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Biomimicry and Artificial Intelligence for Climate Change Mitigation

Nour ElDin,N.*, PhD, Architecture department. Faculty of Fine Arts, Helwan University

Abstract

The climate change we are facing nowadays is causing notable changes and harmful impacts to the environment. Therefore, there is a crucial need for sustainable practices, and efficient solutions to the CC problems.

Nature have been constantly adapting to changing environmental conditions. Throughout history, nature have shown successful examples that we should learn from. "Biomimicry" is concerned with emulating nature models and systems. The term "biomimicry" comes from the Greek word "Bio" means "life" and "mimicry" to imitate. (Benyus, 1997).

However, the sophistication and complexity of various database of nature, climate change, etc... require the integration of artificial intelligence to direct adaptation practices, manage the navigation through this large data.

The paper will discuss the biomimicry approach and its role in mitigating climate change, followed by addressing the role of (AI) in managing the biomimetic database, weather data. Discussing how (AI) assist in leveraging variables, inputs, creating algorithms, automatically updating databases, offering scenarios, assist in decision making, and less time consuming. So that the designer's intervention is concerned with overriding the outcomes not starting from scratch, as well as combining the randomness of biomimetic data and the models that evolve overtime, interdisciplinary and the climatic changes, for the development of more efficient solutions.

Keywords: Artificial Intelligence, Biomimicry, Climate change, Adaptation.

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1. Introduction

According to the Intergovernmental Panel on Climate Change (IPCC), there is an urgent need to mitigate climate change and global warming [1] where there is an increase in average global temperature to less than 2°C above pre-industrial levels. Mitigating climate change is therefore substantial, including the attainment of global net-zero emissions by 2050.

Therefore, there is a need to understand how species interact and respond to this climate change through observing and learning from their adaptive strategies. Imitating nature communities and mimicking their eco-system. Analyzing their functions, processes, past solutions to climate changes.

However, emulating nature's complex process to understand and utilize those complex systems, as well as the relationship between different processes in nature .

In the past few years, Artificial intelligence (AI) have been immensely growing and capturing the attention, making a rapid expansion and break throughs.

The paper is concerned with the role of (AI) in monitoring, analyzing, large database of nature models, tracking continuous climate changes, to automatically mitigating building materials, response mechanisms inspired by nature. It will also address how can AI be used to develop a definition for environmental good that is flexible yet robust, and its potentials to determine how people make environmental decisions.

Proposing a framework related to the effect of artificial intelligence in climate change mitigation, and its role in identifying priorities, forecasting, scenarios analysis, and better understanding to sophisticated challenges suggesting strategies based on nature adaptive techniques. The transfer of function from biological data into application promotes the need to new research areas across many disciplines.

2. Artificial Intelligence

Artificial intelligence is a continuously growing promising discipline, receiving a widespread recognition. It has been evolving, becoming used by almost everyone in their everyday life, through social media that mingles with algorithms, suggesting tailored videos, ads, targeting consumers search patterns, for example Alexa and Siri, google maps, etc.. In this paper the focus will be on the impact of using AI to tackle climate challenges issues.

AI has the potential to analyze data, managing complexity of variables, data, information related to climate change, monitor changes, track changes, automatically respond and adapt. Accordingly, the development of appropriate feedback loops, efficient strategies for managing those changes. Enabling the delivery of prompt analysis, flexible, accurate, dynamic, and adequate solutions. Thus, avoiding the delay of manually processing data and rapidly respond.

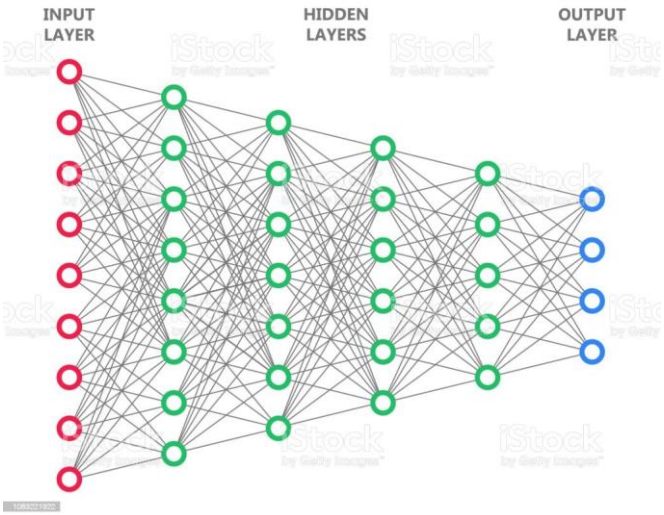

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Figure 1: Conceptual benefits of AI in managing large data

AI is increasingly spreading approach , that is sought to be an appropriate method to track the dynamic climate changes , benefiting from the sensory subdivisions of machine intelligence, where image sensors enable machines to "see" and microphones enables machines to "hear", [2]AI knowledge is derived from identifying patterns humans can't identify , relying on old data , [3] current, and predicted conditions, enabling decision making and future actions .

AI has the ability to understand different environmental parameters , weather data from temperature, humidity, rainfall , wind current, etc.…

2.1. Potentials of AI can facilitate in climate actions [4]

- **Extracting data into actions**

Through filtering information within large amounts of unstructured data, that humans could provide more with difficulty. For example, through analyzing satellite imagery to identify areas of cities vulnerable to floods.

- **Improving predictions**

Benefiting from past data to predict what will happen in the future, through incorporating auxiliary information.

- **Optimizing complex systems**

Optimization and controlling complex challenges with variety of variables. For example, reducing the required the energy for heating and cooling within a building.

- **Accelerating scientific modeling and discovery**

Blending known physics-based constraints with approximations learned from data. AI can offer promising candidate materials.

2.2. AI and energy efficiency in buildings and cities

In this paper the Focus will be on Buildings and cities. AI has the potential of increasing energy efficiency within buildings and urban environments, where AI can be used to label infrastructure in satellite imagery. AI can assume energy use within buildings, as well as translating data from smart meters. It can also optimize energy conservation, heating, cooling, lighting, etc.…

On the urban scale, AI can be used as sensor systems and extracting data, reduction of emissions and waste management.

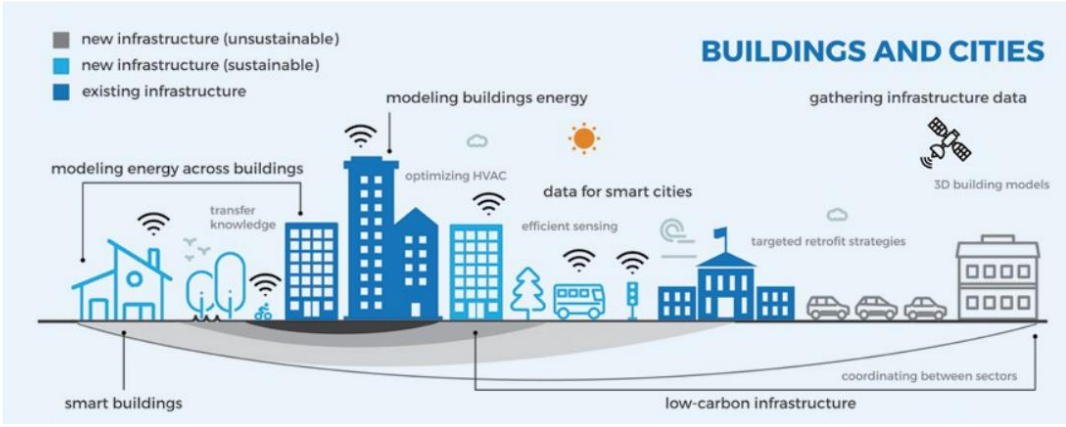

Figure 2: Selected AI-for-climate applications within buildings and cities. Figure reproduced with permission from Tackling Climate Change with Machine Learning *[4]*

AI has the potential to manage these complex issues. In May 2022, a global survey conducted by the Boston Consulting Group(BCG),in collaboration with four other organizations: the AI for Good Foundation; the United Nations Development Program (UNDP); the United Nations Educational, Scientific and Cultural Organization (UNESCO); and the UN Office of Information and Communications Technology (OICT).The results showed that 87% of public- and private-sector climate and AI leaders showed the abilities of AI in mitigating climate change . Figure 3.

Figure 3:Public and Private sector leaders overseeing AI supporting climate change mitigation

3. Biomimicry Potential to climate change

Implementation of collective behavioral biological large, complex systems, inspiration of lessons of how nature adjusts both gradually and rapidly to different stimulus. The essence of biomimicry in learning mitigation and adaptation strategies. Exploring nature's potentials and evolution techniques, whereas evolution do not only rely on adapting but on developing successful strategies.

By looking into nature, we can observe that Flora and Fauna have always been able to mitigate and adapt to rapid changes and harsh environments. [5] The vast changes in climate change and GHG emissions, global warming, urges the necessity and demand to eliminate and manage those changes, by emulating nature's strategies, to solve the impacts of those changes. Mimicking nature operates on three levels: a) organism level, b) behavior level, c) Ecosystem level. In this paper, the focus will be on mimicking the ecosystem level for mitigating climate change, for greater benefits, as it is more holistic, Figure 4. Ecosystem biomimicry is concerned with mimicking the interaction of the organisms within the entire eco system in relative to each other, both individually and collectively [6]. Consequently, maximizing the benefits, optimizing efficiency, delivering best options. Ecosystem ensures remaining optimal using past and present data, and the ability to always update data and self-adjust, self-heal.

Figure 4:Ecosystem biomimicry (Adopted from *[7]*)

4.The proposed framework

The proposed framework seeks avoiding the long cycle stages, meanwhile, delivering responsive solutions, adapting to changing conditions, managing climate changes. In this paper, the focus is improving the process of interpreting relevant data, reducing the time consumed in decision making processes, to deliver optimal, adequate solutions, derived from three main pillars: climate change data, biological data and artificial intelligence, Figure 5 .AI algorithms play an important role in understanding physics and scaling nature solutions , creating relations between forms and functions.

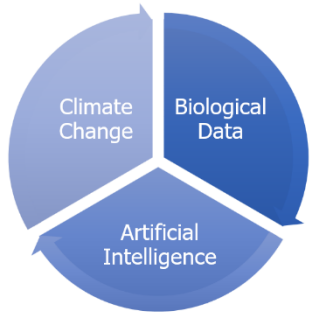

Figure 5:Proposed framework main pillars (The Researcher)

Using AI will not eliminate the human element, nor delegating their role to AI, nevertheless, the tool will have the potential of rapidly react to climate change drivers, avoiding the struggle of gathering, analyzing, vast amount of data, benefiting from the three pillars into more accurate outcomes. The focus in this paper is the application of AI to assist in decision making in the early design stages, managing the biological knowledge and climate change challenges, though the biomimetic process.

The paper discusses AI potentials in being dynamic, incorporating automatic feedback loops, ensuring self-improvement, whether on short-term or long-term.

The following figures, Figure 6 and Figure 7 illustrates the proposal steps, starting with analyzing nature strategies and biological systems, using the biomimetic approach, abstracting their principles into algorithm, proposing the relevant, appropriate corresponding design strategies. Constantly updating, whenever defined factor is changed, relying on historical and live data, in addition to predicting future, expected scenarios. Thus, providing the opportunity to mitigate the challenge before it even exists. The algorithms will implement some approximation of nature based solutions, classifying and analyzing large random data sets, towards optimal solutions, to ensure the most successful strategies, and minimize the time and cost in the idea generation process in the conceptual stage.

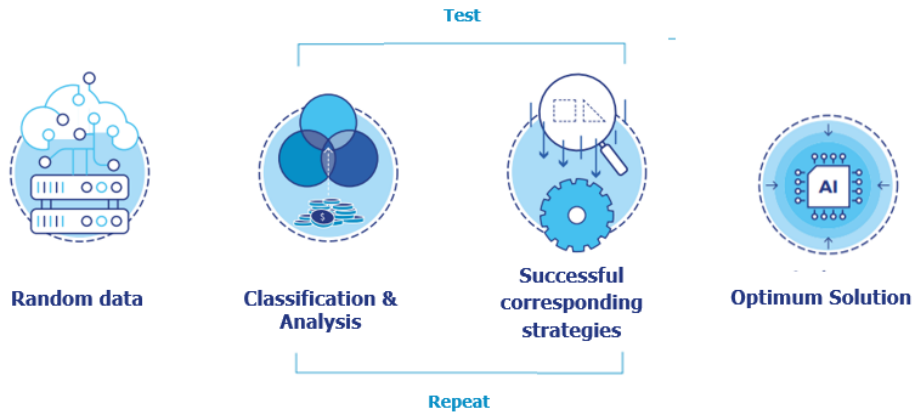

Figure 6: AI as a tool for climate action (The Researcher)

Therefore, AI will assist in the problem solving, unlocking the realm of possibilities and respond to different variables .Adopting and integrating AI will immensely benefit mitigating climate change , improving the drawbacks, enabling the extraction of broad scale data, reducing the dimensionality of a complex problem.

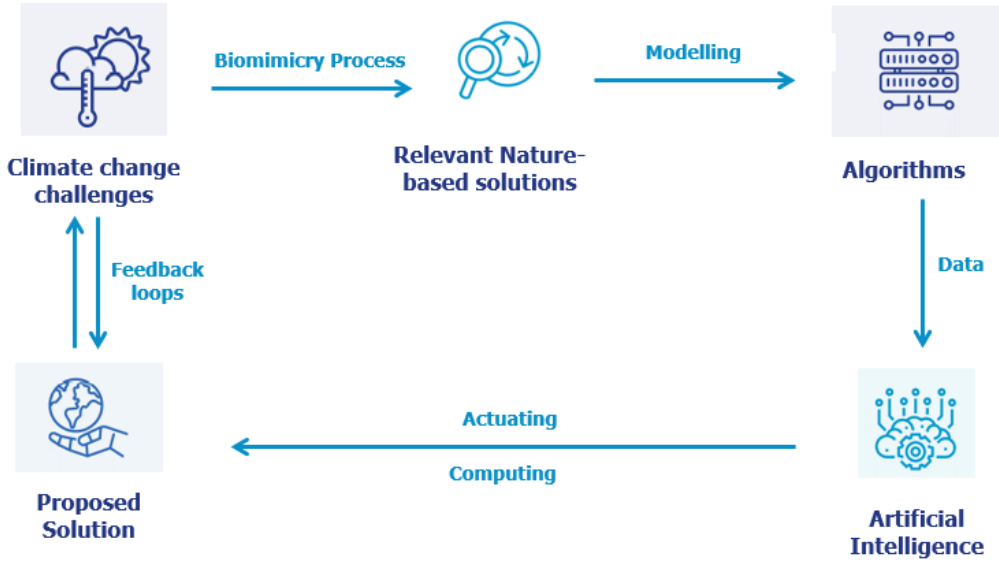

Figure 7: Proposed framework, (The Researcher)

The framework will act as an open source that will use intelligence (AI) to aid in the decision making of using nature-based ideas, expanding the biomimetic database, with corresponding applications related to climate change. Thus, the use of artificial intelligence will be accelerating, optimizing the conventional problem-solving process.

With a combination of a vast database of natural history and computational resources to extract insights and optimize the data for a given situation.
AI will immensely contribute in analyzing strategies that have been able to survive for an extended period or was able to adapt in its relevant context, therefore , some species tend to extinct .Resulting flexible tool that is able to perform multiple real time processes, based on detecting climatic challenges, analyzing information, organizing data, to identify the optimum configuration , Suitability of a model, including scale adjustment, combining of more than one feature in one design.

5. Tools and Methods

This paper proposes the application to one of the latest natural language processing (NLP) techniques, to assist with nature inspired designs, bridging the gap between nature domain and solution domain.
This section will discuss the potentials of AI , in merging data-driven approach and knowledge-based artificial intelligence, using Pre-trained Language Model (PLM) to automatically retrieve and map biological data, proposing nature inspired solutions, to automate the retrieval and mapping of biological information through text generation using the potentials of Generative Pre-trained Transformer (Chat GPT) as a base, generating three types of concepts generators, depending on the level of complexity. Finally, the generated concepts can be evaluated. Therefore, minimizing the time needed to generate and evaluate many natures inspired concepts.
Thus, by properly applying deep learning -based them to biological data and design problems, shows great promises in overcoming the challenges facing designers in understanding and recognizing the biological knowledge and information. Resulting and understandable representation to the natural language.
There are several examples that shows the potentials of the PLM and its ability to understand human language as well as the knowledge and logic behind it. BERT [8] or GPT [9], [10]are two of the most used PLMs in the field of NLP processing, due to their potentials in many NLP tasks like text completion and classification. “Fine-tuning” (Hinton G. S., 2006) and “Prompt-based” learning [9], are the two main mechanisms used by PLM to perform those NLP tasks.
In this paper, the focus will be on the “GBT” for concepts generation and evaluation, for it has the potential of being more knowledgeable to nature due to its pretrained base model on larger datasets than other PLMs. ChatGBT require fewer datasets to fine tune a model, and more promising in natural language generation. Open AI. Unlike BERT that lack the organization and generation of language, as it only relies on learning contextual representation of words, [11].
Also, will focus on the “Fine-tuning” for fine tuning the base model for different tasks, as it does not require a large number of task-specific datasets to re-train the pre-trained model for the desired task. In addition to updating the parameters of the base model within the process. However, Prompt-based, makes no change to the base model but can leverage what the model has already learned with simple prompts.

AskNature website [12],could be used as the dataset to fine tune the GPT model, where "Ask nature" offers more than 221 excellent nature inspired domains, each represented by textual information of a benefits, applications, the challenge, innovation details, and a biomimicry story. This variety more fine-tuning strategies , through reformulating and customizing the textual data into input-output pairs. By customizing the "AskNature" dataset and combining different fine-tuned models, different nature inspired design strategies could be generated.
Data composition of each innovation sample in the fine-tuning dataset, is described as follows: "Benefits" and "Applications" are described in the form of keywords, describing the advantages and applications of the innovation. The "Challenge" is described in form of a paragraph, with a statement to the challenging problem. "Innovation details" in form of a paragraph with an Introduction to the aims to solving the challenge., A paragraph to the "Biomimicry Story", describing the nature's strategy that is applicable as analogy for solving the challenge.
By fine-tuning the GPT model for text completion task, by first, defining the challenge that needs to be tackled, nature strategies are then retrieved accordingly, extracting the biological knowledge, which is then mapped to the solution domain. Second, assessing a correlation between the domains for evaluation, through separate text classifiers, fine-tuned from GPT base model, whether the generated solution solve the given problem or took inspiration from the biological data.
The generated outputs depend on the level of complexity desired by the user as follows:
A: Minimum constrains, taking only keywords from the "application" as input, not to limit the resulting output, this type is more general provides variety of results.
B: More detailed input, not only defining the input, but describing the "innovation" output expected.
C: Describing the problem in a more detailed form, presented as a paragraph, to limit the number of outputs.
The three types of generators are fine-tuned from ChatGBT, to gradually decreasing training loss of all three types.

6. Conclusion

The climate change we are experiencing nowadays shows major impact on environmental systems around the globe. Therefore, climate change mitigation, along with adaptation and resilience is crucial, in order to minimize its consequences and the resulting harm.
Artificial intelligence along with the field of biomimetics, show a great potential in mitigating climate change, by making use of the data input (ex: weather, temperature, humidity, etc..) in reference to their analogues in nature (plants, animals, insects, etc..), , creating correlations, suggesting solutions , based on their ability to receive large data amount continuously , generating biomimicry -based , accurate, appropriate, and adjusting relevant strategies and proposals, using data-driven techniques , enabling decision making and translating them to design principles.
There is a great opportunity to utilize such power and change our traditional workflow particularly in the early concept stages of the project to provide quick and appealing alternatives. AI won't replace architects, AI is going to replace their tasks, As it still involves an iterative process by architects doing prompt engineering and other tuning.

AI has the potential to combat and monitor climate change, assist in climate-focused AI solutions, from across sectors, domains. This would involve deriving best practices and lessons learned from nature and identifying their opportunities and potentials .

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