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ORIGINAL ARTICLE

Biomimicry as an approach for bio-inspired structure with the aid of computation

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Abstract Biomimicry is the study of emulating and mimicking nature, where it has been used by designers to help in solving human problems. From centuries ago designers and architects looked at nature as a huge source of inspiration. Biomimicry argues that nature is the best, most influencing and the guaranteed source of innovation for the designers as a result of nature's 3.85 billion years of evolution, as it holds a gigantic experience of solving problems of the environment and its inhabitants. The biomimicry emerging field deals with new technologies honed from bio-inspired engineering at the micro and macro scale levels. Architects have been searching for answers from nature to their complex questions about different kinds of structures, and they have mimicked a lot of forms from nature to create better and more efficient structures for different architectural purposes. Without computers these complex ways and forms of structures couldn't been mimicked and thus using computers had risen the way of mimicking and taking inspiration from nature because it is considered a very sophisticated and accurate tool for simulation and computing, as a result designers can imitate different nature's models in spite of its complexity.

1. Introduction

"It has become part of the accepted wisdom to say that the twentieth century was the century of physics and the twenty-first century will be the century of biology. Two facts about the coming century are agreed on by almost everyone. Biology is now bigger than physics, as measured by the size of budgets, by the size of the workforce, or by the output of major discoveries; and biology is likely to remain the biggest part of science through the twenty first century. Biology is also more important than physics, as measured by its economic consequences, by its ethical implication, or by its effects on human welfare" [1]. During history, architects and designers have looked to nature as an inspiration source for different kinds of forms, techniques and function. The philosophers of ancient Greece looked at organisms which offered them perfect models having a very mesmerizing harmony and proportion between their parts, where that was the classical ideal of beauty at that time. The structure, unity and beauty of any design are synonymous with the quality of integration of its forming parts and thus no small part could be removed without deforming and damaging the whole. These thoughts were the main concepts at the age of Aristotle, as it was the essential esthetics and characteristics of

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the best way to have a work of art in the natural history of the Aristotelian age.

It was so trivial at that time the way architects and designers understood nature, they looked to biology as a source of inspiration from the beginning of science. They had a superficial way for imitating and mimicking the forms of plants and animals. But from decades ago architects found other way of understanding nature as methods and analogies of growth and evolution. Those architects had changed the way of design in a very prominent way as it was obvious in their writings, for instance the bold ideas of Le Corbusier and Frank Lloyd Wright. Le Corbusier thought that biology is the greatest word in architecture and planning. But the way they saw nature was still missing where the biological analogy was about superficially artistic picture from nature's wonders and creatures and that was clear in the buildings and products of the industrial age. When we talk about analogies in nature we must think of a deeper way of understanding science and nature not just artistic picture imitation.

2. Biomimicry overview

"The term 'Biomimicry' first appeared in scientific literature in 1962, and grew in usage particularly amongst material scientists in 1980s. Some scientists preferred the term 'Biomimetics' or less frequently 'bionics'. There has been an enormous surge of interest during the last ten years, brought about to a large extent by individuals like biological-sciences writer ***Janine Benyus***, professor of biology ***Steven Vogel*** and professor of Biomimetics ***Julian Vincent***, who have all written extensively in this subject area. Julian Vincent defines it as 'the abstraction of good design from nature', while for Janine Benyus it is 'the conscious emulation of nature's genius'." (Michael [2]). There is no difference between 'Biomimicry' and 'Biomimetics', where Biomimicry is used at developing sustainable design solutions and Biomimetics has been applied to the military technology field.

The biomimicry term appeared in 1982 and it was invented and published by the famous scientist Janine Benyus in her most significant 1997 book (Biomimicry Innovation Inspired by Nature). Biomimicry was manifested in her book as "the new science that studies nature's models and imitating these designs to solve human problems". She also claimed looking to nature as a "Model, Measure, and Mentor" and she also suggested that the main aim of biomimicry is sustainability. Biomimicry is the most brilliant and genius way to look for sustainable solutions to human's problem by mimicking and emulating nature in its analogies, phenomenon and patterns. Biomimicry's main aim is making a great designs by mimicking the different living organisms which have been evolving through 3.8 billion years.

3. Biomimicry theoretical framework

3.1. Biomimicry approaches

Approaches to biomimicry as a design process typically fall into two categories: Defining a human needs or designing problem and looking to the ways other organisms or ecosystems solve this, termed here **Design looking to biology (Top-Down approach)**, or identifying a particular characteristic, behavior or function in an organism or ecosystem and translating that into human designs, referred to as **Biology influencing design (Bottom-Up approach)** (Biomimicry Guild, 2007).

3.1.1. Design looking to biology (Top-Down approach)

Throughout literature review, this approach has different names as **"Design looking to biology"** [3], **"Top-down Approach"** (Jean [4] and **"Problem-Driven Biologically Inspired Design"** [5], **"challenge to biology"** (Biomimicry institute) (Fig. 1). They all have the same meaning and they also point to the way designers look to nature and organisms for solutions, where designers must recognize exactly their design problems and to match their problems with organisms and creatures that have solved similar problems. This king of approach is as a result of the designers knowledge of the aims and triggers of their design.

3.1.2. Biology influencing design (Bottom-Up approach)

Just like the previous approach, this approach has different names and expressions such as **"Biology Influencing Design"**, **"Bottom-Up Approach"**, **"Solution-Driven Biologically Inspired Design"**, and **"Biology to design"**. They all refer to the same meaning, where this approach depends on the previous knowledge of biological research and solutions not to search for a solutions in nature, then applying this knowledge on the design problem you already have (Fig. 1).

3.2. Levels of biomimicry

In addition to these two approaches demonstrated previously, there are three levels of biomimicry have to be applied also to design problems. From the biomimetic technologies and techniques, it is obvious and well noticed that there are three levels of mimicry: the organism level, behavior level and ecosystem level. The organism level illustrates the mimicking of certain organism or the mimicry of a part from the whole organism. The second level is the mimicry of behavior of which every organism behaves. The third level is the mimicking of the whole ecosystem and this level is considered the hardest level as it focuses on a functionally very hard issue to mimic. Through each level there are five dimension which determine at which extent the mimicry exists. The design is listed as biomimicry in the way it looks like (form), what it is made of (material), how it is made (construction), how it works (process) and what it's capability (function). The three levels of mimicry are described in Table 1. These levels are very important and they complete the biomimicry approaches.

4. Bio-inspired structures

From the dawn of history architecture inspired its structures from nature and it is manifested at the old temples of the ancient Egyptian civilization, for instance, the columns of the temples which were inspired by the lotus plant, the sacred plant for the Egyptians. Trees and plants generally have been used as a source of inspiration for the ornamented structural columns of the classical order at the Greek and Roman ages respectively. Two of these columns' capitals (the Corinthian and Composite order) were inspired by Acanthus plant, where these columns appeared widely in the Greek and Roman architecture (Fig. 2(a)). Throughout this period of time it