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Research Article

Sponge City Design Based on Intelligent Displacement Optimization

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The concept of sponge city urbanization construction is the important guiding idea, to quickly eliminate the end drainage characteristics of the traditional urban drainage system; the effect is very poor under the actual extreme precipitation weather conditions. The failure of the drainage system will cause urban waterlogging and even sewage overflow, thus causing the collapse of the entire urban water system. In a variety of heavy precipitation weather frequency as the background, this paper first makes a detailed introduction about the concept of sponge city, mainly describes the features and functionality of the sponge city, compares them and the function of traditional urban drainage system, and finds out the advantages and disadvantages of the sponge city on the function, especially on the end of the drainage function, which is even better than traditional drainage system. Finally, through modern computer intelligence technology, the artificial neural network is combined with the sponge city drainage system, and the influence of rainfall prediction module and centralized coordinated optimization sponge processing module on the urban drainage is added on the basis of the traditional drainage system. As a reliable idea to solve the sponge bottom problem with weak urban drainage function, the feasibility of this idea is proved theoretically.

1. Introduction

On July 20, 2021, Zhengzhou, Henan Province, was hit by the worst rainstorm in 100 years. More than 300 people were killed, nearly 90,000 houses collapsed, more than 8 million mu of crops was affected, and the direct economic loss was more than 110 billion yuan. In the face of natural disasters, even today with advanced science and technology, human beings are still very small and many people feel that advanced science and technology are also extremely weak [1–3]. How to scientifically and effectively prevent and reduce the severity of rainstorm and flood disasters? In fact, people have been thinking about this problem for a long time and many reasonable and effective schemes have been given. The Three Gorges Dam is a typical example. The dam can artificially regulate the flow of water in the lower reaches of the Yangtze River according to the rainy season and can plan the release of water to cope with extreme storms [4–6]. However, the Three Gorges Dam is the overall control and adjustment of the whole middle and lower reaches of the Yangtze River [7–9]. In view of the regional extreme weather such as Zhengzhou rainstorm, people also put forward the sponge city scheme to solve the drainage problem of the whole city. Since the concept of sponge city was first proposed in 2012, China has been continuously promoting the construction process of sponge city and has achieved good results in the first batch of pilot cities [10–13]. Traditional urban drainage system design concept is "quickly ruled out" and "focus on" at the end; it mainly consists of gray facilities such as ditches and drainage pump stations, especially the pump station, which requires high manual control. The design can be applied to the situation of small rainfall and heavy rain; heavy rainfall conditions will lead to waterlogging. A more serious situation will appear before the Zhengzhou storm [14–16]. Sponge city, as the concept of modern urban water control, first breaks this concept, taking "source dispersion" and "slow discharge and slow release" as the core concept and optimizing and rebuilding existing resources such as parks and rivers in the city to realize the dynamic cycle of urban drainage. In

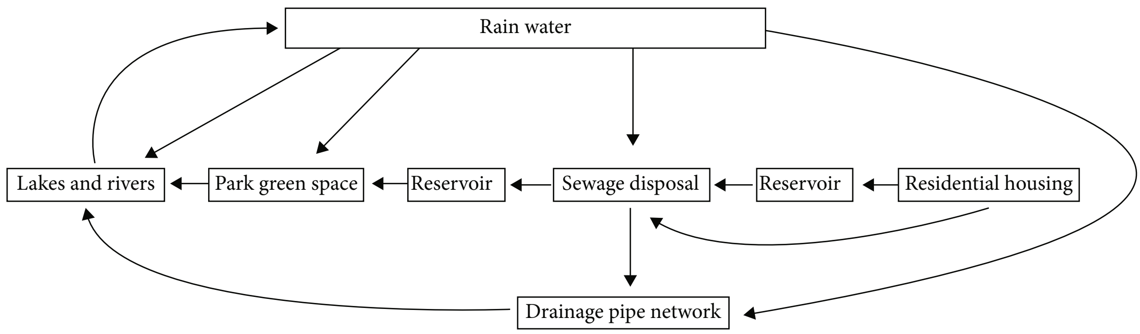

Figure 1: Conceptual model of sponge city.

this paper, by studying the application of computer artificial neural network technology in sponge city, we find out the method of constructing sponge city in different areas in accordance with regional characteristics [17, 18].

2. Introduction to Sponge City and Computer Artificial Neural Network

2.1. Brief Introduction to the Characteristics and Model of Sponge City

2.1.1. Characteristics and Functions of Sponge City. Sponge city, as its name implies, is a city like a sponge, which can absorb water and wring it out when needed. Sponge city is a city with the characteristics of sponge water absorption. In the case of a large amount of precipitation, a large amount of water absorption can be quickly eliminated. When the rainfall is low and water is needed, the water can be squeezed out and sent to the place where it is needed. This makes our cities resilient to climate change and extreme rain. Sponge city characteristics can be summarized as six words "permeability, hysteresis, storage, net, and row"; the first is "bleed," which refers to the material; through the use of strong permeability such as porous brick instead of the original material in the park, the drain daily rain gathered in more places, such as the road, or uses the compound soil grow plants in the park. It allows rainwater to better seep into the ground, rather than accumulate on the concrete and evaporate. "Stagnation" means retention, which means that the retention time of rainwater in the urban natural environment increases through the urban spongy body, such as rainwater park, wetland park, and sunken green space, so as to share the flow for the main urban drainage pipe or river trunk stream. "Storage" refers to the collection of infiltration rainwater through the establishment of water storage facilities; "net" refers to the purification of accumulated rainwater; "use" means to reuse the treated water; "discharge" means to strengthen the urban drainage function. From these six characteristics, several functions of sponge city are derived:

(1) Reduce the drainage pressure of municipal pipe network in case of heavy rainfall, and improve the city's ability to adapt to natural disasters

(2) Purify acid rain and other pollution brought by precipitation to improve the urban water environment

(3) Create unfavorable conditions for rainwater reuse, and improve rainwater reuse efficiency

In addition to the above functions, sponge city can also purify harmful gases in automobile exhaust through large areas of green space, wetlands, and other sponges; slow down the current heat island effect in the city; and improve the urban ecological environment.

2.1.2. Sponge City Model Research. According to the characteristics and functions of sponge city, a brief model diagram of sponge city is obtained as follows (Figure 1).

We will track and investigate the comprehensive water environment treatment project in inner cities of the province. The project takes the new urban comprehensive livable embankment as the core; carries out river training, river training, and green park construction on a river area of more than 20 kilometers; and dredges all ditches along the river. Some adjacent ditches are connected through manual excavation, so that all water systems in the region are interconnected. Many sponge city concepts are used in this project. It can even be said that this project is the construction of modern urban spongy body, which is a part of the city to build sponge city. Based on the concrete example of the project, we analyze and study the six characteristics and three functions of sponge city.

"Seepage and stagnation" correspond to "reducing the drainage pressure of municipal pipe network in case of heavy rainfall and improving the city's ability to adapt to natural disasters." Aiming at these two characteristics and functions, it is mainly realized by constructing green land parks along the river and connecting with artificial water systems. The project is expected to build more than 600,000 square meters of green space, use a large number of permeable materials such as permeable bricks in the construction of community parks radiated by various ditches, and use composite soil for plant planting in the green belt (Figure 2).

According to the soil profile, it can be seen that the diversified and multilayer soil structure not only has good water permeability effect but also has the function of primary filtration of rainwater. At the same time, in the season

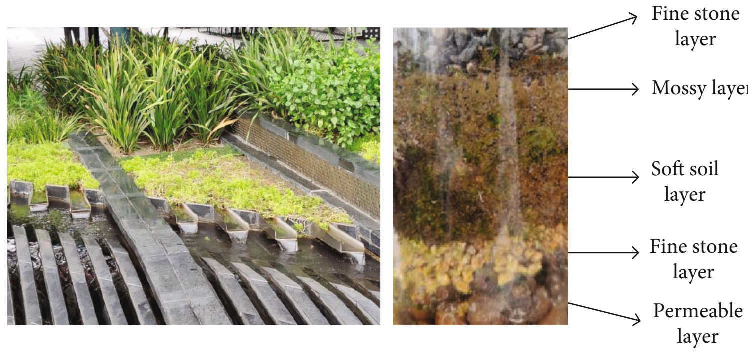

Figure 2: Examples of landscape design conducive to drainage and composite ventilation structure model.

of heavy rainfall, through the good water permeability of the green park, part of the rainwater is effectively absorbed, while the other part is collected into the ditch. Because the ditches extending in all directions have been connected, the retention time of this part of rainwater in the ditch becomes longer, so as to share the flow pressure for the main stream. The project improves the adaptability of the city to natural disasters, which is also reflected in the 20 km long river embankment repair and water body treatment measures. Most of the original banks along the river are native banks. Whenever the summer wet season comes, the banks will always be flooded to a depth of one to two meters. After the river embankment is built, the river bank can be effectively protected from flooding. An important task in water treatment is to dredge the river channel and clean up the silt in the river channel, which can reduce the river resistance, increase the river flow, and reduce the probability that the river will damage the riverbank ecological environment. In terms of "storage, purification," and "use and discharge," the project has built a sewage treatment plant with a daily sewage treatment capacity of 60,000 cubic meters. After collecting and treating the urban sewage, part of it will be discharged into the river for natural review. At the same time, a matching storage tank will be built to store another part of the water diversion resources. This part of water will be mainly used for the water cultural landscape of green parks, plant maintenance, and toilet flushing water in the region. The existing gate of the river channel is also used to build a gate on the adjacent side to connect the river with the newly built park ditch. On the one hand, it is convenient to discharge the water trapped in the ditch system. On the other hand, in the dry season, the gate is lowered through the main river channel to store water, and the water is introduced into the ditch system as compensation.

Through the analysis and study of examples, we focus on the combination of computer artificial neural network technology and sponge city. There are two main reasons. One is that the first four characteristics have quite mature technology at present, especially in sewage treatment, which has been able to achieve full automation of unattended. Second, through the investigation of the project, we found that in the case of extreme precipitation weather, the original natural drainage effect is limited.

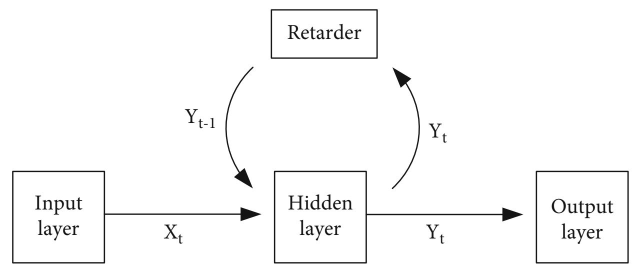

Figure 3: Recurrent neural network model.

2.2. Introduction to Computer Artificial Neural Network. Based on the theory of metacranial nerve, since the 20th century, people have obtained a simplified human brain model with some basic functions of human brain through the processing of functional information such as imitation, abstraction, and simplification of human brain cells; then, the simplified model is simulated in the computer system of the human brain and can realize the function of the brain to process information and the modern concept of relatively narrow AI has been obtained. Analog neurons in an artificial neural network act like synapses in a biological brain, with each connection transmitting signals from one artificial neuron to another. The artificial neurons receiving the signals can process them and then send signals to additional artificial neurons connected to them. In a typical neural network, each layer is made up of multiple artificial neurons. Different layers can perform different kinds of transformations on their inputs. The signal travels from the first layer (input layer) to the last layer (output layer), perhaps passing through these layers many times in between. We selected the circulating neural network RNN, which is widely used in machine translation, speech recognition, generated image description, video tagging, and other fields and studied the sponge city design with intelligent displacement optimization. The further significance of recurrent neural network (RNN) is that it is the basis of many deep learning models and many new neural networks are constructed based on RNN.

2.2.1. RNN Model of Recurrent Neural Network. Cyclic neural network is a sequential network based on repeated neural use, which consists of an input layer, hidden processing layer, and output layer (Figure 3).

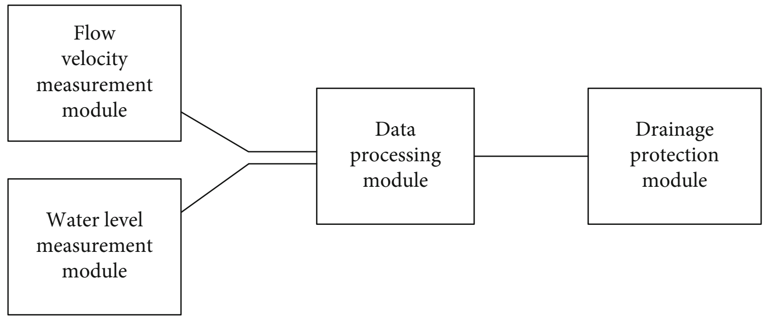

Figure 4: Traditional drainage system model.

The neurons in the same layer network are directionally connected into a ring, so that the output information at the moment is not only related to the corresponding input but also related to the output information at the previous moment. This shows the memory of the recurrent neural network. But this kind of memory can only realize the long-term circular transmission of information in theory. When the data information circulates in the network for a long time, there will be gradient loss and data explosion. However, in our study of the characteristics and functions of sponge city, there is no need for multiple cyclic processing of data information. As for the subsequent added prediction module, because the climate is changeable and the temperature and humidity change rapidly before the imminent rainfall, there are certain requirements for the timeliness of algorithm learning, and the cyclic neural network has the ability of real-time learning. Therefore, RNN can meet our design requirements.

3. Sponge City Design with Displacement Optimization Based on Recurrent Neural Network (RNN)

3.1. Analysis of Existing Sponge City Drainage System. In the traditional urban drainage system, the construction of pumping stations to pump water occupies a large proportion of the drainage system. According to relevant data statistics, the number of pump stations and installed pump capacity in China is very large, but the actual operating efficiency is very low and even cannot reach 50% of the installed capacity. So almost half of all energy is wasted. For the drainage system of the new sponge city, our design concept is to adjust the operation of the pump according to the actual situation, so that the discharge water flow is in a state of dynamic balance, so as to reduce the installed capacity of the pump. The design of the existing drainage system model is divided into four aspects: (Figure 4).

(1) Flow velocity measurement and acquisition module: using the device of double flow velocity sensor to measure the flow velocity of the area needing drainage, judging the size of water by the flow velocity of water, its advantage is to ensure the accuracy of flow velocity in measuring rainstorm and moderate rain. One velocity sensor is used to measure the velocity of moderate to heavy rain, and the other is used to measure the velocity of light rain and heavy rain. The results of existing examples show that the double flow rate sensor is very accurate in the calculation of liquid flow and volume

(2) Water level measurement module: using ultrasonic ranging module to measure the water level, the module inputting a pulse signal of more than 10 microseconds can send out 9 30 kHz cycles of electrical frequency and detect echo. When a round-trip signal is detected, an echo signal can be output. The height of the water level can be calculated by measuring the time of the round-trip signal

(3) Data processing and display module: using computers to process and display data. In terms of data collection for the first two modules, data transmission can be carried out in real time by using solar 4G or 5G data generators. This kind of technology in the construction machinery fuel consumption monitoring process has a relatively mature technology

(4) Drainage and automatic protection module: composed of pump pumping and motor control gate drainage and automatic protection module, timely adjust the height of the gate and the power of the pump to prevent excessive overflow of water level. The parameters of water pump and motor should be selected according to the actual use parts

3.2. Research and Analysis on the Application of Cyclic Neural Network RNN to Drainage System. The adaptability of cities to natural disasters is generally divided into three aspects. On the one hand, natural disaster prevention is carried out, such as precipitation prediction of weather forecast and seismic wave monitoring, and natural disaster prevention and control measures are carried out according to different forecast information. On the one hand, we should publicize the knowledge of natural disaster prevention and organize emergency drills. Another aspect is the natural disaster in the process of handling measures, such as the use of emergency pumps in heavy rain for pumping. The recurrent neural network (RNN) is mainly applied to precipitation prediction and drainage system. Due to the limited data acquisition conditions, this paper provides design ideas

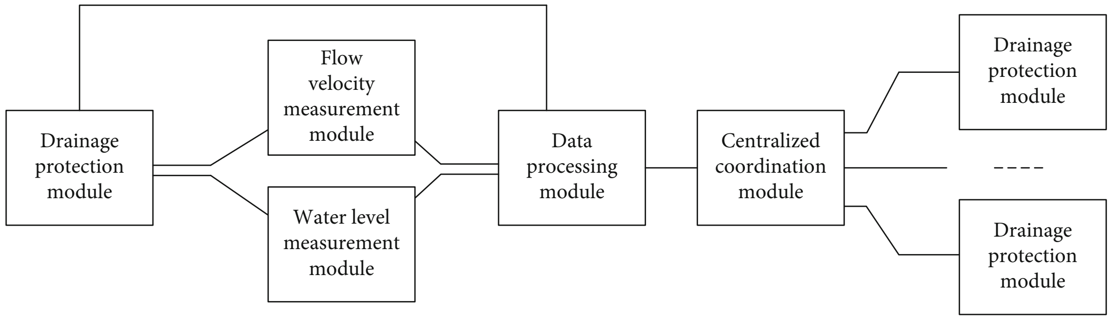

Figure 5: Sponge city drainage system based on precipitation prediction and displacement optimization.

for sponge city and does not conduct specific data test and simulation.

Combined with the existing drainage system model, we consider adding a precipitation prediction module before the velocity acquisition module. The influence factors of precipitation are considerable, but according to the existing research, data show that the nature of the precipitation and evaporation in a long time will form a dynamic balance and the relationship between evaporation and precipitation and is directly related to the environmental temperature and humidity, so you can use the temperature and humidity sensor to local environmental temperature and relative humidity for a long time as the input data acquisition. The precipitation is output as the result of training through the recurrent neural network model. Before putting into actual use, the local meteorological data is needed for statistical analysis; in the past nearly 5-10 years, the environment temperature and humidity data is divided into two generations into the model of training, the first half as the input and the second half of the amount of validation for the output; when the model prediction error is less than 30%, to the corresponding initialized weights, adjust the coefficient vector, momentum term coefficient, etc. According to the memory of circulation, neural network model at the same time, in the process of actual precipitation forecast, nearly 15 days of the weather forecast as another data collecting information, for accurate training data for a short period of time, will get the results for storage; the results of the simulation training did not complement each other with past data correction; make further improvement in prediction accuracy.

At the same time, considering that the unidirectional fluidity between the original drainage system modules will lead to the instability of the whole system and the function of the whole drainage system will be affected as long as a certain module has a problem, we can add a centralized coordination control module between the data processing module and the drainage module to realize the dynamic connection between the modules. When the precipitation prediction module outputs the precipitation results to the data processing module through prediction, the data processing module will determine whether to adjust the water volume according to the comprehensive data of the flow velocity measurement module and the water level measurement module and send the instructions to the centralized coordination module to coordinate the operation of each pump station in the regional water system in advance, pump water from the storage tank, reserve the corresponding rainwater capacity, and increase the water absorption capacity of the sponge, avoiding urban waterlogging. (Figure 5).

4. Conclusion

Today, the sponge city is still the focus of the new urban development direction in China;; with the global climate anomaly result in recent years, we often can see extreme weather in what is happening; remove early pilot outside of large cities and other small cities and extreme climate environment can all be sponge urban design concept as a guide to urban construction, guiding ideology for promoting urban development. We applied artificial neural network, the intelligent technology, to the design of the new sponge city, combined the drainage concept of the traditional city with that of the sponge city and added precipitation prediction module and centralized coordination module in the drainage system to dynamically control the displacement in real time. Through the prediction of precipitation in specific areas and centralized analysis of precipitation data, the ability of sponge city in preventing extreme precipitation weather is strengthened. By connecting various modules of traditional drainage system with centralized coordination module, the displacement optimization design of sponge city is realized, which makes up for the weak drainage capacity of sponge city at the end. At present, many places are building urban wetland parks based on regional water systems. In the construction process of wetland parks, comprehensive consideration of water drainage is helpful to improve the adaptability of cities in extreme precipitation weather. The ideas proposed in this paper still need a large number of experimental data to be improved and demonstrated, and more efforts need to be made in the follow-up.

Data Availability

The figures used to support the findings of this study are included in the article.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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