Quantitative analysis of stadium operation management and spatial layout optimization based on computer placement algorithm

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Abstract

Focused on the problems of the high investment and maintenance cost, slow recovery of the capital and complicated later-period management of large-scale stadiums, this paper proposes a spatial layout optimization strategy based on PSO-GSO algorithm. It extends the behavior classification model of swarm members in GSO algorithm, and adopts the random search together with the angle search of GSO and step size search of PSO algorithm, to well achieve the optimization of spatial layout of stadium. Finally, this paper makes a quantitative analysis on the influence factors of the stadium management. The simulation results show that the PSO-GSO algorithm proposed in this paper has good application in the spatial layout optimization of stadium, and the largest influence factors on the management are the facilities condition and consumption level.

Keywords: stadium management, PSO-GSO algorithm, computer placement, spatial layout optimization, influence degree analysis

1 Introduction

With the transformation of social economic system, sport becomes more related to economy in our country, and sports industry becomes a hot research topic [1]. Stadium resource is an important part of sport industry and an important material guarantee for its development which directly affects the reform and development of sports industry [2].

Recent years, the operation of stadium is a widely studied topic with emergence of many meaningful papers. The extended management concepts greatly met the people’s requirement of physical fitness, and achieved well economic and social profit [3]. At the same time, a variety of operation styles, sports competition, sports show, fitness, training market etc., make the supplementary service items increase significantly. Sports industry becomes a comprehensive market integrating sports, entertainment and consumption [4]. In light of the existing problems in our stadium management, many researches proposed a series of special methods from marketing strategy to service quality. Li analyzed the management situation of Meihu Sports center in Yiwu, Zhejiang province, raised a concept of Yiwu Style for the operation strategy of national stadiums [5]. Yu et al. proposed three opinions: (1) To construct appropriate spatial layout of sports industry, and develop the industry with stadium construction; (2) To be actively opening to outside world and persist the road of industrialization; (3) To establish a healthy laws and regulation system to ensure the development orderly and healthily[6]. Some researches discussed the development trend of stadium from management concept and style combining he management situation in our country [7]. Chen Ming put forward three management styles of casual style management of public stadium, competitive style operation management, and mixed style [8]. Zhu et al. analyzed the main operation styles of current stadiums, leaned from the experience of successive stadium management cases at home and abroad, and raised the main idea for future stadium management reform: independent management, contract operation and enterprise management [9].

In order to well manage the stadium, this paper put forward an optimization strategy of the spatial layout of stadium based on PSO-GSO algorithm, and quantitatively analyzed the influence degree of the stadium management so as to find an appropriate road for stadium development.

2 Group search optimizer

Group Search Optimizer (GSO) was jointly proposed by S. He, Q. H. Wu and J. R.Saunders in 2006, originating from the foraging behavior of social animals like birds, fishes and tigers [10].

GSO is a group consisting of some individuals. In a n-dimensional searching space, the place of individual i after k iteration is $X_i^k \in R^n$, with angle $\varphi_i^k = (\varphi_{i1}^k, ..., \varphi_{i(n-1)}^k) \in R^{n-1}$, and angle direction $D_i^k(\varphi^k) = (d_{i1}^k, ..., d_{in}^k) \in R^n$.

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$$d_{i1}^k = \prod_{p=1}^{n-1} \cos(\varphi_{ip}^k) , \tag{1}$$

$$d_{ij}^k = \sin(\varphi_{i(j-1)}^k) \prod_{n=i}^{n-1} \cos(\varphi_{ip}^k) , \tag{2}$$

$$d_{in}^k = \sin(\varphi_{i(n-1)}^k) . \tag{3}$$

GSO algorithm includes three kinds of members: the finder, entrants and stragglers in PS model. For the convenience of calculation, PS model is simplified to assume that only a finder is searching each time, the entrants and stragglers left. The simplest entry strategy is to assume all the entrants are added to resource when searching the finder. In the optimization problem, the unknown optimal solution can be randomly distributed in anywhere of the search space. Each individual in the group is searching the optimal position in searching space. Because these three kinds are same in traits, each individual can switch among them.

In GSO algorithm, the fundamental scanning strategy is introduced from White crappie, taking the visually scanned region as n -dimensional space, through the maximum angle $\theta_{\max} \in R^{n-1}$ and maximum distance $l_{\max} \in R^l$ in 3D space.

The behavior of finder X_p in k generation is written as follows.

1) Finder scans from zero angle to randomly selected region. The point before zero angle is

$$X_z = X_p^k + r_1 l_{\max} D_p^k(\varphi^k) . \tag{4}$$

The point of right side is

$$X_r = X_p^k + r_1 l_{\max} D_p^k(\varphi^k + r_2\theta_{\max/2}) . \tag{5}$$

The point of left side is

$$X_l = X_p^k + r_1 l_{\max} D_p^k(\varphi^k - r_2\theta_{\max/2}) . \tag{6}$$

Here, $r_1 \in R^l$ is a random number satisfying the normal distribution, with mean value 0 and standard deviation 1, and $r_2 \in R^{n-1}$ is also a random number uniformly distributing in $(0,1)$.

2) Finder will find the optimal point in the best resource. If this optimal point has a better resource than current position, then it will fly to this position; otherwise, it will stop at current position and turn to a new angle.

$$\varphi^{k+1} = \varphi^k + r_2\alpha_{\max} , \tag{7}$$

where α is a constant, and $\alpha_{\max}$ is the maximum angle of turn.

3) If finder cannot find a better position after iteration, then it will go back to zero.

$$\varphi^{k+1} = \varphi^k . \tag{8}$$

In GSO algorithm the copy of region is the most commonly used search behavior. At k iteration, the region copy behavior of the i entrant is seen as being close to finder randomly.

$$X_i^{k+1} = X_i^k + r_3(X_p^k - X_i^k) , \tag{9}$$

where $r_3 \in R^n$ is a random number distributing in $(0,1)$ randomly.

3 The optimization of GSO algorithm based on particle swam optimization algorithm

3.1 PARTICLE SWARM OPTIMIZATION ALGORITHM

Particle Swarm Optimization (PSO), is bionic optimization algorithm for solving complex optimization problems proposed by Kennedy and Eberhart in 1995 based on foraging behavior of birds with strong robustness. It has two theory bases, artificial life and evolutionary computation.

This algorithm initializes a group of random particles firstly, then finds the optimal solution through iteration. In each iteration, particle updates itself by tracking two extreme values. One is the optimal value particle wants, called as individual extreme value p^{best} , and the other is the best solution in the whole population, called as the global extreme value g^{best} . In addition, not the whole population, but part of it is required as the neighbor of particle, then the extreme value of all the neighbors is the local extreme value.

When it find two extreme values, particle will update itself speed and location according to Equations (10) and (11)

$$\begin{aligned} v[i] = v[i] + c_1 \cdot rand() \cdot (p^{best}[i] - present[i] + \\ c_2 \cdot rand() \cdot (g^{best}[i] - present[i]) \end{aligned} , \tag{10}$$

$$present[i] = present[i-1] + v[i] , \tag{11}$$

where $v[i]$ is the particle velocity, $present[i]$ is position of current particle, $rand()$ is a random number in $(0,1)$, c_1 and c_2 is learning factor, usually $c_1 = c_2 = 2$.

Originating from the foraging behavior of birds, PSO algorithm is similar to genetic algorithm. It is also an optimization tool based on iteration. Currently the algorithm is widely used in function optimization, neural network training, data mining, fuzzy system control and other applications. It has achieved favorable effect in continuous spatial optimization area. Therefore, we combine it with GOS algorithm in the application of spatial structure optimization.

3.2 PSO-GSO ALGORITHM

PSO-GSO algorithm extends the behavior classification model of group member in GSO algorithm adopting random search and a way of angle search, and step search of PSO algorithm at the same time. The PSO-GSO algorithm after optimization is realized as follows.

In a n-dimensional space, the position of member i after k iterations is $X_p^k \in R^n$. Before iteration, the position of every member can be initialized with random value. After k iteration, the fitness value of each member's position is calculated to find the best member as the finder, denoted as X_p^k, starting from zero angle, and then searching from three directions following the Equations (4), (5) and (6) so as to find better positions.

For other members, searchers are randomly selected with a certain probability to follow the finder and participate the search with random step size according to Equation (9).

The left members are stragglers randomly selecting search angles and distance following Equations (7) and (12), and moving location following Equation (13).

$$l_i = \alpha \cdot r_1 l_{\max}, \tag{12}$$

$$X_i^{k+1} = X_i^k + l_i D_i^k(\varphi^{k+1}). \tag{13}$$

After k iterations, if finders don't update, namely meeting the Equation (14), then algorithm steps into PSO algorithm program, and finder is set as the optimum position P_g^k, namely Equation (15). If it is the first time to step into PSO, then searcher or straggler is set as the optimum position P_i^k, and then next optimum position P_i^k is selected with Equation (16) where $M(X^k, P^{k-1})$ represents a process of obtaining new optimum position by substituting P^{k-1} with a better individual.

$$f(X_p^k) \geq f(X_p^{k-1}), \tag{14}$$

$$P_g^k = X_p^k, \tag{15}$$

$$P_i^k = M(X_i^k, P_i^{k-1}). \tag{16}$$

In PSO algorithm, the selection of particle swarm follows the GSO, calculating flying speed and position with Equations (10) and (11).

The fitness of position of each member is calculated after ending PSO algorithm to find the optimum position P_g^k. If $f(P_g^k) < f(X_p^k)$, then the position of the finder of next iteration is replaced by the optimum position P_g^k in latest particle swarm, namely Equation (17).

$$X_p^{k+1} = P_g^k. \tag{17}$$

4 Simulation research

This paper evaluates a stadium with proposed model, divided into quantitative analysis of operation management and spatial layout optimization.

4.1 QUANTITATIVE ANALYSIS OF OPERATION MANAGEMENT

The experiment object is the operation management data of a stadium, and this paper mainly studied the influence degree Y. Because the operation condition of stadium has many influence factors, this paper mainly considered some data following, facilities X_1, service X_2, managers X_3, government support X_4, media propaganda X_5 and consumption level X_6.

Our goal is to establish multiple linear regression model to study the management influence factor Y through variables $X_1 \sim X_5$. We deal with the statistic data with SPSS16.0, and establish the model as follows.

$$\begin{aligned} Y &= \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \\ &+ \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \varepsilon \end{aligned}, \tag{18}$$

β is the regression parameter and ε is random disturbance term. There exists probably a multicollinearity problem between each variable. To eliminate it, we take back regression method to screen the entry variables according to definite standards (entry probability ≤ 0.05, emigration probability ≥ 0.10), as shown in Table 1.

TABLE 1 Statistical regression analysis

Model	Non-standardized coefficients		Standard Coefficient	t	Sig	Collinearity statistics	
	B	Standard error				Tolerance	VIF
Constant	98.7	82.3		5.41	0.01		
X_1	0.01	0.00	0.81	8.62	0.00	0.272	3.675
X_6	0.74	0.32	0.21	2.30	0.05	0.272	3.675

From Table 1 we can see that the facilities and consumption level has significant influence on the management Y. At the same time, they pass the F and t test with small VIF value, which indicates that they have no colinearity between each other.

The error test is demonstrated in Figure 1.

The residual probability statistics chart tells it follows the normal distribution. The proposed model proves to be efficient.

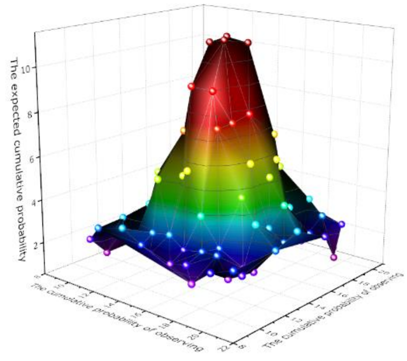

FIGURE 1 The residuals charts of the impact degree model

4.2 THE OPTIMIZATION OF SPATIAL ARRANGEMENT

This paper took the improved algorithm to optimize the spatial layout of this stadium, with the effect picture as follows. Figure 2 and Figure 3 show that the proposed algorithm can optimize the spatial layout of the stadium well, with better convergence rate than GSO algorithm

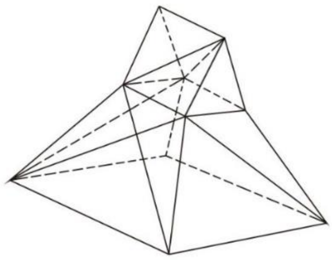

FIGURE 2 The optimization of space structure

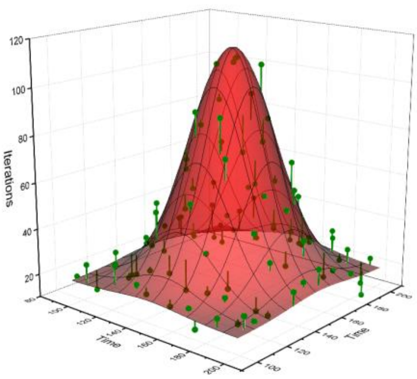

FIGURE 3 Convergence rate

5 Conclusions

Large-scale stadium, as a material basis of all kinds of sports events and national fitness, is a necessary hardware facility in the development of sports industry. However, it becomes a general problem that the management efficiency of stadium is bad due to the high investment and high maintenance cost, complicated management, and that it is only design for sport events but never considers the utilization after events. In light of current situation, this paper put forward a spatial layout optimization strategy based on PSO-GSO algorithm, and quantitatively analyzed the management of a stadium. The simulation results show that the largest influence factors of the stadium management are facilities condition and consumption level. Our proposed algorithm can deal with the spatial layout optimization problem and provide a data basis for the stadium development.

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