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Article

Exploring biomimetic inspiration and biomechanical optimization in brand design strategy

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Abstract: Nature's principles serve as a source of inspiration for biomimetic design incorporating them to achieve the best functionality and creativity. Biomechanical optimization takes this approach further by focusing on the effective use of physical resources and dynamics. They offer a solid foundation for brand design. This research seeks to look into a new method for biomimetic and biomechanical brand design using a deep learning (DL) model called Resilient Ant Colony Optimized Generative Adversarial Networks (RAC-GAN). The dataset comes from primary sources, including current brand logos and biomimetic images from nature such as plant structures, animal shapes, and natural patterns. These biomimetic images show a range of organic forms and textures that can flash creative and practical design elements. The team filtered the collected images to get rid of duplicates and adjusted to have the same resolution. They applied techniques similar to contrast enhancement to make sure the training data was high-quality. After pre-processing, the dataset into the RAC-GAN model used biomimetic principles to copy organic patterns, while biomechanical optimization made sure the created designs balanced creativity with functionality. The suggested model combines generative modeling with ant colony optimization to guide the creation process. The aim is to make sure the design is strong and works well by using ant-like paths that change to find the best setups. The RAC-GAN methodology demonstrated its ability to generate new concepts for logos that remained accurate to the brand's values.

Keywords: biomimetic inspiration; biomechanical; brand design; Resilient Ant Colony Optimized Generative Adversarial Networks (RAC-GAN); brand logos

1. Introduction

Two new trends in brand designs are biomimetic thought and biomechanical optimization, which allow designing products achieving realistic wants deeply communicating with the user's emotional and enjoyable levels of interest [1]. Biomimicry is the art of emulating nature's proven patterns and strategies. It offers wonderful lessons for effectively solving design challenges that developed over time. Designers can create items with wonderfully designed functionality that is extremely sustainable by understanding used in systems and processes of nature [2]. Biomimetic design offers branding methods inspired the nature creates complexity in patterns and abilities that really make things connect to sustainable and innovative standards [3]. The manufacturer continues to connect with eco-aware customers, a biomimetic logo format allows the creation of visual identities reflect the herbal performance determined in nature. Such a layout philosophy inscribes on the herbal formalities, shades, and systems to communicate about the center values and project logo. By emulating the magnificence of usual techniques, the logos can hint at an intelligence of accord, explosion, and flexibility, which firm the commitment of the logos to sustainability [4]. Whether through the replication of herbal shapes or the integration of organic textures, the logos no longer situate out visually that aligns with the environmental mindset of the modern customer. In today's world real and caring for the environment are key, using nature-inspired ideas in logo design can make a brand stand out in a busy market. Through similar views and aesthetics, these techniques establish an intimate connection between the logo and its audience, fostering devotion and giving the impression of sincerity [5]. The brands to come up with more appropriate logos that convey much more importance and essence through inspiration by tried and tested patterns and procedures from nature [6]. This approach of architectural thought, which focuses on being ecologically conscious and deriving inspiration through the natural environment, aligns well with the present environmentally conscious consumer base. By copying the shapes, colors and patterns that are found in nature, these logos communicate balance, strength, and growth messages that appeal to customers who have an appreciation for authenticity and are environmentally conscious [7]. At its core, nature-inspired branding speaks directly to the heart of the values of a brand through a design that reflects the beauty and utility of nature. An image is based on the detail structure of a leaf can suggest growth and lasting power, but an image that is based on a tree trunk may typically suggest strength and smoothness [8]. To simple restoration, these naturalistic designs reestablish the emblem's commitment to environmental values and add depth to a story that deeply resonates with the audience. Biomimetic manufacturers can differentiate manufacturers in crowded markets, shoot hobby, and beautify loyalty by using matching the values of consumers [9]. As producers flow into an increasingly trouble making landscape and include biomimetic layout concepts to guide sustainability and innovation, this holistic technique marks a dating among the brand and its target market and invites consumers to identify with the logo and its values [10]. The study powerful logo emblems which have utilized biomimetic and biomechanical strategies, figuring out key insights and exceptional practices that can be adapted for use in diverse industries.

Contributions of this study

- Through its emphasis on the effective utilization of physical resources and dynamics, biomechanical optimization further refines this methodology.
- This study uses a deep learning (DL) model called Resilient Ant Colony Optimized Generative Adversarial Networks (RAC-GAN) to investigate a unique method for biomimetic and biomechanical brand creation.
- High levels of creativity were shown by the RAC-GAN model in creating unique, visually beautiful logos that also followed brand identity guidelines.

The paper is organized into several sections: Part 2 covers the literature review, Parts 3 and 4 present the methodology and outcomes, and Parts 5 and 6 provide the study's discussion and conclusion.

2. Related works

The effort could address optimization strategies to overcome the real-time challenge using generative form designs based on algorithms constructed in unit dimension with Computer-Aided Three-dimensional Interactive Application (CATIA)

V6. Analysis System (ANSYS) Workbench was used to simulate the samples after they had been optimized using Rhino 7 software [11]. To apply spiral design biomimicry to the design of a swimming glove product by summarizing the technical procedures used in each stage. Increased propulsion in the water results in faster swimming, which is why swimming gloves are designed that way [12]. The relationship between biomimicry and artificial intelligence (AI) explains how copying the structures and functions of the natural world can lead to creative solutions [13]. The story went on to emphasize AI's role in speeding biomimetic research and innovation after providing an outline of biomimicry's historical foundations and noteworthy accomplishments. Six limbs serve various purposes to respond to the fundamental and important topic of optimality, including the human arm, the whale flipper, the bird wing, the human leg, the feline hindlimb, and the frog hindlimb [14]. A systems approach that ensures the functioning of the material structure by integrating topology optimization into bio-inspired design while considering additive manufacturing processing circumstances. The spiderweb, turtle shell, and labyrinth were the three lightweight material construction designs that were used to illustrate the approach [15]. The system included growing, modeling, simulating, and testing lightweight sandwich composites stimulated by organic fashions, utilizing biomimetic principles. Initially, natural and sturdy design templates were analyzed and abstracted to formulate the very last center systems. The structural and mechanical performance of these constructions was then assessed using numerical analysis [16]. The aim was to develop synthetic biomimetic materials that have characteristics like shape memory and self-healing capabilities to seamlessly integrate them into the additive manufacturing industry through rigorous synthesis and characterization processes [17]. The existence of harsh conditions offered a giant possibility to conduct precise experimental checks for incorporating biomimetic textiles into garb systems [18]. To demonstrate how utilizing precise styles from nature can enhance vicinity branding through a bio-design idea. The qualitative study took a look at tested patterns derived from local fish, flora, and plant life in Taman Negara, Pahang, employing a three-step bio-layout analysis framework [19]. Biomimetic generation holds the promise of notably remodeling the enterprise and serving as a pathway to shift from an excessive-carbon financial system to a sustainable low-carbon one. When accomplished, biomimetic innovation, layout, and commercialization present startups and small-to-medium corporations with a unique opportunity to improve the world even as improving profitability [20]. The improvements in biotechnology and nanotechnology have more suitable for organic vesicles and facilitated the design and production of biomimetic nanovesicles (BNV). To review key research concerning the usage of BNV in drug and gene delivery systems, as well as their programs in vaccines [21]. A contemporary optical olfaction device was evolved to categorize the exceptional VOCs launched through cigarettes. It employed superior methodologies, including unsupervised independent component analysis (ICA) and supervised linear discriminant analysis (LDA) to make certain thorough statistical analyses [22]. Highly transformational biomedical engineering solutions can be conceived from the intricate, functionally graded, fractal, multifunctional geometries and structures of nature, but they are extremely difficult to model [23]. Development design techniques for the creation, design, and application of goods, machine tools, processes, and manufacturing systems utilizing the bio-space and biological phenomena integrated with the technical space by a global team [24]. The design process for growing a corporate emblem photo employed a back propagation (BP) neural community to research the relationship between brand styling and the morphological imagery of animal and plant patterns [25]. By adjusting the community parameters, it predicted the design of logo perceptual imagery.

3. Methodology

The methodology includes gathering a dataset of logos and biomimetic images sourced from nature, encompassing numerous plant structures, animal forms, and natural patterns. These images have been filtered to eliminate duplicates and resized to make a certain uniform resolution. Contrast enhancement techniques were applied to enhance the high quality of the dataset. The refined dataset was pre-processed and input into the RAC-GAN model. The training of the RAC-GAN framework integrated biomimetic ideas to copy natural styles, even as biomechanical optimization was hired to strike a balance between creativity and functionality. By integrating generative modeling with ant colony optimization, the model was designed to navigate an adaptive pathway, figuring out optimal configurations to provide modern and logo-steady emblem designs. **Figure 1** depicts the method flow of the proposed technique.

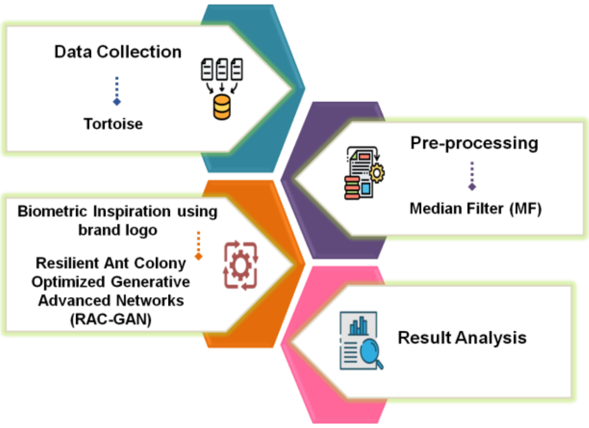

Figure 1. A detailed guide to the sequential steps of research design, and analysis.

3.1. Dataset

The information has been obtained with a specific purpose from the primarily, which includes research of the already existing logos and various images from nature that act as an inspiration for these brand logos. It entails a close analysis of the logos that have elements representing of plant's structure, an animal's shape, or a natural pattern. The data will be gathered and examined to discover common biomimicry themes and their relevance to the branding process. The tortoise served as one of the main sources of inspiration for the biomimetic images included in the study's dataset. The unique patterns and structures seen on tortoises' shells can be used as creative design components in corporate logos. The dataset highlighted the distinctive geometric patterns and inherent robustness of tortoiseshells by showcasing a variety of organic forms and textures. The tortoise data image is shown in **Figure 2**.

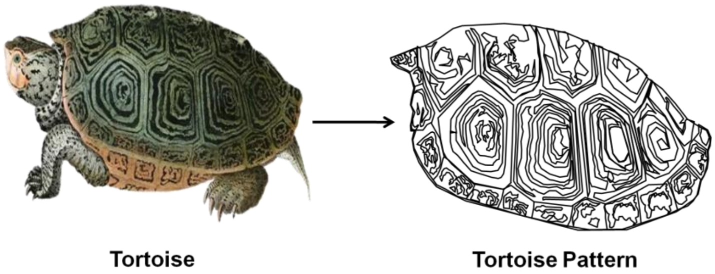

Figure 2. The tortoise and the art of pattern recognition.

3.2. Biomimetic inspiration using preprocessing for median filter (MF)

Biomimetic idea performs a vital role in enhancing photograph preprocessing techniques, particularly through the software of the median filter (MF), which emulates natural filtering techniques discovered in biological systems. The MF excels at doing away with salt-and-pepper noise, a commonplace artifact in digital pix. Its operational mechanism entails scanning the image pixel and substituting every pixel price with the median of its neighboring pixels. Specifically, the filter sorts the neighboring pixel values in numerical order, and the median price from this taken-care-of list replaces the pixel being processed. By focusing on the median instead of the mean, the clear-out efficiently minimizes the impact of outlier values, ensuring that the ensuing image retains crucial structural information whilst decreasing undesirable noise. The MF is significantly more effective in removing noise without compromising the sharpness of the picture via Equation (1).

$$e(w,z) = median_{(v,u)\in Lwz}\{h(v,u)\} \tag{1}$$

In this case, the MF of the window is represented by a median, and Lwz stands for the coordinate sets centered at points $(w, \text{and } z)$ inside a rectangular sub-image window.

3.3. Biomimetic inspiration using Resilient Ant Colony Optimized Generative Adversarial Networks (RAC-GAN)

Biomimetic suggestion performs a crucial position in advancing generation, especially in optimizing complex systems. One captivating software for this idea is the integration of RAC within GANs, resulting in RAC-GAN. In nature, ant colonies show off great trouble-fixing abilities, characterized by their capacity to evolve, analyze, and cooperate in locating the most appropriate paths to food sources, even in dynamic and uncertain environments. By mimicking those organic strategies, RAC-GAN leverages the collective intelligence of synthetic ants to enhance the performance of GANs, in particular in producing super-synthetic information. This resilience is, in particular, useful in packages such as image technology, in which keeping quality at the same time as making sure variability is critical. By mimicking the conduct and efficiency of ant colonies, the emblem design technique harnesses the collaborative optimization competencies of those algorithms, taking into consideration progressive and adaptive visual elements. This technique results in a brand that not only captures the essence of resilience and teamwork determined in nature but additionally embodies cutting-edge technology, symbolizing a logo that values each herbal inspiration and innovative solutions. Furthermore, RAC-GAN's adaptive nature allows it to better handle noisy statistics and different perturbations, making it suitable for diverse fields, inclusive of laptop imaginative and prescient, healthcare, and environmental modeling. By incorporating biomimetic concepts, RAC-GAN not only drives the bounds of generative modeling but also offers a promising road for growing sturdy and efficient algorithms that can address actual global challenges more effectively.

3.3.1. Generative adversarial networks (GAN)

By modeling organic processes, biomimetic concepts with GANs include utilizing natural standards to create and lay out new materials, structures, or structures. GANs, a class of devices getting to know algorithms, consist of neural networks, such as the generator, and the discriminator, which work together to create and refine sensible record outputs. By training GANs on datasets derived from biological bureaucracy and functions, researchers can mimic the difficult designs determined in nature, including the efficiency of lotus leaves, the structural integrity of spider silk, or the camouflage abilities of chameleons. By mimicking the aesthetics and functionalities discovered in biological organisms, designers can generate emblems that not only replicate an emblem's identity but also evoke natural beauty. This system includes educating GANs on a numerous dataset of organic paperwork and present emblems, allowing the network to examine problematic styles and patterns. The result is a unique blend of creativity and nature-stimulated aesthetics, permitting manufacturers to set up an extraordinary visual presence whilst emphasizing sustainability and organic connections. As brands increasingly seek to resonate with eco-conscious purchasers, this technique gives a compelling avenue for brand layout that celebrates the concord among era and the herbal international. This method permits the era of novel designs that can be both useful and aesthetically attractive, allowing advancements in fields such as materials, technological know-how, architecture, and product layout. A generator $G(y)$ and a discriminator $D(w)$, where y is random noise, make up a classical GANs framework. The tool for discrimination $D(w)$ seeks to distinguish between the actual and false data, while the generator $G(y)$ attempts to produce an increasing amount of verisimilar data in an attempt to "fool" it. Throughout the training phase, these two combative opponents also known as the min-max game are tuned to dominate one another in a zero-sum game. Random noises $z \in RN$ are supplied. And then, the generator $G(y)$ will create synthetic data, $\widetilde{w}$ = $G(y)$. The discriminator $D(w)$ will receive input data from both the actual data x and the false data $x^{\sim}$. It will then produce a scalar representing the likelihood that the input data are from the genuine data distribution $P(x)$ as opposed to the generator $G(y)$. The adversarial training procedure optimizes the two antagonistic players. GANs learn the generator $G(y)$ and the discriminant $D(w)$ by resolving the Nash equilibrium problem. This aggressive process has the following value function in Equation (2).

$$\min_{G} \max_{D} U(D,G) = \mathbb{E}_{w\sim o_{data}\,(w)}[\log D(w)] + \mathbb{E}_{y\sim o_{y}(y)}[\log(1 - D(G(y)))] \quad (2)$$

where $o_y(y)$ = $V(0,\ 1)$ represents the noise at random distribution, which has a uniform probability in the early phase of most GANs. In classic GANs, perceptrons with multiple layers are used to build both the generator $G(y)$ and the detector $D(w)$.

- From the viewpoint of a generator

The expression $w_G = G(z)$ denotes the generator's modeled transformation of a random vector y into the target sample w_G. The chance that the produced samples are part of the distribution of actual data, or training G, is maximized o_{data} by w_G. The fixed, straightforward sample prior distribution that GANs were predicated on $o_z(o)$ by Equation (3).

$$\min_G U_H(D,G) = \min_G \mathbb{E}_{y\sim o_y(y)}[\log(1 - D(G(y)))]) \tag{3}$$

- From the viewpoint of discriminator $D(w)$

The output of the GANs architecture is within the range [0, 1] as it utilizes a sigmoid neuron at the final layer of discriminator $D(w)$. The system that discriminates attempts to give actual data a high value (the upper limit is 1) and bogus data from the generator is given a low value (the low limit is 0) for Equation (4).

$$e(w,z) = median_{(v,u)\in Lwz}\{h(v,u)\} \tag{4}$$

Even though certain GAN frameworks are designed to learn discriminators, the original GANs and the majority of their variations are families of techniques for learning generative models that are grounded in game theory. This research also aims to develop an efficient generative model that can produce high-quality synthetic sensor data that is readily available. This study primarily addresses the deployment of GAN models rather than the framework's optimization and stability.

3.3.2. Resilient ant colony optimization (RAC)

Biomimetic inspiration comes from nature's intricate structures and tactics to solve complex problems in various fields, such as optimization. One fantastic technique is Resilient Ant Colony Optimization (RACO), which emulates the foraging behavior of ants. In nature, ants showcase fantastic adaptability and overall performance while seeking out food, utilizing pheromone trails to talk and guide their fellow colony individuals. This set of rules complements conventional ant colony optimization strategies with the aid of integrating resilience strategies, permitting it to adaptively respond to dynamic environments and disruptions. By using mechanisms similar to ant foraging conduct, RAC optimizes hassle-fixing techniques in complicated scenarios, making it a strong tool for diverse applications, along with logistics, community optimization, and aid management. This progressive method showcases the capability of nature-inspired designs in growing efficient, adaptive algorithms that replicate the resilience and efficiency found in organic systems. RAC complements this concept via a manner of incorporating resilience mechanisms that permit the algorithm to efficiently deal with dynamic and unsure environments. By mimicking ant colonies' collective intelligence and their capability to adjust to converting situations, RAC optimizes resource allocation and path-locating approaches throughout diverse programs. This nature-inspired approach not best improves computational performance but also offers sturdy answers that may adapt to actual-worldwide annoying situations, making it a precious tool in fields inclusive of logistics, telecommunications, and AI. The reciprocal of the mean square error (MSE) at diverse coordinates correlates to the pheromones generated via the ant in that vicinity, making optimization for gaining knowledge of quotes analogous to a traveling salesman problem for ants. The first step entails the random distribution of n ants over the range of values in the dimensional coordinate gadget. Even though the MSE of every ant's position varies, the pheromone starting levels in every position are uniform, as stated in Equations (5) and (6):

$$\tau_{ji}(0) = \tau_0 \tag{5}$$

$$\tau_0 = n/K_n \tag{6}$$

where K_n is the path length that the closest neighborhood heuristic constructs. The next place to be relocated to is chosen by ant l ($l = 1, 2, \cdots, n$) based on the random proportion rule. The following Equations (7) and (8) are the selected probability:

$$o_{ji}^{l}(s) = \begin{cases} \dfrac{\left[\tau_{ji}(s)\right]^{\alpha}\left[\eta_{ji}(s)\right]^{\beta}}{\sum_{t\epsilon b_l}\left[\tau_{jt}(s)\right]^{\alpha}\left[\eta_{jt}(s)\right]^{\beta}} i\epsilon b_l \\ 0, others \end{cases} \tag{7}$$

$$\tau_0 = n/K_n \tag{8}$$

The pheromone on the edge of the range of values for μ_1 and μ_2 in the preceding image is identified as τ_{jt}. The set of all feasible places that the l^{th} can occupy in the following step is denoted by b_l. A heuristic component that shifts from location j to position i is called η_{ji}.

As shown in Equations (9) and (10), the more favorable the global search is, the larger the value of the heuristic factor η. It is more favorable for local searches when the values are lower. Additionally, the point where the l^{th} ant had passed was recorded, which prevented the ant from selecting a spot it, had previously reached. Upon reaching a specific amount of repetitions, every ant has finished its displacements. The position of every ant was measured for its MSE, and the pheromone of each site was updated along with the details of the ant that had the lowest MSE. A second update dealt with the pheromones that the ants on their route were releasing. The first update dealt with the volatilization of pheromones in the following formulas:

$$\tau_{ji} = (1-\rho)\tau_{ji} 0 < \rho \leq 1 \tag{9}$$

$$\tau_{ji} = \tau_{ji} + \sum_{l=1}^{n} \Delta\tau_{ji}^{l} \tag{10}$$

Here $\Delta\tau_{ji}^{l}$ is the pheromone that is emitted at the position of the l^{th} and can be described as follows: where ρ is the coefficient of pheromone volatilization for Equation (11).

$$\Delta\tau_{ji}^{l} = 1/MSE \tag{11}$$

This means that more pheromones are emitted at the ant's site the smaller the MSE is there. Furthermore, in later iterations, other ants are more likely to choose that spot. This can be defined as follows, which was added to this study to balance the searching powers of local and global search by Equations (12) and (13).

$$\eta(j) = \omega_{start} - \omega_{start} - \omega_{end} \cdot (2j/j_{max} - (j/j_{max})^2) \tag{12}$$

$$e = 1/n \sum_{j=1}^{n} \sqrt{(w_j - w_0)^2 - (z_j - z_0)^2} \tag{13}$$

where m is the ant population, f is the measurement function of the ant colony's convergence, $(w_j - w_0)$ is the precise location of the j^{th} ant, and (w_0, z_0) is the optimal ant position for a pheromone. **Algorithm 1** depicts the RAC-GAN.

Algorithm 1 Resilient Ant Colony Optimized Generative Adversarial Networks (RAC-GAN)

```
Initialize parameters:
    −Number of ants $(n)$
    −Pheromone levels $(\tau_{ji})$
    −Initial pheromone $\tau_0 = n/K_n$
    −Maximum iterations (max_iter)
    −Learning rates $(\alpha, \beta)$
    −Volatilization coefficient $(\rho)$
    −Heuristic information $(\tau_{ji})$
1. Initialize GAN Components:
    −Generator G$(y)$
    −Discriminator D$(w)$
2. Set Initial Pheromone Levels:
    $\tau_{ji}(0) = \tau_0$ for all edges
3. For each iteration $t$ from 1 to max_iter:
    $a.$ For each ant $l$ from 1 to $n$:
        $i.$ Randomly distribute ant lover design space
        $ii.$ While not at conver gence:
            −Select the next position based on probabilities:
            $o_{ji}^{l}(s) = \begin{cases} \frac{[\tau_{ji}(s)]^{\alpha}[\eta_{ji}(s)]^{\beta}}{\sum_{t \epsilon b_l}[\tau_{jt}(s)]^{\alpha}[\eta_{jt}(s)]^{\beta}} i \epsilon b_l \\ 0, others \end{cases}$
            −Update position of ant $l$
        $iii.$ Calculate $MSE$ for ant $l$ at current position:
            $\frac{1}{MSE} = calculate_{MSE}(w_i)$ where $w_i = G(y)$ based on ant's position
    $b.$ Update Pheromone Levels:
        $i.$ For each edge $(i, j)$:
            −Update pheromone based on MSE:
            $\tau_{ji} = \tau_{ji} + \sum_{l=1}^{n} \Delta\tau_{ji}^{l}$ for $l = 1$ to $n$
            where $\Delta\tau_{ji}^{l} = \frac{1}{MSEifantl}$ selected $edge\ (i, j)$
4. Resilient Ant Colony Optimization:
    $a.$ Update Heuristic Information:
        $\eta(j) = \omega_{start} - \omega_{start} - \omega_{end} \cdot \left(\frac{2j}{j_{max}} - \left(\frac{j}{j_{max}}\right)^2\right)$
5. Train GAN:
    $a.$ For each training step:
        $i.$ Generate synthetic data:
            $\widetilde{w} = G(y)$ where $y$ is random noise
        $ii.$ Train discriminator $D(w)$:
            $\min_{G} \max_{D} U(D, G) = \mathbb{E}_{w \sim o_{data}(w)}[log\ D(w)] + \mathbb{E}_{y \sim o_{y(y)}}[log(1 - D(G(y)))]$
6. Output:
    −Return generated logos $\widetilde{w} = G(y)$ with optimal design features using RAC optimization.
```

This technique utilizes RAC to enhance the generative procedure, drawing thought from the adaptive pathways that ants hire to find out top-of-the-line answers inside their environments. By mimicking this natural behavior, the model adeptly navigates the elaborate layout space, ensuring that the generated outputs no longer most effectively showcase an excessive diploma of creativity but also adhere to mounted brand design ideas. The incorporation of biomechanical optimization in addition refines the layout system, fostering greater performance in useful resource utilization even while simultaneously balancing the creative nuances with the purposeful requirements of branding. This dual cognizance of aesthetic appeal and sensible functionality empowers the model to produce exclusive emblems and branding elements that resonate deeply with the organic characteristics observed in nature. In the end, this progressive approach is a valuable tool in the layout field and it not only improves the creative process but also guarantees that the final products are in line with the broad objectives of contemporary logos.

4. Results

Using the RAC-GAN model, this study effectively established a unique technique for biomimetic and biomechanical brand creation. Through the integration of biomimetic concepts and biomechanical optimization, the model produced creative and visually appealing logos that were in line with the ideas of brand identity. The dataset was thoroughly pre-processed to improve quality and consistency. It included a variety of biomimetic pictures as well as current company logos. An Intel Core i7-7700HQ CPU operating at 2.81 GHz, 8.0 GB of RAM, and a GeForce GTX 1050 Ti GPU are used in the arrangement to enhance the efficiency of CAD. To evaluate the proposed method’s efficiency, we Comparison of our proposed RAC-GAN method with the traditional system [26]. By using ant colony optimization techniques, the RAC-GAN showed excellent design quality and efficiency, producing distinctive logos that struck a compromise between originality and practicality.

4.1. Application and evaluation of GAN-based computer-aided brand logo design

The computer-aided brand logo design approach based on GAN is employed for practice after this study case has been verified. To make sure that the created logo can meet the brand image and marketing plan, this article first thoroughly examines and comprehends the brand background, market positioning, and target audience of each case. Next, the GAN model is tailored and optimized based on the unique requirements of each situation. This involves fine-tuning model parameters, choosing the right network architecture, and refining training approaches. Several distinctive and creative brand logo design schemes have been effectively developed for each example through iterative training and adjustment. In terms of illustrating real-world outcomes, this article uses graphics and visuals to convey the developed logo design scheme and make its impact easier to understand. **Figure 3** shows the brand logo designs.

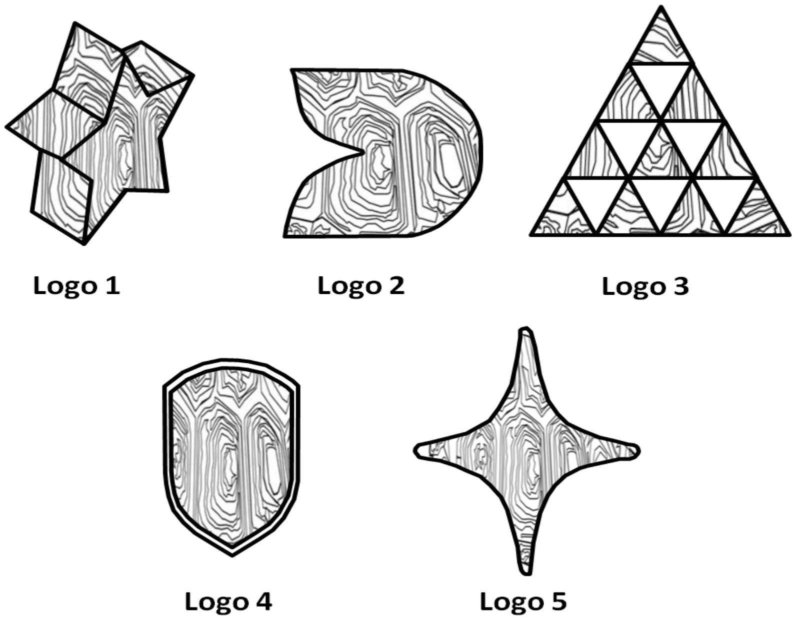

Figure 3. A detailed framework for developing cohesive logo design schemes.

4.2. Precision

Precision is a key performance metric in category duties that measures the accuracy of positive predictions. It is defined as the ratio of real effective predictions to the overall range of tremendous predictions. High precision indicates that the model has a low false positive rate, meaning that when it predicts a positive outcome, it is likely to be correct. In the context of biomimetic suggestion, precision will become critical because it ensures that designs drawn from nature are accurately represented and efficiently applied in programs. By incorporating biomimetic principles, fashions can acquire higher precision, leading to extra applicable and efficient outcomes in layout and choice-making tactics. **Figure 4** and **Table 1** depict the findings and comparison of precision.

Table 1. Comparison of precision completion rates between traditional systems.

Quantity of Tasks	Traditional System [26]	RAC-GAN (Proposed)
0	82	85
5	84	86
10	86	90
15	85	89
20	83	86
25	82	85
30	84	88
35	82	86
40	81	84
45	82	85
50	83	87

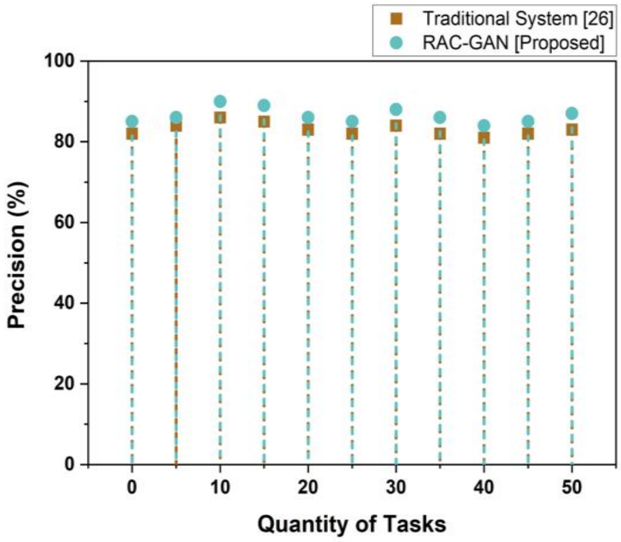

Figure 4. A comparative analysis of precision metrics evaluating diverse applications.

The data depicted in **Figure 4** summarizes the results of the ordinary system relative to the suggested RAC-GAN model at different numbers of tasks. In the tasks 10, the ordinary reaches 86% in precision, while RAC-GAN better with 90%. When the task basket increases RAC-GAN never fails to register higher precision values than any other model in use today, peaking at 90% with tasks 10, meaning that it can differentiate complexity in brand design tasks very well when compared to the ordinary system.

4.3. Recall

Recall is an overall performance metric that measures the capability of a model to efficaciously pick out relevant instances inside a dataset. It is described as the ratio of true high-quality effects to the sum of true fantastic and fake negative effects. In the context of biomimetic ideas, integrating natural principles into the design method can enhance a model's potential to capture relevant features, thereby improving consideration. However, it's crucial to balance and remember with precision to make certain that the version maintains general effectiveness without producing immoderate fake positives. **Figure 5** and **Table 2** depict the recall results.

Table 2. Comparison of recall between traditional system and RAC-GAN.

Time	Traditional System [26]	RAC-GAN (Proposed)
0	72	74
10	73	77
20	74	78
30	75	79
40	74	76
50	73	75

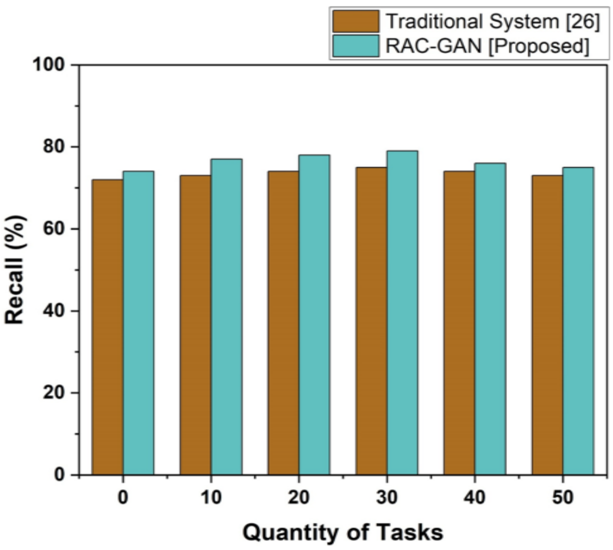

Figure 5. Recall the performance of the traditional system compared with RAC-GAN across varying task quantities.

The **Figure 5** time series data indicates that the RAC-GAN model outperforms the traditional system in logo generation over time. For instance, at 0 minutes, the traditional system scores 72, while the RAC-GAN achieves a score of 74, demonstrating an initial advantage. As time progresses, the RAC-GAN continues to outperform, reaching a score of 79 at 30 minutes compared to the traditional system's 75, highlighting its efficiency and effectiveness in design quality.

4.4. Time

Time is an essential concept that measures the development of occasions to collect reports and understand exchange. It is split into beyond, gift, and future, influencing various factors of lifestyles, from everyday exercises to historical contexts. In nature, time is frequently observed through cycles, such as the converting seasons or animal behaviors, which can encourage biomimetic designs that align with those herbal rhythms. The biomimetic concept attracts these time-related styles in nature to innovate answers that harmonize with ecological standards. Ultimately, time shapes expertise in life and reports with it, each in nature and with the technologies created. **Figure 6** and **Table 3** depict the outcomes of time.

Table 3. Comparison of time between traditional system and RAC-GAN.

Quantity of Tasks	Traditional System [26]	RAC-GAN (Proposed)
0	20	15
40	45	40
80	65	60
120	85	80
160	100	95
200	110	105
240	135	130

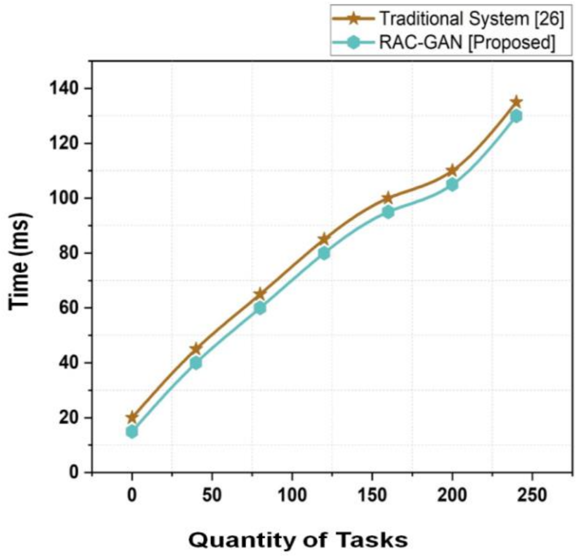

Figure 6. Performance comparison of traditional system and RAC-GAN based on quantity of tasks.

The RAC-GAN framework has better performance compared to the classical system with respect to the increasing number of tasks. At 0 tasks the classical system finished tasks 20 while RAC-GAN finished 15. In extreme cases where the tasks increase to 240, the classical system achieved tasks 135 while RAC-GAN achieved tasks 130, indicating its competitiveness and dependability at airflow handling higher volumes of work as shown in **Figure 6**.

4.5. Logo design for with and without biomimetic

The data presented indicates a significant improvement in various logo design factors when biomimetic inspiration is utilized. For color, the percentage of effectiveness rises from 70% to 85%. Texture shows an increase from 60% to 80%, reflecting a notable enhancement. Similarly, typography sees an elevation from 75% to 90%, highlighting the value of biomimetic concepts in text presentation.

Designing logos with biological factors in mind has the added benefit of improving the total visual appeal of the designs. The usage of color for instance rises from 70% to 85%, revealing that one of the palettes that use colors taken from nature makes a more pleasant and balanced design. Textures rise from 60% to 80% showing the use of natural intricate textures that add dimension and interest to the logo illustrations of products as shown in **Figure 7** and **Table 4**. Typography improves with an increase from 75% to 90% which means that more natural forms of fonts are easier to read and draw attention to the brand and its qualities. The shape goes up from 65% to 82% showing biomimetic shapes are plausible to the masses, making it more interesting and purposeful. Reference across different platforms, maintenance of design quality remains important and hence scalability improves from 68% to 87% which shows that biomimetic designs work well with a given size without distortion. To conclude, there is also an increase in the proportion of images and icons used, which rises from 55% to 78%, suggesting that images taken from nature help deliver the messages of brands and reach customers more effectively. These parameters demonstrate the effectiveness of the biomimetic approach in designing logos.

Table 4. Impact of biomimetic inspiration on logo design factors.

Logo Design Factor	Without Biomimetic Inspiration (%)	With Biomimetic Inspiration (%)
Color	70	85
Texture	60	80
Typography	75	90
Shape	65	82
Scalability	68	87
Imagery and Icons	55	78

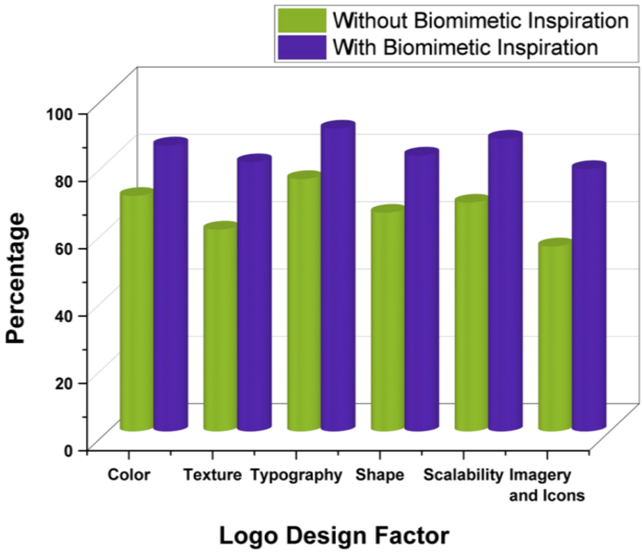

Figure 7. Comparison of logo design factors with and without biomimetic inspiration.

5. Discussion

The search for biomimetic biomechanical thinking in symbolic design offers modification strategies that can dramatically increase the creativity and potential of tangible identity. By exploiting natural systems and adapting those through biomechanical concerns brands can create logos that don’t challenge simple ideas. However, they also conform to the values of functionality and flexibility found in a natural global context. The RAC-GAN model serves as a complicated tool in this progressive framework, integrating advanced deep getting-to-know strategies with insights derived from organic systems. The dataset used, comprising several arrays of logo logos and biomimetic pix, shows a careful curation of natural bureaucracy, textures, and patterns which could inspire particular format elements. The preprocessing steps, consisting of duplicate removal and evaluation enhancement, are crucial in ensuring the higher of facts fed into the RAC-GAN, ultimately, most important to extra sensitive outputs. The RAC-GAN model is able to reproduce the organic shapes and patterns found in nature by applying the principles of biomimicry. Similar to how ants adapt to discover the shortest paths to properties, the generative approach’s integration of RAC enhances the version’s capacity to travel complex format areas. This adaptive method promotes a balance between visual novelty and logo capability by enabling the version to identify pinnacle-rated arrangement combinations. The suggested RAC-GAN model performs better than the traditional implementation by effectively producing designs that strike a balance between originality and usefulness, leading to higher best outputs over a range of assignment quantities. Due to its superior algorithms, which complement precision with flexibility, it is extremely useful in assembling disparate layout requirements. Results from the RAC-GAN version show that it can generate not only logo images that are unique and pleasing to the eye but also those aligned to the elementary requirements of a logo identity. It is a combination of biomechanical optimization and biomimetic thinking with the support of potent DL frameworks, such as RAC-GAN, which demonstrates excellent advancement in the field of emblem format, promising that the future will indeed be a synthesis of creative inspiration from nature and realistic perfection.

6. Conclusion

The logo layout totally enables biomimetic and biomechanical processes, thus proving the dynamism of the RAC-GAN model in making great and stable logos inspired by nature. Apply organic principles identified in their organizations and systems to fulfill the straightforward necessity of satisfying aesthetic excellence for logos but without negating realism and consistency with logo identification. This revolutionary method opens new avenues for designers, permitting them to draw from the widespread reservoir of natural notion while adhering to purposeful requirements. The success software of the RAC-GAN version underscores the importance of interdisciplinary association, merging design, biology, and artificial intelligence. Ultimately, this research covers the way for future explorations in biomimetic layout, encouraging manufacturers to undertake sustainable and green design practices rooted in nature. This takes a look at used various evaluation metrics, accomplishing advanced performances inclusive of precision of 87%, recall of 75%, and Time of 130 (ms).

Limitations and future study

Despite the promising results completed, several boundaries have to be acknowledged. The dataset, while diverse, was restrained to modern emblem emblems and biomimetic snapshots, which won’t seize the substantial array of capacity layout inspirations discovered in nature. Exploring the combination of personal feedback within the layout procedure ought to enhance the model’s responsiveness to emblem identity and consumer preferences, leading to even more effective and tailored branding answers.

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