TEST Engineering & Management

July - August 2020
ISSN: 0193-4120 Page No. 5811 - 5818

Optimization of Urban Disaster Prevention and Mitigation Based on Computer Three-dimensional Mapping

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Article Info
Volume 83
Page Number: 5811 - 5818
Publication Issue:
July - August 2020

Article History
Article Received: *25 April 2020*
Revised: *29 May 2020*
Accepted: *20 June 2020*
Publication: *28 August 2020*

Abstract

With the continuous acceleration of urban construction, relying on policies such as "new urbanization", cities have developed greatly, but the supporting infrastructure is relatively lagging behind. From the perspective of space, this paper changes the traditional two-dimensional map mode, and builds three-dimensional map based on SWMM model and geographic information data, so as to realize the three-dimensional visualization of multi-scale urban disaster prevention data, support the refined management and governance of the city, and be timely and effective. Disaster prevention and mitigation are carried out to reduce urban losses.

Keywords: *Three-Dimensional Mapping, Drainage and Waterlogging Prevention, Disaster Prevention and Mitigation;*

1. Introduction

With the continuous acceleration of urban construction, construction under the guidance of policies such as "new urbanization" and "featured towns" has opened a new model[1-2]. Although the scope of the city continues to expand, the construction and renewal of its supporting infrastructure, such as hospitals, drainage, schools, etc., are relatively lagging behind. Especially in the face of once-in-decade or once-in-century floods, it is easy to cause urban waterlogging. The urban drainage system is not handled in time, causing problems such as excessive and dirty water in the city[3-4]. Some scholars have put forward concepts such as "city on the sea", and proposed new solutions to urban diseases with the idea of combining design with nature[5], but because many infrastructures are built underground, a simple two-dimensional map cannot be intuitive The response problem[6], therefore, it is necessary to carry out three-dimensional mapping, realize two-dimensional and three-dimensional linkage, and conduct more refined governance and management of the city.

In this paper, we build a drainage object information model, based on the SWMM hydraulic model, combined with a self-developed three-dimensional basic platform, design a three-dimensional geographic information system for urban drainage and waterlogging prevention, and realize the management of urban drainage facilities in three-dimensional space, storm simulation,

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drainage capacity evaluation, Early warning to realize the optimization of disaster prevention and reduction in the city.

2. Overall Framework

Integrate the characteristics and needs of GIS and hydrological industries, define urban drainage and waterlogging prevention data models, and establish urban drainage and waterlogging prevention databases. Based on the drainage and waterlogging prevention data model, supported by 3DGIS technology, and based on the self-developed three-dimensional basic platform for secondary development, the development of a three-dimensional visualization module for drainage facilities, a simulation module for urban storm waterlogging, a drainage network planning and design module, and an emergency management interface Module, drainage facility editing management module and other functional modules. Taking a certain sub-basin as a demonstration, the three-dimensional drainage and waterlogging prevention platform was applied and practiced.

The establishment of urban drainage and waterlogging prevention infrastructure is subject to influence from various fields from the outside world and is determined by its own complex system.

(1) Economic cost

The completion of a disaster relief facility and the allocation of its resources require a lot of manpower, material and financial resources. Therefore, its economic costs must be considered to maximize the economic benefits generated under limited capital conditions.

(2) Traffic location

The occurrence of urban emergencies is not only uncertain, but also contagious. In response to this feature, the disaster-affected area needs to make timely emergency response to avoid further spreading of the disaster. This requires the establishment of disaster relief facilities in convenient transportation locations, so that the distance weighted from the disaster relief facilities to each disaster point in the city is the smallest, and the emergency response time The shortest.

(3) National policies and laws, technical specifications, and safety standards

First, the establishment of disaster relief facilities must undoubtedly comply with the relevant provisions of existing national laws and regulations; secondly, the structural layout and resource allocation of disaster relief facilities must meet the corresponding technical standards. For example, the radiation radius of a city fire station is 7 kilometers. The travel time from the disaster relief facility to the emergency demand point is controlled within 5 minutes; finally, the disaster relief facility itself must have corresponding safety standards to ensure that no emergencies occur to the greatest extent, and always maintain the capability of emergency rescue.

3. Drainage and water logging prevention database

1.1. Data collection

The related data model of urban drainage and waterlogging prevention mainly includes rainfall data, topographic data, ground feature hydrological parameters and drainage facility data. In order to verify the model parameters and verify the trend of the model, the hydrological monitoring data of the surface and underground pipeline network is also needed.

Collect basic geographic information data, planned land data, drainage facility survey data, verification data and other data materials, and organize them. The basic geographic information data includes the basic topographic base map, image base map, three-dimensional topographic model, and current three-dimensional fine model of the area The results of the census of geographical and national conditions, etc., these current topographic data cooperate with the planned land to provide references for the judgment of the underlying surface of the city and the water permeability of the catchment area. The general survey data of drainage facilities includes the types, quantities, functional

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attributes, pipe diameters, plane positions, elevations, directions and other information of various drainage facilities, combined with real-time rainfall and flow monitoring data of important nodes to construct and verify drainage models.

1.2. Data model

Meteorological data, terrain data, surface data, and drainage facility data constitute the complete content of the urban drainage and waterlogging prevention data model. Define the relationship structure of the data model according to the functional requirements of the drainage and waterlogging prevention geographic information platform. The data model includes drainage systems, drainage facilities, drainage pipelines (drainage pipes, drainage pipes), drainage pipe points (rainfalls, inspection wells, drainage pumping stations, interception facilities, storage facilities, overflow weirs, valves, gates, drainage), receiving water bodies, urban roads, rain gauges, flood-prone areas, urban land, subcatchments, underground spaces, structures, underground entrances and exits, urban topography, etc. Based on this data model, a geographic information database structure was established to provide basic support for subsequent platform development and 3D visualization of drainage and waterlogging prevention objects.

1.3. Drainage and waterlogging prevention database

The drainage and waterlogging prevention database includes a basic two-dimensional geographic database, a basic three-dimensional geographic database, an urban watershed database, an urban drainage facility database, and a rainfall and flow database. On the basis of data collection, the data types and contents are sorted, and then integrated into the database. , To provide a data basis for the next drainage model establishment and platform construction, as shown in Figure 1.

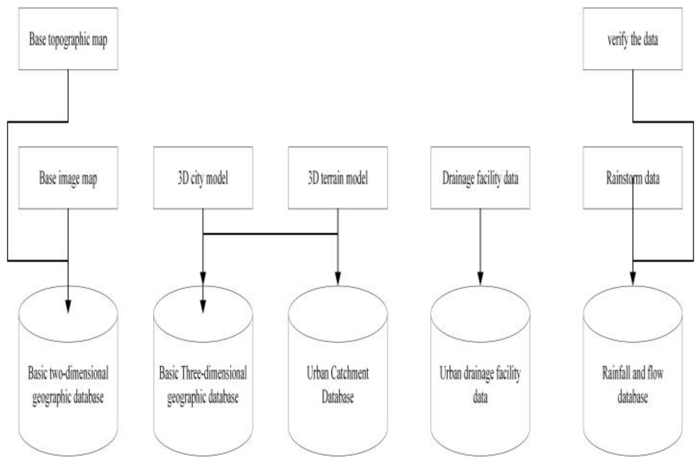

Figure 1. Construction of drainage and waterlogging prevention database.

4. Drainage model based on SWMM

This platform uses SWMM as the support for the construction of the drainage model. SWMM can manage, analyze, and design a dynamic rainwater-runoff simulation model. It consists of three modules: runoff model, confluence model and pipe network model, which can simulate the city. The hydraulic operating status of the drainage network. Use SWMM software to establish the drainage model of the area, and provide basic support such as drainage model operation, analysis and editing for the three-dimensional drainage and waterlogging prevention geographic information platform. The model building process includes:

Published by: The Mattingley Publishing Co., Inc.

July - August 2020
ISSN: 0193-4120 Page No. 5811 - 5818

1.4. Drainage data processing

Collect and sort out the corresponding data, mainly including basic two-dimensional and three-dimensional geographic data, planning, basic geographic data, drainage facility survey and other data, as the data basis for the construction of the district drainage model.

1.5. Urban Catchment Division

Dividing subcatchments is the key task of model building. The division of subcatchments is the dispersion of large watersheds to reflect the differences in the spatial distribution of various characteristic parameters. In view of the large slope of mountainous cities and obvious topography, topography is the main basis for dividing watersheds in catchments. However, for urban built-up areas, urban areas are composed of a variety of underlying surfaces. Buildings, blocks, roads, and drainage pipe networks divide the city into tiny areas. Therefore, this topic comprehensively considers the terrain and the underlying surface of the city, and uses the results of topographic hydrological analysis as the basis for macroscopic division, supplemented by the reference of the current status of the urban underlying surface, urban roads, and urban communities, combined with the elevation map and slope produced by DEM Maps and slope maps, artificially further refine the sub-watersheds to form the final watershed.

1.6. Model parameter calculation

In order to simulate the hydrological and hydraulic conditions of the drainage system, the SWMM model needs to set a large number of parameters for the composition of the drainage system during the simulation process. These parameters can be divided into two categories: hydrological model (rainfall model) parameters and hydraulic model (pipe network convergence) parameters.

Hydrological models are generalized models, and are affected by comprehensive factors such as weather, climate, and ground. Most of the parameters show uncertainty and nonlinearity. The parameter values contain certain physical meanings, as well as reasoning and generalized components. According to whether the parameters need to be calibrated, hydrological parameters are divided into measurement parameters and calibration parameters. The measurement parameters are directly calculated by measurement or physical relationship. Generally, no adjustment is required during model calibration, such as sub-catchment area, average slope, pipe network Length, slope, rainfall, etc. The calibration parameters are the parameters that the model needs to be calibrated. In the SWMM calculation, the initial value is estimated in advance according to the value range determined by the parameters, and finally the optimal values of the parameters determined by the inversion of the measured data are shown in Table 1.

Table 1. Types of SWMM hydrological parameters.

Classification	Parameter
Measurement parameters	Catchment area (Area), average surface slope (Slop), impervious surface percentage (%)
Calibration parameters	Permeable area/impermeable area storage volume (Destore), permeable area/impermeable area roughness coefficient (N), initial infiltration rate (Max Rate), stable infiltration rate (Min Rate), infiltration attenuation coefficient (Decay)

Hydraulic model parameters are generally pipe network attribute parameters. Many parameters can be used to obtain real data with the help of GIS functions, but some parameters are also uncertain. According to whether it is calibrated or not, it is also divided into measurement parameters and calibration parameters.

Among the above parameters, the measurement parameters are obtained by extracting and calculating the SHP geometric information and attribute information of the catchment surface, pipelines, and pipe points. Some parameters are

July - August 2020
ISSN: 0193-4120 Page No. 5811 - 5818

already in the attribute information, such as pipeline material, pipe diameter and elevation information, which have been collected during the underground pipeline survey, and can be directly assigned to the corresponding attribute field of the element, and extracted during subsequent data output; partly The parameters need to be calculated from the geometric information of shp, such as water surface area, pipeline length, etc., obtained by ArcGIS measurement tools and calculation tools, assigned to the corresponding elements, and extracted during subsequent data output.

For the calibration parameters, there is a certain range of empirical values for different types of catchment surfaces, pipelines, and pipe points by querying relevant manuals, specifications, documents and other materials.

1.7. Model file generation

A program for the secondary development of a three-dimensional platform based on independent intellectual property rights, extracts geometric information and attribute information from the database, and writes engineering information, water catchment information, drainage facility information, and rainfall information into a specific format in accordance with SWMM model requirements In the .inp file, directly generated this format can be recognized by SWMM, which can realize data switching between the 3D platform and the SWMM model.

1.8. Model parameter calibration

The basic method of parameter calibration is to compare the results of repeated simulations with several independent rainfall-response measured series data, and repeatedly adjust the model parameters. The parameter adjustment method is manually adjusted by personnel and integrated computer optimization algorithm until the best fitting parameter set is found.

5. Three-dimensional drainage and anti-logging platform

1.9. 3D basic platform construction

On the basis of the Jijing 3D core engine with independent intellectual property rights, carry out the construction of the 3D basic platform, support the integration of massive 3D data, build a database, publish, and apply integrated solutions, and realize the comprehensive integration and distribution of 3D geospatial data resources Management, centralized sharing and service.

1.10. 3D visualization module of drainage facility objects

Based on the parametric driving method, the design and visual modeling of drainage pipelines and pipe points are carried out, and based on the three-dimensional simulation module of rainstorm and waterlogging, the data results of drainage facilities are analyzed and visualized, as shown in Figure 2.

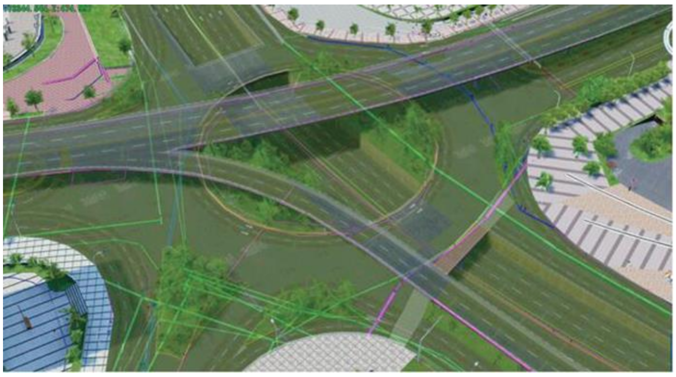

Figure 2. Visual simulation of drainage facilities.

1.11. Drainage facility editing module

The editing module of urban drainage facilities, based on the visual display and query of drainage and anti-logging facilities, supports the editing of the spatial location, attributes and topological relationships of drainage facilities, dynamically maintains and updates the complex network topological relationships of drainage facilities, and supports GIS-based facilities Connectivity analysis and upstream and downstream analysis. ①Data quality inspection, with external professional pipeline inspection tools, to realize the quality inspection of pipeline data, including basic pipeline attribute

Published by: The Mattingley Publishing Co., Inc.

July - August 2020
ISSN: 0193-4120 Page No. 5811 - 5818

inspection, spatial location inspection and other types of inspection. ②Data storage management, supports batch import function of drainage pipelines and facilities in SHP format, INP file format, and provides basic analysis data for establishing drainage and waterlogging prevention management information system. ③Data editing, you can edit, modify, add or delete pipeline points and pipelines, and modify the positions and other attributes of pipeline points and pipelines.

1.12. Three-dimensional simulation analysis module for urban rainstorm and waterlogging

Using the advantages of 3DGIS spatial analysis and spatial simulation, model analysis and function development are carried out based on the geographic spatial characteristics of urban areas, the movement characteristics of surface and pipe network water flow, and the occurrence characteristics of waterlogging, and the SWMM model output pipe point overflow water is converted into a flooded area The submerged area and depth of the flooded area, and further carried out three-dimensional visualization simulation, realized the visual simulation analysis of the submerged area of the waterlogged area.

The waterlogging simulation based on SWMM and 3DGIS includes pipe overflow analysis, accumulation analysis, accumulation depth analysis, and three-dimensional visualization simulation. ①Analysis of the overflow water volume of pipe points is obtained through SWMM model analysis and converted into vector point data; ②The idea of water diffusion analysis is to respectively obtain the water volume reached after the overflow of the pipe point in the catchment area, calculate the water capacity, and Determine the overflow boundary condition and overflow direction of stagnant water; ③The depth analysis of stagnant water is mainly by inputting the vector data of the catchment area with the amount of stagnant water, and the volume calculation tool is used in the digital elevation model to calculate the surface elevation of the stagnant water, and the surface elevation Compare the depth of water accumulation at each location.

The application was carried out with a certain sub-watershed as a demonstration area. This area is located in the city center. Due to the early construction of the drainage pipe network, mostly combined systems, there have been water accumulations in previous heavy rains. Combining regional characteristics, establish an urban drainage model adapted to a certain mountainous terrain, realize visual editing of three-dimensional drainage pipe network and torrential rain scenario simulation analysis, and realize the urban warning response function based on sensor data to realize emergency warning applications in urban torrential rain and waterlogging environments.

(1) Platform efficiency

In terms of SWMM model construction, modeling uses GIS secondary development to write programs to directly generate text files in a specific format of SWMM model, which is easy to recognize by SWMM, and realizes data switching between GIS platform and SWMM model. This method is used when the modeling area is cumbersome and lengthy, which not only saves modeling manpower and material resources, but also shortens modeling time and improves modeling efficiency. In terms of 3D loading and rendering efficiency, the efficiency of the 3D core engine is comprehensively improved by tackling key problems in the model LOD, GPU rendering and drawing, caching system, block spatial index, model dynamic calling mechanism, and GIS-oriented scene organization. Among them, the model texture stitching method is adopted during rendering, which improves the loading speed and rendering efficiency of the model. On the basis of making full use of existing rainstorm analysis methods and integrating three-dimensional visualization technology, compared with traditional urban rainstorm analysis and facility management, the three-dimensional drainage and waterlogging prevention platform visually displays surface buildings, terrain, underground pipelines, and

Published by: The Mattingley Publishing Co., Inc.

July - August 2020
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underground spaces as three-dimensional spatial elements. , Especially for mountainous cities has very important application value.

(2) SWMM model accuracy verification

Through the real-time rainfall data published by China Weather Network, the actual rainfall data of a certain place and the monitoring flow of sub-basin outlets are used for model verification, and the accuracy of model parameters and the rationality of model structure are tested. Verification method: input the measured rainfall data into the drainage and waterlogging prevention model, calculate the simulated flow data under this rainfall situation, and compare the simulated flow with the measured flow. The simulation comparison results show that the simulated values calculated by inputting the measured rainfall data of the two rainfalls basically conform to the trend and magnitude of the measured values.

In order to test the accuracy of model fitting, the coefficient of determination R2 is introduced, and the calculation expression is shown in formula (1):

$$R^2 = 1 - \frac{\sum_{i=1}^{n}\left(Q_{iAnalog\ value} - Q_{iObservations}\right)^2}{\sum_{i=1}^{n}\left(Q_{iObservations} - Q_{Average\ of\ Observed\ Data}\right)^2} \quad (1)$$

The coefficient of determination is between 0 and 1. Generally speaking, the larger the coefficient of determination, the better the fitting result of the model and the higher the degree of explanation of the dependent variable by the independent variable. According to calculations, the coefficients of determination of the two rainfalls are 0.78 and 0.83, respectively, indicating that the constructed drainage SWMM model is accurate and reliable.

6.Conclusions

Through the "Urban Three-dimensional Drainage and Waterlogging Prevention Geographic Information Platform" research and the application of demonstration areas, the integration and visualization of urban drainage facilities in a three-dimensional geographic environment can be realized, which can provide comprehensive evaluation, planning, design, management and early warning of urban drainage facilities. software platform.

Acknowledgments

Innovation of the informatization and thematic practice teaching platform for urban and rural planning majors under the background of double innovation (Grant No. JG2018-344).

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