Landscape Architecture Carbon Emission Lifecycle Management Tool Based on Artificial Intelligence

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Abstract. In the contemporary discourse, carbon emissions have emerged as a focal point of global concern due to their role in inducing climate warming and precipitating ecological collapse. The establishment of a comprehensive carbon emission management system, coupled with effective measures, holds the potential to mitigate climate change, safeguard ecological integrity, improve health conditions, and promote global sustainable development. The Carbon Lifecycle AI Project Management Tool (CLA) proposed in this paper makes use of Large Language Model (LLM) and image processing model to intelligently analyze and manage the carbon emission of landscape architecture throughout its life cycle, and focuses on solving the carbon emission problem in landscape architecture. By gathering, integrating, and analyzing data related to landscape architecture, including information on material selection, plant configuration, and energy utilization, comprehensive monitoring and management of carbon emissions from landscape architecture are achieved. CLA not only offers real-time monitoring and analytical capabilities for carbon emissions but also identifies emission reduction opportunities and provides corresponding optimization recommendations, thus offering crucial support for the sustainable development of the landscape architecture industry.

Keywords: Artificial intelligence; CLA; Large language model; Carbon emission management tools; Landscape architecture; Emission reduction opportunity.

1. Introduction

Landscape is an important carrier of harmonious coexistence between human and nature, and an efficient management tool for urban which play an role in urban and regional development[1]. With the development of social economy and the improvement of people’s living standards, people’s demand and expectation for landscape architecture are also increasing. In recent years, the landscape architecture field has introduced new technologies, such as the Internet of Things, big data, etc., to provide new ideas and methods for landscape planning and design. These technologies bring new productivity, such as the Internet of Things technology that realizes information exchange and communication[2]. Big data technology can be applied to landscape planning and design, mainly through the introduction of new investigation methods, expands the data collection methods, and broadens the data collection scope. The added relevant information provides a basis for comprehensive, high-precision, and high granularity research, helps to discover and mine relationships between related elements[3].

Artificial Intelligence, a technology that is transforming all walks of life, serves as a tool for a wide range of uses (West and Allen 2018), will have far-reaching impacts and huge changes in finance, healthcare, e-commerce, traffic management, public safety and other fields[4]. Artificial Intelligence covers a wide range of technological tools such as Machine Learning (ML), Deep Learning (DL), Natural Language Processing (NLP), Computer Vision (CV), Knowledge Graphs, etc. They can realize functions such as perception, understanding, analysis, generation and reasoning of data[5]. In order to give full play to the potential of artificial intelligence technology in the landscape industry, this paper proposes an artificial intelligence-based landscape image-text information platform that can realize image processing and text generation functions. It provides users with professional and personalized landscape planning and design solutions consultation. The platform uses artificial intelligence technologies such as natural language processing (NLP),
machine learning (ML) and deep learning (DL), combined with domain knowledge base and reasoning engine. It understands, expands, matches and recommends user questions. It generates image-text solutions that meet user needs and preferences. The platform not only improves the efficiency and quality of landscape planning and design, but also enhances user participation and satisfaction, and promotes the innovation and development of landscape architecture.

The main contributions of this paper are as follows: (1) Design and implement an artificial intelligence-based landscape image-text information platform that can provide users with professional and personalized landscape planning and design solutions consultation. (2) Propose and apply a problem-requirement expansion and extension method, using natural language processing technology and domain knowledge base, to perform semantic understanding, intention recognition, key information extraction, vector representation, semantic relationship mining and other processing on user questions, providing a more comprehensive and accurate understanding of problem requirements. (3) Propose and apply a landscape plant planning and design block generation example, using deep learning technology and pre-trained models, to train and optimize models for specific domain landscape plant planning and design requirements, generate plant tables that meet user design conditions, and combine natural language generation models and professional prompt interaction systems to generate detailed and accurate landscape planning and design instructions.

2. Methodology

2.1 Carbon emission calculation method for building life cycle

The whole life cycle of a building can be divided into four stages: preparation stage, production stage, transportation stage and construction stage. The carbon emissions generated at each stage are calculated using different formulas.

The total carbon emissions of a building are the sum of the incremental carbon emissions of the building components at each stage of the building (see formula (1)). The carbon emissions data for each stage of the building consists of three parts: "People, machinery and materials", and the carbon emissions of components, people, equipment and supporting materials for each stage of the building should be calculated (see formula (2)).

\[ C_i = C_{mp} + C_{cp} + C_{tr} + C_a \]  \hspace{1cm} (1)

\[ C_s = C_c + C_p + C_a + C_{sm} \]  \hspace{1cm} (2)

\( C_i \) is the total carbon emission of a building; \( C_{mp} \) is the total carbon emission in the material preparation stage; \( C_{cp} \) is the increment of carbon emission in component production stage; \( C_{tr} \) the increment of carbon emission during component transportation.; \( C_a \) is the increment of carbon emissions during the assembly phase of a component.

\( C_s \) is the total carbon emission at each stage; \( C_c \) is the carbon emission of components; \( C_p \) is the carbon footprint of people; \( C_a \) is the carbon emission of the device; \( C_{sm} \) is the carbon footprint of the supporting material.

2.1.1 Preparatory stage

The carbon emissions of this stage only need to calculate the emissions of various materials in all components, the formula is as follows:

\[ C_{mp} = \sum_{i=1}^{n} \left( \sum_{a=1}^{n} F_a \times Q_a \right) \times Q_i \]  \hspace{1cm} (3)

I is a type i building component; \( Q_i \) is the number of building components of the first type; \( F_a \) is the carbon emission coefficient of Class a materials (the carbon emission coefficient is set according to the standard carbon emission coefficient released by IPCC, and different countries and regions can also set different values according to the carbon emission factor report of local authorities); \( Q_a \) is the number of class a materials in Class i constructs.
2.1.2 Production, transportation, and construction stages

The carbon emission calculation content of the three stages (component production, transportation and construction stage) is different, but the calculation structure is the same, so the carbon emission calculation formula is explained together. Carbon emissions are calculated as follows:

\[
C_{cp/tr/c} = \sum_{i=1}^{n} (C_p + C_e + C_{sm}) \tag{4}
\]

\[
C_{cp} \quad \text{is the carbon emission of personnel at this stage; } C_e \quad \text{is the carbon emission of the equipment in this stage; } C_{sm} \quad \text{is the carbon emission of supporting materials at the present stage.}
\]

\[
P_a \quad \text{represents the number of workers required by process a to process Class I parts at this stage; } F_p \quad \text{is the personnel standard time carbon emission factor, and its value is the same as that of fuel carbon emission factor); } T_{pa} \quad \text{is the number of personnel hours required to process a during the processing of Class i parts at this stage.}
\]

\[
C_e = \sum_{a=1}^{n} E_a \times F_{ea} \times T_{pa} \times Q_a \tag{6}
\]

\[
E_a \quad \text{is the energy intensity of Class a equipment processing Class i components at this stage; } F_{ea} \quad \text{is the energy carbon emission coefficient of Class a equipment, and its value is the same as the material carbon emission coefficient); } InT_{pa} \quad a \quad \text{is the running time of Class a equipment processing Class i components at this stage}[6].
\]

2.2 Build carbon emission database based on artificial intelligence

2.2.1 Database Construction

In order to store and manage image data and text data related to landscape architecture learning, design and other related fields, selecting a database management system to build the database is critical. A database provides a platform to organize, store and retrieve the planned and actual performance data of projects in a logical and efficient manner. The database management system queries the stored project data using SQL (structured query language) to generate different management reports for control purposes. In this paper we have used MySQL as the database management system, and used Python for data manipulation and query.

According to the geographical location of the building, project scale, project life and others, the carbon emissions of the building are estimated at the four stages of preparation, production, transportation and construction. The problem chain framework is shown in Figure 1.

![Diagram of carbon emission database](image-url)
LLM outputs the problems in the preset problem chain to the user one by one, and performs the following operations after each problem is output: In the first stage, the first keyword is extracted according to the received user input data for the current problem, and then the preset planning and design database is searched according to the extracted first keyword to obtain the site information corresponding to the current problem; The LLM then asks whether a design scheme is required based on the planning and design condition information corresponding to each problem in the preset problem chain. If the user needs, according to the preset problem chain each problem corresponding to the planning and design condition information search method database, confirm the design scheme and design material selection, and then the planning and design scheme, design material selection output to the user, according to the user's reply content to modify the design scheme; If the user does not require a design proposal, the LLM searches a pre-generated carbon emission database based on the planning design condition information corresponding to each issue in the preset problem chain, providing the design options directly to the user.

In the second stage, according to the obtained site information and design material selection, the data is imported into the carbon emission calculator for simulation. According to the simulated results of the carbon emission database, the carbon emission of the building in different cycles is calculated, and then the carbon emission is compared with the specific standard to determine whether the carbon emission exceeds the standard, and the emission reduction opportunity is identified and the user is asked whether to reduce emissions. If the user is not satisfied, the carbon emission database is retrieved, the design materials and design area are optimized with LLM, and then the emission reduction planning and design scheme is exported to the user, and the planning and design scheme is modified and improved according to the user's reply, and the final data is exported.

2.2.2 Database collection and preprocessing

During this stage, in order to collect more image and text data for training LLM, we utilized methods such as web crawlers, social media platforms, and professional databases to obtain a large amount of landscape architecture-related images and textual information. Subsequently, preprocessing work such as deduplication, cleaning, and annotation was carried out. The image data can provide a large number of planning schemes for the database, while the textual data can provide rich information for the material carbon emission database. We also compiled professional databases according to industry needs, such as the Database of Common Landscape Plants in China, as shown in Figure 2.
2.2.3 Identify mitigation opportunities and propose strategies

Our goal is not only to calculate the total carbon emissions of the site, but more importantly to achieve carbon neutrality and build a more ecologically livable city. Therefore, our model will achieve this goal by identifying emission reduction opportunities and proposing corresponding strategies.

First, the model will measure the total carbon emissions of the site and compare them with emission standards. The purpose of this step is to determine whether the current level of carbon emissions exceeds the prescribed standard, thus providing a benchmark for subsequent mitigation strategies. If the total carbon emissions of the site exceed the standard, then we will need to take more aggressive emission reduction measures to achieve carbon neutrality. Secondly, the model will pull relevant cases from the method database and simulate them to generate a variety of possible carbon emission reduction processes. By simulating different emission reduction processes, we can predict and evaluate the effect of emission reduction under different strategies. These strategies may involve the selection of materials, the optimization of building design, the improvement of energy use, etc., aiming to reduce the carbon emissions of the whole life cycle of the building.

3. Discussion

3.1 Large-scale language model comparison

To illustrate the advantages of the landscape architecture text information platform proposed in this paper from a professional perspective, we compare it with a general large language model ChatGPT. ChatGPT is an open-domain chatbot based on the GPT-3.5 model, which can have natural and fluent conversations with users. We chose a typical landscape design problem as a test case, namely “Hello, I want to design a 2000 square meter pocket park plant planting design in Beijing area, with the theme of welcoming the future, do you have any good suggestions?” and asked the two platforms this question respectively, and observed and analyzed their answers.

After application, we find that the answers of the two platforms are different as follows: ChatGPT's answers are more general and general, and lack of professionalism; CLA gives the material selection table by retrieving the database and calculates the corresponding carbon
emissions, which makes its answer more accurate and specific. ChatGPT's answer mainly gives some common design suggestions, such as plant selection, vertical gardens, etc., without in-depth analysis of the characteristics and needs of Beijing area and pocket park. CLA biological answer is based on the climate and soil conditions in Beijing, as well as the area and theme of Pocket Park, providing users with specific material configuration information, design guidance and corresponding carbon emissions, which can better meet the design needs of users. ChatGPT's answers are more text-based, while CLA's answers are more targeted answers that have been continuously optimized.

3.2 Trends of AI in landscape architecture

Through the platform construction and problem-solving attempts, we believe that AI can provide help in the following scenarios for landscape architecture. For example, through the use of various artificial intelligence software, such as Midjourney, DALL-E, Stable Diffusion[7], users’ text input can be converted into AI-generated images, providing a faster and more innovative way for architectural design. In addition, artificial intelligence can also use technologies such as BIM, IoT, etc., to achieve collaborative management and intelligent operation of construction projects[8]. In the medical industry: artificial intelligence is mainly applied to diagnosis, treatment, prevention and other links in the medical industry. By using various AI software, such as IBM Watson, Google DeepMind, Microsoft Healthcare Bot, etc[9], medical data can be analyzed and mined, providing more accurate and effective support for medical decision-making[10].

In the areas of landscape architecture, the employment of artificial intelligence predominantly assumes a facilitative role, enhancing the scientific rigor and operational efficiency of projects, without infringing on the expertise of professionals in the field. In terms of its application domain, AI tends to concentrate on specific technical niches, encompassing advanced image processing, automated text generation, and intricate digital modeling. Therefore, its integration within landscape architecture is characterized by a specialized and customized approach, rather than a generalized or standardized methodology. Furthermore, the complexity of landscape architecture, which necessitates the consideration of multifaceted factors such as the natural environment, societal cultures, and user preferences, poses a considerable challenge in the application of AI. Consequently, the current utilization of AI in landscape architecture represents a novel and exploratory endeavor, advancing the frontiers of knowledge in this interdisciplinary field.

To sum up, the actual application trend of artificial intelligence in the landscape architecture industry shows its great potential in improving the efficiency and quality of landscape planning and design, and also shows the difference with other industry development trends and application methods. Under the tide of the era of intelligent life of all people, AI entering various industries is the inevitable of The Times. Therefore, this paper believes that in landscape architecture design, artificial intelligence technology should not be regarded as a substitute or threat, but should be regarded as an auxiliary tool and innovation driving force for planning and design. Through cooperation and complementarity with human designers, landscape planning and design at a higher level and lower carbon can be achieved, and better contribute to the improvement of the quality of human living environment.

4. Conclusion

This study aims to build an artificial intelligence-based landscape architecture carbon emission lifecycle management tool, aiming to solve the problems of low efficiency, high cost and insufficient information in traditional landscape planning and design methods. By building a database of design methods and applying natural language processing, machine learning and deep learning technologies, the system can provide users with professional and personalized landscape planning and design scheme consultation, so as to effectively improve the efficiency and quality of planning and design. In addition, by building the problem chain and carbon emission database, as
well as using natural language processing, machine learning and deep learning technologies to understand and reason users' problems, the system can provide users with more intelligent responses, propose problem-demand extension and extension methods, and combine natural language generation models and professional prompt interaction systems to establish problem-solution matching models. Through data integration and analysis, using natural language processing and deep learning algorithms, this system can provide more personalized solutions to meet the preferences and needs of users, and scientifically manage carbon emissions to achieve the full life cycle management of landscape building carbon emissions.

Although CLA has many advantages, there are still some shortcomings that need to be further discussed. First of all, although the platform provides a comprehensive and comprehensive solution in terms of carbon emission management, in the practical application process, it may be limited by data quality and integrity, especially in the construction and update of carbon emission database, there are difficulties and uncertainties in data acquisition. Second, although the platform provides designers with design methods and information, in practical applications, designers may still need to have some knowledge and experience related to carbon emissions in order to better use the platform for design optimization. In addition, although the model can be optimized automatically, in some complex cases, the algorithm may not be efficient or the results are not accurate enough, which needs to be further optimized and improved. In summary, although CLA has important application prospects and value in the field of building carbon emission management, it still needs further research and improvement to enhance its practical application effect and sustainable development ability.

Future research directions include but are not limited to: further improving the construction of carbon emission database to improve data quality and integrity; research and develop intelligent algorithms and optimization techniques to improve the algorithm efficiency and result accuracy of CLA; optimize the user interface and interactive experience of CLA to improve user usability and ease of operation; explore the role of CLA in supporting sustainable building assessment and policy development; develop interdisciplinary cooperation to apply CLA to a wider range of fields, such as urban planning, energy management, environmental protection and other fields. Through the continuous development of the above research directions, the application effect and sustainable development ability of CLA can be further improved, and greater contributions can be made to the promotion of carbon emission reduction work and the sustainable development of the construction industry.

References


