

Research on Intelligent Layout Planning of Flower Base under the Perspective of Multi-model Integration

Li Pan¹, Mingyuan Liu^{2,*} and Ziyi Xiong²

¹ School of Automotive Engineering, Lanzhou Vocational Technical College, Lanzhou, China

² Innovation Academy for Precision Measurement Science and Technology, CAS, Wuhan, China

*Corresponding author: lmyszq1017@163.com

Abstract. In this paper, particle swarm algorithm and Monte Carlo simulation are used to focus on the optimization of the layout of the flower base, and a multi-objective decision-making model based on the behavior of tourists and planting efficiency is constructed. Firstly, for the path planning, two design schemes are proposed: single entrance and single exit and double entrance and three exits; through particle swarm algorithm to optimize the calculation model of tourists' sight range; combined with Monte Carlo simulation to construct the queuing system; and comprehensively balance the time satisfaction and viewing efficiency. It is found that the single-entrance layout has a significant advantage when the flow of visitors is controllable, while the multiple-entrance design is more adaptable during peak hours. Secondly, for multi-flowering peony planting, a regression model of yield and production value based on quadratic saturated D-optimal design was established, and an improved immunity algorithm was introduced to optimize the planting density ratio, so as to clarify the spatial allocation strategy among subspecies in different flowering periods. The results of the study show that reasonable path planning and planting structure optimization can significantly improve the operational efficiency of the base, which provides a methodological reference for the sustainable development of modern urban agricultural parks.

Keywords: Planting layout; multi-objective optimization model; particle swarm algorithm; Floyd's algorithm.

1. Introduction

With the rapid development of modern urban agriculture, the optimization of spatial layout and planting structure of flower bases, as an important carrier for the integration of ecotourism and agricultural economy, has become the key to enhance the comprehensive benefits^[1]. Traditional flower base planning often focuses on static landscape design, ignoring the behavioral characteristics of tourists and dynamic operational needs, resulting in peak hour traffic congestion, decline in the viewing experience, while a single flower planting mode is difficult to meet the diversified needs of consumers.

To address this situation, this paper takes multi-objective optimization theory as the framework and constructs a dynamic planning model that integrates visitor behavior simulation and planting benefit analysis^[2]. The study firstly optimizes the path layout through particle swarm algorithm^[3], establishes a queuing system by combining Monte Carlo simulation^[4], and quantitatively analyzes the impact of different entrance and exit designs on tourists' time satisfaction and viewing efficiency. Secondly, for multi-flowering peony subspecies intercropping planting, a quadratic saturated D-optimal design was used to construct a yield and production value regression model^[5], and an improved immune algorithm was introduced to optimize the planting density ratio^[6], which revealed the synergistic efficiency mechanism among different flowering varieties. The research results show that the synergistic optimization of multi-entry path planning and differentiated planting structure can significantly improve the utilization rate of spatio-temporal resources and comprehensive benefits of flower bases.

2. Multi-Objective Optimization of Flower Layout

This section requires the development of two layouts that simultaneously satisfy the need to make more flowers visible to flower-viewers and to allow more people to view the base on a daily basis.

2.1. Optimization Model Preparation and Construction

2.1.1 Parameter preparation

Consider the planting density of flowers in the rectangle for 73 plants/m², in order to enhance the customer's return rate to set the satisfaction threshold, when the satisfaction rate is higher than or equal to 0.5, indicating that 70% of the customers may next visit or recommended to their loved ones around the ornamental, flower base opening hours for the morning 9:00 - 17:00 pm, shift work in the middle of the day without breaks, a day of business open time for 8 hours, flower lovers regardless of men and women and the average height of 164cm. The average height is 164cm, the viewing angle of the flower-appreciation people is 56 degrees above and 74 degrees below, the number of service counters is n, the customers do not take into account men and women, old and young, and it is assumed that the speed of traveling between the viewing room is 0.5m/s.

2.1.2 Queuing model

In practice, the stochastic service process is usually simulated with the help of computer simulation software, such as Monte Carlo simulation.

To demonstrate the model, set the parameters initialization has (the initial moment of each workstation 1,2,3, the initial number of people served, the initial idle time with the overall working time, etc.), that is:

$$t = tw = tf1 = tf2 = tf3 = tl1 = tl2 = tl3 = K = k1 = k2 = k3 = 0 \quad (1)$$

t is the total time, tl is the idle time of the service desk, K is the total number of people served, tw is the moment t , the sum of the waiting time of all customers, tf is the moment t , the sum of the idle time of the service desk. Set the time termination conditions for: $t = 60$, waiting time more than 30min customers will automatically leave, not counted in the statistics.

2.2. Multi-Objective Optimization Model

2.2.1 Time satisfaction function

Based on the established satisfaction function, set i, j are the starting point and real-time position of tourists, respectively, the length of the path traveled by tourists sightseeing flowers is d_{ij} , the time required by tourists sightseeing flowers is t_{ij} , the walking speed of tourists sightseeing flowers is v_{ij} , L_j and U_j for tourists sightseeing tours of flowers, the upper and lower bounds of the time, there are $L_j \leq U_j$, the introduction of descending semigossi-distributed time-satisfaction function:

$$f(t_{ij}) = \begin{cases} 1, & \text{if } d_{ij} \leq L_j v_{ij} \\ \frac{1}{1 + \beta_i (d_{ij} / v_{ij} - L_j)^2}, & \text{if } d_{ij} > L_j v_{ij} \end{cases} \quad (2)$$

Where $\beta_i (\forall i \in W)$ is a positive time sensitivity coefficient, the larger its value indicates the stronger the sensitivity.

2.2.2 Landscape planning program

Design a single-entrance-single-exit flower path and a double-entrance-three-exit flower path, on the basis of which the simulation of visitors and the evaluation of advantages and disadvantages are

carried out. The blank spaces are all flower planting places, the planting area is 73 plants/m², the width of the pedestrian path is 3m, and the rectangular flower ornamental land is 200m long and 100m wide.

2.2.3 Objective function

$$Maxf(t_{ij}) \tag{3}$$

$$MaxS \tag{4}$$

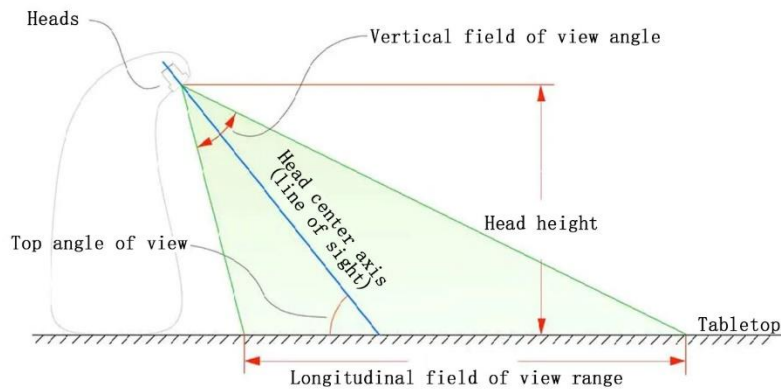


Fig. 1 Line of sight

Fig. 1 above for the normal range of human vision, assuming that the ornamental customers, regardless of gender, young and old, the average height of 164cm, the viewing angle of the flower-appreciating people for the upper 56 degrees, the lower 74 degrees, then there is a range of visual field as shown in the figure, assuming that flower-appreciating people enjoy the flowers of the head to maintain a certain angle, will not change the level of the angle of the sandwich, then deduct the width of the path part of the path as well as visual field blind spot, the ornamental flowers there are three kinds of situations.

Situation 1:

Flower viewer normal flower viewing, there is no path obstruction of the visual field in the walking path of viewing (i.e., there is no path appearing in the field of view blocking the flower viewer to view flowers), there is a calculation formula as follows.

$$S = \pi(b^2 - a^2) \tag{5}$$

Where b is the farthest visual field distance at the upper angle of the line of sight, and a is the closest visual field distance at the lower angle of the line of sight.

Situation 2:

Flower viewers normally view flowers, and in the walking path of viewing there is a situation where the path obstructs the field of view (i.e., a part of the path appears in the field of view, blocking the flower viewer from viewing the flowers), there is a calculation formula as follows.

$$S = \pi(b^2 - a^2) - \pi xy \tag{6}$$

Where b is the farthest visual field distance of the angle on the line of sight, a is the nearest visual field distance of the angle under the line of sight, x is the elliptical horizontal axis of the visual field area covered by the path, and y is the elliptical vertical axis of the visual field area covered by the path.

Situation 3:

A flower viewer viewing flowers normally, and a situation where a path obstructs the visual field during the walk of viewing (i.e., a whole section of the path appears in the visual field, blocking the flower viewer from viewing the flowers), there is a calculation formula as follows.

$$S = \pi(b^2 - a^2) - \pi y1(b - x1) + \pi y2(b - x2 - x1) + \pi y3(a - x1) \quad (7)$$

Where b is the farthest visual field distance at the angle on the line of sight, a is the closest visual field distance at the angle below the line of sight, $x1$ is the shortest distance between the path and the person's position in a straight line, $x2$ is the width of the path in which the visual field area is covered by the path, $y1$ is the longitudinal long axis of the oval in which the visual field area is covered by the path, $y2$ is the longitudinal short axis of the oval in which the visual field area is covered by the path, and $y3$ is the length of the side of the ellipse left in the visual field area that is covered by the path.

$$MaxNum \quad (8)$$

Filter based on satisfaction, if satisfied:

$$f(t_{ij}) \geq 0.5 \quad (9)$$

Indicates that the customer viewing satisfaction if higher than or equal to 0.5 will next visit or introduced to relatives and friends around the next viewing, then there are $Num = Num + 1$, if the customer waiting time in the queue is more than 30min, it means that the customer is dissatisfied, will automatically leave the queue is not counted in the statistics.

2.3. Solving the Model

Assuming that the number of optimization variables is D , the search space of the particle swarm is D -dimensional, in which there is a swarm of particles composed of tourists in the flower base as particles.

The position of particle i at moment t :

$$x_i^t = (x_{i1}^t, x_{i2}^t, \dots, x_{id}^t), x_{id}^t \in [l_d, u_d] \quad (10)$$

Velocity of particle i at moment t :

$$v_i^t = (v_{i1}^t, v_{i2}^t, \dots, v_{id}^t), v_{id}^t \in [v_{\min}, v_{\max}] \quad (11)$$

$vmin$ is the minimum value of the path point particle velocity; $vmax$ is the maximum value of the path point particle velocity; ld is the lower limit of the path point particle search space; ud is the upper limit of the path point particle search space.

Two positions are recorded for each iteration of the pathpoint particle:

One is the individual optimal position:

$$p_i^t = (p_{i1}^t, p_{i2}^t, \dots, p_{id}^t) \quad (12)$$

The other is the population optimal position:

$$p_g^t = (p_{g1}^t, p_{g2}^t, \dots, p_{gd}^t) \quad (13)$$

Where: $1 \leq i \leq m, 1 \leq d \leq D$.

The velocity and position of particle i at the moment $t + 1$ is updated as follows:

$$v_{id}^{t+1} = \omega v_{id}^t + c_1 r_1 (p_{id}^t - x_{id}^t) + c_2 r_2 (p_{gd}^t - x_{id}^t) \quad (14)$$

$$x_{id}^{t+1} = x_{id}^t + v_{id}^{t+1} \quad (15)$$

v_{id}^{t+1} is the d th dimensional component of the flight velocity vector of particle i at moment $t + 1$ iteration. x_{id}^{t+1} is the d th dimensional component of the position vector of iterative particle i at the

moment $t + 1$. $c1$, $c2$ are learning factors to adjust the learning maximum step size. $r1$, $r2$ are two random numbers with values in the range $[0,1]$ to increase the search randomness. ω is the inertia weight, a non-negative number, which regulates the search range of the solution space, according to experience, when $\omega \in [0.9,1.2]$, the algorithm has better search performance.

2.4. Result Analysis

Table 1. Layout Design Results

| | Average time satisfaction | Average number of radiant flowers | Average number of customers |
|------------------|---------------------------|-----------------------------------|-----------------------------|
| Layout Design I | 0.81526 | 72568 flowers | 637 people |
| Layout Design II | 0.73264 | 85215 flowers | 524 people |

According to table 1, for the first single-entrance-single-exit flower path scenario, this single-entrance-single-exit design is suitable for when the number of people at the same time is small, and the overall effect of the tourists' visit will be better. For the second scenario of the flower path with two entrances and three exits, this dual-entrance, dual-exit design is suitable for when the number of visitors is high at the same time, and the overall viewing effect of the visitors will be better.

3. Optimization of Path Planning for Intercropping Planting of Flower Subspecies with Multiple Flowering Times

In this section, we consider two different planting layouts based on five subspecies of peony flowers with different blooming times, while satisfying the requirements of making more flowers visible to flower-appreciators and allowing more people to view the base every day and evaluating the advantages and disadvantages of each.

3.1. Parameter Preparation

Considering that the five subspecies of peonies in the rectangle are planted as Lipstick Red, Yu Ji Yanzhuang, Silver and Red Ciao Pair, Golden Jade Jiaozhang and Yellow Blossom Kui, with staggered planting in terms of form and color, and with different blooming periods but most of them are open in spring and summer, the spacing of planting varies, so that it can bring a better viewing experience to the customers.

3.2. Planting Spacing Optimization Model

3.2.1 Establishment of regression model between yield and economic output value and various factors

The intercropping of varieties takes into account the situation between two subspecies of peony in the same region during the same flowering period. For example, if we consider the planting of silver-red coquettish pairs and golden-jade interlocking chapters under the intercropping model, the yields and economic output values of the two species are lower than those of single-cropped silver-red coquettish pairs and golden-jade interlocking chapters, and the group composite yields, and output values are higher than those of single-cropped silver-red coquettish pairs and golden-jade interlocking chapters.

According to the quadratic saturation D-optimal design data model:

$$Y = a_o + \sum a_i X_i + \sum a_{ij} X_{ij} + \sum a_{ii} X_i^2 \tag{16}$$

The regression simulation of yield (Y) and economic output value (Z) of the middle crop group with the density (X_1) and silver red coquettish pairs (X_2) of Jinyu Jiaodongzhang in the actual simulated experimental points, the quadratic saturated D-optimal design is one of the experimental designs with high accuracy, and the correlation coefficient of the experimental fitted value and the measured value reaches to be highly significant, which indicates that the established regression model has high accuracy and strong practical value, and can be used for the analysis of the actual production. The mathematical model was established as follows. The mathematical model is established as follows:

$$Y = 12163.87 + 570.1X_1 + 25.9X_2 - 688.03X_1^2 - 199.59X_2^2 + 20.25X_2 \quad (17)$$

$$Z = 25022.86 + 770.11X_1 + 277.36X_2 - 1179.07X_1^2 - 991.13X_2^2 + 0.71X_2 \quad (18)$$

$$P < 0.01, R = 1.000 \quad (19)$$

The correlation coefficient between the fitted value and the measured value, $R = 1.000$, reaches the highly significant level, indicating that the established regression model has high precision, has certain practical value, and can be used for the analysis of intercropping group yield.

3.2.2 Effect analysis

(1) Main effect analysis of factors

Since the regression coefficients have been standardized, the size of the absolute value of the partial regression coefficients in the model can directly determine the importance of each factor. From the primary partial regression coefficient of the regression model, it can be seen that the coefficient of the density of Jinyu Jiaodongzhang (X_1) is greater than that of the density of Yinhong Qiaozhang (X_2) at each experimental point. From the quadratic regression coefficients, it can be seen that the effect curves of density (X_1) and density (X_2) of Jinyu Jiaozhang and Yinhong Qiaozhang are convex parabolic lines, and there are suitable intervals, and failure to reach or exceeding the suitable intervals may lead to low group yield and economic output value. From the interaction term regression coefficient, it can be seen that the density (X_1) of Jinyu Jiaozhang and the density (X_2) of Yinhong Qiaozhang have a positive effect.

(2) Single factor effect analysis

The use of “dimensionality reduction method” will be one of the factors fixed at zero level, you can get another factor and the effect of the dependent variable between the equation, in order to further analyze the independent variable of different values when the change rule of the dependent variable. The single-factor effect analysis of the planting density on group yield and economic output value of Jade Cross Chapter: fix the density of silver red coquettish pairs (X_2) at the zero level, respectively, and get the effect equations of the planting density of Jade Cross Chapter (X_1) and the group yield (Y) and economic output value (Z).

$$Y = 12285.96 + 486.93X_1 - 592.45X_1^2 \quad (20)$$

$$Z = 25022.86 + 770.11X_1 - 1179.07X_1^2 \quad (21)$$

One-way effect analysis of silver red cochineal on density on group yield and economic output value: fixing the density of golden jade cochineal (X_1) at zero level, the effect equation of silver red cochineal on density (X_2) with group yield (Y) and economic output value (Z) was obtained.

$$Y_A = 12163.87 + 25.9X_2 - 199.59X_2^2 \quad (22)$$

$$Y_B = 12400.3 + 36.51X_2 - 229.58X_2^2 \quad (23)$$

$$Y_C = 12285.96 + 8.68X_2 - 173.09X_2^2 \quad (24)$$

$$Z_A = 25022.86 + 277.36X_2 - 991.13X_2^2 \quad (25)$$

$$Z_B = 25010.89 + 403.66X_2 - 1224.68X_2^2 \quad (26)$$

$$Z_c = 24736.32 + 186.78X_2 - 1075.29X_2^2 \quad (27)$$

(3) Factor interaction effect analysis

There are interaction effects of the density of Jinyu Jiaodongzhang and the density of Yinhongqiaozhang on the group yield and economic output value, and the group yield and economic output value show a trend of increasing and then decreasing with the increase of the planting density of Jinyu Jiaodongzhang and Yinhongqiaozhang.

3.3. Multi-objective Optimization Model

3.3.1 Garden planning program

A garden path grid is set as the base path, and the entrance and exit are set as the multi-entry and multi-exit paths, on the basis of which the simulation simulation and evaluation of the advantages and disadvantages of tourists are carried out. The blank spaces are all flower planting places, and the planting area is as shown in the above section, setting the width of the pedestrian path as 3m, and the length of the rectangular flower ornamental place as 200m and the width as 100m.

Floyd algorithm:

Assuming that the adjacency matrix of the graph G-rights is A_0 , the

$$\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (28)$$

To hold the length of each side, where:

$$\begin{aligned} a_{11} &= 0 \\ a_{ij} &= \infty \\ i, j &= 1, 2, \dots, n \end{aligned} \quad (29)$$

There are no edges between i, j . They are replaced in the program by sufficiently large numbers that are not possible for each edge.

$$\begin{aligned} a_{ij} &= w_{ij} \\ i, j &= 1, 2, \dots, n \end{aligned} \quad (30)$$

w_{ij} is the length between i, j .

The basic idea of Floyd's algorithm is to recursively generate a matrix sequence A_0, A_1, \dots, A_n , where $A_k(i, j)$ denotes the length of the shortest path whose vertex sequence number is not greater than k that passes on the path from vertex v_i to vertex v_j .

The following iterative formula is applied for the calculation:

$$A_k(i, j) = \min(A_{k-1}(i, j), A_{k-1}(i, k) + A_{k-1}(k, j)) \quad (31)$$

Where k is the number of iterations, $i, j, k = 1, 2, \dots, n$. Finally, when $k = n$, A_n is the value of the shortest path between the vertices.

3.3.2 The objective function

$Max f(t_{ij})$ indicates the maximum customer satisfaction, customer viewing satisfaction if higher than or equal to 0.5 will be the next visit or introduced to relatives and friends for the next viewing, there are $Num = Num + 1$, if the customer waiting time in the queue is more than 30min,

the customer is dissatisfied, will automatically leave the queue is not counted in the statistics. $Max S$ indicates the maximum area of flower viewing by customers, including cases where there is no path obstructing the view, cases where part of the path obstructs the view, and cases where all the paths obstruct the view, and $Max Num$ indicates the number of repeat customers.

3.4. Solving the Model

3.4.1 Improved immunization algorithm

Immunogenetic Algorithm (IGA) is a new algorithm constructed based on the original genetic algorithm framework by introducing new immunization operators from scratch. Negative Selection Algorithm (NSA) is an immune algorithm that mimics the “negative selection” mechanism of thymic T-cells. NAG draws on the autologous-allogeneic recognition mechanism of the immune system, eliminating unfavorable cells and retaining those that are capable of detecting alloantibodies, so as to realize the dynamic detection of the immune system. B-cell algorithm (BCA) is an immune algorithm based on the self-learning and self-organizing mechanism of the immune system. Based on the doctrine of clonal selection, BCA has a strong ability to find the best. Adopting the uniqueness network mechanism, BCA uses networks with multiple coexisting patterns. Improved vaccination algorithm: Since each vaccine itself already contains location information, this information should be utilized when injecting the vaccine, instead of using the original random injection method. Multiple Swarm Artificial Immunization Algorithm Optimization on Multiple Peak Functions (MAIA) Improved Antibody Selection Parameters for:

$$e_v(i) = \frac{ax_v}{C_v} \quad (32)$$

Where ax_v is the matching coefficient of the antibody antigen and C_v is the antibody concentration.

3.4.2 Taboo search algorithm

The taboo search algorithm (TS) is a meta-heuristic stochastic search algorithm, a search method used to jump out of a local optimum, that is, for a portion of the local optimal solution found, it is consciously avoided (but not completely isolated) so as to obtain more search intervals. It starts from an initial feasible solution and selects a series of specific search directions (moves) as a trial, choosing to realize the move that allows the most change in the value of a specific objective function. In order to avoid falling into local optima, the TS search employs a flexible “memory” technique, which records and selects the optimization process that has been performed and guides the next search direction.

3.5. Stability and Result Analysis

The results show that both the immune algorithm and the forbidden search algorithm are able to effectively solve the proposed optimization model of the open-row scheme, and successfully begin to gradually converge after about 200 generations, but it is more obvious that the optimized immune algorithm optimization results are lower for the model is more appropriate, the specific convergence of the situation is shown in Fig. 2.

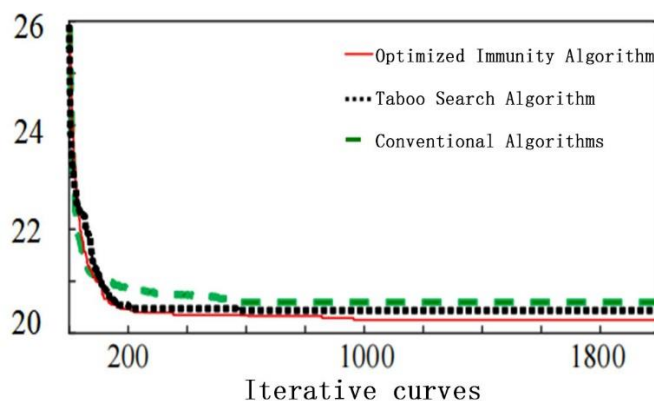


Fig. 2 Algorithm Comparison

3.6. Result Analysis

Table 2. Layout Design Results

| | Average time satisfaction | Average number of radiant flowers | Average number of customers |
|------------------|---------------------------|-----------------------------------|-----------------------------|
| Layout Design I | 0.84336 | 80263 flowers | 594 people |
| Layout Design II | 0.77694 | 87467 flowers | 683 people |

As shown in table 2, for the first flower path scenario, horizontal three rows and vertical three columns, the multiple entrances and multiple exits design is able to significantly improve the time satisfaction and visit efficiency of the tourists, although the tourists visit a relatively short route. For the second flower path scenario, with three horizontal rows and four vertical columns, this design is suitable for when the number of visitors is high at the same time, and the overall viewing effect of the visitors will be better compared to the first one.

4. Conclusion

In this paper, a multi-objective optimization model integrating visitor behavior simulation and planting benefit analysis is constructed for the dynamic operation demand of the flower base. The results show that the synergistic optimization of path planning and planting structure can significantly improve the utilization rate of spatial and temporal resources of the base. In terms of path design, the single-entrance layout optimizes the search of path points by particle swarm algorithm, which can effectively improve visitors' time satisfaction in low traffic scenarios, while the multiple-entrance design combined with the shortest path solution of Floyd algorithm can achieve higher visitor throughput during peak hours. For the optimization of multi-flowering planting, the improved immunity algorithm determines the optimal planting ratio of Jinyu Jiaozhang and Yinhong Qiaoyou through the antibody concentration adjustment mechanism, which verifies the synergistic potential of intercropping mode. The study found that there is a significant trade-off between time satisfaction and viewing efficiency in different layout schemes, which should be dynamically selected according to the actual passenger flow characteristics. The innovation of this study is that it breaks through the limitation of traditional static planning and incorporates the behavioral characteristics of visitors and crop growth patterns into a unified optimization framework, which provides methodological support for the fine management of urban agricultural parks. Future research can further expand to multi-season dynamic adjustment strategies and realize real-time optimization by combining with Internet of Things (IoT) data to enhance the practical application value of the model.

References

- [1] ZHANG Deshun, CHI Zhiwei. Discussion on parameterized layout of exhibition gardens--Taking the Japanese garden of the 8th China Flower Expo as an example[J]. China Garden,2014,30(05):87-91.
- [2] LU Yuming, CAO Longhao, DONG Xianjuan, et al. Constrained multi-objective evolutionary algorithm based on mean vector angle and dynamic reduction mechanism[J/OL]. Control and Decision Making,1-8[2025-03-15]. <https://doi.org/10.13195/j.kzyjc.2024.1229>.
- [3] MA Yu, WEI Wenhong. An improved particle swarm optimization algorithm based on simplified equations[J]. Journal of Dongguan Institute of Technology,2025,32(01): 41-47.DOI: 10.16002/j.cnki.10090312.2025.01.007.
- [4] Deng Shuo. Practical exploration of Monte Carlo method in cultivating students' computational thinking[J]. China Modern Educational Equipment,2024, (16): 45-48.DOI: 10.13492/j.cnki.cmee.2024.16.014.
- [5] Jiao C-Y, Zhou S-M. Secondary saturation D-optimal design[J]. Shandong Agricultural Science,1989, (02):46-49+42.
- [6] YANG Zhen, LI Wanqing, ZHANG Xiongtao. An immunization algorithm based on directional sampling and adaptive selection[J]. Computer Engineering and Design,2024,45(08): 2364-2370.DOI:10.16208/j.issn1000-7024.2024.08.017.