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Nature-Inspired Algorithms as a Part of the Biomimetic Architecture: A Brief Discussion

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Abstract

Biomimetic architecture is mainly derived from biological phenomena. It is a significant method to solve architectural design and engineering problems. Biomimicry aims to mimic biological concepts and behaviors and apply them in buildings. Biomimetic architecture methods are presently classified into three levels: the organism level, the organism behavior, and the ecosystem level. This paper contributes to conceptualizing a novel approach that leverages the capabilities of the biomimetic architecture. The proposed architectural method is composed of two main modules: direct and indirect mimication. This novel method is elaborated through the thematic analysis method by a brief discussion. This research's main finding is the novel biomimetic architecture method.

Keywords: Biomimicry; biomimetic architecture; design problems; architectural design process; natural algorithms; genetic algorithm; swarm algorithm; biomimetic algorithms.

1. Introduction and background

Biomimetic architecture (BA) was recently involved in solving diverse building design problems using various methods. BA was applied throughout the historical ages in the inspiration of buildings forms, approaches, and decoration [1].

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There are three levels of applying biomimicry in architecture; the organism level, the organism behavior, and the ecosystem level [2]. As illustrated in Figure 1 current applications of biomimetic architecture are mainly classified into applications on individual buildings, and applications on an urban scale or complex projects. The organism level aims to apply mimication on buildings by specific organisms working individually without mimicking how the organism participates in a larger context. Gherkin tower (2003) by Norman Foster is a good example of the mimication on the organism level. As presented in Figure 2 Gherkin tower mimics the sponge of Venus basket in dispersing underwater stresses on the organism level [3]. Regarding the level of an organism's behavior, it aims to mimic the behavior of the organism within its larger context. As presented in Figure 3 the Eastgate Centre by Mick Pearce and Arup Associates is a large complex (shopping mall and offices), located in Harare, Zimbabwe. The building depends on a passive cooling system mimicked from self-cooling mounds of African termites [4]. Concerning the ecosystem level, it is the involution of multi environmental components simultaneously targeting an urban scale or a complex project [2]. Graham Wiles innovated a closed-cycle system transforming cardboard into caviar in Wakefield, UK [5].

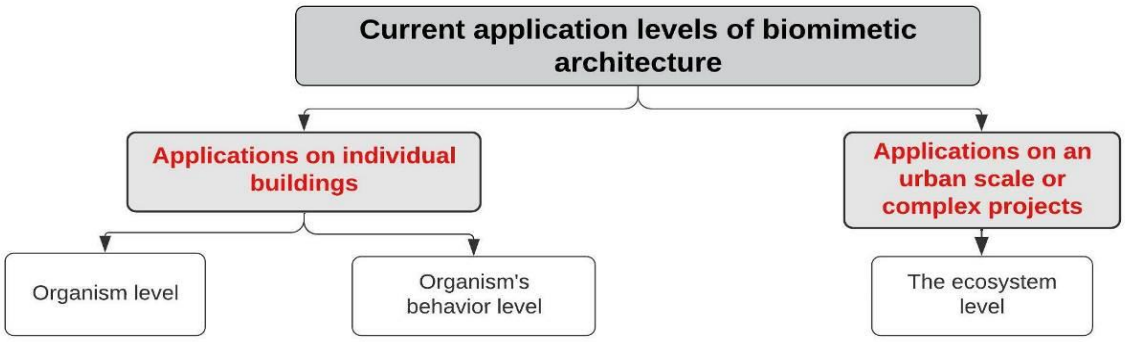

Figure 1 : Classification of current application levels of biomimetic architecture [2]**.**

Figure 2 : Gherkin tower (2003) by Norman Foster [3]**.**

Figure 3 : The Eastgate Centre (1996) [4]**.**

Referring to the previous studies concerning biomimetic architecture, various studies were carried out. Louis Vitalis and Natasha Chayaamor-Heil [6], discussed the relationship between science and architecture. They introduced a new relation that deals between design and science as two forcings that shift the concentration beyond the ordinary procedures. Lazaara Ilieva and his colleagues [7], classified the applications of biomimicry in architectural engineering as applications of biosynergy, clear zero optimization, innovation, and societal transformation. Hasan Bayhan and Ece Karaca [8], performed a SWOT analysis for the applications of biomimetic architecture and kinetic architecture concepts. They [8], merged those concepts to gain from their strength and opportunities. This new hybrid method will enrich the sustainability aspects. Many other publications investigated various applications of biomimetic architecture such as in [9, 10, 11, 12, 13]. The literature on biomimetic architecture concepts, approaches, and applications refers to its significant impact on the architectural engineering sector. Referring to the Cambridge dictionary [14], the algorithm is defined as; a group of mathematical equations or rules that help in solving numerical problems. Nature-inspired algorithms (NA) are mathematical equations or rules inspired by the natural system such as genetic and swarm algorithms. Part of the architectural engineering problems is compromising between design parameters and objective functions in the early design stage [15]. Design parameters are mainly the variable parameters of a building such as a layout organization, orientation, window to wall ratio, shading device dimensions, layout organization, and building form. Objective functions are mainly classified into qualitative and quantitative objectives. Natural (biomimetic) algorithms can solve design problems concerning various design parameters and objective functions as presented in Figure 4 [16].

Nature-inspired algorithms (NA) solve architectural engineering problems using indirect mimication. While direct mimication applies the concepts beyond the adaptions of biological creatures. The indirect mimication uses the concluded algorithms derived from biological concepts in solving architectural problems. Genetic algorithms (GA) and swarm algorithms (SA) are examples of nature-inspired algorithms. Those are metaheuristic algorithms that facilitate and promote the decision-making processes for complex problems [17, 18, 19].

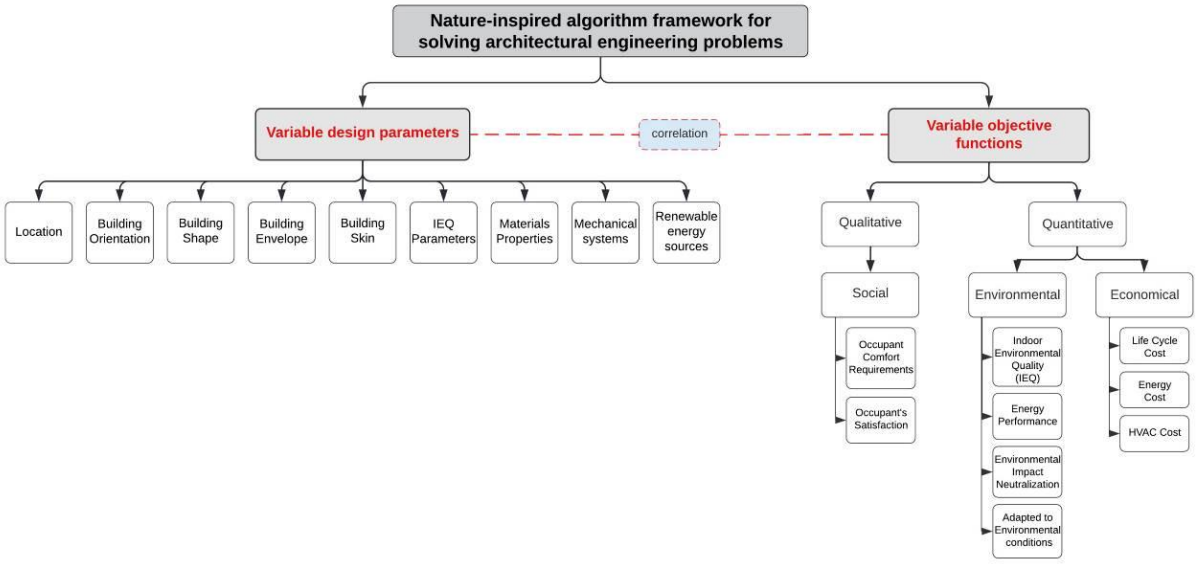

Figure 4 : Nature-inspired algorithm framework for solving architectural engineering problems [16]**.**

The applications of nature-inspired algorithms in solving architectural engineering problems have a significant impact on the literature. M. Pena and his colleagues [20], reviewed the applications of nature-inspired algorithms in architectural conceptual design. They [20], figured out that most of the literature utilizes evolutional computational mechanisms. Additionally, most of the literature was demanding originative and innovative forms. While the least of the literature operated from's optimization. Moreover, Berk Ekici and his colleagues [21], reviewed the applications of evolutionary and swarm algorithms in the early design stage. They [21], classified the applications into sustainability, functionality, structure, and cost. Furthermore, Randa Khalil and his colleagues [16], reviewed the use of nature-inspired algorithms and swarm algorithms in particular in settling architectural engineering riddles. They [16], classified the swarmative applications into, design process, adaptive system, building retrofit, and adaptive structure. The nature-inspired concepts and applications in the literature indicate a considerable influence on the architectural engineering district. This paper focuses on the physical mimication of biomimetic architecture in building and layout sectors (direct mimication). Furthermore, it focuses on the use of numerical algorithms which were inspired by nature in solving architectural engineering problems (indirect animation). This paper contributes to merging both benefits of biomimetic architecture applications levels and nature-inspired algorithms. This novel (integration) method will improve and facilitate solving architectural engineering problems. Those problems are related but not limited to the design process, adaption process, and retrofitting process. Furthermore, the integration between both approaches may lead to significant solutions.

2. Method configuration and results

This research depends on the thematic analysis method. It mainly integrates two methods into one method through a brief discussion. Whereas proved the significant impact of using biomimetic architecture and nature-inspired algorithms in the architectural engineering sector, as demonstrated in [6, 7, 8, 20, 21, 16]. It's essential to develop these concepts to lead to novel gains. This research presents a novel biomimetic architecture method.

This novel method combines the benefits of biomimetic architecture and nature-inspired algorithms. This method classifies the applications of biomimetic architecture into direct and indirect mimication. Direct mimication refers to the implantation of nature-mimicked systems in the building to either adapt or develop the function and environmental process. Organism and organism behavior are included in the direct mimication category. Referring to the indirect mimication category reflects the utilization of arithmetical functions inspired by nature in solving architectural engineering problems. The indirect class includes but is not limited to the applications of the design process, building retrofit, and adaptive structure and systems. These arithmetical equations can deal with various design parameters and objective functions to comprise sustainable aspects. Nature-inspired algorithms such as genetic and swarm algorithms and ecosystem levels are included in the indirect mimication category. Figure 5 illustrates the biomimetic architecture novel method.

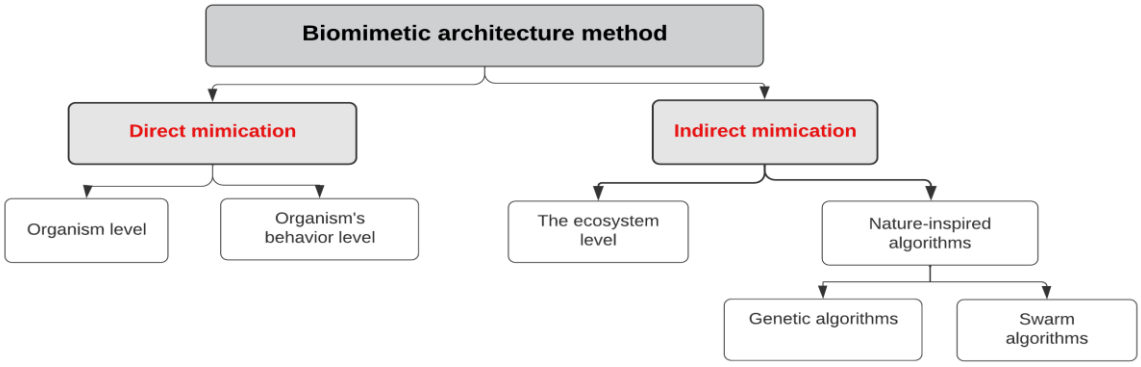

Figure 5 : Biomimetic architecture novel method.

3. Conclusion

This paper demonstrates the current classification of application levels for biomimetic architecture. Additionally, it presents the benefits of utilizing nature-inspired algorithms in solving architectural engineering problems. Nature-inspired algorithms mainly compromise between various design parameters and objective functions. Those algorithms mayhap apply to different architectural procedures such as design processes and retrofitting scenarios. Furthermore, this paper presents the literature review for the applications of biomimetic architecture and nature-inspired algorithms in the architectural engineering sector. This paper presents a novel method by applying the thematic analysis method. This novel method combines the advantages of both, current applications of biomimetic architecture and nature-inspired algorithms. Furthermore, this novel method reclassifies the biomimetic architecture into direct and indirect mimication. Regarding the direct mimication category, it includes organism and organism's behavior levels. The indirect mimication category includes nature-inspired algorithms such as genetic and swarm algorithms and the ecosystem level. Future studies mayhap investigate the possibilities of combining direct and indirect biomimetic architecture methods. The previously mentioned idea conceivably promotes solving complex architectural problems in terms of the design process, retrofitting scenarios, and adaptation scenarios. Finally, this paper presents a novel method for biomimetic architecture. This method mayhap reinforces the consequences of applying biomimetic architecture to solve architectural engineering problems.

4. Declaration of conflict of interests

The authors have declared no conflict of interests.

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