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Research Article

Research on Internal Layout Optimization of Logistics Node under the Conditions of Complex Terrain Based on Computer Vision and Geographical Simulation System

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This paper solves the problem of logistics node space relationship beyond expression based on computer vision technology, proposes internal layout optimization mathematical model of logistics node on the basis of overall consideration of function zone geometry shape, the optimal area utilization rate, and the minimum material handling cost, and then designs a highly mixed genetic simulated annealing algorithm based on multiagent to get layout solution. Through contrasting, the result has shown that the model and algorithms put forward in this paper can realize large-scale internal layout optimization of logistics node under the conditions of complex terrain and multiple constraints.

1. Introduction

Layout problem can be widely found in city planning, transportation, architectural design, machinery manufacturing, and other fields, with a high degree of complexity. Logistics node internal layout problem can be divided into discontinuous layout and continuous layout; when the function zone number is greater than 15, it has been proved that these two kinds of logistics node layout optimization belong to NP-hard [1]. As early as 1970s, there have been some computer algorithms and programs being applied to layout planning with remarkable effect [2, 3].

But on the whole, there are still some shortcomings on the research of layout programming of logistics node, affecting its theory and application values. Layout optimization of logistics node should take various aspects and detailed technical requirements into consideration; the present research usually considers a large amount of data as follows [4]:

$$\{P, Q, R, S, T\}, \tag{1.1}$$

where P expresses product, Q expresses quantity, R expresses process route, S expresses service and support, and T expresses time. Research on layout problem is mostly confined in the rectangular function zone, and irregular function zones could be transformed into rectangular ones through various ways. For traditional layout method, selected region is taken as a "white paper," without taking into consideration the internal geographic barriers and trunk road on the regional segmentation and also the requirements of activity relationship between the surrounding regions and interior regions. Moreover, most of the published researches on layout problem established objective function minimizing the logistics cost as follows:

$$\min Z = \sum_{j=1}^{K}\sum_{i=1}^{K} C_{ij} \cdot f_{ij} \cdot d_{ij}, \tag{1.2}$$

while they ignored function zone's geometry shape, area utilization rate, and other factors. In general, the in-depth research on internal layout optimization of logistics node under the conditions of complex terrain and various constraint conditions is urgently necessary, because internal layout optimization problem of logistics node is characterized by complex terrain, being subject to various factors and multiple constraint conditions as well as the relationship between spatial form and location beyond expression. Based on the computer graphics and pattern recognition method, computer vision technology is introduced to express space relationship difficult to be expressed, and this paper takes function zone geometry shape, the optimal area utilization rate, and the minimum material handling cost into consideration so as to achieve the comprehensive facilities layout optimization of logistics node. This paper gets the initial solution by taking the advantage of construction algorithm in generating initial solution and carries on solution optimization by combining the ideas of improved algorithm and evolutionary algorithms [5, 6].

2. Model Formulation of Internal Layout Optimization of Logistics Node

2.1. Foundation of Mathematical Model

The internal layout programming of logistics node must be on the basis of topography and physiognomy of the selected location and determines the planar or spatial position of each part composing node. Still, according to the internal operation procedure, it ascertains the internal operation flow, on which basis, it plans the location and layout of each function unit.

In order to further expound the mathematical model of this problem, firstly assuming that the planning region is divided into grid unit with W rows and L columns (hereby supposing that the spacing requirements of each function zone have been considered the in required area of each function zone), namely, the total quantity of land use unit is $W \cdot L$. D_{ij} means the straight line distance between function zones i and j. K kinds of function attribute types should be arranged. X_{ijk} represents the function attribute type k of cell (ij), and X_{ijk} is a quadratic variable. If the function attribute type of cell (ij) is k, then its value is 1; otherwise it is 0. G_k denotes the kth kind of function type scale. $S_{L_{ij,i'j'}}$ shows the adjacent quantity sum of cell (ij) and cell $(i'j')$. Function zone shape, dimension, and other factors are processed by introducing penalty function in the irregular degree, area ratio, and other parameters in following application of mode recognition.

There may be many programming objectives which should be abided by in the layout programming of logistics node. In this paper, objective function of the minimum logistics cost is adopted to formulate the following optimization model:

$$\min Z = \sum_{j=1}^{K}\sum_{i=1}^{K} C_{ij} \cdot f_{ij} \cdot d_{ij} + \sum_{j=1}^{M}\sum_{i=1}^{K} C'_{ij} \cdot f'_{ij} \cdot d'_{ij} + \sum_{j=1}^{N}\sum_{i=1}^{K} C''_{ij} \cdot f''_{ij} \cdot d''_{ij}, \tag{2.1}$$

$$\text{s.t.} \sum_{i=1}^{W}\sum_{j=1}^{L} X_{ijk} = G_k \quad \forall k, \tag{2.2}$$

$$\sum_{k=1}^{K} X_{ijk} = 1 \quad \forall i, j, \tag{2.3}$$

$$S_{L_{ij,i'j'}} \geq 1 \quad \forall (ij, i'j'), \tag{2.4}$$

$$m_{i_1 j_1 k, i_2 j_2 k} = 1, \tag{2.5}$$

$$d_{i_1 j_1, i_2 j_2} > D, \tag{2.6}$$

$$i \notin B_{ij}, \qquad j \notin B_{ij}, \tag{2.7}$$

$$\max_{i_1 j_1, i_2 j_2} d_{i_1 j_1, i_2 j_2} \leq (\lambda a)^{1/2}. \tag{2.8}$$

Of which, C_{ij} is the logistics cost of per unit good and unit distance between function zones i and j; f_{ij} means the logistics capacity between function zones i and j; d_{ij} donates the straight line distance of material handling between function zones i and j; C'_{ij} is the logistics cost of per unit good and unit distance between function zone i and key control point j; f'_{ij} represents the logistics capacity between function zone i and key control point j; d'_{ij} stands for the straight line distance of material handling between function zone i and key control point j; C''_{ij} is the logistics cost of per unit good and unit distance between function zone i and key control line j; f''_{ij} shows the logistics capacity between function zone i and key control line j; d''_{ij} means the straight line distance of material handling between function zone i and key control line j; $m_{i_1 j_1 k, i_2 j_2 k}$ represents Manhattan distance of two cells $(i_1 j_1)$ and $(i_2 j_2)$ with function attribute as k; $d_{i_1 j_1, i_2 j_2}$ denotes Euclidean distance of cell $(i_1 j_1)$ with function attribute as k_1 and cell $(i_2 j_2)$ with function attribute as k_2; B_{ij} shows the cell set of one grid cell (ij) forbidding layout area; $d_{i_1 j_1, i_2 j_2}$ means the distance between cell $(i_1 j_1)$ and cell $(i_2 j_2)$; a represents plot area; λ is a kind of measure of compact shape; K is the quantity of function zone; M is the quantity of key control point; N is the quantity of key control line; L is the minimum enclosure rectangle length of logistics node plot; W is the minimum enclosure rectangle width of logistics node plot.

In the model, formula (2.1) means that in order to consider the logistics costs among each function zone and key control line as well as the minimum cost among each function

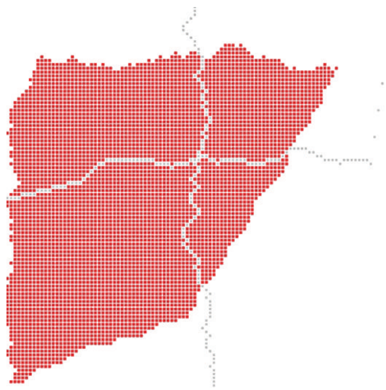

Figure 1: Representation method of land plot with complex shape.

zone and key control point, the constraint conditions (2.2)–(2.8) are, respectively, function zone scale, grid occupancy, adjacency, distance, direction, and shape compact constraint [7]. In addition, there may be other constraint conditions in the specific and practical problems, for example, the transverse and longitudinal distances between building and high voltage corridor, shape constraint of function zone, parallel constraint between function zone shape and main road, and so forth.

2.2. Graphical Representation of Model

2.2.1. Geometric Drawing Expression of Complex Land Plot

Before making function zone and facility layout by using computer tools, firstly it needs to transfer planning area into data format. Three kinds of commonly used polygon representation methods are vertex sequence method, isometric scanning method, and grid fitting method. In this paper, with an eye to the diversity of function zone form, isometric scanning method is adopted to denote the complex land plot shape of logistics node. Simultaneously, in order to simplify the analysis, vertex sequence chain code (Freeman chain code) is used to conduct the form analysis on function zone configuration. As for the fixed (existed) function zone, in the process of algorithm optimization, the functional attributes of corresponding pane of function zone are set as nonchangeable, namely, realizing the retention to the fixed (existed) function zone. For example, the planning area is divided into grid diagram with 100×100 panes; red area is planning scope, while gray area is the planned and constructed road in the region, as illustrated in Figure 1.

2.2.2. Expression of Function Zone Shape and Constraint Conditions

By borrowing computer vision and pattern recognition methods, this paper identifies and restricts the function zone shape and size. In computer vision and pattern recognition, shape is the representation of binary image to target range, which can be regarded as target contour. In the spatial programming problem of logistics node, two kinds of spatial units can be taken as decision variable: for "natural" plot segmented by road and regular grid cell segmented by regular grid, on the basis of advantages and disadvantages of both sides, different scholars took varied spatial cells as decision variable [8–11]. On combination of both, this paper picks regular grid cell as spatial decision variable and adopts Freeman chain code to describe the shape and spatial information of each function zone. And the function zone shape and constraint were given by introducing irregularity degree and the minimum bounding rectangle.

(1) *Description on Function Zone and Representation of Grid Vertex Chain Code*

As for functional zone shape, this paper borrows ideas from Bribiesca who proposed the method of marking image by boundary pixel vertex [12]. Chain code is a kind of coding representation method to boundary points, which is characterized by a series of connected tangential paths with specified length and direction are used to represent the target boundary. As every tangential path has the fixed length and limited quantity, only should the starting point of boundary be indicated by coordinates [13]. This paper adopts Freeman chain code with eight orientations to remark the shape of each function zone. Boundary chain code of function zone can be expressed as $\{(x_0, y_0)1/a_0a_1a_2 \cdots a_{n-1}\}$, where (x_0, y_0) means the starting grid coordinate on the boundary of function zone, and $a_i \in \{0, 1, 2, 3, 4, 5, 6, 7\}$ is the eight-orientation chain code of function zone. The boundary chain code of a function zone can be illustrated as

$$L = x_0, y_0, d_1, d_2, \ldots d_{P-2}. \tag{2.9}$$

Among which, P is regional boundary length (i.e., circumference).

For the acquisition of detailed information of Freeman chain code, please refer to the literature [14], and for the boundary straightness detection of function zone, please see the literature [15].

(2) *Regularity Degree of Regional Boundary*

Based on the eight-orientation chain code above, a function zone could be indicated as

$$L = x_0, y_0, d_1, d_2, \ldots d_{P-2}. \tag{2.10}$$

In the formula, P is regional boundary length (i.e., circumference). Regularity degree could be used to denote the degree of boundary regularity:

$$\sigma = R(L) \tag{2.11}$$

In the formula, L means the boundary of the segmented region, and R is the operator of regularity degree.

To get regularity degree of region is to obtain that of regional boundary. L is the known boundary chain code, which could be used to convert bidimensional region to one-dimensional function, setting

$$a_i = \begin{cases} 0 & |d_i - d_{i-1}| = 0, 4, \\ 0.5 & |d_i - d_{i-1}| = 2, 6, \\ 1 & |d_i - d_{i-1}| = 1, 3, 5, 7, \end{cases} \tag{2.12}$$

of which when $i = 0$, let $d_{i-1} = 0$.

Thuswise, regularity degree could be expressed as

$$\sigma_1 = \frac{1}{P}\sum_{i=0}^{P}\sum_{k=0}^{i} a_k. \tag{2.13}$$

Setting one-dimensional function $y = f(x)$, firstly define

$$y_i = f(x_i) = d_i. \tag{2.14}$$

The equalizing value of function $y = f(x)$ is

$$\mu = \frac{1}{P}\sum_{i=0}^{P} f(x_i) = \frac{1}{P}\sum_{i=0}^{P} d_i. \tag{2.15}$$

As thus, regularity degree could be denoted as

$$\sigma_2 = \sqrt{\frac{1}{P}\sum_{i=0}^{P}\left(f(x_i) - \mu\right)^2} = \sqrt{\frac{1}{P}\sum_{i=0}^{P}\left(d_i - \mu\right)^2}. \tag{2.16}$$

Then comprehensive regularity degree σ could be illustrated as

$$\sigma = w_1\sigma_1 + w_2\sigma_2, \tag{2.17}$$

where w_1, w_2 indicate the weights of σ_1 and σ_2.

(3) *The Minimum Bounding Rectangle, Area Ratio, Macroaxis, and Minor Axis of Function Zone*

Under the condition of considering area ratio constraints, it is of extreme importance for improving land utilization rate if taking the own shape feature of function zone with irregular shape into full consideration and choosing the minimum bounding rectangle for layout. No minimum bounding rectangle exists at concave vertex. So when a vertex is determined as concave vertex, it should be eliminated by the way of connecting its adjacent points and then reconducting vertex numbering. And the operation is repeated till all of vertexes are concave vertexes. For the detailed solving steps of the minimum bounding rectangle, please refer to the literature [16].

It is defined that the area ratio of function zone i is the minimum bounding rectangle area divided by its actual area. It is expressed as the following formula:

$$m_i = \frac{S_i}{Sj_i}. \tag{2.18}$$

In the formula, m_i means area ratio of function zone i, and S_i denotes actual area of function zone i, Sj_i indicates the minimum bounding rectangle area of function zone i.

Meanwhile, to define the long edge of the minimum bounding rectangle of function zone i as macroaxis, state side length by lj_i; to define the short edge of the minimum bounding rectangle of function zone i as minor axis, state side length by wj_i.

(4) *Representation of Shape Features and Constraints of Function Zone*

The shape of each function zone inside the logistics node often satisfies certain geometric conformation, such as common rectangular and circle. In production practice, besides resulting in investment waste, improper, oversized, and low efficiency used area of function zone also brings about management waste and inconvenience. Consequently, it is of necessity to adopt and introduce irregularity degree to improve the shape of irregular workshop and increase the area utilization rate of the construction. In order to make the function zone shape to satisfy the constraint, we borrow ideas from the regional characteristics of the shape, which could equally and effectively describe shape characteristics [17, 18]. This paper adopts the following typical characteristic value.

(A) Area

Function zone area ρ_g is the percentage of function zone g accounting for the total area of logistics node, reflecting the scale character of function zone

$$\rho_g = \frac{\sum_i \sum_j \sum_{k=g} X_{ijk}}{\sum_i \sum_j \sum_k X_{ijk}}. \tag{2.19}$$

(B) Discrete Degree

Shape discrete degree v_g is similar to the bounding box of function zone g, reflecting the discrete level of this function zone grid relative to the center of function zone. Due to its statistical characteristics, it is obviously more robust than rectangular bounding box

$$v_g = \frac{\sqrt{\sum_{(x,y)\in \mathrm{G}} (x-\overline{x})^2 + (y-\overline{y})^2 / G_g}}{\max(W, H)}, \tag{2.20}$$

where G expresses function zone g, and G_g is the scale of function zone g.

(C) Eccentricity

Eccentricity e is the ratio of minor axis and macroaxis of the most suitable ellipse of function zone, roughly reflecting the shape of function zone and possessing rotational invariance

$$e = \frac{I_{\min}}{I_{\max}} = \frac{u_{20} + u_{02} - \sqrt{(u_{20} - u_{02})^2 + 4u_{11}^2}}{u_{20} + u_{02} + \sqrt{(u_{20} - u_{02})^2 + 4u_{11}^2}} \in [0,1], \tag{2.21}$$

of which $u_{pq}=\sum_{(x,y)\in \mathrm{G}}(x-\overline{x})^p(y-\overline{y})^q$.

Finally, the shape character of function zone can be expressed as $F_i = (v_i, e_i)$. Shape character vector of logistics node containing m function zones can be illustrated as $\{F_1, F_2, \ldots, F_m\}$, and shape similarity can be described as the combination of the three. Shape similarity is obtained by computation to measure satisfaction degree of constraint conditions of function zone logistics node. Supposing that there are function zone i, area weighting w_ρ, discrete degree weighting w_v, and eccentricity weighting w_e, then logistics node similarity is as follows:

$$o_i = \exp\left[-w_\rho(\rho_i - \rho)^2 + w_v(v_i - v)^2 + w_e(e_i - e)^2\right]. \tag{2.22}$$

In the formula, p, v, and e are respectively, the optimal values of area, discrete degree and eccentricity of function zone; w_ρ, w_v, w_e express the weights and $w_\rho + w_v + w_e = 1$.

It is defined that the shape similarity of logistics node is the weighted average of all function zone similarities in the logistics node:

$$O = \sum_{i=1}^{m} \omega_i n_i s_i. \tag{2.23}$$

Among which, ω_i is weighting of the ith function zone, and n_i is grid number of the ith function zone. The higher the value, it illustrates that it is more consistent with the shape constraint conditions.

(D) Representation of Shape Constraint of Function Zone

For the shape and dimension constraint on each function zone, it is mainly divided into shape constraints and dimension constraints. This paper takes irregularity degree, area ratio, and other indicators as penalty function to conduct constraint on the shape of each function zone.

The condition of only including shape constraints mainly refers to rectangular, and over here, shape constraints are added into the fitness function:

$$\text{Fitness}\ (2) = \alpha\frac{1}{\sigma} + \beta\frac{\mathrm{S}}{\sum_i Sj_i} + O. \tag{2.24}$$

As for the condition of containing both shape and dimension constraints, set l as length constraint of function zone and w as the width constraint. And over here, shape constraints are added into the fitness function:

$$\text{Fitness}(2) = \alpha\frac{1}{\sigma} + \beta\frac{\mathrm{S}}{\sum_i Sj_i} + \gamma\left(\sum_i \frac{l}{lj_i} + \sum_i \frac{w}{wj_i}\right) + O. \tag{2.25}$$

(5) *Representation of Distance between Function Zones*

Regarding to the internal layout optimization problem of logistics node, this paper uses three kinds of distances for distance computation, including M distance, L distance, and Euclidean distance. M distance is mainly applied to the computation of logistics handling distance between function zones, and L distance is used for the correction strategies of shape concentration ratio and regularity degree of function zone, while Euclidean distance is applicable to the computation of grid attractor (repeller) of this function zone. Three kinds of distance computation formulas are as follows:

$$M_{ij} = |X_i - X_j| + |Y_i - Y_j| \text{ means } M \text{ distance between function zones } i \text{ and } j;$$
$$L_{ij} = \max(|X_i - X_j|, |Y_i - Y_j|) \text{ indicates } L \text{ distance between function zones } i \text{ and } j;$$
$$D_{ij} = \sqrt{(X_i - X_j)^2 + (Y_\mathrm{i} - Y_\mathrm{j})^2} \text{ denotes Euclidean distance between function zones } i \text{ and } j, \tag{2.26}$$

where, (X_i, Y_i) and (X_i, Y_i) express the gravity centre of function zones i and j.

(6) *Introduction of Dynamic Attractor (Repeller)*

Quantization processing is conducted to the allocation space of function zone. By means of mapping the action of $f(x, y)$, it is converted into a comparable value so as to determine the feasibility of the current locating place and its superiority and inferiority [19, 20]. It locates some attractive points, attractive lines (attractors) or rejection points, rejection lines (repellers) in the layout space to make function zone approach to or stay away from attractive point due to the attraction or rejection when doing layout. Accordingly, the effect of layout optimization is achieved [21]:

$$f(x_i, y_i) = \sum_{t=1}^{m} \omega_t f_t(x_i, y_i). \tag{2.27}$$

$f(x_i, y_i)$ is the overall positioning function, and $f(x_i, y_i)$ is the positioning function concerning each attractor (repeller). m is the quantity of attractor (repeller), n is the quantity of function zone waiting for layout. x direction is horizontal direction, and y direction is vertical direction.

(x_i, y_i) means the base point's coordinate of function zone waiting for layout.

(x_{0i}, y_{0i}) represents the coordinates of layout attractor (repeller), which could be taken as a certain key control point and or key control line of layout space. If taking key control point, it usually chooses the logistics node exit and entrance, transportation hub, and so fotrh. of layout space; if taking key control line, it can choose significant transportation channel based on the practical requirements.

α_{tk} states weighting factor, $\sum_k \alpha_{tk} = 1$. Weighting factor α_{tk} can be selected according to the importance of constraint conditions with various directions in the layout.

ω_t means weighting factor, $\sum_t \omega_t = 1$. ω_t is determined by its role played in the layout of each attractor (repeller). It indicates attractor if weighting factor is a positive value, and conversely, it is repeller.

Located evaluation function is as follows:

$$\min f(x_i, y_i). \tag{2.28}$$

The above-mentioned evaluation function is proposed on the combination of the features of layout problem and on the basis of heuristic method. In this paper, the located evaluation function is to make the minimum distance between function zone and the fixed attractor in the layout space or to make the maximum distance between function zone and the fixed repeller in the layout space. During the layout process, function zones cannot interfere with each other, and they should also be located in the programming space. Attractor (repeller) location falls into the categories of static and dynamic modes. The location mode of static attractor (repeller) means that the value of the location of attractor (repeller) of each weighting factor remains unchanged in the layout, while dynamic attractor (repeller) varies with the change of layout conditions.

This paper solves algorithm and dynamic location rules based on the heuristic layout of dynamic attractor. And the combinations of corresponding layout strategy with the application of attractor (repeller) will simplify algorithm, reduce complexity, and facilitate popularization and application so as to make function zone location more reasonable [20].

(7) *Translation, Scaling, and Rotation of Function Zone*

Because the layout problem of function zone is very complicated, it is necessary to make large scale of moving, rotation, interference inspection, and other operations so as to obtain better layout results. In the paper, by borrowing ideas from image analysis and image recognition methods, the following formula is adopted for the scaling, translation, and rotation of function zone:

$$\begin{aligned} X' &= X/\mathrm{Zoom}\,X \cdot \cos(\mathrm{r}) - Y/\mathrm{Zoom}\,Y \cdot \sin(\mathrm{r}) - \mathrm{Mov}X, \\ Y' &= X/\mathrm{Zoom}\,X \cdot \sin(\mathrm{r}) + Y/\mathrm{Zoom}\,Y \cdot \cos(\mathrm{r}) - \mathrm{Mov}Y, \end{aligned} \tag{2.29}$$

Of which, rotation angle r takes three conditions of 90°, 180°, and 270°.

3. Solving Algorithm and Computer Realization

This paper adopts CORELAP, CRAFT, ALDEP, MULTIPLE, and other classic facility layout programming methods to get the initial solution group. When the initial solution is generated, the graphical description is only rough, the land plot is divided into less than 100 grids, and a simple description to their relationship is made. After the initial solution is generated, it is converted into more sophisticated network representation, on the basis of which, the solution is further optimized.

Due to the complicated land conditions, high difficulty in logistics node internal layout, and multiple constraint conditions, it needs to take a very long time to get layout solution. For this kind of problem, the heuristic method is a suitable way of solving problem. On the basis of highly mixed genetic simulated annealing algorithm (GA-SA) based on multiagent, which combines multiagent technology, genetic algorithm, and simulated annealing algorithm, and that evolutionary operations are made of three-layer agent operations in the algorithm, this paper makes solution optimization to the initial solution [3]. And real number coding is applied to internal layout problem, namely that individual genotype is $[1, 2, 3, \ldots, N]$, and N stands for the total function zone quantity, here 1 represents the first function zone, and the rest could be increased by analogy. Evolutionary operations are made of three-layer agent operations in the algorithm for algorithm improvement as follows.

(1) *Global Agent Operation*

(A) Selecting Operation

This paper adopts common roulette method to select high-fitness chromosome.

(B) Global Coordination Operation

Based on the layout situation of the whole logistics node, global agent coordinates the location relationship between each function zone and transmits the coordination information to function zone agent, including the coordination and adjustment to the location relationship among each function zone inside the logistics node, such as conducting the location exchange between two even more function zone agents. For more detailed information, it can refer to CRAFT and MULTIPLE to determine the location adjustment operation among function zone agents.

(2) *Function Zone Agent Operation*

(A) Interlace Operation of Function Zone Agent

The commonly used interlaces contain single-point interlace, double-point interlace, multiple-point interlace, uniform interlace, and so on. According to the actual situation of the internal layout of logistics node, here single-point interlace is adopted, and interlace is conducted at the location attribute of function zone agent.

(B) Adjustment Operation of Function Zone Agent

Each function zone agent of every chromosome could choose the whole optimization strategy of its own function zone, for instance, the whole movement, rotation, centralization, and other operations, which will be conveyed to grid agent. Function zone agent conducts movement operation based on its location and operation relationship with other function zone agents. When the grid agent of function zone is too dispersive or disordered, the attractor of this function zone agent could be enlarged to conduct centralization operation so as to make each function zone agent meet shape compact constraint.

(3) *Grid Agent*

(A) Mutation Operation

Mutation operation takes grid agent exchange mutation, namely, it randomly selects a grid and exchanges it with the neighborhood grid. And attention should be paid to whether the adjacent function zones are connected during the mutation. Meanwhile, considering that it may generate irrational individual in the mutation or other operations, here the above-mentioned attractor (repeller) will be used for correction.

4. Case Study

In the paper, case analysis is conducted by internal layout optimization of logistics node with a dimension of 40×40. Related function zone is shown in Table 1. The from-to table

Table 1: The situation of functional area.

Id	Functional area name	Functional area color	Scale upper limit	Lower limit on scale
1	Cargo trading area	clGreen	160	160
2	Storage area	clYellow	640	640
3	Business area	clRed	160	160
4	Business office area	clWhite	160	160
5	Industry area	clBlack	480	480

between function zones is illustrated in Table 2, and the attributes of key control point and key control line related to each function zone of logistics node as well as its logistics links to each function zone are shown in Tables 3, 4, 5, and 6. ALDEP and MULTIPLE methods are applied to generate initial solutions, among which, the generated optimal solutions are, respectively, shown in Figures 2 and 3. Simulation parameter settings on genetic simulated annealing algorithm are as follows: regional length and regional width are both 50, population scale is 50, maximum simulation algebra of simulated annealing algorithm (SA) and genetic algorithm (GA) are both 100. Agent operation parameters of genetic simulated annealing algorithm are as follows: global coordination operation probability of logistics node system agent is 0.05, crossover probability and shape adjustment (focus) operation probability of functional area agent are 0.6 and 0.5, respectively, and move probability and swap mutation probability of grid agent are both 0.05. And objective function variation curve in the optimization process is indicated in Figure 4, and the optimized solution is shown in Figure 5. Compared with the traditional facility layout programming methods, the objective function variation of the optimized solution is upgraded, and also it can solve the layout problem under the conditions of complex terrain and multiple constraints, while the traditional facility layout programming methods cannot. Based on the analysis on the above-mentioned example and the optimization solution results, what can be seen is the following.

(1) The process of generating internal layout solution of logistics node is very complicated and time consuming. With the increase of problem scale, planner's work will increase exponentially. On this condition, the advantage of automatically computer-aided generating layout solution will be more obvious. Internal layout planning problem of logistics node is a nonlinear, high-dimensionally large-scale optimization problem. On condition of the existing computation resources, traditional optimization algorithm cannot gain the optimal solution within limited time. It is appropriate to adopt the GA-SA based on multiagent. And the initial application results show that GA-SA generate internal layout solution of logistics node meets programming requirements. However, unless all of the planning objectives, actual constraint conditions, and other factors are taken into consideration, the methods built in this paper can only be taken as a kind of fast and simple optimization method at the early stage of decision-making process. And the programming solution generated can only provide reference for managers and planners.

(2) The research thought and framework of layout optimization proposed in this paper cannot only be applied to the internal layout optimization problem of logistics node, but also other layout optimization problems in lots of fields like city planning, machinery manufacturing, and other fields. These problems are still always nonlinear and of high dimensionality. It is of great difficulty and complexity to deal with them by traditional optimization methods. As long as the programming objectives and actual constraint conditions are taken into reasonable consideration, it will be a good way to apply this thought and framework to the layout optimization of other fields.

Table 2: From-to table between functional areas.

Functional area 1	Functional area 2	Per logistics cost	Functional area 1	Functional area 2	Per logistics cost
1	1	0	3	4	0
1	2	90	3	5	0
1	3	15	4	1	0
1	4	0	4	2	0
1	5	0	4	3	0
2	1	0	4	4	0
2	2	0	4	5	0
2	3	0	5	1	0
2	4	50	5	2	0
2	5	65	5	3	0
3	1	0	5	4	0
3	2	15	5	5	0
3	3	0			

Table 3: Key control line properties.

Id	Name	Type	Location
1	Lateral main road	Y	50
2	Vertical main road	X	50
3	External main road	X	0
4	External main road	Y	100

Table 4: Key control point properties.

Grid id	Grid line id	Grid column id
1	100	50
2	100	50
3	−100	−100
4	−10	10
5	110	110

Table 5: Logistics relations table between functional area and key control point.

Functional area id	Key control point id	Per logistics cost	Logistics volume
1	3	50	50
2	3	50	50
3	3	40	100
4	3	40	100
5	3	30	30
1	4	50	50
2	4	50	50
3	4	40	100
4	4	40	100
5	4	30	30

Table 6: Logistics relations table between functional area and key control line.

Functional area id	Key control line id	Per logistics cost	Logistics volume
1	1	30	20
2	1	20	20
3	1	50	20
4	1	40	20
5	1	20	20
1	2	30	20
2	2	20	20
3	2	50	20
4	2	40	20
5	2	20	20
1	3	40	20
2	3	20	20
3	3	50	20
4	3	50	20
5	3	20	20
1	4	40	20
2	4	20	20
3	4	50	20
4	4	50	20
5	4	20	20

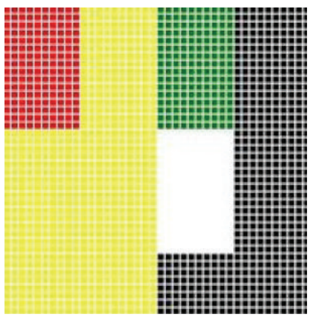

Figure 2: The initial solution got by ALDEP.

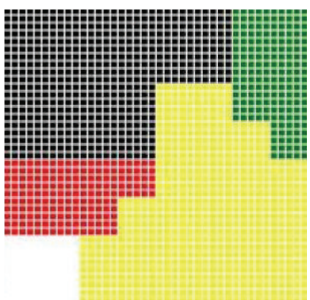

Figure 3: The initial solution got by MULTIPLE.

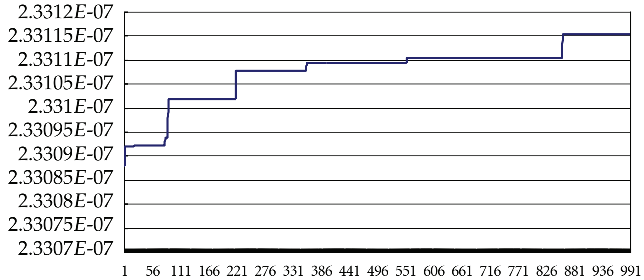

Figure 4: Optimization process diagram based on GA-SA and multiagent.

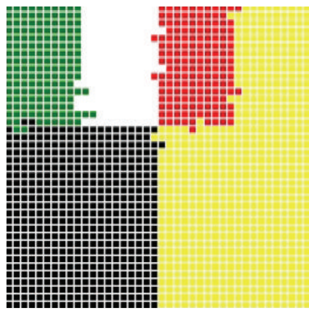

Figure 5: Optimal project drawing.

5. Conclusions

Of course, this research is just preliminary, and further in-depth research is needed. More optimization constraint conditions and objectives should be taken into account so as to better meet the practical planning requirements. In the future, our work will pay attention to further improving algorithms or exploring new optimization algorithm to improve the computing efficiency by the combination with other optimization methods and algorithms. At the same time, it is necessary to develop an internal layout optimization auxiliary decision-making software platform of logistics node integrating various optimization tactics. Of course, the research thought and method established in the paper are also applicable to the layout optimization of other fields.

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