Employing Data-Driven NOA-LSSVM Algorithm for Indoor Spatial Environment Design

A Case Study of Physical Bookstores

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***Abstract*—This study aims to enhance the precision and efficiency of indoor spatial design for college physical bookstores in the context of the new media environment. To achieve this, a novel intelligent analysis model was developed by integrating the Navigator Optimization Algorithm (NOA) with the Least Squares Support Vector Machine (LSSVM). The research analyzes the relationship between the new media environment and bookstore design, identifies key design principles, and establishes performance metrics. The proposed NOA-LSSVM model optimizes design parameters by utilizing a hybrid convergence-divergence search mechanism, achieving improved accuracy and computational efficiency. A case study of Jilin Jianzhu University's bookstore was conducted to evaluate the model's performance. The NOA-LSSVM model was compared with three other optimization algorithms: the Flower Pollination Algorithm (FPA), Whale Optimization Algorithm (WOA), and Sine Cosine Algorithm (SCA). Results showed that the NOA-LSSVM model achieved superior accuracy, with a Mean Absolute Percentage Error (MAPE) of 2.9, significantly lower than FPA (4.6), WOA (3.8), and SCA (4.2). Additionally, the model exhibited faster convergence and enhanced design efficiency, optimizing the bookstore's functional zones and spatial layout to balance dynamic and quiet areas effectively. In conclusion, the NOA-LSSVM model demonstrates a robust capability to optimize indoor spatial design in the new media environment, outperforming traditional methods in accuracy and practicality. This study provides valuable insights for integrating intelligent algorithms into spatial design processes, with the potential for broader applications in other commercial or educational spaces. Future research should focus on extending the model's generalizability and incorporating advanced media technologies for enhanced user experiences.**

***Keywords*—New media environments; data-driven algorithms; indoor spatial environment design; mariner optimization method**

I. Introduction

In order to enhance students' learning materials and services, the growth of college physical bookshops is being actively supported to strengthen their impact in the area of education [1]. The proliferation and use of new media, facilitated by the advancement of Internet technology and the exponential growth of Internet users, has presented unparalleled prospects and difficulties across all sectors of society. Consequently, physical bookshops are also confronted with the need for modernization and adaptation. To adapt to the growing market need, physical bookshops are integrating new media technologies to expedite their transition and bolster their competitiveness [2]. Conducting research on the interior space design of college physical bookstores in the new media environment may stimulate innovation in bookstore space design and enhance the quality of services. Additionally, it can serve as a valuable resource for the growth of campus bookstore markets and industry transformation [3].

The study on the interior space design of college physical bookshops in the new media environment is presently in its first phase. It primarily focuses on two aspects: the use of new media technology in the design of physical shops, and the analysis of how new media technology is applied [4]. Wang and Wang [5] examine the successful collaboration between college physical bookstores and publishers in order to address the high cost of textbooks. Sari [6] introduces new design concepts to modify the layout of college physical bookstores. Bae [7] investigates the current state of development of college physical bookstores and proposes effective strategies to renovate them. Soureshjani et al. [8] suggests several reform measures to transform bookstores into vibrant spaces that promote a new culture of wisdom and reading. Al-Ansari et al. [9] thoroughly discusses the appeal of college campus bookstores and presents a new development strategy that is suitable for the digital era. Nyboer [10] analyzes the challenges from various perspectives such as cultural experience, construction mode, and business model, and provides a range of practical solutions. The integration of intelligent algorithms and the interior space design of college physical bookshops in the new media environment has become an essential approach for the future development of intelligent and digital space design. Intelligent algorithms may be categorized as supervised learning, unsupervised learning, semi-supervised learning, and other ways. The utilization of data-driven intelligent algorithms in analyzing the application of new media technology in indoor space design has become increasingly prevalent. This method plays a crucial role in researching the design of college physical bookstores in the new media environment. It enhances the efficiency of indoor space design and expedites the design process [11]. Despite the ongoing improvement in educational conditions and the increasing importance of campus physical bookstores, there are still several issues in the process of integrating intelligent technology into the interior space design of college bookstores. These include: 1) a lack of research on the application of new media technology in the interior space design of college bookstores; 2) ineffective utilization of data generated during the design process of college bookstores; and 3) the immaturity of intelligent technology used in college bookstore interior space design.

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This paper strives to address the intellectual requirements of college students in physical bookstores by integrating new media technology and artificial intelligence. It proposes an application analysis model for the interior space design of college physical bookstores in the new media environment, using an improved data-driven algorithm. The study investigates the correlation between the new media environment and the layout of indoor spaces in bookstores. It takes advantage of various research methods such as literature research, survey research, interdisciplinary research, and inductive comparison. The study analyzes the design process of indoor spaces in college physical bookstores and develops an intelligent application analysis scheme for such spaces. This scheme combines the navigator optimization algorithm with the LSSVM model. Additionally, the study proposes a new media model based on the NOA-LSSVM model. A novel media-based NOA-LSSVM model is offered as an analytical tool for the interior space design of college physical bookshops, using the Voyager optimization algorithm and the LSSVM model. Using the physical bookshop of Jilin Jianzhu University as a case study, the effectiveness of the proposed NOA-LSSVM model is examined and evaluated by comparing it with other application analysis methodologies.

This paper is structured as follows: Section II explores the relationship between the new media environment and the physical layout of college bookstores, providing a detailed analysis of the design process and identifying key principles and metrics for indoor spatial design. Section III introduces the NOA-LSSVM model, detailing the principles of the Navigator Optimization Algorithm (NOA) and Least Squares Support Vector Machine (LSSVM), and describes how these are integrated into a data-driven intelligent analysis framework. Section IV presents a case study of Jilin Jianzhu University's bookstore, demonstrating the model's application, design outcomes, and a comparative evaluation of its performance against other optimization algorithms. Finally, Section V concludes with key findings, highlighting the NOA-LSSVM model's superior accuracy and efficiency in optimizing design processes while outlining potential areas for further research and practical implementation.

II. Design Interior Space of College Physical Bookstores

A. *The Connection between the Contemporary Media Landscape and the Physical Layout of Bookstores*

The emergence of new media complements the growth of physical bookshops. Its implementation impacts individuals' perception of the reading experience, enhances the interior spatial setting of bookstores, and maximizes the creation of a favorable reading ambiance [12]. The indoor space design of college bookstores has undergone significant changes in response to the new media environment. These changes primarily include: 1) improving the overall spatial experience; 2) diversifying the nature of the space; and 3) enhancing the spatial environment, as depicted in Fig. 1.

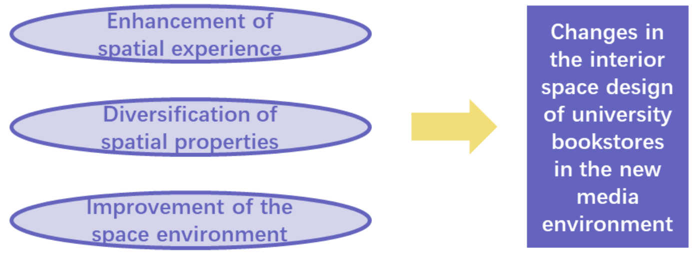


Fig. 1. Changes in the new media environment on the interior space design of college bookstores.

B. *Analysis of the Interior Space Design Process of College Physical Bookstores*

1) The key aspects of designing the interior space of college physical bookshops: The need for college physical bookshops among college students has seen significant changes with the progress of time. The interior space design of these bookstores has evolved to focus on utility, industry diversification, experience elements, and artistic aspects [13], as shown in Fig. 2.

Fig. 2. Trends in the design of physical bookstores in universities.

2) Analysis of the design process: The interior space design of college physical bookstores follows specific development direction and design principles, namely the humane principle, functional principle, experiential principle, and epochal principle (as depicted in Fig. 4). This design process includes various steps such as space planning and layout, illumination design, color matching and style, display and exhibition design, furniture and decorations selection, air-conditioning and ventilation system, sound and noise control, online and offline combination, out-of-store time and budget control, detail design, and others [14] (as highlighted in Fig. 3).

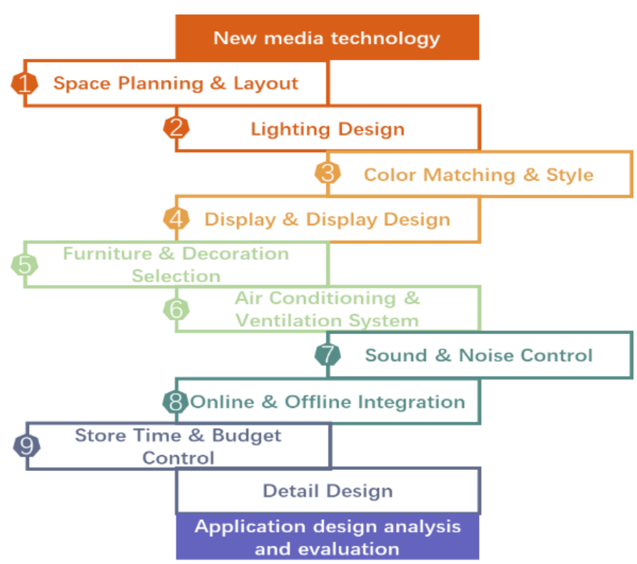


Fig. 3. Design process of physical bookstores in universities.

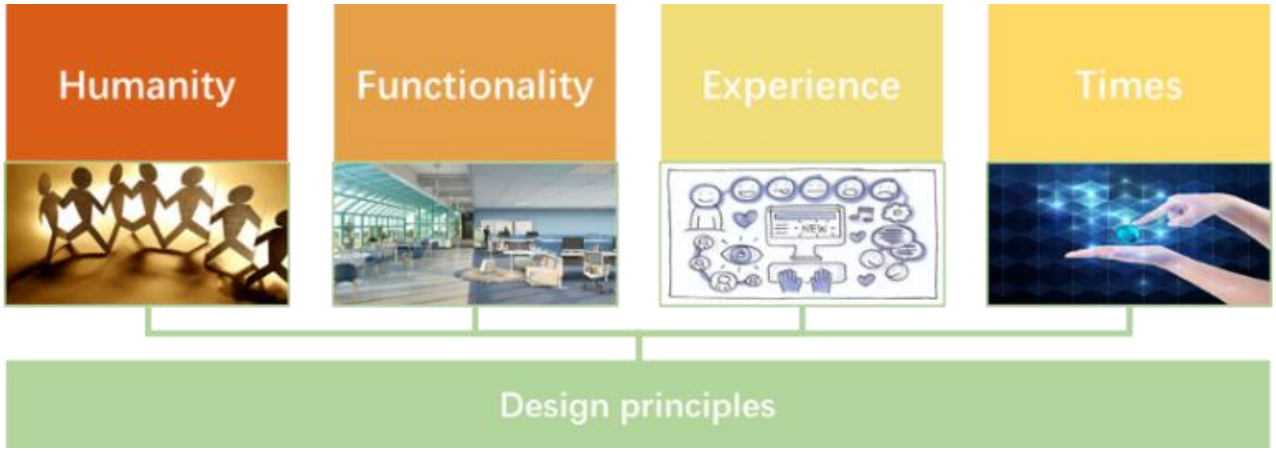


Fig. 4. Design principles.

3) Develop a process to obtain metrics for analyzing application design: This paper tests the application analysis indexes for indoor space design of college physical bookstores in the new media environment. The analysis focuses on three aspects: design elements S, functional space K, and design research Y, as illustrated in Fig. 5.

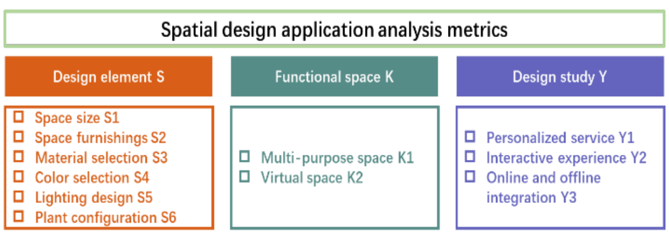


Fig. 5. Indicator analysis of the application of interior space design of college physical bookstores in the new media environment.

- Design element S comprises of space size S1, space furnishings S2, material selection S3, colour selection S4, lighting design S5 (Fig. 6), and plant setup S6 (Fig. 7);

Fig. 6. Lighting design.

Fig. 7. Plant configuration.

- The functional space K comprises of two components: multifunctional space K1 and virtual space K2;
- Design study Y comprises of personalized service Y1, interactive experience Y2, and the integration of offline and online platforms Y3.

C. Program for Designing the Interior Space of Physical Bookstores in Higher Education Institutions

Focusing on the problem of application analysis of interior space design of college physical bookstores in media environment, this paper proposes a method of application analysis of interior space design of college physical bookstores based on data-driven algorithm, and the specific design scheme is shown in Fig. 8. The scheme analyzes the process of interior space design of college physical bookstores in media environment, extracts relevant application analysis indexes, collects application analysis data, standardizes and annotates the dataset, combines Voyager optimization algorithm [15] and LSSVM model [16], constructs the application analysis model of interior space design of college physical bookstores in media environment, and carries out the performance validation and analysis of the model by using examples.

According to the design scheme, the research on the application analysis method for the interior space design of college physical bookstores in the media environment includes key technologies such as the extraction and construction of application analysis indexes, data collection and pre-processing, design model construction and optimisation, and case validation and analysis, as shown in Fig. 9.

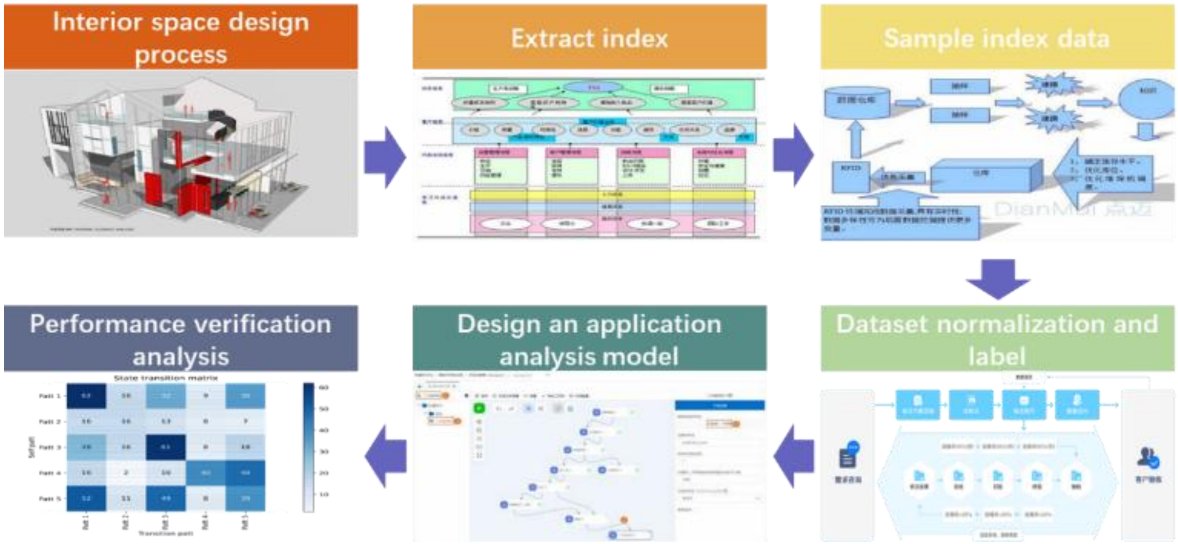


Fig. 8. Applied analysis of interior space design of physical bookstores in higher education design scheme.

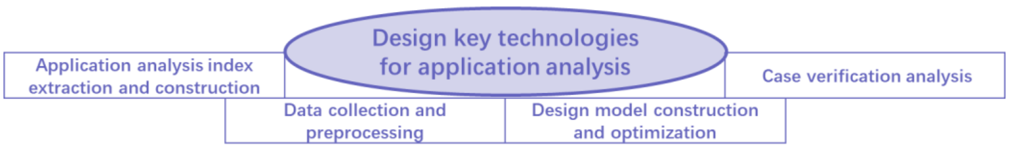


Fig. 9. Key techniques for applying analysis to interior space design of physical bookstores in universities.

III. Intelligent Analysis Algorithm for Interior Space Design

A. NOA-LSSVM Model

1) Voyager optimisation algorithm: Navigator optimization algorithm (NOA) [15] is a new type of meta-heuristic intelligent algorithm inspired by the exploratory behaviour of navigators. The NOA algorithm alternates between "searching" and "exploiting". The NOA algorithm alternates between "searching" and "exploiting", when the search period is even, the navigators search for the solution by divergence; when the search period is odd, the navigators search for the solution by convergence, and find the optimal solution by alternating iterations.

The navigator position is a candidate solution and the expression is:

$$P = \begin{bmatrix} P_{11} & P_{12} & \cdots & P_{1d} \\ P_{21} & P_{22} & \cdots & P_{2d} \\ \vdots & \vdots & \ddots & \vdots \\ P_{n1} & P_{n2} & \cdots & P_{nd} \end{bmatrix} \tag{1}$$

where n is the number of navigators and d is the number of decision variables.

The navigator adaptation values are expressed as follows:

$$F = \left[F_1, F_2, \cdots, F_n\right]^T \tag{2}$$

a) Convergence mode: The position update formula for the convergent search performed by each navigator during the convergence cycle is as follows:

$$P_{ij}^{k+1} = P_{gj}^{k} + D_{ij} \cdot e^{bt} \cdot \cos(2\pi t) \tag{3}$$

$$D_{ij} = \left|P_{gj} - P_{ij}\right| \tag{4}$$

Where, k is the number of iterations; D_{ij} is the distance between the position of mariner i and the current optimal position in the j^{th} dimension; b is the shape coefficient of the solenoid, which takes the value of 1; and t is a random number. Logarithmic spiral is shown in Fig. 10.

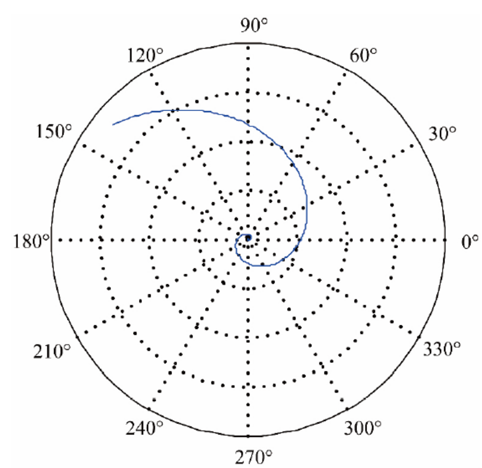


Fig. 10. Logarithmic spiral.

b) Divergent approach: The NOA algorithm uses the Levy flight strategy [17] as a model for dispersion, and the specific dispersion model is as follows:

$$P_i^{k+1} = \begin{cases} P_i^k + rL(d)\left(P_g^k - P_i^k\right) & k < N_{iter}/2 \\ P_i^k + r\left(L(d)\cdot P_g^k - P_i^k\right) & k \geq N_{iter}/2 \end{cases} \quad (5)$$

Where r is a constant, set to 0.7; $L(d)$ is the Levy flight step (Levy flight trajectory in 3D space is shown in Fig. 11); N_{iter} is the maximum number of iterations.

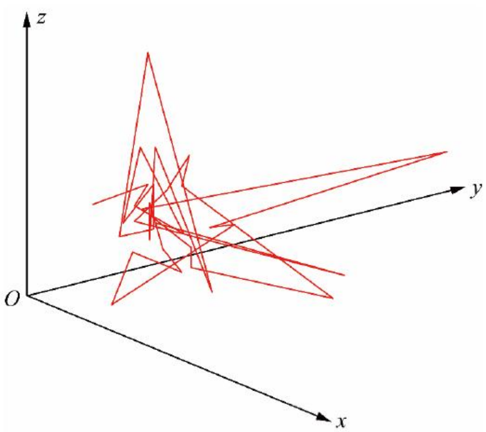


Fig. 11. Levy flight path in 3D space.

c) Search cycle: The search cycle is an important tool used by the NOA algorithm to alternate between "searching" and "utilising". If the number of search cycles is set too large, the number of iterations in each search cycle will be too small, and the navigators will not be able to fully diverge or converge; if it is set too small and similar to the idea of traditional intelligent algorithms of searching for excellence, the navigators will not be able to effectively "use" the "search". If the setting is too small, it is similar to the idea of traditional intelligent algorithms, and the "search" of navigators cannot be effectively "utilised". After testing, when the number of search cycles to take the maximum number of iterations 1/30 ~ 1/10, you can achieve better results, the number of search cycles in this paper to take 1/20 of the number of iterations.

d) Transboundary processing techniques: In order to avoid the navigator to enter outside the boundary, the NOA algorithm adopts an out-of-bounds processing technique. When the navigator crosses the boundary and $z < p$, its boundary crossing processing technique is as follows:

$$P_{ij} = \begin{cases} P_{j\max} & P_{ij} \geq P_{j\max} \\ P_{j\min} & P_{ij} < P_{j\min} \end{cases} \quad (6)$$

where P_{ij} is the position of the jth dimension of the ith navigator; $P_{j\max}$ and $P_{j\min}$ are the upper and lower bounds of the jth dimension of the navigator, respectively; p is a constant set to 0.5; and z is a random number.

When a navigator crosses the border and $z \geq p$, his or her crossing is handled with the following technique:

$$P_{ij} = \begin{cases} P_{j\max} - Ce_1\left(P_{j\max} - P_{j\min}\right) & P_{ij} \geq P_{j\max} \\ P_{j\min} + Ce_1\left(P_{j\max} - P_{j\min}\right) & P_{ij} < P_{j\min} \end{cases} \quad (7)$$

Where C is a constant with a value of 0.01 and e_1 is a random number.

According to the optimisation strategy of the NOA algorithm, the pseudo-code of the NOA algorithm is shown in Table I with the following steps:

- Step 1: Initialise the number of navigators, dimensions and the number of search cycles to generate the initial position of the navigator;
- Step 2: Calculate the initial navigator fitness value and update the optimal fitness value;
- Step 3: At each odd search cycle, update the mariner position using convergence; at each even cycle, update the mariner position using divergence;
- Step 4: During each iteration, compare the navigator fitness value with the global optimum and update the global optimum;
- Step 5: Interpret whether the maximum number of iterations is reached, if so output the optimal solution, otherwise jump to step 3.

TABLE I. PSEUDO-CODE OF THE NOA ALGORITHM

Algorithm 1: NOA algorithm	
1	Initialize navigator number, dimension, search periods;
2	Generate navigator population;
3	Calculate fitness and output best fitness;
4	For t=1:Max iter
5	If t== odd search periods
6	Use convergence to update the navigator's position,
7	Else
8	Use divergence to update the navigator position;
9	End
10	Update navigator's position;
11	Bound position using upper and lower limits;
12	Update best navigator position;
13	End
14	Output best solution.

2) LSSVM algorithm: Least Squares Support Vector Machine (LSSVM) [18] A variant of Support Vector Machine

(SVM) [19]. Compared with the traditional SVM, LSSVM simplifies the computational process by solving the model parameters through the least squares method, which transforms the optimisation problem into the solution of a system of linear equations.LSSVM is not only suitable for classification problems, but also widely used in regression problems. It has high computational efficiency and good generalisation ability, which is especially suitable for dealing with large-scale datasets.

a) LSSVM basic principles: The core idea of LSSVM is to use the least squares method to solve the parameters of the SVM model by eliminating the Lagrange multipliers in the form of minimising the sum of squares of the errors and transforming the original convex quadratic programming problem into a system of linear equations. This system of linear equations can be solved by numerical methods (e.g., Cholesky decomposition, iterative methods, etc.) to obtain the parameters of the model. The output of the LSSVM model is obtained by a linear combination of the kernel functions in a high-dimensional space, as shown in Fig. 12.

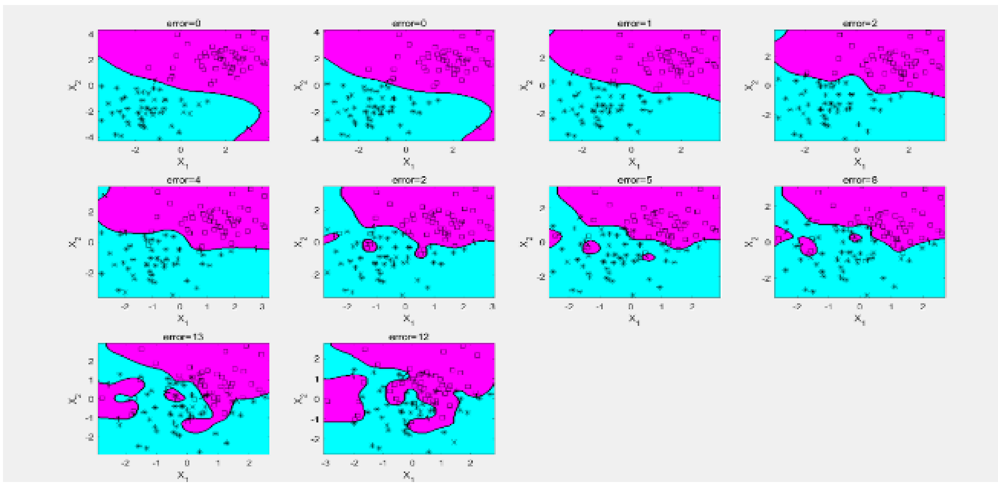


Fig. 12. Structure of LSSVM algorithm.

b) Features of LSSVM: The idea of LSSVM is characterized by the following features: a) great computing efficiency; b) resilience to noisy data; c) simplicity in finding parameter solutions; d) application to nonlinear problems; and e) absence of sparsity [20], as seen in Fig.13.

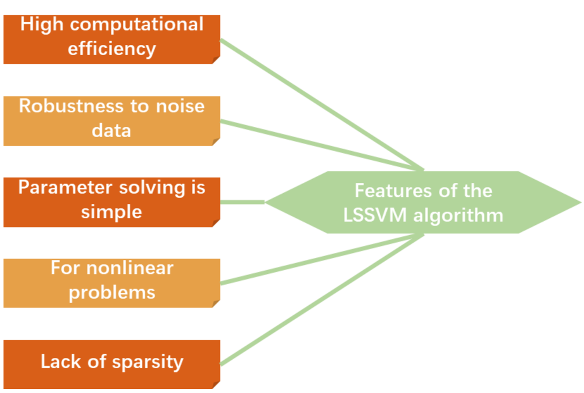


Fig. 13. Characteristics of the LSSVM algorithm.

c) Utilization of least squares support vector machines (LSSVM): The Least Squares Support Vector Machine (LSSVM) is used in several domains (Fig. 14), such as financial market analysis, medical diagnosis, bioinformatics, image analysis, industrial control, and machine learning. Due to its high computing capacity and strong generalization abilities, it has become a very effective tool for tackling real-world issues [21].

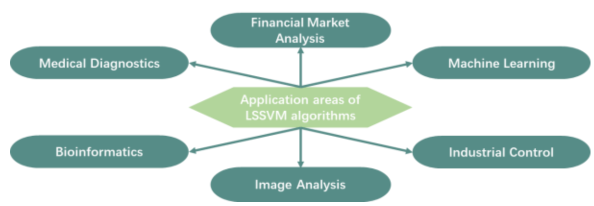


Fig. 14. Application areas of LSSVM algorithm.

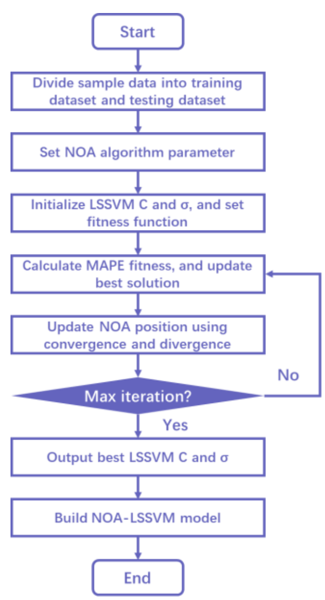


Fig. 15. Flowchart of NOA-LSSVM algorithm application analysis.

3) NOA-LSSVM model: This work employs the NOA algorithm to enhance the accuracy of application analysis in the LSSVM model. The algorithm optimizes the parameters of the LSSVM, namely the penalty coefficient and kernel bandwidth, using the MAPE as the fitness value function. The NOA algorithm is employed to search for optimization through both convergence and divergence modes. The specific flow chart of the application analysis using the NOA-LSSVM model is depicted in Fig. 15.

B. Application of NOA-LSSVM Model in Intelligent Analysis

Combined with NOA-LSSVM model, this paper proposes an intelligent analysis method of college physical bookstore indoor space design based on NOA-LSSVM model, and the specific application analysis diagram is presented in Fig. 16. Firstly, examine the relationship between the new media environment and the indoor space of bookstores. Analyze the process of designing the indoor space of physical bookstores in colleges and develop a design scheme for the indoor space of physical bookstores in colleges. Extract the application analysis of the design of the indoor space of physical bookstores in colleges within the media environment. Secondly, collect the index data for the design of the indoor space of physical bookstores in colleges based on the established set of indices. Preprocess the input data, annotate it, and output the scores for the application analysis. Utilize the NOA-LSSVM algorithm to construct an intelligent analysis model for the interior space design of physical bookstores in colleges. Finally, use an example to verify the feasibility of the design scheme for the interior space of physical bookstores in colleges, as well as the efficiency of the intelligent analysis algorithm for interior space design based on the NOA-LSSVM model.

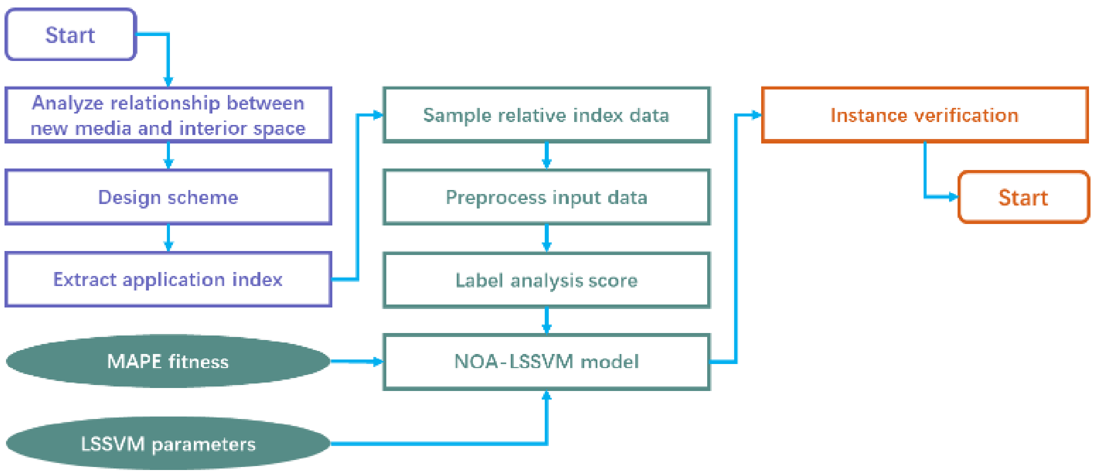


Fig. 16. Flow chart of intelligent analysis of interior space design for college physical bookstore based on NOA-LSSVM model.

IV. Example Analyses

A. Presentation of the Case

In order to verify the feasibility of the interior space design scheme of college physical bookstore and the effectiveness and feasibility of the intelligent analysis algorithm of college physical bookstore interior space design based on NOA-LSSVM model, this paper takes the indoor space design of physical bookstore in the Jilin Jianzhu University as an example to be analysed.

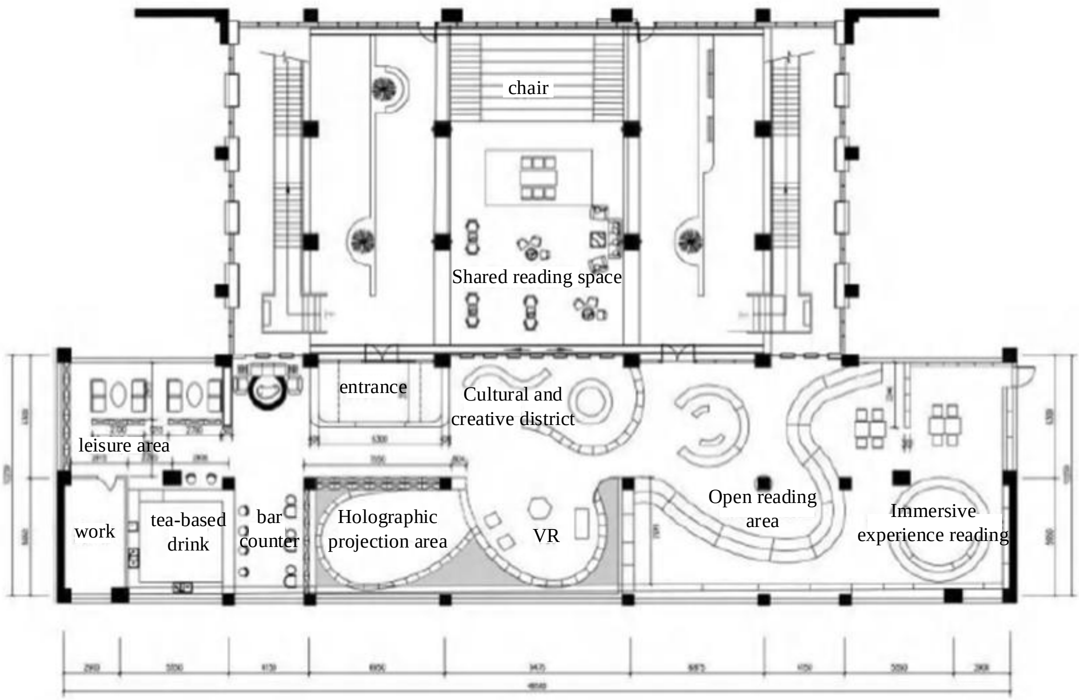
The current layout is shooting to investigate the impact of the new media environment on college physical bookstore spaces. It focuses on the bookstore space design of Jilin Jianzhu University. The goal is to showcase the changes brought about by the integration of new media into various aspects of life, as well as the higher expectations of college teachers and students for campus bookstores. Following the principles of the era, experience, functionality, and humanization, the design aims to create a new type of college physical bookstore that combines book purchasing, cultural exchange, leisure, immersive reading, and experiential services. The bookstore is an innovative university physical shop that offers book purchasing, cultural interchange, leisure activities, immersive reading experiences, and experiential services.

B. Algorithm Configuration

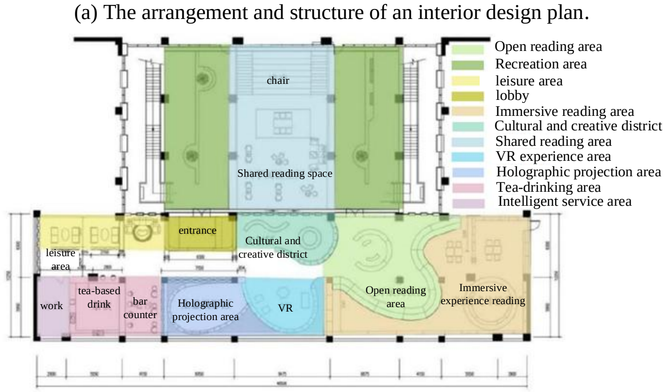
This work used the Flower Pollination Algorithm (FPA) [22], Whale Optimization Algorithm (WOA) [23], and Sine Cosine Algorithm (SCA) [24] as comparison algorithms to optimize the parameters of the LSSVM model. The optimization technique was iterated 500 times, with a population size of 50. The NOA algorithm underwent 25 search cycles, while the other parameters of the algorithm were established according to references [22-24].

C. Design Outcomes

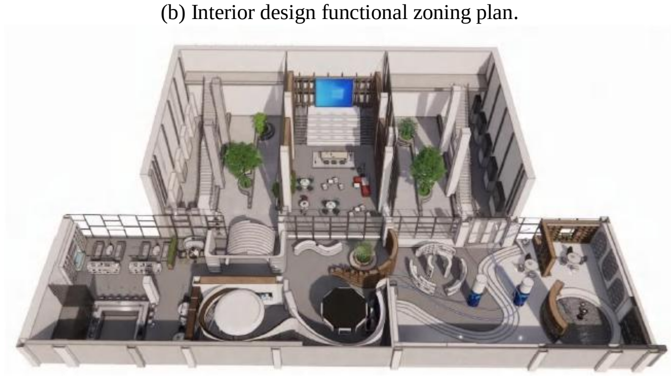
According to the indoor space design method of college physical bookstore under the new media environment designed in this paper, this paper takes the physical bookstore of Jilin Jianzhu University as an example, and designs and analyses the indoor space plan layout and functional partition diagram, specifically as shown in Fig. 17.



(a) The arrangement and structure of an interior design plan.



(b) Interior design functional zoning plan.



(c) A top-down perspective

Fig. 17. Interior design.

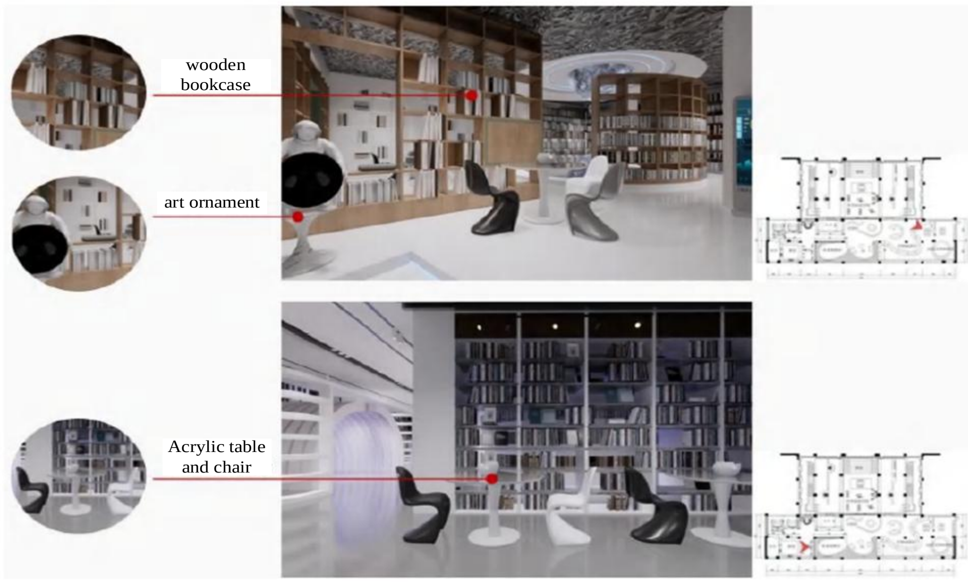
The bookstore, depicted in Fig. 17, has a T-shaped layout that utilizes flexible curves and straight lines to separate the space. Curved bookshelves are strategically placed to direct the flow of the interior. The bookstore is divided into eleven functional zones, taking into account the balance between movement and stillness. The dynamic zone includes the recreation area, shared reading area, tea area, and intelligent service area, while the other zones are designated as relatively quiet areas.

The physical bookstore's interior design is examined from the perspectives of reading spaces, shared reading spaces, open reading spaces, virtual reality experiences, 3D holographic projection spaces, immersive reading spaces, foyer spaces, tea and beverage spaces, leisure spaces, cultural and creative spaces, and intelligent service spaces, as shown in Fig. 18.

D. Evaluation of Algorithm Performance Outcomes

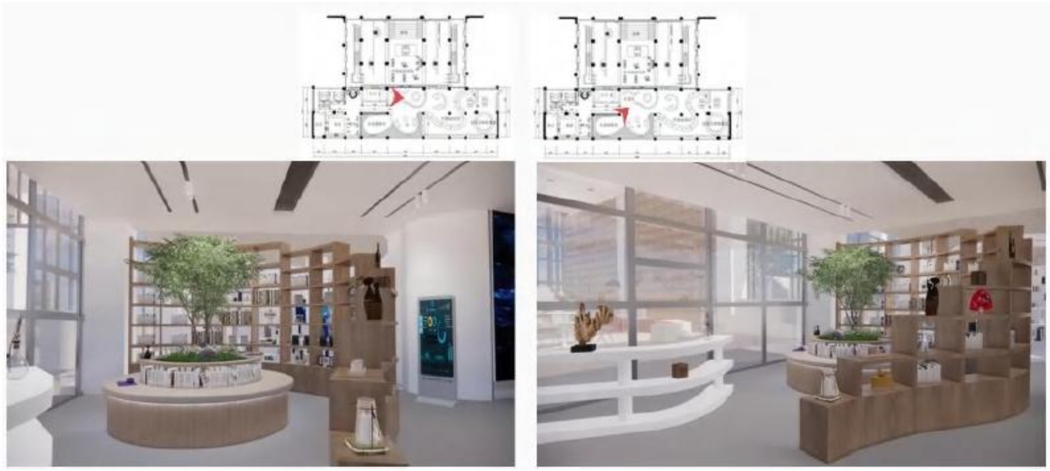
To evaluate the efficiency and superiority of the intelligent analysis algorithm for interior space design of college physical bookshops using the NOA-LSSVM model, this study randomly picks five test sets and presents the test results in Table II and Fig. 19.

The outcomes of optimizing the LSSVM parameters of FPA, WOA, SCA, and NOA algorithms are shown in Table II, while the optimization curves of FPA, WOA, SCA, and NOA algorithms are displayed in Fig. 19. The figure demonstrates that the intelligent analysis algorithm for the interior space design of a college physical bookstore, based on the NOA-LSSVM model, exhibits faster convergence speed and superior convergence accuracy. The Mean Absolute Percentage Error (MAPE) achieved is approximately 2.9, which is lower than the MAPE values obtained by other algorithms such as FPA, WOA, and SCA.



(a) Reading space design.

(b) Designing the spatial experience for virtual reality.



(c) Designing cultural and creative venues.

Fig. 18. Interior design effect schematic diagram.

TABLE II. RESULTS OF DIFFERENT ALGORITHMS TO OPTIMISE LSSVM PARAMETERS

No.	LSSVM Parameters	FPA	WOA	SCA	NOA
1	C	102	200	160	120
2	σ	0.05	0.08	0.39	0.02

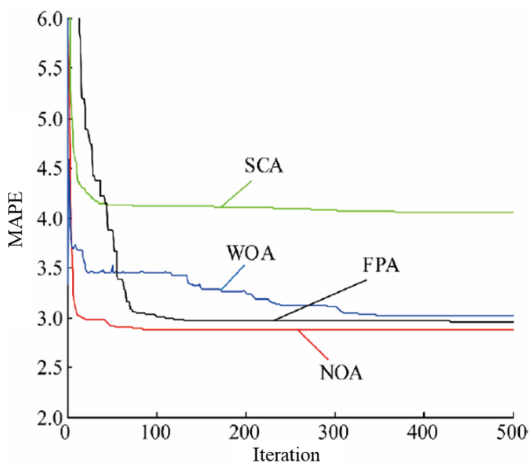


Fig. 19. Optimisation curves for different algorithms.

V. CONCLUSION

In this paper, we suggest a method for designing the interior space of a college physical bookstore that is based on the NOA-LSSVM model. This method involves analyzing the relationship between the new media environment and bookstore design, designing the interior space design scheme for the college physical bookstore under the new media environment, extracting the intelligent analysis indexes of the interior space design, combining the NOA algorithm to find the optimal parameters of the LSSVM, and establishing the NOA-LSSVM-based college physical bookstore indoor space design intelligent analysis model. The physical bookstore at Jilin Jianzhu University is used as a case study to analyze and compare other intelligent analysis models for interior space design. The results indicate that the NOA-LSSVM model has smaller MAPE results, higher analysis accuracy, and can enhance the efficiency of interior space design for college physical bookstores in the new media environment.

The study demonstrates the effectiveness of the NOA-LSSVM model in optimizing indoor spatial design for college bookstores under the new media environment. However, it has some limitations. First, the model's generalizability remains uncertain as its application is only validated within a single case study, lacking tests in diverse bookstore types or cultural settings. Second, the research does not deeply explore user behavior and preferences, which are critical in designing user-centered spaces. Third, while emphasizing the importance of new media, the study provides limited details on integrating specific technologies such as AR/VR or social media into the design process. Future research should focus on extending the model to broader scenarios, integrating multi-source data like user behavior and new media interaction data for more comprehensive analyses, and exploring in-depth applications of advanced technologies to create interactive and immersive environments.

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