LAYOUT OPTIMIZATION OF URBAN UNDERGROUND PIPELINE BASED ON 3D DIGITAL CITY

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ABSTRACT:

With the fast development and utilization of underground space resource in cities, the spatial distribution of urban underground pipelines becomes more and more complex. How to efficiently utilize the latest technology, realize underground space resources' management, visualization, layout optimization and mine applications, are challenging issues in current digital city development. Taking into account of the frequently changing and complicated information of underground pipeline, we are facing great difficulty in data management. With the comprehensive integration management requirement of 3D digital city and underground pipeline system, we present layout optimization based on three-dimensional (3D) digital city.

The objective of this paper is to describe design and implementation of underground pipeline 3D visualization and layout optimization based on 3D digital city. Firstly, the automatic conversion from two-dimensional (2D) pipeline data to 3D model is realized and we also integrates management with ground data, such as 3D house, 3D model, DEM, vector data, RS image, etc. which can quickly determine the relative positions of underground pipelines in a more intuitive way. Secondly, in accordance with related national standards, and the ensured accuracy and validity of pipeline data, an underground pipeline layout optimization method is realized, which is on the basis of spatial analysis and principle expanding. It analyzes the pipeline boundary layout in order to guarantee the distribution rationality; also it can ensure optimization of the pipeline layout. Finally, take the data of a city for example, an underground 3D pipeline optimization system based on 3D digital city is developed, which is according to the overall architecture and optimization method. It offers a set of techniques for the pipeline layout optimization and simulation, and provides decision support for urban underground resources management, pipeline planning, and urban planning, etc.

1. INTRODUCTION

Underground pipeline is an important component of urban infrastructure, which is called city's "lifeline". It responds to fulfil energy transference and material transportation, which is the basis of city's survival and development [1]. With fast expansion of cities, urban material flow and energy flow are increasing significantly, and the intensity and density of urban underground pipelines are also dramatically increasing. How to manage underground pipeline dynamically and effectively and to study the pipeline layout optimization method is a hot research issue, especially the study of pipeline layout optimization.

Currently, most management of underground pipelines is manual, or in two dimensional. It has disadvantages on intuitive pipeline visualization, low efficiency and difficult dynamical management, which consequently lead to pipeline accidents frequently. How to meet the requirements of management departments and construction units has become imperative [2]. It is significant to explore layout optimization method of underground 3D pipeline, recognize the optimization principles and provide technical support and decision making for urban underground resources management, pipeline planning and construction of 3D digital city. During the development of current digital city, underground pipeline layout optimization is not only helpful for related department interacts with underground pipeline to facilitate their construction, but also helpful for researchers use latest technology effectively to realize layout optimization of underground space resources and make better management.

2. RELATED RESEARCH

At present, urban underground pipeline system has been focus on visualization, spatial analysis and route optimization of 3D pipeline. With continuous development of technology, people are gradually changing their attention on pipeline from 2D environment to 3D platform. However, the representation of the variability of underground pipeline is still lacked. So, some new method is urgent to deal with the uncertainty and vagueness of the layout of pipeline.

Urban Pipe Network Visualization System (UPNVS) is designed and organized by spatial metadata, which is based on the analysis of the features of urban pipe network and the requirements of the 3D model; 3D spatial data model is the basic of data representation and spatial visualization [1]. Pipeline visualization is always a challenge, UPNVS, which compared to traditional 2D visualization, has clearly reviewed

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3D visualization urban underground pipeline is much more intuition.

A new methodology is proposed for automated route selection for the construction of new power lines which is based on geographic information system. It used a dynamic programming model for route optimization. Environmental restrictions are taken into account together with all of the operating, maintenance, and equipment installation costs [3]. It describes the method of GIS spatial analysis which is applied to electric line routing optimization. This methodology is used for generate a new economic lines by the selection of route, at the same time, geographic factors and evaluating the uncertainties is consider to associated with routing costs. So, GIS spatial analysis is identified as the powerful tool to develop automatic reveal of the layout of urban underground pipeline.

According to the characteristics of urban underground pipeline, we investigate the principles of pipeline layout optimization, and by the application of GIS spatial analysis. Pipeline layout optimization is integrated management of urban underground 3D pipeline by using the technology of 3DGIS. As a result, the method of urban underground 3D pipeline layout optimization is put forward in this paper.

3. LAYOUT OPTIMIZATION OF URBAN UNDERGROUND PIPELINE BASED ON 3D DIGITAL CITY

3.1 Flow Chart of Pipeline Layout Optimization

This paper discusses establish of underground 3D pipeline model dynamically. And based on 3D digital city, we propose the layout optimization method of underground pipeline.
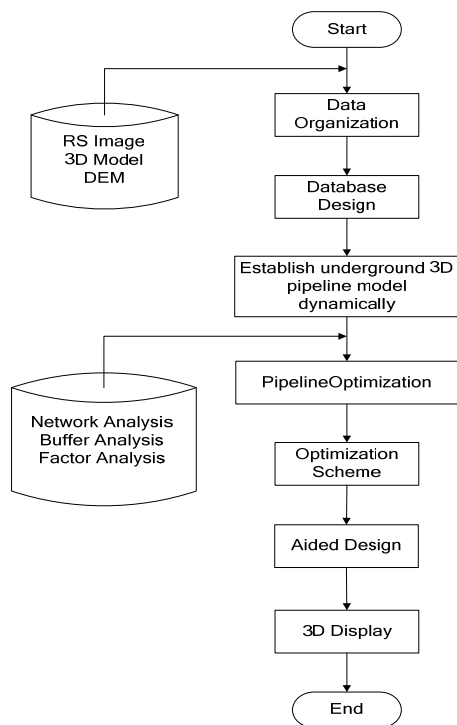
Figure 1. Flow chart of pipeline layout optimization

As show in Figure 1, it describes the process of urban underground pipeline layout optimization. According to

relevant requirements, we firstly organize and manage the data of remote sensing image, digital elevation models, and 3D building models, etc. and then import them into 3DGIS system. Secondly, with the data of pipe node, tube-well, and 2D pipeline, etc. We implement underground 3D pipeline dynamically, which is related with ground-level structures, furthermore, locate positions of pipe sections quickly is in a more intuitive way. Thirdly, with the existing road network, we select the starting and ending points of the pipeline, by utilizing GIS spatial analysis to generate several pipeline layout schemes automatically. Fourthly, based on national norms and standards, collision analysis of pipeline layout is put forward, which is used to search for the adjacent pipelines. Besides, horizontal and vertical spacing distances between pipelines and facilities are measured. Finally, according to horizontal and vertical spatial analysis between pipelines and facilities, we consider the factors of the process of underground pipeline layout optimization, propose the solution to lay out underground pipeline optimally, and reveal the results of optimization analysis in 3D environment.

3.2 Data Organization

All the about data of pipe node, well and 2D pipeline should be imported into spatial database according to the industry standards and the design of database. It is worth to mention that in the code scheme and database construction, the underground pipeline data mainly include pipe nodes and pipelines. Pipe nodes are feature points (such as bend, tree, cross, etc.) or accessory points (such as well, valves, etc.) [4]. Pipeline is a line according to certain connection composition of pipe nodes. Models of valve, bend, tree and cross are shown in Figure 2.
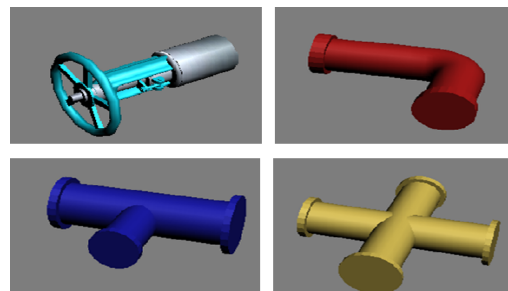

Figure 2. Pipeline valve, bend, tree, and cross models

The attribute information of pipeline include the number of start point and end point, type of pipeline, the depth of pipeline layout and tube's diameter, etc. Spatial entities such as pipe nodes, pipelines and facilities, which is embodied in underground space, are always represented improperly. Understanding the features of underground pipeline profoundly has become an important issue to lay out pipeline rationally. Generally, urban underground pipeline is usually invisible, complex, and potential, etc. the features of underground pipeline can be characterized as follows [5]:

a) The prominent feature of pipeline distribution is invisible. Since most of the pipelines are buried underground, pipeline management demands accuracy and completeness.

b) The distribution of pipeline is complex. There are several different kinds of urban pipelines, and the relationship between them is tight. The pipeline system is so enormous that if some part doesn't work, it will influence the other pipelines around it.

c) With the continuous development of urban, urban underground pipeline is constantly changing, expanding and updating, and the extent and density of urban pipeline layout

keep growing. The data of pipelines are also required to update dynamically.

3D visualization is a time consuming and since it requires a large number of spatial information. We must process the data of remote sensing image, digital elevation model and 3D building models into 3DGIS system in the light of relevant requirements. First of all, remote sensing image and DEM are fused in 3D software, and then import the results into 3DGIS system. Moreover, a batch of 3D architectural model is exported in the form of model file. Meanwhile, model conversation is advanced accordingly with modelling software. In addition, 3D architectural model is integrated into 3DGIS system and modify some parameters correspondingly according to remote sensing image.

3.3 Realization of Layout Optimization of Urban Underground Pipeline Based on 3D Digital City

A lot of work has been done on 3D visualization, however, it is still a challenge to establish underground 3D pipeline model dynamically. The establishment of underground 3D pipeline model is based on the pipe node data, well and 2D pipeline, also corresponding to ground-level structures to locate the position of pipe sections quickly in a more intuitive way. 3D visualization of underground pipeline is more suitable for the representation of spatial relationship between all kinds of pipeline clearly, so we can review the connectivity and intersection structured of pipeline quickly and easily. Compared with the traditional 2D visualization, 3D visualization presents complex relationship to technical staff of urban planning departments and construction units, especially improves human-computer interaction further. Based on 3D digital city platform, we propose the method for pipeline layout optimization which enables 3D Digital City as a tool to organize and manage underground pipeline information.

Spatial analysis which describes and represents urban underground pipeline information accurately and completely has been developed for pipeline layout optimization. Currently, GIS spatial analysis is well-known and widely used in two dimension space for practical applications in 2D GIS. With its specific function of extracting, displaying and transferring invisible geographical spatial information, GIS spatial analysis is gradually used in three dimension environment. 3D spatial analysis method is defined as a key technology in underground pipeline layout optimization. Underground 3D pipeline layout optimization method is mainly used to execute basic analysis in the underground pipeline, and collect statistical information and excavate spatial data of pipeline [6]. Exploring the method of underground pipeline layout optimization by using GIS spatial analysis, the management of underground pipeline in digital system is helpful for resource management in urban planning department.

3.3.1   3D Network Analysis
Network analysis is a process of geographic analysis and model optimization deals with geographic network and urban infrastructure network. It discusses state of the network, simulates and analyzes resource flows of network and distribution, then achieves optimization of network structure and resource, etc [7].

Underground pipeline layout is based on different roads and districts. We firstly set starting and ending points according to existing road network and pipelines the topologies though utilizing 3D network analysis, we can obtain several network schemes. Other factors, such as the minimum distance between pipelines and facilitates in national norms, are considered to optimize the allocation of underground pipeline resource.

3.3.2   3D Buffer Analysis
Buffer analysis refers to create region with a certain width around point, line and surface entities automatically [8]. By means of 3D buffer analysis, band area with a certain distance around entities is created, and influence region between entities and the nearby objects can be identified clearly. The analysis is mainly used to create buffer area of pipe nodes or pipelines. Consequently, buildings and facilities within the buffer area are identified, and the results are outputted statistically.

Collision analysis is mainly utilizing buffer analysis of GIS spatial analysis to deal with the pipeline in 3DGIS. Collisions often exist between pipelines, pipelines and buildings, pipelines and facilities. According to the related national norms and standards, such as Code of Urban Engineering Pipeline Comprehensive Planning, collision analysis is used to search for buildings and facilities around pipeline.

3.3.3   Influencing Factors Analysis
On the basis of horizontal and vertical spacing, the impact factors among pipelines, pipelines and buildings, pipelines and facilities are analyzed. Besides, we can calculate horizontal and vertical spacing statistically between pipeline layout and the surrounding pipelines, buildings and facilities. Ultimately, compared with related national norms and standards, we can determine whether the horizontal and vertical spacing are in compliance with them. If not, the scheme is unreasonable. By adjust the positions of pipeline layout dynamically; we can avoid accident between pipelines, construction materials and facilities.

3.4 Optimization Scheme

According to the existing road network, we select start point and end point of pipeline which needs to layout. Then we utilize 3D network analysis to deal with road network, and generate several pipeline layout schemes automatically. 3D buffer analysis (Figure 3.) is used to process collision analysis of pipelines in 3D environment. On the top of that, according to analyzing influence factors of pipeline layout optimization, flow scheme for underground pipeline layout optimization is proposed. And we show optimization result in 3D digital city.

For the purpose of meeting requirements of pipeline layout optimization, making use of the latest technology to manage all types of underground professional pipeline effectively, we can sum up critical factors in the process of collision analysis and put forward layout optimization scheme in 3D space environment. Therefore, by means of 3D spatial analysis method and influence factor analysis, we can apply the results into urban underground resources management, pipeline planning, construction planning and 3D digital city applications.
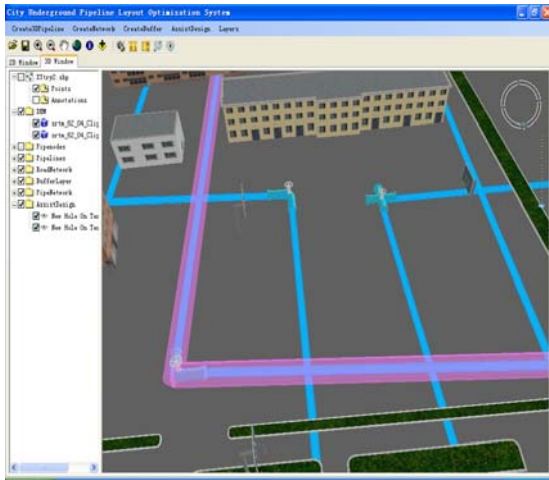
Figure 3. 3D buffer analysis result

3.5 Aided Design

Aided design does not only include adding, deleting pipe node and pipeline, but also include manage pipe node and pipeline dynamically. Based on pipeline layer, we take the number of pipe node and pipeline as identifier, then add and delete the data of pipe node and pipeline into the spatial database. When adding pipe node and pipeline (Figure 4), input various properties information of pipe node and pipeline. At the same time, with the continuous changing and complicated information of underground pipe nodes and pipelines, we can update and manage pipe nodes and pipelines database correspondingly and effectively. Aided design is capable of achieving the management of urban underground pipeline dynamically. Underground pipeline system can monitor and control various changes, so it's able to update the existing underground pipeline files quickly and ensure truth and accurate reflection of underground pipeline layout.
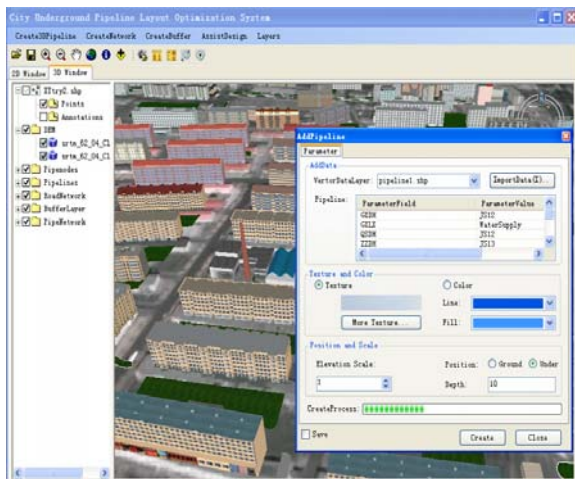

Figure 4. Add pipeline operation process screenshot

4. EXPERIMENT

According to the process of urban underground 3D pipeline layout optimization described above, we conduct an experimental through the application of spatial analysis, and horizontal and vertical space analysis between pipelines and facilities. We propose a layout optimization solution for underground pipeline and reveal results of optimization analysis

in 3DGIS system. With underground 3D space model and pipeline layout optimization analysis, we can adjust pipeline dynamically and lay out pipeline in a more rational way. Ultimately, we can get layout optimization solution for underground pipeline layout (Figure 5).

The method of underground pipeline layout optimization based on the 3D digital city is implemented and the mining of optimization information in various pipelines on the basis of underground pipeline optimization method is realized. It facilitates the effective management of related departments which manages every corner of city's pipeline. The method enhances the layout of urban underground pipeline effectively and creates more convenience for community.
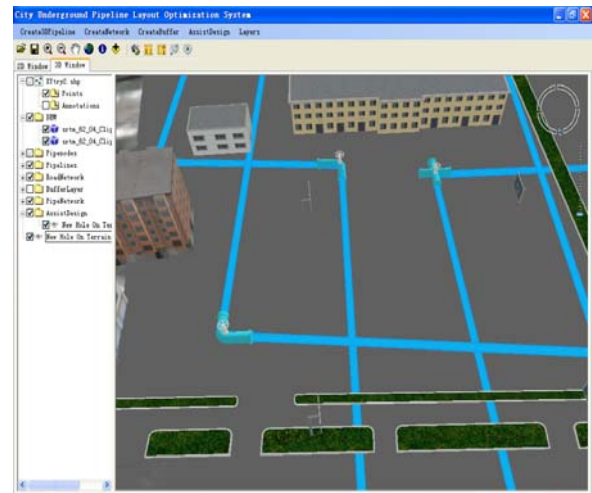

Figure 5. Experiment result

5. CONCLUSION

This paper proposes a method of underground 3D pipeline layout optimization based on 3D digital city. The purpose of optimization method is to obtain urban underground 3D pipeline optimization system, which is associated with characteristics of 3D spatial data and the process of layout optimization. We realize the fusion of various kinds of data and underground 3D pipeline model dynamically, also achieve the data mining of pipeline layout optimization. Consequently, this method is not only helpful for related department interacts with underground pipeline to facilitate their construction, but also helpful for providing technical support and assist decision support for urban management, urban normal operation, and 3D digital city construction, etc.

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