Rezaei, 2014 a, p. 105).

Iconic design: This method follows the form of iconic buildings. Through a copy-and-pasteaction, the so-called standard elements or buildings are repeated irrespective of the geographical conditions or environmental requirements to create the design. Iconic design method may not be found suitable for creative minds. However, the method has its own supporters and it appears that common builders use it (Lawson, 2010, p. 204), (Rezaei, 2014 a, p. 110).

Canonic or geometrical method (combination method): A set of rules and principles govern the last method put forth by Broadbent. Canonic design relies on the use of such rules as grid planning, proportioning system and the like. The classical architectural styles and Renaissance successors offered opportunities for such an approach and we have seen how Vitrovius and later on Alberti laid down such rules (Lawson, 2010, p. 205), (Rezaei, 2014 a, p. 122).

[Canonic design] calls in syntaxes or canons to guide design thinking. Examples include measurement systems, harmonic proportions or grids, on which design decisions are based. When visiting a building, these non-physical elements are sometimes hard to capture; when analyzing a project, they are often straightforward to identify and communicate (Lindekens & Heylighen, 2004, p. 221)*, (Rezaei, 2014 a, p. 122).

Analogical or metaphorical design: In this method, the designer makes analogies with other fields to create a new method to organize the problem. The method is also based on a general technique which has been highly recommended and is used for creative thinking. Santiago Calatrava's sketch book features various designs of different parts of human body anatomy.

Calatrava has drawn inspiration from the designs through the method of the body flexibility to stable forms which would allow it to take on different loading patterns (Lawson, 2010, p. 205).

Telling a story (narrative design): Broadbent himself maintains that among his four categorized tactics, the analogical method heralds another way of creating forms. The narrative method can to some extent be called the product of expanding the analogical method of Broadbent. However, the narrative design has an application which is beyond a mere analogy as in this method the designer tells a story which can be used to interlink the main features of the design (p. 206).

McGinty

Analogies: Analogy is a strategy used for solving a design problem through finding a given phenomenon inside or outside the domain of architecture. Analogies identify possible literal relationships between things. One thing is identified as having all the desired characteristics and thus it becomes a model for the project at hand. It is probably the most frequently used device for formulating an architectural concept (McGinty, 1979, p. 223), (Rezaei, 2014 a, p. 131).

Metaphor or simile: If there are abstract relationships between the design solutions and the phenomena, the method is called "metaphors" according to McGinty. He believes metaphors and similes identify possible patterns of parallel relationships while analogies identify possible literal relationships (Rezaei, 2014 a, p. 138).

Essence: This method is the result of discovering and identifying the roots of an issue. In fact, the designer designs the project after searching the essence of a project and transferring it into concept statements. The designer produces the outcome through exaggerating the main issues and magnifying the important element of the project. Symbols imply that the essences can be characterized in specific forms so the public can understand (McGinty, 1979, p. 230).

Programmatic: This is a direct response created through a problem-solving approach by finding direct solutions to the requested requirements. The main starting point of the method might be a program, client's or user's requests, regulations, standards and/or the like. In the programmatic method, the designer looks inside the problem or a similar problem to discover appropriate concepts. The designer may make his work unique through programs and/or may overtake the program in this method (Rezaei, 2014 a, p. 146).

Ideals: Ideal concepts express the individual or public eternal values which are brought to the problem by designers (McGinty, 1979, p. 234).

This method is in fact the signature of the designer. If we consider the programmatic method a bottom-up method in which the designer gets the design via the program, the ideal method is a top-down method which has been brought to the project by the designer (Rezaei, 2014 a, p. 150).

Charles Jencks (2002) categories

Organi-tech: This method is an effort aimed at creating ecological architecture articulated with technology while respecting special structure considerations.

This is the type of architecture which links structure with nature. In fact, it is the combination of technology and structure which is environment-friendly (Jencks, 2002, pp. 229-234).

Fractal: Jencks claims that this method heralds the formation of some type of urban development which, like a rainy forest, is constantly growing and simulating itself. This pattern is much richer and more interesting than the repetition of a series of similar elements. The method can be employed in architecture by using natural and computer models (pp. 163-164).

Blobmeisters: This architectural movement addresses the creation of a series of bubble-like forms in design using computer analogies (cyberspace, digital hyper surfaces) like egg-shaped and bubble forms which are some type of rounded fractals (Rezaei, 2014 a, p. 162)

Enigmatic signifier: Suggestive and unusual forms which represent surrealistic sculpture rather than architecture. The key to the enigma is a multivalent symbol. The observer may assume that he is watching several different objects at the same time. Due to their vagueness, these forms can always be linked to the site, construction, the language of architecture and any other phenomenon (p. 166).

Datascape: According to Jencks, the datascape method is a combination of digital, democratic and ironic spaces. This method involves constructing based on different assumptions and then allowing the computer to model various results around each one. These are then turned into designs and presented polemically to the press, the public and the politicians. The built implications of these choices are exaggerated and turned into an ironic democratic poetry (p. 168). From the beginning of the project, all stakeholders and people involved in the project put forth and produce different data. Meanwhile, the data are translated into a spatial research or organization. Finally, the juxtaposition of the informative diagrams produced as a result of the diversity of data creates a spatial matrix and the data are shown and distributed as such (De Vries, 2013).

Landform: This method benefits from the form of land and tends to merge floor, wall and roof into a seamless continuity. One example of this method is the Yokohama project of FarshidMoussavi (Rezaei, 2014 a, p. 174).

Cosmogenesis: Using metaphysics is another approach to architecture which Jencks refers to. This method is about spiritual issues, public and esoteric meanings which might shape an architectural project (p. 177). Charles Jencks says some philosophers, notably Mary Midgley, argue that new concepts such as Gaia have credibly emerged among people. This shows that a new general theme has come into being which consider the land as a self-sufficient, living system. The notion that land is a dynamic creature which gives different feedbacks is one of the new scientific models (Jencks, 2002, p. 249).

Kari Jarmakka's categories

Nature and Geometry as Authorities: Jormakka and his co-authors divide this method into biomorphic, quadratureand triangulation architecture.

They believe that many designers prefer to ground their architecture on a basis more universal, timeless and general, regardless of historical or political contingencies. Therefore, they have often turned to models taken from nature or geometry (Jormakka & Schurer, 2007, pp. 9-12).

Music and mathematics as models: Jormakka has proposed this method in three parts; musical analogies (using direct analogies of music such as notes and the form of their position); higher dimensions (translating musical values to color composition or multi-dimension geometry); and proportions (using mathematical and geometrical sequences and rules) (pp. 20-27).

Accident and unconscious: Jormakka attributes the main source of the two architectural methods to accident and the subconscious. He calls these two methods heterotopia and surrealist devices. In these methods, the designer sometimes claims that the design comes forth unconsciously through playing with the design. The surrealistic methods lack a clear logic in designing. The main theme of this method is to combine unrelated factors with one another and to turn them into a new, unexpected architectural space (pp. 32-39), (Rezaei, 2014 a, p. 186).

Rationalistic approaches: Jormakka names the subdivisions of the rationalistic method of architecture as the performance form and design research. In this method, the designer chooses a real and correct way to get the answer. The method is based more on rational science or solid knowledge than on creative inspiration or subjective intuition. The scientific facts of the project, especially the facts related to the project and the design site, are the most important elements of architecture here. The *'form-follows-function'* slogan of the modern architecture, guarantees the optimality and efficiency of the architectural product in this method (p. 188).

Precedent: Typological designs and the transformation of a specific model are two methods to respond to precedents in the category of Jormakka et al. The starting point at which the new architectural work comes into being can be an existing architectural building. In other words, the project contains some references to the works which exist in the architecture world (p. 190).

Responses to site: According to Jormakka, regionalism and contextualism are reactions to the site in which the design might take shape. In regionalism, the designer may adopt some features from the region or nation and not necessarily from the immediate environment. Contextualism is another method of finding design solutions based on the context and site in which abstract diagrams might be drawn about the morphology of the environment (roof angles, window axes, texture, etc) and then designers try to reconstruct a new composition with similar contextual characteristics (p. 192).

Generative processes: In the last classification, Jormakka talks about five new methods in which drawings, illustrations or different variables are manipulated in order to generate new forms (p. 194).

A-Superposition and scaling

According to Jormakka, superposition and scalingof the contextual subjects are one of the methods invented by Eisenman.

In this method, the designer tries to overlay or superpose different illustrations in different scales. The pictures might be selected from the context of architecture through giving angle or following the network of new and old streets or any different significant features of the place (Rezaei, 2014 a, p. 194)

B-Morphing, Folding and Animate form

Morphing is another method to which Jormakka refers while explaining the experience of Eisenman with regard to categorizing his generative forms. In this method, two or more images are selected, essential points selected in each, and then one would be gradually transformed into the other. This process is generative, meaning that the second picture does not appear suddenly but it fades in as the first one fades out. Jormakka notes that the word "folding" means some sort of origami or a handicraft made by folding a piece of paper which is sometimes used architectural design in accordance with complicated concepts such as chaos or catastrophe theory. Jormakka does not provide further details about the method, though, and instantly links it to the next method, that is, the animate form (pp. 194-198), (Jormakka & Schurer, 2007, pp. 66-69).

C-Datascape

The method derives from the meaning of the term "datascape" which is a combination of the deconstructive system and design research approaches, often with a touch of irony. The method was developed by the Dutch architect Winy Maas who was a partner of the MVRDV architecture firm (p.71)

D-Diagram

Jormakka defines diagram as an abstract means of thinking about organization, relationships and possible worlds. The diagrammatic or abstract machine is not representational. It is instrumental in the production of new objects, situations or architectural forms (p. 72), (Rezaei, 2014 a, p. 202).

E-Parametric design

In a parametric design a set of independent parameters are chosen and systematically varied according to some criteria in order to arrive at not just one object but a series of variations. Usually the parameters are given a geometrical interpretation (Jormakka & Schurer, 2007, p. 75).

This is a bottom-up design method. In other words, the architect does not impose a pre-determined form on the design. On the contrary the design is gradually formed, normally by using a computer, as parameters change so that the final generation of the design becomes unexpected for the architect. This method can sometimes be a valuable step in the process of designing (pp. 75-80).

Miscellaneous Methods

There are other design methods including the visual compositions, animal architecture, translucency technique (blur), collage, diversity and plurality, field, flows in design, genetics of form, surface or skin design and tornado (Rezaei, 2014 a, pp. 210-234).

Rezaei (2014a) has shown that these are similar to the previous discussed methods, even though they provide some techniques for contemporary designers.

Animal architecture

Architecture inspired by natural phenomena and their relevant design outcomes or principles maysimply follow three natural features including inanimate natural objects, living plants and animal structures. Animal architecture, however, branches from bionic and organic architecture and so closely links to science and universe (Heidari & Rezaei, 2015). Living animals might be assumed as themost complete existential stage of nature sincetheyare all animate and motile, meaning they can move spontaneously and independently in their lives. These characteristics make them different from the inanimate objects and plants. A role of bone parts in the body of vertebrates is mechanically similar to the skeleton of a building. Each structure needs a skeleton for the purpose of maintaining stability and balance. The bone skeleton of animals, alongside tension elements such as muscles, tendons and joints form a system which tops the most perfect architectural works (Sharghi & Ghanbaran , 2008, p. 112). As noted earlier, animal architecture, according to Bahamon and Perez, are divided into four classes, namely anatomical structures, constructive structures, social constructive structures and temporary structures (Table 1).

Accordingly, two main analogies happen through design process of animal architecture: Analogy with the structure of their either physical bodies or places where they live that might accommodate individual animal or social groups (habitats). Considering body and habitatas metaphors or analogies, we may re-arrange discussed categories by Bahamon. Animal anatomical structure, for instance, corresponds to the body shape allegory, whereas temporary animal structure, animal constructive structure as well as social animal constructive structures could be distinguished as an analogy tohabitat form. Both analogies in architectural design process; however, may take place in formal, visual, objective and direct approaches or conceptual, behavioral, subjective and indirect (Rezaei, 2012, 2014 a, 2014b). In the case of organic architecture we may call them anatomical and ecological analogies (Steadman, 2008) . Most designed projects have largely focused on the former and less underlined the conceptual aspects.It means animal architecture has so far been explained mainly based on body and habitat aesthetic values. Beyond the form, a designer may also practice the method in another way by considering experiential aspects.

Conceptual analogies or less tangible metaphors could be provided by researching animal behavior or the way they live. Two unique characteristics of animals i.e. being motile and animate have considered less in the processes of animal architecture. Qualities such as traditional wild life patterns, species life cycle, energy use or waste management may also be applied into the architectural design process. In that, Table 2 demonstrates formal and conceptual approaches in which analogies range from objective (body and home) to subjective (life qualities) sources. For example, animal waste producing biogas used as a renewable source of energy could inform a type of animal architecture design beyond the mere formal analogies.

Using biogas in design, as an example, will increase energy efficiency and make it more dynamic. Hence, animal architecture could include conceptual in addition to formal methods (Heidari & Rezaei, 2015). (Table 2)

Animal architecture in comparison with the other design methods

Animal architecture overlaps significantly withsome other methods in the following terms.

Analogical method in the categories of Geoffrey Broadbent and Bryan Lawson

Geoffrey Broadbent's analogical method puts forth analogy with phenomena in general, while animal architecture is an analogy but on a smaller scale, that is, analogy with animals. Thus, the method might be considered as a subdivision of Broadbent's analogical method.

Analogical and metaphorical method in McGinty's categories

In too methods put forward by McGinty, non as, analogy and metaphor, analogy with natural and non-natural phenomena is once again proposed at a general level. In the analogical and metaphorical methods, analogy is put forth respectively directly and in an abstract and indirect manner. Therefore, animal architecture which is an analogy with animals and beasts can be also considered as a subdivision of the method.

Organi-tech method in Charles Jencks' methods

Organi-tech method aims at creating organic architecture by using technology and observing special structural principles. Thisin factproduces in theshapes of design which follows a relationship between the structure and the nature. Animal architecture also establishes a relationship between animals and beasts which are part of the nature and the structure. One point however, deals with is the use of computer in Jencks' methods. As a matter of fact, animal architecture can be carried out through a mere analogy with animals without having to use computers and it can also lead to the creation of forms modeled on the nature of signals like the organi-tech through using software systems and the computer. Thus, in this section, parts of animal structure which gets help from software systems and the organi-tech method overlap.

Method of turning to nature and geometry (biomorphic) in the category of Kari Jormakka et al

The first method put forth by Kari Jormakka was turning to the nature and geometry which involves biomorphic and the formation of squares and triangles. They cover, for example, the TWA terminal designed by Eero Saarinen in New York which shows the overall form of the building as a soaring bird and St. John the Divinein New York designed by Santiago Calatrava which has drawn inspiration from the skeleton of a dog and some other examples which are modeled on animals. These are indicative of overlapping between the two methods and animal architecture. In fact, these examples are part of animal architecture.

Even though one may categorize animal architecture designs in different methods such as analogical, metaphorical, organi-tech and turning to nature or geometry, all examples of animal architecture overlap with four mentioned methods of animal architecture (Heidari, 2015, pp. 59-60).

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