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Article

Bioinspired adaptive landscape design: Environmental responsiveness strategy based on biomimetic principles—Driven molecular and cellular biomechanics

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Abstract: In an era of ecological degradation and urban growth, the significance of delving into the cellular and molecular biology realm becomes evident for bioinspired adaptive landscape design. At the cellular and molecular level, organisms possess intricate mechanisms that govern their responses and adaptations. This study, within the context of landscape architecture, explores how these microscopic biological processes can inspire macroscopic design strategies. This study investigates the use of biomimetic principles in landscape architecture, incorporating bioinspired adaptive techniques such as Integrated Elephant Herding Inspired Swarm Optimization (IEHSO) to optimize design solutions that draw inspiration from natural systems to create resilient and sustainable environments. The efficiency in resource utilization and biodiversity enhancement in nature can be attributed to the precise regulation of molecular pathways and cellular functions. By investigating dynamic interactions in ecosystems, design techniques that mimic nature's adaptive strategies, such as self-organization, resource efficiency, and biodiversity enhancement, can be uncovered. Concepts like fractal geometry, modular design, and the golden ratio, which are prevalent in natural forms, may have its origin in the growth patterns regulated by cellular and molecular cues. Bioinspired approaches lead to novel solutions for solving concerns such as climate change, habitat loss, and urban heat islands using case studies of contemporary landscape projects, which have been demonstrated. The proposed method is implemented using Python software. The IEHSO model demonstrates precision (91.3%), F1-score (93.85%), recall (93.8%), and accuracy (95.1%) significantly enhancing sustainable environments. The findings show that adaptable landscapes have the potential to reflect the complexity of natural systems while also actively contributing to environmental sustainability. This study aims to highlight the essential role of cellular and molecular biology in creating landscapes that are not only aesthetically pleasing but also ecologically sustainable and robust, thereby advancing the field by bridging the gap between microscopic biological phenomena and macroscopic landscape design.

Keywords: biomimetic; landscape design; integrated elephant herding inspired swarm optimization (IEHSO); cellular and molecular biology; environmental responsiveness

1. Introduction

The relationship between nature and design has drawn a lot of attention, especially in the field of landscape architecture, which constituted the idea of bioinspired adaptive landscape design essential for developing ecologically conscious environments [1]. The creative method integrated biomimetic ideas to develop solutions that enhance ecological sustainability and produce beneficial changes to the environment based on concepts from the well-organized, functional biosphere [2]. The strategies were developed from rising trends like climate change, urbanization, and environmental degradation, which complicate the design techniques to support a flexible ecosystem [3]. For millions of years, nature has adapted and developed several systems that affect water, optimize resources, and sustain various biodiverse habitats [4]. Perhaps landscape designers create conditions in environments that could bring human requirements into balance with assistance from natural processes. Landscape has been defined as the process of designing or making use of spaces derived from nature; landscape architecture borrows a lot from nature in terms of patterns and techniques in biomimicry [5]. For instance, learning about how desert plants retain water and how ecosystems self-regulate might help designers create landscapes that become more resilient to climate extremes. By emphasizing resilience, the adaptive design philosophy seeks to build landscapes that could react quickly to changes in the climate, biodiversity, and human activity. Critical environmental concerns addressed the bioinspired landscapes through the ability to improve air and water quality and promote biodiversity [6]. Plants respond to their environs in many ways, spanning geography, time, and organizational levels. Plants may live despite being sessile and unable to determine their habitat, which is astonishing. Plants adapt to environmental changes through phenotypic plasticity, which allows a single genotype to create different phenotypes [7]. Plant biomechanics studies often focus on the rigidity of plant organs in response to external stresses. The bark, a stem tissue that plays a crucial role in organ integrity, has previously received little attention. Based on a recent revelation that the interior bark is involved in the posture regulation of sloped tree stems [8].

1.1. Social and ecological benefits of adaptive landscape design

Bioinspired adaptive landscape design places a strong emphasis on finding context-specific solutions that capture the special qualities of the environment. By encouraging solutions that were customized to the unique ecological, cultural, and social settings of the environment [9]. Designers might build landscapes that are visually attractive and ecologically useful for interacting with the local ecology to discover native species. The local ecosystem becomes more concerned with the sustainability and well-being of surroundings to create a sense of place and encourage community involvement. Moreover, the integration of technology and data analysis was imperative in augmenting the effectiveness of bioinspired landscape design [10]. The utilization of adaptive management enables designers to make well-informed decisions that augment the resilience and sustainability of landscape designs. Adaptive landscape design draws inspiration from bioscience that has significant social benefits to the ecosystem [11]. A well-designed area might promote social interaction, boost mental health, and improve overall quality of life. Furthermore, landscapes might be used as tools to emphasize the significance of ecological concepts and motivate the next generations to encourage and safeguard the natural surroundings. Despite the enormous potential of bioinspired design, effective implementation necessitates cooperation among a wide variety of customers, ecological experts, designers, and urban designers with the community [12]. Multidisciplinary cooperation encourages creative solutions that represent the needs of the community and constitute the environment. Engaging the local ecosystem in the design process ensured finished landscapes that represent the community values of the environment [13]. In ecology, ‘resilience' refers to a system's ability to respond to disturbances. Ecosystems can exhibit strong ‘resistance' with modest changes in status or function. Ecosystems with minimal resistance may eventually recover and return to their prior state, or they may even benefit from disturbances [14]. In landscape design; biomimetics frequently incorporates intricate biological processes that were challenging to comprehend the duplicate completely. It might be difficult to translate biological concepts into workable, scalable solutions. The study aims to develop a novel Integrated Elephant Herding Inspired Swarm Optimization (IEHSO) approach to optimize design solutions that draw inspiration from natural systems to create resilient and sustainable environments. This research investigates the use of biomimetic principles in landscape architecture and incorporates bioinspired adaptive techniques.

1.2. Contributions of the study

- The Integrated Elephant Herding Inspired Swarm Optimization (IEHSO) approach is used to optimize design solutions that draw inspiration from natural systems to create resilient and sustainable environments.
- This research investigates the use of biomimetic principles in landscape architecture and incorporates bioinspired adaptive techniques. To create harmony among constructed environments and nature encourage ecological awareness in landscape architecture.
- The result findings demonstrate that bioinspired adaptive landscapes effectively mitigate issues like climate change, habitat loss, and urban heat islands, showcasing their potential for both aesthetic appeal and environmental sustainability.

The article is divided into the subsequent parts: Part 2 presents the related work with an overview of the research; Part 3 provides the details of the study’s strategy for the suggested approach in methodology; the evaluation result is outlined in the experimental result in Part 4 and Part 5 contributes the discussion and Part 6 concludes the research with the conclusion.

2. Related works

The bio-generation constituted the reflection of bio-inspired constructed surroundings, such as biological replication and ecological consciousness presented by Arora and McIntyre [15]. Three primary domains of design include additive manufacturing (AM), development engineering, and environmental degradation adaptation. Mitigation elaborated on the necessity and applicability of bio-generation. The experimental outcome demonstrated how people and their surroundings have mutualistic ties to support psychological health. Using basic object-oriented models, Le Fur et al. [16] examined the synthetic ecology relevant to a particular application field in the bio-generation of wild rodent population dynamics. To tackle the intricacy of the area, the architecture was progressively expanded and molded by the incorporation of the application domain. The experimental outcome demonstrated the creation of artificial ecologies and landscapes influenced by biomimetics.

Environments displacing natural habitats for population growth and movement of people in coastal and metropolitan areas were presented by Stachew et al. [17]. The adaptability, flexibility, self-treatment, physical and biochemical soil connection, and resilience of root systems constitute the potential architecture and infrastructure to design environments. The result showed the relevance of coastal infrastructure in natural habitats. The bio-inspiration created a complete model of landscape paradigms and ecosystem design processed in Le Fur et al. [18]. The model was continuously modified to address robustness, intended for the similarity of the actual mechanisms of nature. The experimental outcome demonstrated a bioinspired design.

The bio-inspired solutions in hot and humid regions created an efficiently built environment to replenish the resources that constitute nature closer to the urban areas examined by Solano et al. [19]. The fast population growth concentrated in metropolitan areas has environmental imbalances. The development of resilient habitats constituted the effects of climate change modified by the environment's evolution as an external component of the ecosystem. The experimental outcome demonstrated the extraction of resources and environmental deterioration. The design of bio-inspired helps designers to transition between biological systems and human implementations was presented by Snell-Rood and Smirnoff [20]. In generic function, designers search for characteristics in biological species that carry out similar tasks. To investigate trait function evolved on trade-offs possess biological models that were suitable for certain applications. The experimental result findings demonstrated the bio-inspired models for design inspiration.

By employing multilayered and curved morphological modifications, plants and trees offer adaptable techniques from biological inspirations as demonstrated by Hosseini et al. [21]. To enhance multilayered biomimetic performance inspired by tree morphology and biomimicry morphological method for simulation. The experimental outcome demonstrated the complex and flexible structure of the environment. The system of biological adaption techniques constituted smart materials and technology for contemporary buildings to optimize the energy use of biological processes. The integration of biology technology into a methodical information-transmission approach was examined by Dikou and Kourniatis [22]. The significant influence of bio-inspiration biological principles constituted the production of bio-inspired structures. The experimental outcome demonstrated the morphological features and organic structures of biomimetics.

Biomimicry constituted the adaptation techniques to build an envelope for integrating the importance of biomimicry in an adaptive building envelope was demonstrated by ElDin [23]. The utilization of naturally occurring adaptive mechanisms in buildings improved energy efficiency, adaptability, and durability. The experimental outcome demonstrated how architecture and nature interact in the natural world. Bio-inspiration intends the creative process that involves biological ideas for environment design presented by Chayaamor-Hei [24]. The technical endeavors deal with the multidisciplinary collaboration of biologists and other disciplines to solve real-world issues about the innovation of sustainable development. Many facets of the scientific and social sciences have affected architecture and biology was included in design processes. The experimental outcome demonstrated the expressive architecture of biomimetic forms.

To design a resilient and sustainable constructed environment constituted the ideas of nature. Nature and technology were combined in the design process termed as biomimicry was explained by H Zaki et al. [25]. To create robust and sustainable solutions, an inventive technique that mimics biological processes and systems was employed. The experimental result findings demonstrated the functional features and design solutions of environment. Biomimicry helps to solve engineering problems and promote creativity. Biomimicry in several engineering fields demonstrated its enormous potential to transform technology through environmentally and energy-friendly solutions was demonstrated by Zhang et al. [26]. The applications of biomimicry gain achieved in the direction of efficiency and sustainable technology. The experimental outcome demonstrated substantial improvements in the environment design process. A viable static for sustainable creation and energy-efficient structures included natural features from the facade design of building applications was developed by Bagheri-Moghaddam et al. [27]. The creation of facade solutions design was influenced by biomimetics. The biomimicry substrate design utilized photosynthetics to generate an environment design. The experimental outcome demonstrated the alternative optimized designs.

The molecular mechanisms underpinning plant stress responses, with a focus on subcellular and regional regulation. It covers reactive oxygen molecules, antioxidant defense, hormone regulation, transcriptome regulation, protein changes, and post-translational regulation. It also investigates responses within cells and systemic signaling synchronization between tissues and organs by Raza [28]. The various mechanisms for adaptation in microbial systems, with a focus on genetic modification, artificial evolution, and sequencing of the genome. It finds four trends: fitness trade-offs, route modifications, pleiotropy, and fast adaptability by Bleuven Clara and Landry Christian [29]. Biomechanics research helps us understand how organisms use physical principles to construct tissues, cells, and processes. It aids cellular biologists and ecologists in their understanding of the genotype-phenotype relationship. Engineers and designers draw on physical and engineering ideas to profit from architectural and managerial principles that have been found effective via evolutionary survival by Anja Geitmann et al. [30].

Problem statement

The fast rate of urbanization and ecological deterioration presents obstacles for landscape architecture, requiring inventive methods to establish habitats for both sustainable and functional. Conventional landscape designs frequently missed the complex interactions that exist within ecosystems and fall short of addressing the unique biological, cultural, and social circumstances of the environment. The bioinspired adaptive environment design constitutes a viable solution to complex systems and adaptive techniques seen in nature. But the hard part was ensuring that solutions environment-specific were customized with their features successfully incorporating the design process. The adoption of native species easily comprehends the local ecosystems to improve ecological resilience.

3. Methodology

This research presented an Integrated Elephant Herding Inspired Swarm Optimization (IEHSO) approach to optimize design solutions that draw inspiration from natural systems to create resilient and sustainable environments. This research investigates the use of biomimetic principles in landscape architecture and incorporates bioinspired adaptive techniques. By investigating dynamic interactions in ecosystems, design techniques that mimic nature's adaptive strategies, such as self-organization, resource efficiency, and biodiversity enhancement can be uncovered.

3.1. Data collection

To enhance clarity on the experimental design and data collection, the steps describe in detail how to convert spider web patterns into bioinspired landscape designs. Details on the specific patterns chosen, how they were extracted, analyzed, and quantitatively measured (such as dimensions, shapes, and interconnections of the web strands), would strengthen understanding. Information on the methodologies used to assess tensile strength and resilience could also provide insight into why spider web structures were chosen for their ecological benefits. Furthermore, outlining the criteria for selecting particular spider species or web types, the data collection process for capturing web geometry, and any computational or modeling techniques employed would make the study more replicable. Adding visual representations, such as diagrams or charts, could also clarify how these patterns inform adaptive landscape design, fostering ecological sustainability through the resilience derived from the spider web structure.

3.2. Integrated elephant herding inspired swarm optimization (IEHSO)

The hybrid method improves bioinspired adaptive landscape design by combining Elephant Herding Optimization (EHO) and Chaotic Sand Cat Swarm Optimization (CSCSO). EHO modeled after the matriarchal hierarchy and cooperatively optimized migration toward resource-rich regions that characterize the social behavior of elephants in herds. The worldwide search effectiveness is guaranteed by an algorithm with a good balance of exploitation and exploration. The CSCSO uses chaotic maps to introduce unpredictability and prevent early convergence during the optimization process. The system avoids local optima by maintaining solution diversity through the incorporation of chaotic dynamics into the swarm behavior of sand cats. Biomimetic principles, which draw inspiration from natural ecosystems for the layout and design of landscapes, constitute bioinspired adaptive landscape design. The hybrid IEHSO approach maximizes ecological and aesthetic advantages by adapting to the natural limits. With the help of this adaptive model, which mimics nature's capacity for self-organization and conditional adaptation, design changes are made in a dynamic and flexible manner, promoting biodiversity, energy efficiency, and ecosystem resilience. The hybrid approach promotes environmentally conscious and sustainably aligned landscapes that effectively address environmental issues. Algorithm 1 shows the IEHSO pseudo code.

3.2.1. Chaotic sand cat swarm optimization (CSCSO)

The CSCSO methods constitute bioinspired adaptive landscape design to construct habitats that bear resemblance to natural ecosystems. It incorporates elements of nature into landscape design, such as variety, resilience, and self-organization by using biomimetic concepts. The techniques promote environmentally friendly design solutions that constitute both aesthetically pleasing and shifting environmental circumstances. The real-world engineering and design challenges were complicated, metaheuristic approaches were often advised to minimize execution time and computing expenses. But occasionally, they constitute issues like insufficient search consistency, premature integration, local optimum trap, inefficient search, insufficient population diversity, and the cause of straying from the best course of action. The sand cat swarm optimization (SCSO) has several issues as well. To overcome this, CSCSO was developed. The Dynamic maps are useful for several reasons, including leaving the immediate region and accelerating the search. However, SCSO has a fair and balanced convergence rate to locate the global optimum that influences the convergence rate with great accuracy. Predators were probably blinded by the random working method, which can utilize a small portion of the search field. The CSCSO incorporates the chaotic notion to lessen the efficiency and boost overall efficiency.

A complex system's highly unpredictable behavior termed a chaotic quality. The original settings have an impact on it. The chaos in mathematics characterizes the unpredictability of basic dynamical systems and chaotic structures are exhibited as sources of randomness. A variety of chaotic maps with diverse mathematical equations were utilized. By employing chaos maps, the chaotic behavior constitutes to optimize a function where chaotic mapping guarantees an equitable distribution of the population. Furthermore, by facilitating a more dynamic and worldwide exploration of the search field, maps enable the display of dynamic characteristics. In nonlinear systems, maps exhibit intricate and dynamic behavior. Which exhibit intricate and dynamic behavior in nonlinear systems that frequently yield better results than pseudo-random numbers. Utilizing random sequences of data, the chaos-based optimization technique uses chaotic events produced from erratic maps to create design elements throughout the worldwide optimization procedure.

The CSCSO enhanced worldwide search productivity by incorporating the chaotic feature of not periodic sites into the SCSO's fundamental search procedure. The suggested algorithm blends SCSO with the idea of chaos. Using the chaotic idea utilized for the CSCSO method, this constitutes probability distributions and unpredictable behavior. The CSCSO uses chaotic maps to increase the convergence rate. Additionally, it might avoid local traps more readily than traditional stochastic techniques. Due to comparable unpredictability features with superior quantitative and temporal qualities, chaos in the SCSO is substituted by a chaotic map. The maps were expected to be stochastic for longer duration, and induce chaos in the favorable zone for short starting time. The chaotic maps utilized in the CSCSO method to adjust the regular SCSO algorithm's step size. To provide more reliable and well-rounded solutions, the possibility of population increases.

Following the completion of the SCSO's primary reproduction phase, the newly created position of search operations was updated by using a chaos map. The chaotic map pattern fluctuations might be significantly influenced by the starting value. The chaotic maps exhibit both random and predictable behavior. The SCSO algorithm offers several unique benefits, such as discovering appropriate solutions for operations and exhibiting balanced behavior across exploitation and exploration phases. However, it was equally important to consider the benefits of the chaotic idea. Sand cats are able to resolve multidimensional issues quickly and efficiently through chaotic behavior, which is helpful for later phases. The chaotic maps constitute random processes with predictable characteristics. However, the SCSO's inherent randomness is more chaotic. Improvement in initial solutions and convergence accuracy was achieved by using a chaotic map that helped initialize the population of cats. To improve the SCSO's performance in challenging situations, particularly limited interdisciplinary challenges utilizing the chaotic idea. The CSCSO method utilizes a hybrid approach-based multi-strategy mechanism. The CSCSO algorithm presents two different approaches to phased position update. Using the chaotic model as a foundation, it constitutes the usual position updating technique. The probability of balanced weights expressed in Equation (1).

$$\vec{W}(s+1) = \begin{cases} if o < 0.5 \equiv eq.5 \\ if o < 0.5 \equiv eq.10 \end{cases} \tag{1}$$

Here the random number s ranges from 0 to 1. The SCSO method has aD parameter for significance while arithmetic operation occurs. There was a direct relationship between parameters. Equation (2) represents the system model. The exploration and exploring stages become more functional.

$t = 2^s; l \geq 1$,

$$D = t - t\left(\frac{\sqrt[s]{f^s} - 1}{f - 1}\right) \tag{2}$$

The key factor determining how the algorithm assigns the weight for each step. The exploration phase afforded greater opportunities. The CSCSO approach performs well in confined situations when greater attention is paid to the exploration phase. The exploitation and exploration stages are essential for increasing the flexibility of the CSCSO algorithm. It reduces the fluctuation range of $the Q$parameter, depending on d. Search agents are compelled by the CSCSO algorithm to exploit situations on$Q$, where all other cases are being pushed to seek and locate targets. Chaotic maps were utilized in the other case. Local optimal entrapment and rapid convergence are prevented by a hybrid approach. Equations (3) and (4) represent the impact of chaotic maps.

$$\vec{Q} = 2 \times \vec{d} \times n - \vec{d} \tag{3}$$

$$\vec{q} = \vec{d} \times n \tag{4}$$

Using a chaotic map as a basis, the chaotic vector n is determined. Equation (5) represents the CSCSO model.

$$\vec{Q}(s+1)=\begin{cases}\overrightarrow{W_a}(s)-\overrightarrow{W_{rnd}}.\cos(\theta).\vec{q}|Q|\leq 1\ (a)\\ \vec{q}.\left(\overrightarrow{W_d}(s)-n.\overrightarrow{W_s}(s)\right)|Q|\leq 1\ (b)\end{cases} \quad (5)$$

To locate additional potential local regions in global space with rapid and accurate convergence rates in a variety of issues, with particularly limited optimization problems. While maintaining the same complexity analysis as the original, the CSCSO method outperforms in terms of performance. Equation (6) describes the mathematical model for the suggested procedure.

3.2.2. Elephant herding optimization (EHO)

The EHO constitutes bioinspired landscape design used to create creative solutions that improve bio-diversity, allocate resources more efficiently, and improve both urban and rural landscape's overall functionality. The designers might produce settings that are durable and environmentally sustainable to look visually beautiful. Using biomimetic concepts and natural ecosystems as inspiration, bioinspired adaptive landscape design produces solutions for both efficient and sustainable. To mimic the features of an elephant's nomadic lifestyle, a population-based algorithm called EHO has been developed. Three guiding concepts were applied in EHO. There are a fixed number of clans that make up the population of all agents. The matriarch symbolizes the best agent in each iteration and leads on each tribe. Every time, the worst agent stands for the male elephant, which grows up and leaves his group to live on his own. To simulate the aforementioned behavior, EHO configures the difference among clan operators.

3.3. Tribe operator

The position of the search agent is adjusted based on the connection with the clan head, which might be described as follows in Equation (6).

$$w_{new,dj,i}=w_{dj,i}+\alpha\times\left(w_{best,dj,i}-w_{dj,i}\right)\times rand \quad (6)$$

Here the current and new locations of search agent i clan dj were denoted as$w_{dj,i}$ respectively, and $w_{best,dj,}$ represents the position of the best agent in the clan. Both $rand$and $\alpha$are arbitrary numbers in the interval$[0,1]$. The location of the clan leader is updated in contrast to other member positions by the current positions of all agentsin the clan, as expressed in Equation (7).

$$w_{new,dj,i}=\beta\times w_{center,dj} \quad (7)$$

Here $w_{center,dj}$reflect the central location of all agents inside the clan, which is expressed in Equation (8) as follows,

$$w_{center,dj}=\frac{1}{m_{dj}}\times\sum_{i=1}^{m_{dj}}w_{dj.i} \quad (8)$$

In this case, $\beta\ \in\ [0,1]$ determines how much $w_{center,dj}$influences $w_{new,dj,i}$as the total number of agents in clan dj.

3.4. Segmentation operator

Elephant male life traits were mimicked by the separation operator. The following Equation (9) represents the departure of adult male elephants from the existing clan.

$$w_{worst.dj} = w_{min} + (w_{max} - w_{min} + 1) \times rand \quad (9)$$

Here w_{max} and w_{min} represent the maximum and lower boundaries of the particular position respectively and r represents the random number [0, 1].

3.5. Superior retention approach

EHO implements an elitist technique to prevent the finest elephant populations from being destroyed. Initially, the system saves the elephant individuals. Following iteration, the lowest elephant's fitness values were contrasted with the highest-achieving elephant individuals. The previously saved elephants constitute the chance for the superior agents to be retained. Algorithm 1 shows the process of IEHSO. Ensuring the quality of the current agents was compared with previous agents achieved in this manner.

Algorithm 1 Process of IEHSO

$Initializeelephantpopulation\ (E)$
$Initializesandcatswarmpopulation\ (S)$
$Setnumberofelephants\ (NE)\ andsandcats\ (NS)$
$Initializeadaptivelandscapeparameterswithbiomimeticprinciples$
$Defineobjectivefunctionbasedonthebioinspiredlandscapedesignrequirements$
$Initializechaoticmap\ (e.g., logisticmap) parametersforsandcats$
$Foreachiterationuntilmaxiteration:$
$Foreachelephantclaninthepopulation\ (E):$
$Identifyclanleaderbasedonthebestfitnessintheclan$
$Updateleader'spositionbasedoncurrentpositionandadaptivelandscape$
$Foreachmemberoftheclan:$
$Updatememberpositionbymovingtowardtheclanleader$
$Applybiomimeticprinciplestoadaptmovementwithinthelandscape$
$Forindependentelephants:$
$Randomlyrelocatethembasedonchaosprinciples$
$Updatepositionbyusingchaoticbehaviortoavoidlocaloptima$
$Foreachsandcatintheswarm\ (S):$
$Applyachaoticmaptoupdatethesandcat'sposition$
$Adjustthepositionofeachsandcatusingchaoticbehavior$
$Ifthesandcatisinpursuit:$
$Movetowardprey\ (bestsolutionfound)$
$Elseifthesandcatisexploring:$
$Moverandomlybasedonchaoticbehavior$
$Foreachindividual\ (elephantorsandcat):$
$Applybiomimeticprinciplestooptimizelandscapedesign$
$Adaptivelymodifythelandscapedesignparametersbasedoncurrentfitness$
$Evaluatethefitnessofthepopulationbasedontheobjectivefunction$
$Selectthebestindividuals\ (elephantsandsandcats)\ forthenextiteration$
$Updatepopulationwithelitemembers\ (bestsolutions)$
$Endfor$

4. Experimental results

The study used TensorFlow to complete the recommended task. Where Python software was installed for the procedure to be completed and the experiment was run on a 64-bit version of Windows 7. The Intel(R) Core (TM) i7-7770hq 2.8 GHz CPU and 8 GB of RAM are installed. **Table 1** illustrates the configuration details for experiment execution.

Table 1. Configuration details for experiment execution.

Component	**Details**
Operating System	The 64-bit version of Windows 7
Software Installed	Python
Processor	Intel(R) Core(TM) i7-7770HQ, 2.8 GHz CPU
RAM	8 GB

Structural stability and material efficiency in spider web design

Using natural systems, components, and processes as models and systems for building sustainable solutions and effective building environments is known as bioinspired design, especially in landscape architecture. The spider web has a complicated structure and versatility and serves as a suitable illustration for landscape creation. The spherical shape and radial symmetry of the structure were reminiscent of the intricate weaving of spider webs, which are not only visually stunning but also a prime example of nature's economical use of materials and structural stability. The design pattern of the spider web has several benefits that apply to landscape architecture. The radial symmetry seen in webs enables a balanced stress distribution across the structure. The quality might constitute an inspiration for creating open-air environments that employ the least amounts of materials while maximizing accessibility and visibility. Moreover, the spider webs have extraordinary strength in relation to their weight, indicating landscape environments constructed using comparable lightweight robust materials. Biodiversity-supported biomimetics inspires design with nature. Spider webs refer to productiveness and plasticity in the landscape for the promotion of aesthetics. For example, spider webs elasticity enables it to endure different climatic stresses, such as wind and rain. By using materials and design techniques that were flexible to shifting environmental circumstances, landscape architects imitate the feature. The creation of the spider web serves as an inspiration for a creative building environment. Through an examination of the spider's silk manufacturing process and its highly efficient weaving methods, architects and landscape designers create buildings that are useful for resource efficiency. The technique not only minimizes material waste but also encourages design processes to be more environmentally conscious.

Furthermore, a spider webs intertwined threads represent the significance of ecological interconnectedness in landscape planning. The spider web links improve biodiversity and support healthy ecosystems, a well-designed landscape should incorporate other components. The spider has the capacity to rebuild its web after destruction, which serves for resilient landscape design. Flexible components might vary over time and should be incorporated into landscape designs, where spider adjusts their webs in response to threats and changes in the surrounding environment. Modular systems enable adjustments in response to changing user demands and environmental conditions. A spider web design added to landscape architecture enhances users' visual experience. Environmental settings that promote interaction and exploration are created by visual shapes and architecture. Additionally, patterns in designs tend to induce feelings of peace and well-being, enhancing mental health via a stronger bond with the natural world. The spider web-inspired design pattern aids in bridging the gap across the natural and constructed ecosystems in urban areas. Green areas like parks and gardens that capture the intricacy and beauty of spider webs could enhance air quality, encourage urban biodiversity, and provide locals access to recreational possibilities. The incorporation of natural elements into urban environments promotes interpersonal relationships and community involvement, ultimately cultivating a feeling of inclusion among environments. The spider web pattern is ideal for bioinspired environment design due to its structural efficiency and flexibility. Because of its complex shape, which epitomizes resilience, it can tolerate environmental stresses without losing strength. The spider web design pattern is used for moderate to highly varying regions for temperate and subtropical climate zones. The structure of the web effectively facilitates the removal of moisture from the surrounding air in conditions for natural irrigation and improving the quality of the soil. The flexible construction endures adverse weather patterns, including wind and rain. Increasing the density and complexity of the microclimate provides many different plants and animals with the principle of a balanced ecosystem that adapted to life in a humid and dynamic climate, as shown in **Figure 1**.

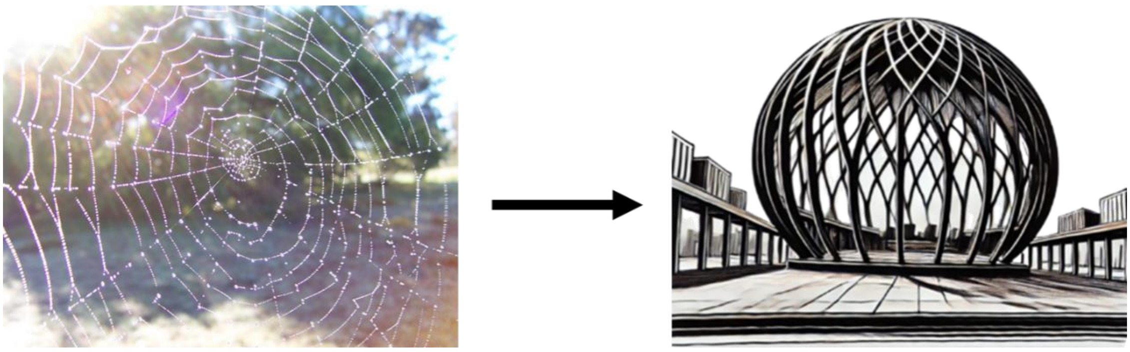

Figure 1. Output of spider web design pattern for bioinspired adaptive landscape design.

The proposed strategy was assessed and its effectiveness was calculated using the following indicators: recall (%), accuracy (%), precision (%), and F1-score (%). An efficiency comparison across the proposed strategy and other traditional approaches was also presented. The traditional methods include Elephant herd optimization (EHO) and Chaotic Sand Cat Swarm Optimization (CSCSO).

Evaluating the model's accuracy by calculating the ratio of successfully expected to total occurrences, accuracy offers a robust assessment of the system's efficiency. **Figure 2** and **Table 2** illustrate an evaluation of accuracy in comparison between suggested and traditional methods. Compared to traditional methods like EHO and CSCSO, which have an accuracy of 93.65% and 92.1%, the proposed IEHSO attains an accuracy level of 95.1%. The proposed method provided superior results to optimize design solutions from natural systems to create resilient and sustainable environments.

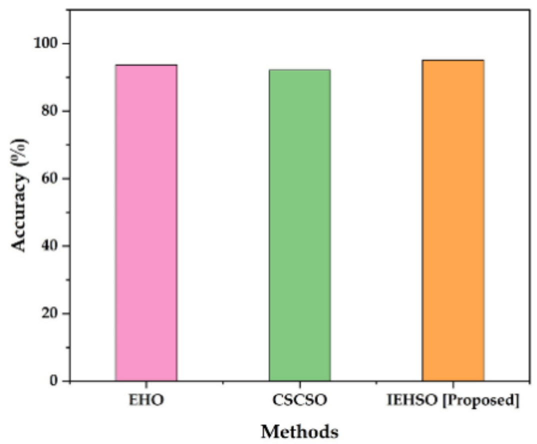

Figure 2. Result of accuracy.

Table 2. Result parameters.

Methods	Accuracy (%)	F1- Score (%)	Recall (%)	Precision (%)
EHO	93.65	91.55	92.35	89.76
CSCSO	92.1	90.85	91.15	90.4
IEHSO [Proposed]	95.1	93.85	93.8	91.3

A model's precision level indicates how accurately it anticipated results. The assessment is the proportion of precisely predicted positive results to the total expected benefits. **Figure 3** and **Table 2** illustrate an evaluation of precision in comparison between suggested and traditional methods. Compared to traditional methods, EHO and CSCSO have a precision of 89.76% and 90.4%, and the proposed IEHSO attains a precision level of 91.3%. The proposed method provided better results for analyzing design solutions from natural systems to create resilient and sustainable environments.

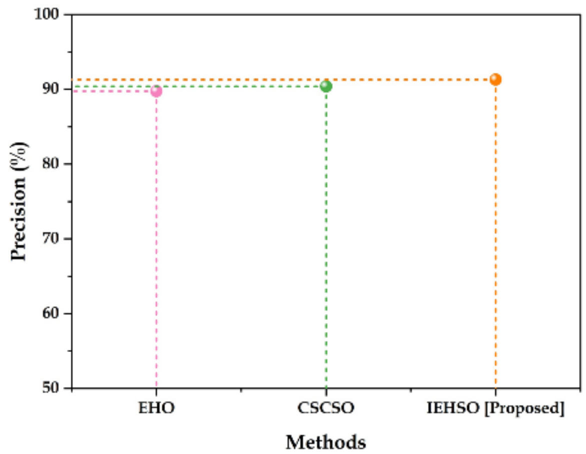

Figure 3. Result of precision.

Recall is a statistic that assesses a model's capacity to locate all pertinent instances of a class. It assesses the model's accuracy in identifying every pertinent among the total number of real positives. **Figure 4** and **Table 2** present an evaluation of recall in comparison between suggested and traditional methods. Compared to traditional methods like EHO and CSCSO with a recall of 92.35% and 91.15%, the proposed IEHSO attained a recall level of 93.8%. The proposed method provided a better outcome to assess the design solutions from natural systems to create resilient and sustainable environments.

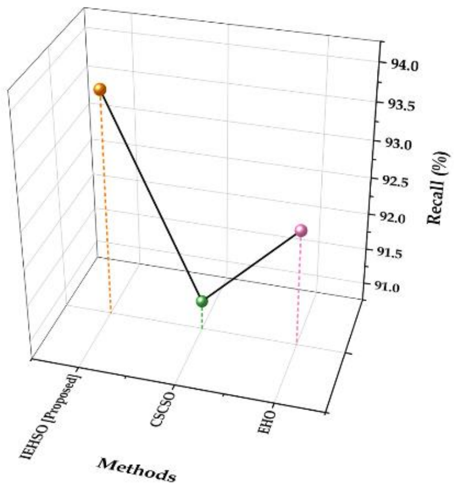

Figure 4. Result of recall.

F1-score is a statistic that was used to assess how well a classification model performed. Recall and precision are its harmonic means. **Figure 5** and **Table 2** present an evaluation of the F1-score in comparison between suggested and traditional methods. Compared to traditional methods like EHO and CSCSO with an F1-score of 91.55% and 90.85%, the proposed IEHSO attained an F1-score level of 93.85%. The proposed method provided superior results for analyzing design solutions from natural systems to create resilient and sustainable environments.

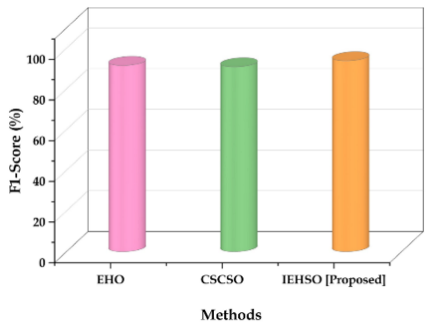

Figure 5. Result of F1-Score.

5. Discussions

The elephant herd optimization in a bioinspired landscape environment has some constraints. It was difficult for practitioners to execute since it involved sophisticated algorithms and precise environmental data. Its efficiency in complex environments might have limited EHO scaling issues and a tendency to become locked in the local environment. Furthermore, solutions were specifically designed that might make it difficult to generalize the environmental situations. More obstacles arise from the need for constant adaptation to environmental fluctuation. Different techniques might complicate multidisciplinary collaboration and ethical concerns of biomimetic approaches might be impacted by social acceptability. The Chaotic Sand Cat Swarm Optimization has some drawbacks when paired with bioinspired adaptive landscape design and biomimetic ideas. Initial circumstances and parameter settings might have an impact on the efficiency of CSCSO that produces ideal outcomes. Furthermore, the CSCSO method might not properly reflect the complexity of real-world landscapes, which would restrict its usefulness in a variety of contexts. Reliance on biological concepts might lead to oversimplifications that fail to take complex ecological relationships into account. The complexity of the environment might lead to a rise in computing intensity, which might create problems in resource allocation. The approach's multidisciplinary character necessitates cooperation across different areas, which might make integration and execution more difficult. To overcome this, the proposed method Integrated Elephant Herding Inspired Swarm Optimization (IEHSO) was used to optimize design solutions that draw inspiration from natural systems to create resilient and sustainable environments. Through analysis of dynamic communication relationships within ecosystems, identify various principles of design used by ecosystems, such as self-organization, resource optimization, and the promotion of generic species' diversity. The bioinspired methods show new ways of addressing problems such as global warming, deforestation, and heat islands.

6. Conclusions

Research presented an Integrated Elephant Herding Inspired Swarm Optimization (IEHSO) approach to optimize design solutions that draw inspiration from natural systems to create resilient and sustainable environments. This research intends to explore how biomimetic ideas can be applied to landscape architecture how bio-systems are integrated into adaptive systems and how such systems evolve in different ecosystems and find out design systems based on the lessons from nature as self-organization, resource utilization, and boosting system diversity amongst others. Such notions were considered as fractal geometry, modularity, and the golden section and demonstrated that they can be used to create harmony with nature in landscape design. Research shows that looking to nature to seek new solutions to problems in the form of climate change, loss of habitat, or also the creation of heat islands becomes applicable by presenting several projects of the contemporary landscape. The proposed method is implemented using Python software. In a comparative analysis, the proposed method is evaluated with various evaluation metrics such as precision (91.3%), F1-score (93.85%), recall (93.8%), and accuracy (95.1%). The result demonstrated that the IEHSO method outperforms the bioinspired adaptive landscape design when compared with other traditional algorithms. The result findings show that adaptable landscapes have the potential to reflect the complexity of natural systems while also actively contributing to environmental sustainability. This research intends to promote the discipline of landscape architecture by emphasizing the value of biomimetic design in creating durable, aesthetically pleasing, and environmentally sensitive landscapes.

7. Limitations and future scope

In landscape design, biomimetics frequently incorporates intricate biological processes that were challenging to comprehend the duplicate completely. It might be difficult to translate biological concepts into workable, scalable solutions. Transferring concepts from biology to landscape architecture could not be possible due to a lack of understanding or experience. Future scope moving toward the development of biomimetic ideas in landscape architecture should be standardized with the creation of scalable design models and standards. This might facilitate the large-scale adoption of bioinspired solutions by architects and landscape designers.

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