International Journal for Housing Science and Its Applications
Publish August 4, 2025. Volume 46, Issue 3 Pages 3495-3506

https://doi.org/10.70517/ijhsa463295

Collaborative study of green new energy-based fire protection scheme and digital modeling in high-rise building water supply and drainage system design

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Abstract As an important component of high-rise buildings, the rationality of the design of the water supply and drainage system is directly related to the use of building function and safety. In this paper, the water supply and drainage system of high-rise buildings is digitally modeled through three-dimensional digital technology and constructed as a three-dimensional raster model according to a certain transformation ratio. Improve the A* algorithm, put forward the high-rise building water supply and drainage pipe path optimization algorithm, construct the directed connectivity graph structure, and determine and output the optimal path of the pipeline through the valuation function. Based on the green new energy fire protection program, the high-rise building water supply and drainage pipeline path optimization and simulation experiments are carried out. The application of this paper high-rise building drainage pipe path optimization algorithm automatically arranged by the shortest length of high-rise drainage pipe, and the number of elbows to reach the minimum, the average running time is faster than the traditional A * algorithm 0.0736s, basically achieved the desired layout effect.

Index Terms three-dimensional digital technology, raster model, A* algorithm, high-rise building water supply and drainage pipes

I. Introduction

The emergence of high-rise buildings signifies the progress of the times and the development of urban construction, which not only promotes the development of society, but also improves people's quality of life [1]. However, the resulting new problems have more negative impacts on people's living environment and their own health, and these problems need to be solved urgently. For example, the external space of the residence is too small, the ventilation and sewage inside the residence are hindered, and the energy consumption and material consumption increase [2], [3]. As an indispensable water supply and drainage system in construction engineering, also due to the emergence of high-rise buildings in the technical aspects of the roadblock [4]. It can be seen that the ability to break through the design difficulties of high-rise building water supply and drainage system is the key point in the current engineering practice.

Residents can not live without water, and indoor water supply and drainage design is crucial. It should be based on the concept of overall design, combined with the corresponding design methods, and finally create a healthy and comfortable living environment for the residents. In addition to living water, the problem of fire water supply also needs to be considered in residential design [5]-[7]. Only by solving the problem of fire protection in high-rise buildings, the safety of people's lives and properties as well as the residential environment will be guaranteed [8]. In response to this problem, the relevant departments to update the existing standards, but also developed for high-rise building fire water supply regulations. From this, it can be seen that high-rise buildings in the development process, fire safety water supply and drainage design requirements are also gradually strict [9], [10].

In modern society, with the awakening of environmental awareness and the need for ecological sustainable development, the concept of green building has been widely quoted and gradually gained popularity [11]. What green building advocates is a healthy, environmentally friendly and energy-saving concept, the goal of which is to minimize the negative impact of human activities on the environment and create a safe and comfortable living environment for humans [12]-[14]. In this context, the water supply and drainage system of high-rise buildings, as an important part of green buildings, also needs to be designed and optimized in combination with the green concept [15]. However, the traditional design of water supply and drainage system for high-rise buildings mostly focuses on the function and efficiency of the system, neglecting its role in environmental protection and energy saving [16],

[17]. Therefore, it is particularly important to seek a new design method, principle and equipment selection strategy to realize the greening of water supply and drainage systems in high-rise buildings.

This paper uses three-dimensional digital technology to accurately simulate the complex pipeline layout inside the high-rise building, and constructs a digital model of high-rise building water supply and drainage pipes. Then the digital model of high-rise building water supply and drainage pipes is constructed into a three-dimensional raster model according to a certain transformation ratio, and the three-dimensional matrix is selected to store the models of building structures (walls, beams, and columns) and building pipes (rectangular pipes, cylindrical pipes) as a piggyback on the path optimization algorithm of high-rise building water supply and drainage pipes. The proposed high-rise building water supply and drainage pipe path optimization algorithm collects the relevant node information of the pipe network control cabinet, as well as the relevant data of the pipeline, and processes the collected data, calculates the arrival cost between each connected control cabinet and stores it. And get to get the pipe site number, valve level, water level, water flow rate, node latitude and longitude as well as manually input data such as connectable nodes, node name and other data in the data set. Improve the traditional A* algorithm's heuristic function, so that it can be more rapid, accurate drainage pipe failure and blockage and other emergencies to make a timely response to the real-time optimization of the drainage pipe path, the output of the improved A* algorithm for the optimization of the drainage pipe path results. High-rise building drainage pipe path optimization simulation experiments to test the performance of this paper's high-rise building drainage pipe path optimization algorithm in the drainage pipe optimization performance. At the same time, carry out simulation experiments of high-rise building drainage pipe layout to further explore the effect of this paper's high-rise building drainage pipe path optimization algorithm in high-rise building drainage pipe layout.

II. High-rise building water supply and drainage pipe digital modeling

Three-dimensional digital technology plays a crucial role in the installation of water supply and drainage pipes in high-rise buildings, which enables the entire piping system to be comprehensively designed, planned and optimized before construction through accurate three-dimensional modeling. In this chapter, three-dimensional digital technology will be used to digitally model high-rise building water supply and drainage pipelines [18].

II. A. Basic Overview of 3D Digital Technology

Three-dimensional digital technology, as an important innovation in the field of construction engineering, is changing the traditional design and construction mode, as shown in Figure 1. It carries out a comprehensive digital representation of people, objects and data in the physical world. 3D technology can accurately simulate real projects in virtual environments and enhance project visualization, data accessibility and structured processing capabilities. This technology not only provides a more intuitive visual effect, but also provides designers and engineers with the opportunity to identify problems and optimize the design at an early stage, thus reducing the cost of later modifications and construction risks. The three core elements of 3D digital technology - people, objects and data - complement each other in the application of the technology. The structured presentation of data as a core driver through 3D modeling not only improves the quality of the data, but also makes it more accessible, providing a solid foundation for the construction process.

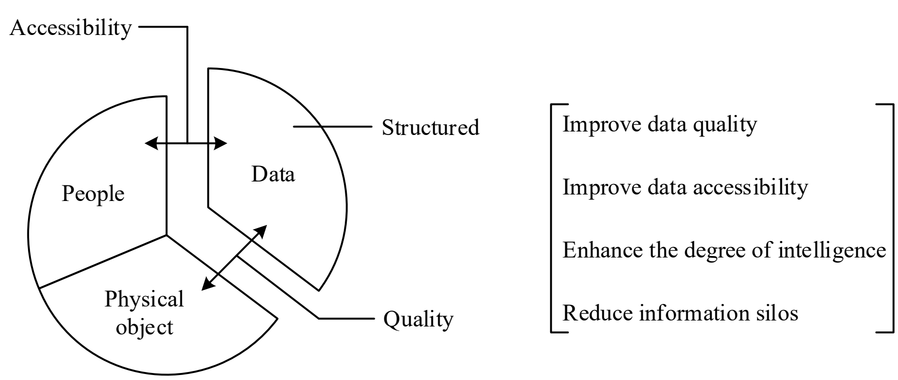

Figure 1: Three-dimensional digitalization technology

II. B. Digitization of water supply and drainage pipes in high-rise buildings

3D digital technology plays a crucial role in building water supply, drainage and fire protection piping installation. It enables comprehensive design, planning and optimization of the entire piping system before construction through accurate 3D modeling. Using 3D technology tools such as BIM (Building Information Modeling), the complex piping layout inside the building can be accurately simulated, avoiding spatial conflicts and design errors in the construction process. On this basis, the introduction of intelligent algorithms further improves the efficiency and optimization of the system. For example, in the path planning of complex building pipe networks, traditional manual design methods are often difficult to find the optimal path efficiently, while intelligent algorithms, such as the A* algorithm and genetic algorithm, can find the optimal solution in an automated way.

The A* algorithm, as a heuristic search algorithm, is commonly used in path planning problems, and its algorithm is shown in Equation (1):

$$f(n) = g(n) + h(n) \tag{1}$$

where $g(n)$ denotes the cost of the current path, and $h(n)$ is a heuristic estimate from the current node to the target node.A* algorithm in pipeline installation can be used to effectively avoid the conflict points and find the shortest path so as to improve the construction efficiency.

Genetic algorithms, on the other hand, optimize pipeline placement by simulating the natural evolutionary process. Its basic process includes selection, crossover, mutation and elimination to find the global optimal solution through multiple generations of iterations. The fitness function of the genetic algorithm can be set as the objective function of minimizing the length of the pipeline and minimizing the number of collisions as shown in Equation (2):

$$f(x) = a \times L(x) + \beta \times C(x) \tag{2}$$

where $L(x)$ denotes the total length of the pipeline, $C(x)$ denotes the number of collision points of the pipeline, and a and β are the weighting coefficients. Through this method, the unreasonable areas in the design are reduced and the construction quality and efficiency are maximized. Three-dimensional technology not only supports real-time pipeline model updating, but also can be combined with intelligent algorithms to realize real-time monitoring and dynamic adjustment in the construction process. When sudden changes occur at the construction site, the data in the 3D model can be fed back through the sensors, combined with the algorithm to make rapid adjustments, re-planning paths and solve construction problems in a timely manner. Based on the integrated application of 3D technology and intelligent algorithms, it makes the installation process of construction pipeline more efficient and accurate, and significantly improves the overall construction quality and management level of the project.

III. Rasterized model of high-rise building water supply and drainage pipes

The design of high-rise building water supply and drainage system is aimed at helping piping design engineers to carry out reasonable piping layout design through path planning algorithms. However, the complex structure of modern building models and the many rules of pipeline layout greatly increase the difficulty of high-rise building water supply and drainage pipeline design. For this reason, this chapter will be the high-rise building drainage pipe digital 3D modeling in accordance with a certain transformation ratio constructed as a three-dimensional raster model, in order to store the model in the form of a three-dimensional matrix, to facilitate the subsequent high-rise building drainage pipe path optimization algorithm piggybacking.

III. A. Model transformation ratios

In rasterization model construction, the transformation ratio is a key parameter. When the transformation ratio of rasterization is smaller, the actual physical volume of unit raster is larger, the model accuracy is lower, but the corresponding number of rasters after the transformation is smaller, and the algorithm's operation efficiency is higher; on the contrary, if the transformation ratio is larger, the corresponding volume of unit raster is smaller, the model accuracy is higher, the number of rasters is larger, and the algorithm's operation efficiency is lower. In the actual application, the transformation ratio of the model needs to be decided according to the computer equipment hardware conditions, project accuracy requirements, time constraints and other factors.

After determining the transformation ratio, the coordinates in the raster model can be calculated according to the two-dimensional coordinate information in the Revit drawings. First of all, take the lower left corner of the building scene in the drawing as the coordinate origin, and obtain the coordinate information of all the building structures in the building scene with the origin as the reference; in the second step, use the diagonal coordinate information of each building structure (take the lower left corner and upper right corner in this study) to get the diagonal raster coordinates through the transformation of formula (3), (4); finally, construct the raster model of the building structure through the diagonal raster coordinates. The specific form of the formula is as follows:

$$Cl_{grid} = \left\lfloor \frac{Cl_{real}}{R} \right\rfloor \tag{3}$$

$$Cr_{grid} = \begin{cases} \left\lceil \dfrac{Cr_{real}}{R} \right\rceil, & \dfrac{Cr_{real}}{R} - \left\lfloor \dfrac{Cr_{real}}{R} \right\rfloor > 0 \\ \left\lfloor \dfrac{Cr_{real}}{R} \right\rfloor, & \dfrac{Cr_{real}}{R} - \left\lfloor \dfrac{Cr_{real}}{R} \right\rfloor = 0 \end{cases} \tag{4}$$

where R is the model transformation ratio, Cl_{real}, Cr_{real} is the coordinate information of the lower-left and upper-right corners of the building structure in the actual drawings, and Cl_{grid}, Cr_{grid} is the corresponding raster coordinate information. In order to ensure that the distribution range of the obstacle grid is not smaller than the actual size of the building structure, downward rounding is applied to the coordinate transformation of the lower-left corner, while upward rounding is adopted for the coordinate transformation of the upper-right corner.

III. B. Building raster model construction

(1) Building scene raster model construction

The architectural scene in Revit is a spatial domain that can be expanded infinitely, in order to improve the efficiency of raster model construction and algorithm operation, and at the same time to restore the actual pipeline layout scene to the greatest extent possible, in the construction of architectural scene raster model construction, we only take the actual architectural area in the drawings as a prototype model construction, and we do not generate the raster model of other invalid areas.

(2) Building structure raster model construction

A large-scale architectural scene usually contains a variety of architectural structures, including load-bearing walls, beams, load-bearing columns, etc., as the skeleton of the building, as well as other structural components such as sinks, isolation doors, elevator shafts and so on. According to the rules of building pipeline arrangement and scene characteristics, this paper classifies all building structures into three main categories: elevator rooms, elevator shafts, etc. are categorized as prohibited pipeline arrangement areas; building structures in which pipelines are not allowed to penetrate in principle, such as load-bearing walls, load-bearing columns, beams, existing pipelines, etc., are categorized as obstacles; and building structures in which pipelines can be directly penetrated, such as non-load-bearing walls and pre-prepared holes, are categorized as non-obstacles.

In order to improve the efficiency of model generation, in the building structure rasterization model of this study: for the building structure belonging to the region of prohibited pipeline rows is marked as obstacle raster region, and no model generation is carried out; for the obstacle structure, it is marked as obstacle raster and the raster model generation of the obstacle is carried out; for the non-obstacle, no marking is carried out (it does not affect the pipeline rows).

Load-bearing walls, load-bearing columns, beams, etc. belonging to the obstacle class of building structures are required to carry out the construction of raster model generation. If the shape of the building structure and the rules of the building pipeline arrangement are not taken into account, only the calculation of raster coordinates is required according to the transformation ratio and the coordinate information of the lower-left corner and upper-right corner of the original model.

The following three core building structures of walls, beams and columns are constructed as raster models according to the transformation ratio of 1:100:

(1) Load-bearing wall

In order to ensure that there is a certain amount of installation space reserved between the pipeline and the actual wall, this study in the model construction process will be the installation space corresponding to the raster model attached to the wall raster model, so that the algorithm in the path search process will be the installation space part of the raster as an obstacle raster, to achieve the purpose of reserving space.

(2) Rectangular load-bearing columns

Since the column is generally outside the piping area, or surrounded by a wall connection, there is no need to install the space grid additional, directly according to the coordinate transformation formula for the grid model construction and labeled as an obstacle grid can be.

(3) Cylindrical load-bearing columns

Since the cross-section is circular, this paper adopts the strategy of redundant modeling for the cylindrical structure.

In addition, because the cylindrical structure can not directly obtain the lower-left corner coordinates and upper-right corner coordinates, only to obtain the center line coordinates and the diameter of the cross-section, so we need to calculate the diagonal coordinates corresponding to the equidistant square according to the coordinates of the center of the circle and the diameter of the specific formulas are as follows:

$$Cl_{real} = Cc_{real} - R \tag{5}$$

$$Cr_{real} = Cc_{real} + R \tag{6}$$

where Cc_{real} is the centerline coordinate information of the column, R is the cross-section radius of the column, and Cl_{real}, Cr_{real} is the coordinate information of the lower-left and upper-right corners of the equidistant square load-bearing column.

(4) Transverse beam

The crossbeam is constructed in the model by considering not only the installation space, but also the reserved space when the pipe is laid below the beam, so there is a raster of the reserved space between the pipe and the bottom of the beam in addition to the raster corresponding to the installation space below the beam.

III. C. Pipeline raster model construction

(1) Column pipeline raster modeling

The traditional raster scene path planning algorithm takes the unit raster as the basic pathfinding state, therefore, unlike the building structure model which can be constructed by using multiple rasters to form a cross-section, the unit raster in the pipeline raster model represents the cross-section of the actual pipeline. In this study, we need to consider two kinds of pipeline cross sections, square and circular, which are described below.

(2) Rectangular pipeline raster model

The construction method of the square pipe raster model is the same as that of the wall and beam, and the diagonal raster coordinates are calculated (transformed to a scale of 1:300) and modeled to obtain the raster model diagram.

However, in the actual building scene, there will be other building structures in addition to the pipes, so in the case of narrower space, the use of short edges as the transformation ratio can more accurately restore the actual space for piping.

To summarize, in the subsequent chapters of this paper, when constructing the pipeline model, the selection of the transformation ratio will consider both the algorithm adaptation and the model accuracy. Based on the scenario of multiple pipelines, the largest pipeline size is taken as the conversion ratio in Chapter 3, and other sizes of pipelines are modeled redundantly, so that the unit grid can completely represent the pipeline cross-section to fit the algorithm definition. In Chapter 4, a new state definition is introduced, where the cross section composed of multiple rasters is used as the basic state for path planning, and the smallest pipe size is used as the transformation ratio, thus improving the accuracy of the model construction.

IV. High-rise building water supply and drainage pipe path optimization algorithm

In the application of traditional A* algorithm in the optimization of drainage pipe path, there are many parameter dimensions, in addition to the coordinates of the nodes, there are parameters such as valve position, water level, water velocity, node latitude and longitude, and lower nodes [19]. Similarly, affected by the valve position, water level, water velocity, and other factors, the original distance evaluation criteria can not accurately assess the cost of the drainage pipe path. Since the nodes of the drainage pipe are affected by the lower nodes, the nodes that can be connected by the current node are limited and certain.

This chapter will improve the traditional A* algorithm on the basis of the rasterized model of high-rise building water supply and drainage pipes, and put forward a high-rise building water supply and drainage pipe path optimization method based on the improved A* algorithm, which is realized in the application of the improved A* algorithm in the optimization of high-rise building water supply and drainage pipe paths through the improvement of the data processing method, the pipe node expansion method of the traditional A* algorithm and the heuristic function.

IV. A. Data pre-processing

The traditional A* algorithm is still essentially a two-dimensional shortest path optimization algorithm, and in the application of drainage pipe path optimization, the traditional two-dimensional coordinate points can no longer meet the requirements of drainage pipe path optimization, due to the influence of valve position, water level, water velocity, node latitude and longitude, and lower nodes.

In order to be able to more accurately optimize the drainage pipe path, the collected data need to be processed. When data preprocessing, it is specifically divided into two steps, namely, data acquisition and processing and cost initialization.

Data Acquisition and Processing. The NETTY server is built to receive the data from the control cabinets of each node of the drainage pipe, which includes dozens of information such as the status of the control cabinets, water level, coordinates, water flow rate, pipe diameter, temperature, etc., and there is a large amount of redundant data. Therefore, the collected data need to be processed to extract coordinate information, water level information, water flow rate, pipe diameter and other data and persisted through the MYSQL database. Finally, the dataset for optimized matching of drainage pipe paths is constructed.

IV. B. Node Optimization

The nodes of traditional A* algorithm need to screen the node with the smallest cost in the neighborhood of the node in performing path optimization. The traditional A* algorithm calculates the cost of four or eight nodes in the neighborhood through a heuristic function every time the node is expanded, and selects the node with the smallest cost as the next node. When the number of nodes is large, the computation of this method rises exponentially, which leads to a significant decrease in the efficiency of the traditional A* algorithm.

Due to the special characteristics of the drainage pipe, the nodes that the current node can be connected to are limited and definite, and the connectivity of the nodes of the drainage pipe path is schematically shown. In this section, the node optimization of the traditional A* algorithm is performed by simplifying the coordinate points, removing the redundant nodes and retaining only the starting point, connectable nodes, and the end point. This reduces the amount of computation in path optimization and improves the efficiency of the algorithm.

IV. C. Heuristic function improvement

The main component of the traditional A* algorithm is the heuristic function, which continuously calculates the path cost and determines the path nodes during the search process [20]. Although the traditional A* algorithm can effectively find out the better paths, the heuristic function of the traditional A* algorithm is not comprehensive enough in terms of parameter dimensions to be considered in the drain path optimization scenario, and the results are not good enough:

$$F(n)=H(n)+G(n) \tag{7}$$

$$H(n)=\sqrt{(B_x-Z_x)^2+(B_y-Z_y)^2} \tag{8}$$

$$G(n)=\sqrt{(A_x-B_x)^2+(A_y-B_y)^2} \tag{9}$$

Drainage pipe path optimization not only requires that the length of the pipe is as short as possible, but also should take into account the speed of the water flow, the thickness of the pipeline, and the pipeline blockage, failure, etc. At the same time, the optimization of the drainage pipe path should try to avoid too many corners, or a sudden large angle of the water flow changes, in order to be able to preferentially select the optimal path of the node, combined with the specifics of the city's drainage path, the integrated pipe diameter, valve level, water level, water velocity, node latitude and longitude to improve the heuristic function in the traditional A* algorithm.

As the corners of the pipeline have a greater impact on the water flow rate, the larger the corners, the easier it is to consume the life of the pipeline, and it is also more likely to pile up, so in this section, the angle parameter is added to optimize the heuristic function based on the angle of the current node, the next node, and the end point constituting the inner angle.

Since the pipeline may be blocked, when the water level is higher than the current open valve level, the pipeline is in a blocked state, so when the water level is greater than or equal to the valve level, the current cost is set to infinity; when the water level is less than the valve level, the calculation is performed according to the normal cost function.

In drain path optimization, Dns is calculated in a special way, as the coordinates of pipe nodes are collected as latitude and longitude, the distance between nodes needs to be calculated according to latitude and longitude, let the latitude and longitude of the first point A be (A_i, A_j), and the latitude and longitude of the second point B be (B_i, B_j), and according to the 0-degree longitude datum, the above two points are counted as (MA_i, MA_j) and (MB_i, MB_j). Then based on the trigonometric derivation, the following formula for calculating the distance between two points can be obtained:

$$F^*(n) = G^*(n) + H^*(n) \tag{10}$$

$$H^*(n) = Dns \cdot \alpha(180-\theta) \tag{11}$$

$$G^*(n) = \begin{cases} Dns \cdot B_d / r \cdot W_v & B_d < val_p \\ \infty & B_d >= val_P \end{cases} \tag{12}$$

$$D = \sin(MA_i * \sin(MB_j) * \cos(MA_i - MB_i) + \cos(MA_j) * \cos(MB_j)) \tag{13}$$

$$Distance = R * Arc(D) * Pi / 180 \tag{14}$$

In this section, parameters such as pipe diameter, valve level, water level, water velocity, node latitude, longitude and angle are integrated to form a multidimensional parameter set to improve the heuristic function and realize the optimization of drainage pipe path based on the improved A* algorithm.

IV. D. Improvement of the A algorithm*

In this chapter, the A* algorithm is optimized through data preprocessing, node optimization and improved heuristic function to realize the drainage pipe path optimization method based on the improved A* algorithm.

Data preprocessing removes a large amount of redundant data, retains the corresponding parameters according to the actual scenario of drainage pipe path optimization, and at the same time initializes the cost, which reduces the amount of calculations in the optimization process and improves the efficiency of the algorithm. Node optimization removes redundant nodes according to the connectivity between the pipeline nodes, and only retains the starting point, connectable nodes, and the end point. This reduces the amount of calculations in path optimization and improves the efficiency of the algorithm. The improvement of the heuristic function solves the shortcomings of the original heuristic function in the drainage pipe path optimization, such as not applicable, unable to judge the blockage and the lack of parameter dimension.

After completing the improvement of the A* algorithm, the drainage pipe path is optimized using the improved A* algorithm, and the optimization process is mainly divided into five steps, with the following.

Step1: According to the parameters required for the optimization of the drainage pipe path, the original data is processed, the connectivity of the nodes is preserved, and the cost between the connectable nodes is calculated and preserved according to the improved heuristic function.

Step2: Add the starting point of the drainage pipe path to OPENLIST, sort OPENLIST from smallest to largest according to the estimated value, take out the first node, and if it is empty, end the search directly.

Step3: Judge whether the current node is the end point, if it is the end point, it means that the optimal path has been found, so it will directly exit, otherwise delete the node in OPENLIST and insert the node into CLOSELIST.

Step4: Iterate over all the connectable nodes of that node and also calculate their estimated value F(X). If the traversed current connectable node is in OPENLIST, compare F(X) with the estimated value, and if F(X) is smaller, set that node as the parent of the current node and update the estimated value. If the current connectable node is in CLOSELIST, skip and continue traversing. If the current connectable node is not in either table, set the node as the parent of this connectable node, find the estimated value of this connectable node and insert it into OPENLIST.

Step5: Jump to Step4 to continue execution until the end point is reached and exit the program.

This chapter implements a drainage pipe path optimization method based on the improved A* algorithm by improving the data processing method, the pipe node expansion method of the traditional A* algorithm and the heuristic function.

V. High-rise building water supply and drainage pipe path optimization simulation experiment

V. A. Traditional high-rise building piping layout limitations

For the high-rise building pipeline path planning problems, there have been many excellent research results in the past decade, but there are still some limitations. According to the existing related research results, the traditional high-rise building pipeline layout model is shown in Figure 2. Traditional building pipeline layout research in the design of the environment model, the real building environment obstacles simulated as a cube, the generated model and the real environment is a big difference, so that the research results are applied to the actual building construction environment, the pipeline path generated by the reasonableness and feasibility is greatly reduced.

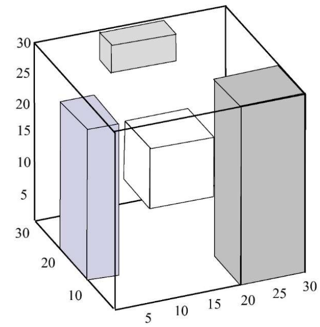

Figure 2: Traditional building pipeline layout model

The piping path generated based on the traditional building piping layout model is shown in Figure 3. Due to the traditional building piping layout model is relatively simple, although there are simulated building obstacles such as columns, beams, walls, floor slabs, pipelines and impassable equipment, but still with the actual building situation is still a lot different. Although the pipeline paths are successfully generated under certain constraints, the research results cannot be applied to the actual building environment, and even if the corresponding pipeline paths are finally obtained, they are not practical and feasible.

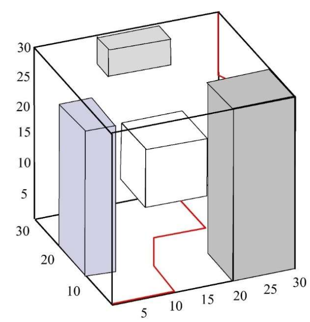

Figure 3: Traditional building pipeline layout model

Table 1: Final path simulation result point set

Number	X	Y	Number	X	Y
1	9	32	22	25	27
2	10	32	23	26	27
3	11	32	24	27	27
4	12	32	25	28	27
5	13	32	26	29	27
6	14	32	27	30	27
7	15	32	28	31	27
8	16	32	29	31	26
9	17	32	30	31	25
10	18	32	31	31	24
11	19	32	32	31	23
12	19	31	33	31	22
13	19	30	34	31	21
14	19	29	35	31	20
15	19	28	36	31	19
16	19	27	37	31	18
17	20	27	38	32	17
18	21	27	39	33	16
19	22	27	40	34	15
20	23	27	41	35	14
21	24	27	-	-	-

V. B. Experimental path analysis of piping in high-rise buildings

In this section, the proposed high-rise building water supply and drainage pipeline path optimization algorithm will be used to carry out the optimization of high-rise building pipeline paths, and the final path simulation result point set is specifically shown in Table 1.

The path finding results of this paper's algorithm are compared with the traditional A* algorithm, as shown in Table 2. This paper's algorithm has improved in the time efficiency of path planning after improving the A* algorithm, and the path planning time is reduced by 0.461ms compared with the traditional A* algorithm. Although there is an increase in the length of the path, but due to the setting of pipeline orthogonality constraints, the pipeline path generated after the improvement meets the required pipeline orthogonality constraints, in addition, due to the setting of the maintenance area, so that the pipeline path and the obstacle grid to maintain the minimum maintenance distance, in line with the requirements of the actual engineering specifications. The simulation results reflect the feasibility and reasonableness of this paper's high-rise building water supply and drainage pipe path optimization algorithm in water supply and drainage pipe path optimization.

Table 2: Data analysis of simulation results

Algorithm	Path planning time	Path length	Number of non-orthogonal pipe corners	The nearest distance to obstacle grid
Traditional A * algorithm	3.345ms	27	14	0
Algorithm of this paper	2.884ms	36	0	1

VI. High-rise building water supply and drainage pipe arrangement simulation experiment

In the previous chapter, this paper examines the feasibility and reasonableness of the high-rise building supply and drainage pipe path optimization algorithm proposed in this paper in supply and drainage pipe path optimization through high-rise building supply and drainage pipe path optimization simulation experiments. This chapter will further carry out high-rise building drainage pipe layout simulation experiments to explore the drainage pipe layout capability of this paper's high-rise building drainage pipe path optimization algorithm under the green new energy-based fire protection scheme.

VI. A. Model space creation

Based on the traditional high-rise building pipeline layout model, according to the requirements of the building pipeline layout design specifications and the characteristics of the building environment, the components of the high-rise building pipeline layout model space. In the three-dimensional space, the 8 vertex coordinates of obstacles are (1,11,1), (6,11,1), (6,21,1), (1,21,1), (1,11,26), (6,11,26), (6,21,26), (1,21,26), in that order. The coordinates of the 8 vertices of the device are (11,26,26), (21,26,26), (21,31,26), (11,31,26), (11,26,31), (21,26,31), (21,31,31), (11,31,31). The coordinates of the 8 vertices of the columns are, in order, (21,1,1), (31,1,1), (31,11,1), (21,11,1), (21,1,31), (31,1,31), (31,11,31), (21,11,31). The coordinates of the construction space are (11,11,11), (21,11,11), (21,11,21), (11,11,21), (11,11,21), (11,21,21), (11,21,21), (21,21,21), (21,21,11), in that order; and the coordinates of the starting point of the planning are (1,1,1), and the end point is (31,31,31). For the arrangement of building pipelines, different pipeline types have different additional constraints. For example, this experiment requires that the arranged pipes are arranged along the wall as far as possible, away from columns, obstacles and equipment. For such additional constraints, the method of setting energy values is used to solve the problem. The energy values are set as shown in Table 3.

Table 3: Energy function value

Properties of space	Energy function value
Obstacle	100
Equipment	100
Pillars	100
Walls	10
Construction space	70
Other	30

VI. B. Comparative experimental program design

The information of the equipment used in this experiment is shown in Table 4.

Table 4: Simulation Equipment Information

Hardware name	Model parameters
Central Processing Unit	Intel(R) Xeon(R) CPU E3-1230 v3 @3.30GHz
Graphics processor	NVDIA Quadro P2200 5GB
Memory	32GB 2400 MHz

By comparing with the traditional A* algorithm to analyze the optimization effect of the high-rise building water supply and drainage pipe path optimization algorithm proposed in this paper, the parameters used in the A* algorithm of this experiment are shown in Table 5. Since the purpose of the experiment is to compare the operation of the A* algorithm before and after the optimization of the data structure and the efficiency of the pipeline layout, so in addition to the length of the cost of the weight of the rest of the weights are set to zero.

Table 5: Parameter information of algorithm

Parameter name	Parameter value
Length cost weight	1.0
Turning cost weight	0.0
Compensation weight of wall / parallel pipe	0.0
High cost weight	0.0
Valuation function factor	1.0
Heuristic function factor	1.0

VI. C. Analysis of simulation results

Using the traditional A * algorithm line after 20 high-rise building water supply and drainage pipe automatic layout and optimization simulation experiments, the generated path diagram is specifically shown in Figure 4. It can be seen that at this time the number of elbows in the arrangement of the drainage pipe is more, the length of the pipe is longer, the layout effect is not very satisfactory.

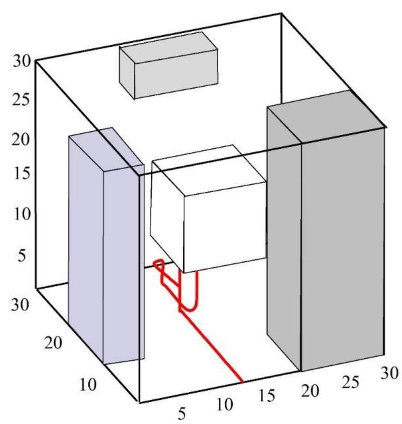

Figure 4: Randomly generated initial pipeline

The experimental results after optimizing the initial path using this paper's high-rise building water supply and drainage pipe path optimization algorithm are shown in Figure 5. It can be seen that the automatically arranged pipes in the 3D building space only successfully avoid obstacles and are also laid along the walls with low energy values. Under the constraint of laying orthogonal pipes, the pipe length reaches the shortest and the number of elbows reaches the minimum, which achieves the ideal layout effect to some extent.

The evaluation of the results of using this paper's high-rise building water supply and drainage pipe path optimization algorithm and the traditional A* algorithm for high-rise building water supply and drainage pipe layout is specifically shown in Table 6. From the table, it can be seen that the value of the fitness function using the algorithm of this paper is 0.0025 lower relative to the traditional A* algorithm, and the quality of the solution is improved accordingly. From the algorithm, the convergence speed of this paper's algorithm is faster than the traditional A* algorithm, and the average running time is faster than the traditional A* algorithm by 0.0736 s. In the length of high-rise building water supply and drainage pipe layout, the number of elbows, this paper's algorithm's average value of 105, 1.4, respectively, are smaller than the traditional A* algorithm, and the value of the energy value of the traditional A* algorithm is less than the traditional A* algorithm by 52. The simulation results demonstrate that the proposed high-rise building water supply and drainage pipe optimization algorithm can better evaluate the quality of the solution. Path optimization algorithm proposed in this paper can be better arranged for high-rise building water supply and drainage pipes.

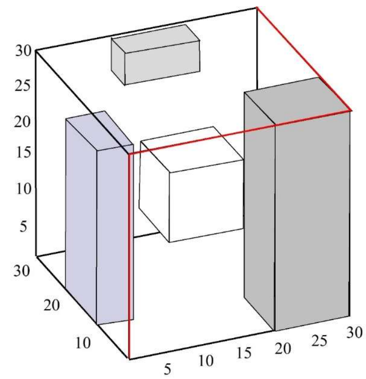

Figure 5: Pipe route path

Table 6: Evaluation index contrast

Evaluation index	The quality of the solution	Traditional A* algorithms	Algorithm in this article
Length	The optimal solution	90	90
	The worst solution	108	166
	Average value	109.2	105
Number of bends	The optimal solution	2	2
	The worst solution	7	3
	Average value	3	1.4
	The optimal solution	1000	980
Energy value	The worst solution	1360	1080
	Average value	1100	1048
Mean value of fitness function		0.0645	0.0620
Average running time (s)		2.2521	2.1785

VII. Conclusion

This paper builds up a digital model of high-rise building water supply and drainage pipes, and transforms the scale to build a three-dimensional raster model, proposes a high-rise building water supply and drainage pipe path optimization algorithm, and improves the application of the A* algorithm in the optimization of high-rise building water supply and drainage pipe paths.

Carry out high-rise building drainage pipe path optimization simulation experiments to test the path optimization performance of this paper's high-rise building drainage pipe path optimization algorithm. Comparing with the path finding results of the traditional A* algorithm, the algorithm in this paper improves the time efficiency of path planning and reduces 0.461ms compared to the traditional A* algorithm. Although there is an increase in the path length, it meets the required pipe orthogonality constraints. The simulation results demonstrate the feasibility and reasonableness of this paper in conforming to the required pipeline orthogonality constraints in the optimization of drainage pipeline paths.

In addition, compared with the non-ideal drainage pipe layout generated by the traditional A* algorithm, which has more elbows and longer pipe lengths, the pipeline automatically laid out by this paper's high-rise building drainage pipe path optimization algorithm has the shortest length and the fewest number of elbows, and it successfully avoids all the obstacles to arrive at the ideal layout effect. The average values of pipe length and number of elbows of this paper's algorithm are 105 and 1.4, respectively, which are smaller than the traditional A* algorithm, and are faster than the traditional A* algorithm by 0.0736s in the average running time, and the value of the fitness function and the value of the energy are lower than that of the traditional A* algorithm by 0.0025 and 52, respectively. The simulation results prove that the high-rise building water supply and drainage pipe path optimization algorithm proposed in this paper can better arrange the high-rise building water supply and drainage pipes when facing a variety of piping layout demand schemes based on the green new energy fire protection scheme and so on.

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