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Optimization of dance drama performance space layout based on multi-dimensional scale computational analysis

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Abstract Dance theater performance space layout directly affects the performance effect and audience experience, and traditional layout methods are difficult to balance practicality and aesthetics. In this study, a layout optimization method based on multi-dimensional scale computational analysis is constructed to address the coordination and appropriateness problems of dance drama performance space layout. Firstly, laser point cloud technology is used for three-dimensional modeling, and contour lines are extracted by Alpha Shapes algorithm to establish a multi-objective optimization model including land suitability, spatial compactness and conversion cost. Then the split-tree genetic algorithm is used to solve the optimization problem of spatial layout for dance performance, and the layout optimization is realized through the steps of chromosome encoding and decoding, fitness function construction and mutation operation. The results show that through 500 iterations, the comprehensive objective function Z decreases from 53.09 to 13.29, a year-on-year decrease of 81.21%; with different objective weights, as the weight coefficient increases from 0.1 to 0.9, the objective function decreases from 29.45 to 4.39, a decrease of 85.74%; compared with the Compared with the reference method, the maintenance cost of this method is reduced to 119,000 RMB/year, and the ROI is increased to 14.7%. The validation test shows that the optimized spatial layout response index of the dance performance is stable without fluctuation, and the layout rationality index is stable at 0.8, which is significantly better than other methods. The multi-dimensional scale calculation analysis provides a scientific basis for the dance drama performance space layout, taking into account the practicality and aesthetics.

Index Terms Laser point cloud technology, Dance drama performance space, Multidimensional scale analysis, Spatial layout optimization, Genetic algorithm, Alpha Shapes algorithm

I. Introduction

Dance drama is a dance genre combining “dance” and “drama”, and narrative is one of its important features. But the dance drama is different from the film can copy the real space scene, and after the camera conversion to achieve the scene switch, also different from the language of literary works or the drama of the dialogue lines, directly across the mind can be [1]. Dance drama is limited to the interpretation on the stage, it is inevitable to need to be more virtual, more accurate interception of the main points of the scene, and through the audience's association to the reproduction of space [2].

In dance theater, the presentation of space is difficult, the limited capacity of the stage, the narrative of body language is limited, in the limited to seek the infinite becomes the most charming place in the stage art [3]. In the limited capacity of the dance drama, the standing image to exhaust the meaning of the dance drama has become the primary task of the creation of the space, the reasonable application of the space not only plays a great role in the ideogram, the narrative function of the space metaphor also greatly assisted in the dance drama plot clues to show, to solve the problems related to the narrative [4]-[6]. Solid space is the place of concretization, which is mainly composed of sets and props, and the use of solid space in the stage can bring the audience into the temporal and spatial background where the story is located [7]-[9].

On the stage, the treatment of solid space pursues relative realism, i.e., the spatial objects on the stage are treated in accordance with life prototypes. The externalization of the character's psychology on stage is accomplished through the application of space, and in the state of consciousness, the quest for imaginative space is mostly for more conscious and logical dance works [10]. Especially the character's reproduction and monologue, which not only carries on between the field and the scene, but also embodies a creative spatial consciousness. At the same time as the objective development of events, the main characters are independent from the group and express their emotional world to the fullest in a frozen time [11], [12]. Therefore, when performing a dance drama, the rational arrangement of the spatial layout of the dance drama plays a crucial role in the performance of the actors and the presentation of the play.

As an important place for artistic display, the layout of dance theater performance space not only directly affects the performance effect, but also relates to the audience's experience and the overall presentation of performing arts. Currently, the layout design of dance drama performance space mostly relies on traditional experience methods, which is difficult to take into account the efficiency of space utilization and aesthetic effect, and the layout form is single and lacks systematic optimization methods. In practical application, the location relationship and scale ratio of the stage area, audience area, logistics area and other functional spaces are often not reasonable, resulting in low space utilization and increased maintenance costs. At the same time, the limited nature of land resources makes the efficient utilization of dance theater performance space particularly important. The traditional layout method often neglects the comprehensive consideration of land suitability and spatial coordination, resulting in serious spatial fragmentation and insufficient compactness, making it difficult to meet the diversified needs of modern dance performance. The development of laser point cloud technology provides a new means for three-dimensional spatial data acquisition, which can quickly obtain accurate spatial geometric information, but how to transform these data into an operable layout optimization scheme is still a challenge. As an important tool for spatial planning and optimization, multidimensional scale computational analysis can quantitatively evaluate the performance of different layout schemes from multiple perspectives, but the applied research in the field of dance theater performance space is still not deep enough. Although intelligent optimization algorithms, such as genetic algorithms, have been widely used in other fields, there are fewer studies on layout optimization for such special spaces as dance and drama performances, and there is a lack of specialized optimization models that take into account the characteristics of performing arts. In addition, the layout of dance drama performance space needs to comprehensively consider various factors such as economic benefits, environmental impact and sustainable operation, which puts forward higher requirements for the optimization method. Therefore, it is of great theoretical value and practical significance to develop a scientific and reasonable optimization method for the layout of dance theater performance space that can comprehensively consider multidimensional factors.

This study constructs a framework for optimizing the layout of dance drama performance space based on multi-dimensional scale computational analysis. Firstly, the laser point cloud technology is used to obtain the three-dimensional geometric data of the dance drama performance space, and the spatial contour lines are extracted by the Alpha Shapes algorithm to establish a three-dimensional model with a strong sense of realism. On this basis, a multi-objective optimization model considering land suitability, spatial compactness and conversion cost is constructed, and the corresponding constraints are set to ensure that the optimization result meets the actual demand. The split-tree genetic algorithm is used to solve this optimization problem, and the optimization of the spatial layout of the dance drama performance is realized through the steps of chromosome coding and decoding, initial population generation, fitness function construction and selection of mutation operation. Through case calculation, sensitivity analysis and application test, the effectiveness and superiority of the proposed method are verified, which provides scientific basis and optimization tool for the design of dance drama performance space layout.

II. Optimized design of dance drama space layout based on laser point cloud

II. A.3D modeling based on laser point cloud technology

II. A. 1) Point cloud data preprocessing

Point cloud data of the spatial layout of the dance theater performance was obtained using a laser scanner through multiple stations. Due to some accuracy problems and human factors, there are different degrees of noise interference in the point cloud data. It is necessary to carry out pre-processing to realize the denoising and streamlining of the point cloud data.

II. A. 2) Contour line extraction

Fitting contour lines on the basis of the preprocessed point cloud data above. Edge points need to be extracted when fitting contour lines, and regularized processing contour lines to obtain feature points to achieve feature extraction.

The Alpha Shapes algorithm [13] is utilized for extracting contour lines, assuming that there exists a point set J and there is a circle rolling outside of that point set, the radius of the circle is denoted using α, the positional relationship between the point set and the circle is determined by the value of α, and there is a variation in α that causes the circle to roll back and forth inside and outside of the point set, resulting in the traces known as the point set Bumping. If the value of α is appropriate, and at the same time the points in the point set are uniformly distributed, then the Alpha Shapes algorithm can extract the inner and outer boundaries of the point set. Algorithm judgment conditions:

Let there be a circle whose radius is denoted by α, and let there be two points in the point set that are on the circle, which are denoted by q_1 and q_2. If no other points appear in the circle, these two points are judged to be boundary points, and the two points are connected to the boundary segment.

Assuming that (x_1, y_2) is the coordinate of the point q_1 and (x_2, y_2) is the coordinate of the point q_2, to obtain the coordinate of the center of the circle q_3, we need to use the distance intersection method:

$$\begin{cases} x_3 = x_1 + \dfrac{1}{2}(x_2 - x_1) + H(y_2 - y_1) \\ y_3 = y_1 + \dfrac{1}{2}(y_2 - y_1) + H(x_1 - x_2) \end{cases} \tag{1}$$

In equation (1):

$$H = \sqrt{\frac{\alpha^2}{J_{q_1q_2}^2} - \frac{1}{4}}, J_{q_1q_2}^2 = (x_1 - x_2)^2 + (y_1 - y_2)^2 \tag{2}$$

By calculating the distance between the center of the circle and other points, comparing the size between α and the distance value, determine whether these points are in the circle. The following is the flow of the algorithm:

(1) Take q_1 as the starting point, search for the distance from the starting point to QA, select the distance points in 2α to build the point set J_1, select any point in the point set, and calculate the center of the circle by using equation (1).

(2) For all points present in the point set, calculate the distance L between it and the center of the circle. If α is less than L, then the line joining q_1 and q_2 is the boundary line, and these two points are the boundary points; if α is greater than L, then skip to the next step.

(3) Repeat the above two steps to obtain the next step of J_1, and end the repetition when all the points in J_1 realize the judgment.

(4) Select the next point in the point set J, repeat the above steps, so that all the points in J realize the judgment. At this point, the extraction of all boundary segments of the building is completed.

II. A. 3) Texture Mapping

The layout model is constructed based on the above extracted contour lines, and the texture mapping of the model is carried out after the completion of the construction, so as to obtain the 3D model of the spatial building with a strong sense of realism. Use the camera to obtain the texture image of the building, and obtain the correspondence between the pixels and the vertex coordinates under the world coordinate system according to the camera coordinate system, the set camera parameters, and the translation or rotation matrix of the world coordinate system.

The rotation matrix obtains the correspondence between pixel and vertex coordinates under the world coordinate system. The principle of texture mapping is shown in equation (3) and (4):

$$(x_c, y_c, z_c) = S_1(x, y, f) \tag{3}$$

$$(x_w, y_w, z_w) = S + \lambda(x_c, y_c, z_c) \tag{4}$$

(x_c, y_c, z_c) and (x_w, y_w, z_w) denote the camera coordinate system and the world coordinate system, respectively; assuming that there exists a point P on the building, $(x_c, y_c, z_c)^T$ denotes the coordinates of the point P in the camera coordinate system; the coordinates of the point P in the world coordinate system are denoted using $(x_w, y_w, z_w)^T$; $(x, y, f)^T$ denotes the coordinates corresponding to that point; S and S_1 respectively denote the coordinate matrix of the origin of the camera coordinates in the world coordinate system and the 3*3 transformation matrix; λ stands for the scale factor.

II. B. Optimization model and constraints of dance performance space

II. B. 1) Optimization models

Consider spatial coordination, land suitability and other factors in the process of reuse space optimization of dance performance layout, and establish the objective function of reuse space optimization of dance performance layout:

(1) Maximize land use suitability

In the process of dance performance layout reuse space utilization decision-making and planning, it is necessary to consider the land suitability needs, and the suitable land use type can be arranged in the optimized area according to the unit quality characteristics, which can improve the land use efficiency, and the expression of the objective function $g_1(u)$ is as follows:

$$g_1(u) = \sum_{i=1}^{M} \sum_{j=1}^{Q} \sum_{l=1}^{L} S_{ij}^l C_{ij}^l \tag{5}$$

(2) Maximize the spatial compactness of land use

In the process of spatial optimization of dance performance layout reuse, it is necessary to reduce the degree of fragmentation of different types of land in the spatial distribution, and to gather the land of the same type to constitute an area with a higher degree of integrity. When constructing the objective function of maximizing the spatial compactness of land use, the neighborhood homogeneity index β_l is set to measure the degree of compactness of different types of land in the process of spatial optimization, and there is a proportional relationship between the degree of land aggregation and the neighborhood homogeneity index β_l, and the former will increase with the latter, setting the number of land areas represented by β_{ijl} represents the total number of L-class land in the neighborhood of unit (i, j), which can be calculated by the following equation:

$$\begin{aligned} \beta_{ijl} &= C_{(i-1)jl} + C_{(i+1)jl} + C_{i(j-1)l} + C_{i(j+1)l} \\ &+ C_{(i-1)(j-1)l} + C_{(i-1)(j+1)l} + C_{(i-1)jl} \end{aligned} \tag{6}$$

Based on the results of the above equation, the optimization function $g_2(u)$ for maximizing spatial compactness is established:

$$g_2(u) = \sum_{i=1}^{M} \sum_{j=1}^{Q} \sum_{l=1}^{L} \beta_{ijl} C_{ij}^l \tag{7}$$

(3) Minimize land use conversion costs

In the process of dance performance layout reuse space optimization, will transform the original type of land use, the transformation process will produce a certain cost, dance performance layout reuse space optimization program, the less the conversion cost, the more reasonable program. Set the conversion coefficient V_{cf} to measure the conversion cost of the dance performance layout reuse space optimization process, and finally there is a smallized land use conversion cost objective function $g_3(u)$ as follows:

$$g_3(u) = \sum_{i=1}^{M} \sum_{j=1}^{Q} \sum_{l=1}^{L} V_{cf} C_{ij}^l \tag{8}$$

II. B. 2) Constraints

Before solving the spatial optimization objective function of dance performance layout reuse, it is necessary to set the constraints of the spatial optimization objective function of dance performance layout reuse:

(1) Set the structural ratio of land use types, and the number of each land use type needs to meet the following requirements:

$$\sum_{i=1}^{M} \sum_{j=1}^{Q} C_{ijl} = C_l, \forall l \tag{9}$$

(2) Each spatial unit will have a type of land in the optimization process:

$$\sum_{l=1}^{L} C_{ijl} = 1, \forall ij \tag{10}$$

(3) Land units are connected to at least one unit within the optimized dance performance layout area:

$$D_{L_{ij,i',j'}} \ldots 1, \forall (ij, i', j') \tag{11}$$

where $D_{L_{ij,i',j'}}$ represents the number of times that unit (i, j) is adjacent to unit (i', j') in the building area of dance performance layout.

(4) In the process of dance performance layout reuse space optimization, the same type of land units need to be connected into a complete area, let $q_{i_1 j_1 l, i_2 j_2 l}$ represent the l class land units (i_1, j_1) and the Manhattan distance that exists between class l land units (i_2, j_2) that satisfies the following conditions:

$$q_{i_1 j_1 l, i_2 j_2 l} = 1 \tag{12}$$

(5) Denote by $f_{i_1 j_1 l_1, i_2 j_2 l_2}$ the Euclidean distance that exists between the l_1 class unit and the l_2 class unit in the process of optimizing the reuse space of the layout of the dance performance. This distance needs to be greater than S, i.e:

$$f_{i_1 j_1 l_1, i_2 j_2 l_2} > S \tag{13}$$

(6) Land types that are prone to air pollution need to be set in the downwind direction during the reuse space optimization process. Set N_{ij} consists of units in the prohibited layout area, and the set needs to meet the following conditions during the optimization process:

$$i \in N_{ij} \text{ and } j \notin N_{ij} \tag{14}$$

(7) Certain parcels can maintain compactness under the shape compactness constraint. The distance $f_{i_1 j_1, i_2 j_2}$ that exists between Land Unit (i_1, j_1) and Land Unit (i_2, j_2) in the Dance Performance Layout Reuse Space Area is subject to the conditions described below:

$$\max_{i_1 j_1, i_2 j_2} f_{i_1 j_1, i_2 j_2} \le (\mu b)^{1/2} \tag{15}$$

where μ represents the compact shape measure; b represents the area corresponding to the parcel.

II. C. Genetic Algorithm for Spatial Layout of Dance Theater Performances

II. C. 1) Chromosome coding and decoding

(1) Coding

Encoding is the process of converting the feasible solution of a problem from the solution space to the genetic space, consisting of chromosomes of genes in a certain structure. In this paper, we use a partition structure (block layout) to express this, such that horizontal and vertical cuts are represented by operators (internal nodes) + and *, and the partition structure contains n given units of operation (called operands or leaves), represented by the alphabetical set $\Sigma = (1, 2, ..., n, *, +)$ of partition trees or Polish expressions for coding representations.

The following guidelines must be followed in the encoding process: (1) 1 chromosome must have n distinct operands (number of operational units) and $(n-1)$ operators; (2) the total number of operands $N(\psi)$ before any 1 element i (including i) in 1 chromosome must be greater than or equal to $M(\psi)+1$, where $M(\psi)$ is the number of operators , otherwise no legal Polish expression can be generated and built.

(2) Decoding

Decoding: the reverse process of encoding, which converts a Polish expression into a partitioned structure (block layout). For a partition tree ψ of length $(2n-1)$, let $i(1 \le i \le 2n-2)$ be any partition point (or position) in the partition tree, and let $n(\psi)$ and $m(\psi)$ be the total number of operands and arithmetic contained from the right-hand side of the partition point to the right-most side of the tree, respectively.

If the partition point i is the 1st position, find the position in the range $2n-1 \sim 1$ from right to left that makes the equation $n(\psi) = m(\psi)$ hold. Then at the split point i the split tree can be divided into (1) a left subtree that includes the elements from $1 \sim i$ in the given split tree, and (2) a right subtree that includes the elements from $i+1 \sim 2n-2$ in the given split tree.

II. C. 2) Initial population generation

When using genetic algorithm [14] to carry out the research on the spatial layout of the dance theater performance, there must be an initial population as the initial solution, which is usually randomly generated, but the randomly generated initial solution can not converge to the optimal solution. At the same time, the number of populations also has a significant impact on the solution, too many, the running time is long, affecting the efficiency of the search; too few populations, it will converge prematurely. Therefore, in this paper, we use the system layout design SLP with randomized method to determine the initial population, and the number of populations is suitable for 20~100.

II. C. 3) Adaptive functions

The fitness function is defined as:

$$fit(v_k) = \frac{1}{F_k + \lambda_k P}, k = 1, 2 \cdots pop - size \tag{16}$$

where, $F_k = u_1 v_1 F + u_2 v_2 \eta : u_1, u_2$; the weights of the sub-objectives, which satisfy $u_1 + u_2 = 1$, according to the actual situation of the enterprise; v_1, v_2 denotes the importance factor, which is determined by the factor analysis method and is mainly used to unify the economic and non-economic factors according to their relative importance, where, $v=\frac{F_i}{\Sigma F_i}, v_2=\frac{\eta_i}{\sum \eta_i}$; λ_k is the total number of operating units in the k th chromosome that do not meet the constraints. P is the value of the large number penalty, which drives towards the legitimate solution.

II. C. 4) Selection

Holland's proportional selection method was used, i.e., the selection probability of an individual was determined based on the proportion of fitness of each chromosome. The selection process is to build 1 roulette model based on these probabilities, and then rotate the roulette wheel pop size (population size) times, each time to select 1 individual for the new population. Let f_i be the fitness of individual i in the population and N be the number of populations. Then the probability that individual i is selected is:

$$P_i=\frac{f_i}{\sum_{i=1}^{N} f_i}(i=1,2,\cdots,N) \tag{17}$$

According to equation (17), the higher the fitness probability, the greater the chance that an individual will be selected.

II. C. 5) Variant operations

For each chromosome 2 types of mutations are used. The first is to replace 2 operators with each other; the second is to exchange the positions of the 2 operands or operators. This mutation is guaranteed to produce legitimate offspring.

III. Layout optimization effect analysis

III. A. Analysis of Case Calculation Results

Case calculation simulation results show that the use of split-tree genetic algorithm can effectively solve the optimization model of the spatial layout of the dance performance, with the increase in the number of iterations, the spatial layout of the dance performance is constantly optimized and updated. With the maximum number of iterations itermax=500 for example, four calculations were carried out as shown in Fig. 1, all of which can quickly converge and effectively solve the better results. The results of the comprehensive objective function Z in each round are different, with strong fluctuation characteristics, but they are better than the value of the comprehensive objective function at the initial moment, indicating that the algorithm is stochastic.

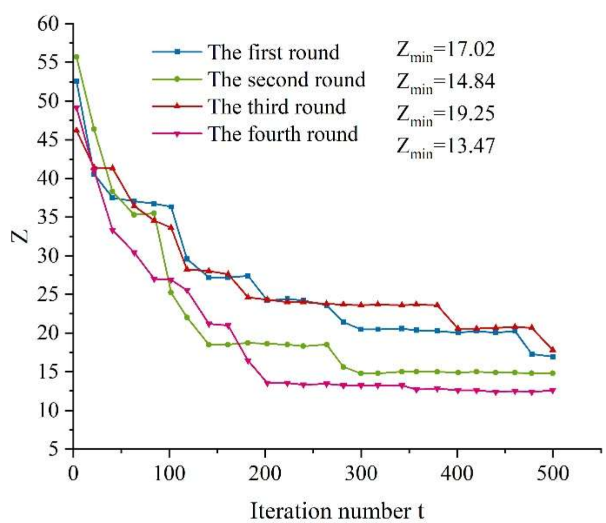
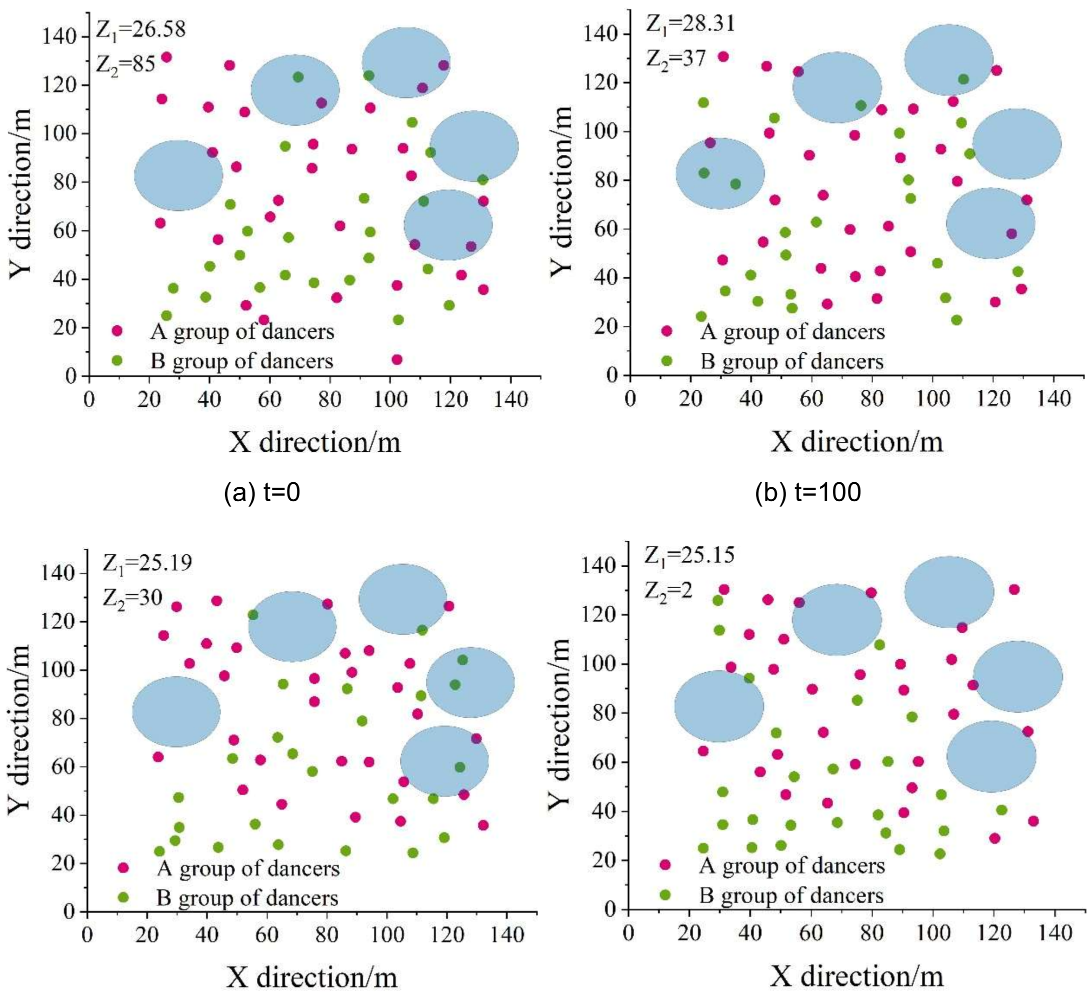


Figure 1: Four rotation of the integrated target function z curve

The result of the 4th iteration is optimal, and the shape of the dance drama performance space layout with the 4th iteration curve is shown in Fig. 2, and (a)~(d) are the schematic diagrams of the dance drama performance space layout under different iteration numbers, respectively. In Fig. 2(a), when t=0, Z_1 is 26.68, and Z_2 is 85. When t=100, the corresponding spatial layout of the dance drama performance is shown in Fig. 5(b), with Z_1 being

28.31, and Z_2 being 37. Through 500 iterations, the integrated objective function Z decreases from 53.09 to 13.29, which is a decrease of 81.21%.



(a) t=0 (b) t=100

(c) t=300 (d) t=500

Figure 2: The performance space layout diagram of the performance of the dance show

III. B. Sensitivity analysis

In order to analyze and identify the main influencing factors of the split-tree genetic algorithm for solving the optimization model of the spatial layout of the dance drama performance, different objective weights, iteration times, and population sizes were selected for sensitivity analysis.

III. B. 1) Impact of target weights

A comparison of the objective function values under different weights is shown in Table 1. The values of λ_1 and λ_2 are set in 9 different combinations at intervals of 0.1 for sensitivity analysis. In order to avoid the influence of chance and randomness, each group of weight coefficients is simulated 10 times, and the mean and standard deviation of the objective functions Z_1 and Z_2 are statistically analyzed.

The set of effective solutions with different objective weights is shown in Figure 3. Figure 3 shows that the algorithm mostly solves sub-optimal pareto-optimal solutions, therefore, multiple tests are performed to get closer to the pareto-optimal curve.

Table 1: The target function of different weights is compared

λ_1	λ_2	Z_1		Z_2	
		Mean value	Standard deviation	Mean value	Standard deviation
0.1	0.9	24.74	1.05	31.42	4.03
0.2	0.8	26.21	1.18	15.8	9.41
0.3	0.7	26.53	0.91	10.2	5.88
0.4	0.6	26.74	1.13	11.7	8.21
0.5	0.5	26.97	1.21	3.6	4.29
0.6	0.4	24.63	0.83	10.2	4.86
0.7	0.3	24.59	1.18	8.2	7.05
0.8	0.2	24.28	1.09	11.1	9.57
0.9	0.1	21.04	0.91	4.9	10.84

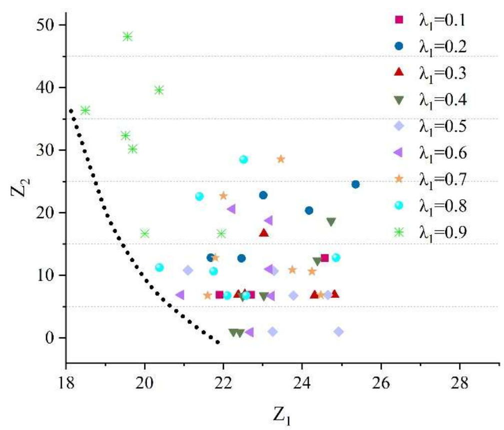


Figure 3: Effective solutions in different target weights

The objective function values under different objective weights are shown in Figure 4. It can be seen that with the increase of the corresponding weight coefficients of the objective function, the overall trend of the objective function value is decreasing. At λ_1 1=0.1, Z_1 =21.68, while when λ_1 =0.9, Z_1 =19.29, which is a decrease of 12.23% compared to the decrease. At λ_2 =0.1, Z_2 =29.45, and when λ_2 =0.9, Z_2 =4.39, which is a decrease of 85.74% compared to that. However, at λ_1 =0.1~0.5, the value of Z_1 =0.5 increases, indicating that with the Split Tree Genetic Algorithm, in the interval of 0.1 to 0.5, the spatial layout of the dance theater performances resides in the ability of the team to be insensitive to the value of λ_1 =0.5. Similarly, when λ_2 = 0.1 to 0.5, the value of Z_2 shows a tendency to increase and then decrease, indicating that with the Split Tree Genetic Algorithm, the coordination ability is not sensitive to the value of λ_2 between the intervals of 0.1 and 0.5.

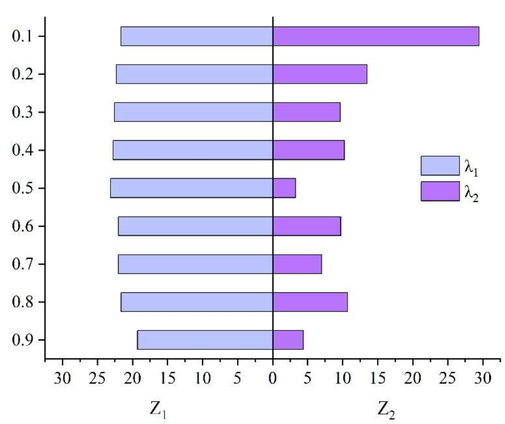
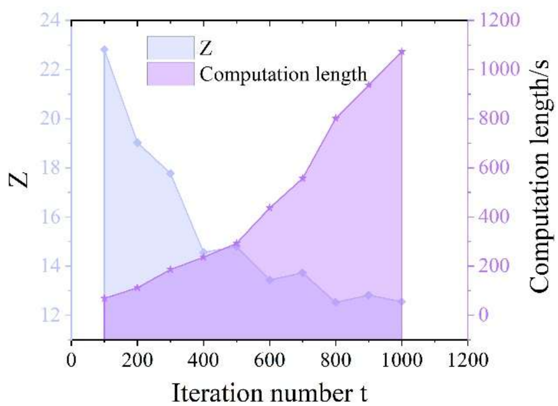


Figure 4: Target function values of different target weights

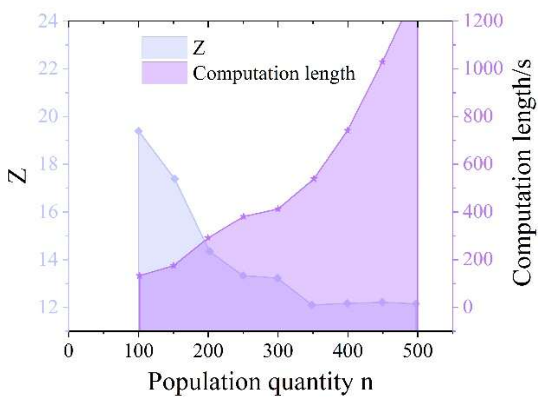
III. B. 2) Number of iterations and population size effects

The change curves of the integrated objective function values under different iteration numbers and different population sizes are shown in Fig. 5. As shown in Fig. 5(a), with the increase of iteration number, the integrated objective function value generally shows a decreasing trend. When $iter_{max}$ =100, Z=23.05, and when $iter_{max}$ =600, Z=13.43, compared with the decrease of 41.34%, and the computation time increased from 68.55s to 437.10s. When the number of iterations increased from 600 to 1000, the value of the objective function only decreased by 6.98%, but the computational time increased by 635.3 s. With the increase of iteration number, the search ability of split-tree genetic algorithm in the search space is gradually enhanced, and it is able to find a solution closer to the global optimum, so the comprehensive objective function value gradually decreases with the increase of iteration number. When the number of iterations is increased to 600, the objective function value changes slightly because the algorithm is close to the neighborhood of the global optimal solution.

As shown in Fig. 5(b), the integrated objective function value shows an overall decreasing trend as the population size increases, with Z=19.4 at $iter_{max}$ =100, and Z=12.1 when $iter_{max}$ =350, which is a 37.58% decrease compared to the increase in the computation time from 132.64 to 538.86s, indicating that increasing the number of populations allows the algorithm to explore more search space and find a better layout scheme, and also increases the computational cost. When $iter_{max}$ is increased from 350 to 500, the change in the objective function value is small, but the computational time increases by 155.75%.



(a) Iteration number



(b) Population quantity

Figure 5: The integrated target function value changes

III. C. Application testing

III. C. 1) Response testing

The data of the layout optimization model of the dance drama performance space is imported into Matlab, a simulation testing tool, and under the framework of response testing, an objective function is first constructed, which integrally considers multi-dimensional factors such as the diversity, flexibility, and aesthetics of the dance drama performance space, aiming to quantitatively assess the effectiveness of various layout optimization solutions.

Subsequently, a bee colony algorithm is introduced as an optimization tool to achieve continuous optimization of the solution. After the algorithm is run, the output clustering results provide a detailed picture of the optimal layout optimization solution, covering key information such as performance areas and layout flexibility, ensuring that the layout optimization solution is both practical and scientific.

Four different optimization methods are used to carry out the respective layout optimization algorithms at the same time, and the changes in the response indexes during the completion of the layout optimization process are synchronously recorded, generating the curve change schematic shown in Figure 6. Comparison and analysis of the index curve changes to draw test conclusions. From the characteristics of the four curves, it can be found that under the same conditions of the four independent spaces, different layout optimization schemes show large differences in the changes of response indicators. Through observation, it is found that the curve of reference method A is relatively smooth, without local jitter, and the overall trend shows a growth trend, but the growth momentum is weak, indicating that the response sensitivity of reference method A reaches the maximum peak value. The response index of reference method C fluctuates more, although the response performance grows faster in the later stage, but the overall stability is poor; compared with the above three groups of reference methods, the curve of this paper's method is smoother, the growth trend is more stable, and the performance control performance in the later stage is excellent. It can be judged that the layout optimization response performance of the validation method is better among the four groups of layout optimization methods, which can better meet the requirements of practical applications.

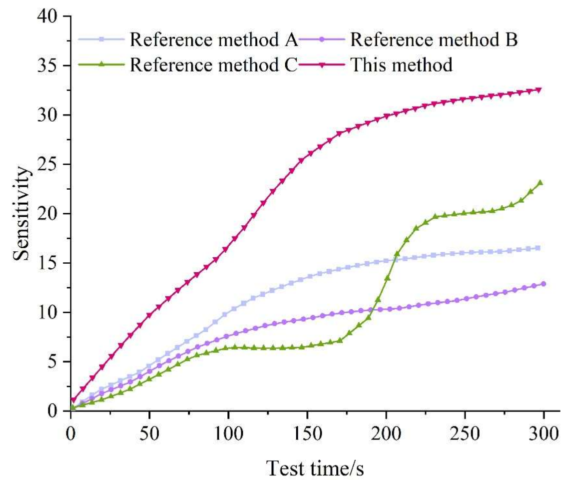


Figure 6: Response index change curves of different layout optimization methods

III. C. 2) Layout Reasonableness Test

In order to verify the reasonableness of the above layout results, the above experiments are repeated 12 times, and 12 groups of dance theater performance space layout response statistical values are obtained. According to the historical experience, the layout deviation comparison is made for its response indexes, if the deviation value, it indicates that the layout result of the method is reasonable; on the contrary, if the obtained deviation value, it indicates that the layout result of the method does not satisfy the reasonableness, and the obtained results are shown in Table 2.

Through the observation and comparison of the indicators, among the four groups of optimization methods, the deviation indicator value of reference method A is the largest, and the deviation value fluctuates more frequently, indicating that there are limitations in the rationality of the layout of the method; the deviation value of reference method B is smaller compared to the reference method, but the fluctuation frequency belongs to the same level, and there are limitations in the reasonableness of the layout as well; the overall value of the reference method C is significantly reduced compared to the above two, and the fluctuation Compared with the above two, the overall value of reference method C is obviously reduced, and the frequency of fluctuation is slowed down, but there is still a certain gap between the performance reflected in the overall indicators and the test requirements; on the contrary, the indicators obtained by the method of this paper have the smallest value without any fluctuation, which indicates that the effect of the layout is stable and the consistency of the effect is good.

Table 2: Statistics of Layout Rationality Test Results

Acquisition number	This method	Reference method A	Reference method B	Reference method C
1	0.8	1.5	1.5	1.7
2	0.8	1.5	1.5	1.7
3	0.8	1.5	1.5	1.7
4	0.8	1.5	1.6	1.3
5	0.8	1.5	1.6	1.3
6	0.8	1.5	1.6	1.3
7	0.8	1.6	1.6	1.1
8	0.8	1.6	1.6	1.1
9	0.8	1.5	1.3	1.1
10	0.8	1.5	1.3	1.1
11	0.8	1.5	1.3	1.1
12	0.8	1.7	1.4	1.1
13	0.8	1.4	1.4	1.5
14	0.8	1.7	1.3	1.6

III. C. 3) Economic efficiency tests

In order to comprehensively assess the practical application value of the layout optimization method, economic benefits are set as the experimental indicators. The economic benefit indicators include maintenance cost, return on investment, land use efficiency, etc., which are directly related to the feasibility and long-term sustainability of the layout optimization scheme. The economic benefit indicators are calculated for each of the four layout optimization methods, and the results are shown in Table 3. As can be seen from the table, the maintenance cost of this paper's method is the lowest, indicating that it has a lighter economic burden in long-term operation. The reference methods A and C have higher maintenance costs, probably because their layout schemes require more maintenance work in actual operation. The validation method has the highest return on investment, indicating that its layout optimization scheme can bring higher ecological service values and thus be more economically attractive.

Table 3: Comparison results of economic benefits of different methods

Method	Maintenance cost(Ten thousand yuan/a)	Return on investment(%)	Land efficiency(Tree number /m2)
Reference method A	17.3	13.4	500
Reference method B	13.1	10.7	450
Reference method C	15.4	12.6	560
This method	11.9	14.7	610

Combining the comparative analysis of the above economic benefit indexes, the validation method performs well in the three aspects of maintenance cost, return on investment and land use efficiency, showing its advantages in economic benefits. It proves the effectiveness and practicability of the method of this paper in the optimization of the space layout of dance performance.

IV. Conclusion

The application of multidimensional computational analysis to the optimization of the spatial layout of dance performances shows remarkable results. The laser point cloud technology combined with the Alpha Shapes algorithm provides an accurate 3D geometric basis for layout optimization, and the multi-objective optimization model constructed effectively balances the relationship between land suitability, spatial compactness and conversion cost. The split-tree genetic algorithm shows good convergence performance in the optimization process, and the comprehensive objective function value is reduced from the initial 23.05 to 13.43 through 600 iterations, which is 41.34%. The sensitivity analysis shows that the weight coefficients have a significant impact on the objective function value, and when increases from 0.1 to 0.9, the objective function decreases by 85.74%, which indicates that the objective weight is a key factor influencing the optimization effect of the layout. The economic efficiency test shows that the maintenance cost of the optimized layout scheme is reduced to 119,000 yuan/year, which is 31.2% lower than the 173,000 yuan/year of the reference method A. Meanwhile, the land-use efficiency is improved to 610 trees/square meter, which is higher than that of other methods. The layout rationality test confirms that the index value of the proposed method stays stable at 0.8 without any fluctuation, showing superior stability and consistency. The experimental results prove that the optimization method of dance performance space layout based on multi-dimensional scale calculation and analysis can effectively improve land use efficiency, reduce maintenance costs, create a more reasonable and economical performance environment, and provide reliable technical support and decision-making basis for the planning and design of dance performance space.

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