The Impact of Natural Simulation on Sustainable Product Design Development: Literature Review

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Abstract:
The vast, rich and diverse nature of the flora and fauna is the foundation, and the endless inspiration for the development of creative thinking and sustainable innovation in all scientific fields such as Architecture, Biology, Electronic Technology, Product Design, Sculpture, Music ... That creative foundation today becomes a key scientific field and is called Biomimetic Design (Biomimetic Design). In the field of applied art design, biomimicry is the first basis of thinking and designing ideas to shape product forms to serve the needs and scientific development of society. As for Painting, it is also the source of emotion to build and create beauty in fine-art works. Because it is the object of nature, the physical structure, rhythm, and color directly affect creative thinking in visual arts, especially in the field of designing applied art. This has long been confirmed by the Greek theory of aesthetics when explaining the nature of art. At that time, they considered the most prominent in biomimicry in the field of product design applied art.

Keywords: *Natural simulation, sustainable product design*

1. Introduction

The designs in nature are wonderful. Nature, over billions of years of evolution, has created effective solutions to numerous complex real-world problems [1], whose functions are often similar to those required. in engineering products, such as the heart acting as a pump [2] or moving joints as in a mechanism [3]. For both natural and technical tasks, resources are limited and must be optimally used to reliably and functionally complete the task. Therefore, designs in nature can serve as inspiration for technical designers [4]. The question is, how to use a systematic, knowledge of these systems to solve design problems? Vincent (2005) [1.5] estimates that "at present there is only 10% overlap between biology and technology in terms of the mechanisms used" so there is a lot of potential in this area. Engineers, scientists and businesses are increasingly turning to nature for design inspiration. The field of biomimicry, the application of natural methods and systems to engineering and technology, has produced a number of discoveries that are far superior to what the human mind can think of. , such as a leaf-inspired solar cell [6]. Its focus is mainly on the long term development of specific technologies such as synthetic spider silk [7]. However, there is no common systematic support available to engineering designers to use nature as inspiration to solve design problems - from concept to reality. idea.

The authors wish to develop a new two-step approach to solving this problem. The first step is "ideas", where potential solutions to a problem are created. The second step is "realization", in which they are evaluated and modified by testing them in both virtual and physical form.

Inspiration is very useful for exploring and exploring new solution spaces [8]. For example, the evidence of this is that the presence of a trigger can lead to more ideas generating in the problem-solving process [9], which positively affects the technical requirements. to creativity [10], or individuals who are encouraged to be more creative than those who are not encouraged [11]. The analogy has long been considered as a powerful means of inspiring novel idea formation, as seen in some systems based on analogies [12,13] and bright methods. Creation was developed with the aim of promoting analogy theory [14], and in other studies has contributed to the understanding and application of analogies [15–18]. Generating a large number of ideas with different principles increases your chances of developing better products [9]; Test ideas in real-world environments that make them more viable in the real world. Creative products are initiated through inspiration, in which the use of

analogies is beneficial. Shu et al (2018) show the application of the biomimetic search method to develop ideas about how to align objects in micro-assembly and reproduction [23,20]. Vakili and Shu (2018) have studied biological simulation where similar keywords about the function of the system are used to help the designers.

Human needs are constantly changing and are changing at a very rapid rate. A series of new demands have led to the introduction of countless unprecedented products, or at least changing the habits, ways of using and redefining the types of products that are shaped in the subconscious mind. consumers. This requires areas of life to evolve at a faster rate and product design is no exception. More than ever, the designer's task does not stop at making designs that meet immediate needs, but also to perform the function of research and forecasting to design products with orientation and application goals for the long-term human needs.

For sustainable development, nature simulation is the most effective solution for product design in general and predictive product design in particular, this direction will bring results. the results are quicker and more than desirable for the ever-present human needs. Therefore, research on the role and application of simulation of nature in product design is extremely necessary.

2. Literature review

2.1. Studies related to the research topic

Nowadays, along with the continuous development of human society, the science of nature research in the world has achieved important achievements, from the perspective of theory to its application in practice. But that development had its downside: too deep, unconscious interference with nature's processes disrupted the ecological balance. To overcome this situation, scientists need to develop research, discover natural values in order to restore balance of ecological environment, recreate a harmonious living environment between nature and human, and bring nature serves the human benefit in a sustainable way.

The mission of Applied Arts as well as design design is to bring beauty to life. Therefore, observing and studying nature, documenting, building design strategies as well as finding inspiration for composition from nature are important work of every design artist. We can see that in the field of applied art in general as well as design design in particular, the vast majority of the most successful works, the most popular design styles are all derived creations. from nature.

Currently, in the world, one of the sciences that is paying much attention to research is bio-simulation technology. Although biology simulation is considered a science with many potentials, its achievements have been used by generations of humanity. Many scientific studies in the world on the field of biomimicry have been published in recent years. In 1998, the author Maibritt Pedersen Zari analyzed the applications of nature simulation in product design. From that point out the levels when applying simulation of nature in product design. I.C. de Pauw, E. Karana, and P.V. Kandachar (2012) identifies nature-inspired design strategies in the development of sustainable products. Since then, we can see the important role and inevitable trend in the future of applying simulation of nature in designing sustainable products.

In particular, through the development of the science and technology of biomimicry, up to now, there are many industrial products designed on the basis of application of nature simulation. In which there are many products that have been commercialized and favored by many consumers such as the motorcycle "Vespa bee", the Volkswagen car - the car simulating the beetle, the Lyon - Satolas railway station. (1989-1994) - bird wing simulation, ... Increasingly, the collaborative groups of biologists and engineers have gained more and more success in developing new technologies and products, Inspired by nature. Not only the biological simulations in the application design from the natural world also create a novel, attractive, useful, practical and it contributes to bringing people closer to nature. However, in Vietnam this science is still limited. The fine arts training in our country has not yet had in-depth research on the application of nature simulation in product design to orient the development in a new stage in accordance with the current social development. now on.

In the current economic integration environment, information tends to be multidimensional. Without a system of methods of observation, research and the process of applying laws and creative values from nature to the creation of applied art, we cannot have a way to selectively select information

Some designers and scientists use specific biomimetic methods as a method to increase the sustainability of what they have created, but in some cases, biomimicry is also used as a single method. as a new source of creativity (Pedersen, 2007). There are two distinct directions in biological measurement as a design process (Goel et al., 2014):

• A solution-oriented, in which an interesting biological mechanism or phenomenon inspires the search for potential applications of its adaptation in the development of a new product. This is also called biological effect design

• Problem-oriented, in which the identification of a given problem stimulates the search for biological mechanisms that can help solve the problem. This is also called bio-oriented design

2.2. Research methods related to the research topic

2.2.1. Aalborg biology inspired design method.

This approach involves four steps and emphasizes the importance of environmental and economic sustainability factors in the designer's project development and evaluation (Colombo, 2007). In the first step (Analysis) a natural system is selected and analyzed to understand its form, structure and functional principles. In the second step (Conversion), the analogies and properties of the system are decoded and interpreted into technical and mechanical terms using mathematical, geometric, and statistical principles. In the third step (Implementation), all of the principles of the relationship between form and structure accumulated from system analysis are applied to the development of new products. In the fourth step (Product Development) a new product is developed and evaluated taking into account environmental and economic factors in its life cycle.

2.2.2. Design method of biomimicry

This method includes five steps and describes in detail the processes involved in natural sample collection and analysis. This method does not include any procedures related to the design transfer of features found in natural samples (Junior et al., 2002). In the first step (Identification of Needs), an unresolved problem is precisely identified in such a way that a subsequent environmental analysis will lead to finding potential solutions. In the second step (Selection and Sampling) the samples of a suitable nature for the problem are selected, after having conducted previous research to identify suitable samples and to gather knowledge of their habitats and the equipment needed to collect. In the third step (Sample Observation), the observation and analysis of samples are carried out to determine the morphological structure, function, process, temporal and spatial distribution and relationship with environment. . In the fourth step (Similarity of the natural system to the product), the possibility and feasibility of applying the similarity between the sample to be studied and the product to design is considered based on the results of analysis. function, form and structure. In the fifth step (Execution of Design) the feasibility of applying sample characteristics to the design, as well as the needs and requirements of the proposed product.

2.2.3. Spiral design method

This method consists of seven steps and emphasizes the life cycle of the product, taking into account issues such as the evolving product manufacturing, packaging and recycling processes. In this method, the repetitions are hidden and an evaluation of the results of each step is also recommended (Biological Research Institute, 2007). In the first step (Identification of Needs), an unmet human need is identified and a design summary with the details and specifications of this need identified. In the second step (Interpretation) the design summary is considered from the point of view of the essence. The problem is approached from a biological point of view

and the functions of the project are transformed into tasks performed in nature. In the third step (Discovery), the best natural models respond to the challenges posed in the design summary sought. In the fourth step (Summary), natural models with mechanisms best suited to a specific project challenge are selected. In the fifth step (Emulation), ideas and solutions based on natural models are developed in a way that mimics aspects of the form, function and of the ecosystem as much as possible. In the sixth step (Evaluation), design solutions that will improve packaging, marketing, shipping, new products, additions, and improvements will be evaluated. In the seventh step (Determination of solutions), the results-based design solutions obtained from the assessment of principles of life are developed and perfected.

2.2.4. Biological-inspired design method

This method consists of six steps and process of problem identification and finding biological solutions supported by clarification techniques, suggestions and real-world examples (Helms et al., 2009). In the first step (Problem Definition), an unresolved problem is selected and further defined through functional decomposition and optimization. In the second step (Framing the Problem), the problem is redefined from a natural perspective questioning how a biological system performs a particular function. In the third step (Search for biological solutions), solutions related to biological problems are searched by techniques such as changing the constraints, analyzing the adaptability of some relevant natural mechanisms. Note, the variation in a solution group and multi-function. In the fourth step (Biological Solution Determination), the structures and surface mechanisms of the biological system involved in the recast function are identified. In the fifth step (Principle Extraction), the key principles of the solution are extracted as a neutral solution, requiring descriptions to remove as much structural and environmental constraints as possible. In the sixth step (Application of Principles), the principles of a bio-inspired solution are extracted into a newly translated field, which involves the interpretation of a domain space (e.g. biology) to another dimension (eg mechanics) by introducing new constraints.

2.2.5. Biological solutions looking for a way to solve the problem

This method consists of seven steps and supports an iterative formulation of design principles inspired by biology (Helms et al., 2009). In the first step (Determination of Biological Solution), a potential solution to the human problem is searched by observing natural phenomena on a macroscopic and / or microscopic scale. In the second step (Determination of biological solution) the components or systems associated with the phenomenon in question are determined to outline the biological solution in the functional notation. In the third step (Extract Principle), the basic principle of the solution is extracted from the analysis of a biological solution in schematic notation. In the fourth step (Framing the Solution), the biological function is examined for how it can be useful to humans. In the fifth step (Problem Detection), a new problem can be identified, which distinguishes it from the solution-finding step in the problem-driven processes. In the sixth step (Problem Definition), the problem posed is similar to the definition of the solution in the schematic notation in order to establish the parallelism between the systems and the components of the generated solution. study and problem. In the seventh step (Application of Principles), the solution principle is transformed into the working principle of the necessary technology concept. This activity will culminate in presenting a solution inspired by the biology of a product or technological system.

The basic methodology of the topic is multidisciplinary and interdisciplinary research to gather, process and analyze the materials. A mixture of both qualitative and quantitative methods is carried out, in which quantitative methods are dominant.

Using methods of gathering, collecting and analyzing published documents, research papers published through printed materials, journal articles, conference proceedings, from knowledge sources various such as color problems, visual principles, plane and space mass forming facilities, ergonomic anthropology and related scientific achievements to elucidate research problems about nature and put into application. On the other hand, to clarify the organic relationship between the natural world and the human-made physical world.

In addition, the methodological framework applied to complete this study as well as being explained about the significance and importance of sustainable development is that the Life Cycle Assessment (LCA) method is directly related to sustainability. firm.

The methodology used in the thesis belongs to the solution-oriented methodology and its objectives are oriented to product design, with special emphasis on sustainability and environmental friendliness. This is done with the help of specialized software used outside of the design process, during the material and manufacturing process selection phase, as well as during the environmental impact assessment phase.

Sustainability is based on three interrelated elements - economic, social and environmental - known as the "three pillars" or "the three pillars of Sustainability, and is described by three nested circles. together in a triangle. Economic sustainability refers to the ability of an economic system to generate continuous and improved economic growth and thus generate income and employment. Social sustainability refers to the capacity of different social actors to ensure well-being and equality among social classes and sexes. Environmental sustainability refers to the ability to conserve and regenerate natural resources over time.

This sustainable model of nested circles implies the integration of these three essential and inseparable aspects of development that are often in conflict with each other. This can be seen especially in developing countries, where people focus mainly on relentless economic growth to achieve a better standard of living, while at the same time looking at the fact that this fact leads to the excessive consumption of the Earth's resources, high levels of environmental pollution and social inequality. Therefore, the goal of sustainable development is to achieve complete interaction and balance between these factors to satisfy basic social and economic needs, while maintaining all resources. Natural resources for future generations and improving the well-being of the environment and the ecosystems life depends on. To eliminate negative environmental impacts and adhere to the three sustainability principles, a Life Cycle Assessment (LCA) was used to assess the environment for the product of this study. The LCA is implemented through Solidworks Sustainable LCA software tool and LCA database.

Life cycle assessment (LCA) is a method of analyzing and quantitatively assessing the environmental impact of a product over its entire life cycle, from start to finish, with all stages. intermediate (raw material extraction, material handling, production, distribution, use, repair and maintenance, disposal or recycling). Environmental impacts related to air pollutant emissions and resource consumption, both of which contribute to a wide range of impacts, such as climate change, stratospheric ozone depletion. Convectional ozone (smoke) generates, eutrophication, acidification, stress toxins to human health and ecosystems, resource depletion, water use, land use and noise.

A complete LCA study according to the ISO 14040 series of standards includes four main stages:

• Define the goal and scope of the product system to be studied.

• Inventory analysis of the product system's relevant inputs and outputs. This involves collecting data for each process included in the product system under study and aggregating the contribution from each process to the total results of the system.

• Evaluate the impact of various potential environmental problems related to the inputs and outputs of the product system using specific indicators.

• Interpret the results from the research and development of recommendations.

The LCA is a decision-making tool that calculates indicators of potential environmental impacts and provides alternatives to the potential improvements of the product under test to identify pollution prevention opportunities. and reduce resource consumption.

The proposed methodological framework includes the following 7 steps.

In the first step (Research Conductive), research is performed to identify a biological system of interest that will be the inspiration and basis for product development.

In the second step (System Analysis) the system is analyzed for form, shape, structure and functional principles to identify and exploit any of its special features in solving a problem or human need.

In the third step (Problem Definition), the problem to be solved is identified together with the design requirements.

In the fourth step (Design Implementation), the design process is implemented by adjusting the special feature (s) resulting from the analysis step in our product.

In the fifth step (Material Analysis), conduct material analysis to discover and find materials that meet the specific requirements and objectives of each part of the product, with an emphasis on recyclability of the product.

In the sixth step (Technical Analysis), carry out a stress analysis to ensure that the materials obtained from the previous step meet the mechanical requirements of each part of the product.

In the seventh step (Optimization), conduct a sustainability analysis to draw conclusions about the materials and manufacturing processes that are best suited for the lower environmental impact.

3. Conclusion

In fact, in the world, countries with developed economy, engineering and technology are all countries applying bio-simulation science in the design and manufacture of industrial products very strongly such as Japan, The US, UK, Germany, China ... Therefore, scientists today affirm that want to develop and change in technology and technology must rely on the wonderful and rich foundation of the great treasure. To have a series of scientific achievements and applied products developed on the basis of biomimetic technology in the past decades is a process of research and creation of scientists and early adopters. strategic investment of countries with developed industries in the world. From a country with backward agriculture and prolonged war, Vietnam's applied arts training institutions are based on the foundation of traditional fine arts. Thinking about science and technology is very low, mainly based on experience. In addition, there is a lack of investment and emphasis on the role of biomimicry in the field of design art. Therefore, domestically applied products have not met the practical needs of society in both form and function. Modern household products and industrial machinery, including toys simulated from nature, are also imported products, accounting for the majority ... From the above fact, biomimicry plays a role. is important in all sciences of contemporary life, and in the field of applied art product design. Especially in the era of industrialization, modernization and international integration. But this is an area that requires linking and cooperating with many branches and scientific fields to create a product. Therefore, in order to develop in the field of design and design of applied art products, we need to invest in training and scientific research, facilities, and technology transfer based on science and technology. biological. Because this is the cradle of training for artists, designers and the first foundation of ideas, creative thinking and technology transfer on the art of biological design (Biomimetic Design) and for a series of applied art products serving the development of the country and mankind.

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