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# *Genetic Algorithm of GIS in Water Pollution Control Planning*

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***Keywords:*** Water Pollution Control, Genetic Algorithm, Geographic Information System, Control Planning Model

***Abstract:*** Water is the source of life. The shortage of water resources and environmental pollution have become the bottleneck restricting economic development. The main pollutants are organic substances, such as sewage nitrogen, biochemical oxygen demand, permanganate index, volatile phenol, etc. These factors affect a wide range of areas and have a high degree of harm. In order to make full use of water resources and reduce water pollution (WP for short here), it is necessary to treat water environment as a whole to make it meet the water quality standards. In this paper, GIS (Geographic Information Science) technology is used for comprehensive evaluation of water quality, and certain mathematical calculation methods are used to achieve quantitative and objective evaluation of water quality, so as to achieve the objective evaluation of water quality and work efficiency. Genetic algorithm (GA) is an adaptive global optimal probability search method, which imitates the genetic and evolutionary process of organisms in nature. In this paper, from the perspective of biological genetics, a GA for directly coding parameters is designed, which solves the problem that traditional nonlinear problems are easy to fall into local optimum. At present, it has been widely used in many aspects. Based on GA of GIS, this paper applies it to WP control planning. The study found that the cost of WP control system based on GA based on GIS was reduced by 30.32 million compared with the cost of WP control before improvement.

## 1. Introduction

In order to adapt to the development of social informatization and continuously improve the informatization of water conservancy and hydropower, GIS technology and GA must be applied to water conservancy, WP and other aspects, and research on precipitation, groundwater survey and

other aspects in specific areas. From the traditional mode of high consumption and low efficiency to the comprehensive planning and information construction, in the actual hydrological survey and protection work, it can closely link the characteristics of water resources, and carry out detailed analysis of various information of water resources, so as to improve the utilization rate of water resources.

There are relevant studies on WP by relevant scholars: Singh Nirala believes that the prevention and control of regional WP is a large system with multiple variables, multiple objectives and multiple levels. It is based on the environmental forecast, and comprehensively considers the environment, economic objectives, technical countermeasures, etc. through systematic analysis [1]. Mekonnen Mesfin M believes that the WP prevention and control system planning is an optimal plan for the comprehensive design of a certain area or a certain area's water environment system [2]. He Xiaodong proposed that WP should be reduced, water resources should be reasonably developed and utilized, and water environment should be protected and improved. Investment must be increased to avoid continuous deterioration of water quality [3]. Li ZHOU believes that industrial enterprises are the main source of WP. With the marketization of urban sewage treatment, the establishment of an economic and reasonable WP prevention and control system is the key to WP prevention and control [4]. Shen Jichuan believes that when planning the WP prevention and control system, it should not only make comprehensive use of various methods, but also take into account the reasonable allocation of water sources, water supply requirements and water resources protection, which often involves many social, political, economic, technical and other issues [5]. In short, the key of WP prevention and control planning is to ensure that the water quality meets the requirements and minimize the cost.

There are relevant studies on GA by relevant scholars: Li Ruihua believes that the main characteristics of GA are population search and data exchange between individuals, and also have unique parallel random adaptive optimization capabilities [6]. Dutta Pijush believes that in the process of solution, because GA is easy to lead to premature convergence of the algorithm, the results obtained are often suboptimal or suboptimal solutions in the whole region, so local search must be carried out in a short time to obtain better results [7]. Mounce S R believes that the GA is not limited to linear, continuous, differential and other specific forms, nor is it limited to the number of parameters and constraints of the model, but under the guidance of the optimal criteria, it can achieve multi-point parallel global optimal solution [8]. Abba SI believes that the GA is different from the traditional optimal algorithm. It does not need to deal with the parameters of the model directly, but only needs to code the representation parameters; GA can not only control a solution in the global range, but also effectively avoid falling into local extremum [9]. Acuna Yenni Paloma Villa believes that in the GA, the initial population is formed by using the coding method, and then the population is processed according to its adaptability to the environment to achieve the goal of survival of the fittest [10]. Like the evolution of biology, the calculation of GA is a repetitive process. Through continuous inheritance and evolution, the population passes the excellent genes to its descendants through the survival of the fittest, and finally forms an excellent individual, which can almost solve the best problem.

The WP prevention and control plan involves different space-time, economic, social, resource and other issues, and these issues are interactive. Therefore, in the face of such a complex environmental problem, it is difficult to ensure the coordinated development of environment, economy and society only by relying on the experience and knowledge of policy makers. GA is an adaptive algorithm that uses computers to simulate the genes of natural organisms. Its biggest advantage is that it does not depend on initial conditions, so it has good search performance. GIS is the main management and analysis method of current spatial data. Combining GA with GIS technology can excavate potential WP control characteristics and patterns from massive spatial data

and provide basis for scientific decision-making.

## 2. GIS Application Function and Application Field

### 2.1. GIS Technology

Geographic information system is based on computer software and hardware to collect, store, manage, calculate and describe the information of the whole or part of the earth [11]. GIS technology can obtain the required information in real time and analyze it, which can not only ensure the accuracy of information, but also ensure the timeliness of information [12]. The data collected by GIS can truly reflect the status quo of the monitored objects, and has good spatial characteristics, which can improve the processing of spatial information, ensure the full use of data, and also update the data in time [13]. GIS technology uses a variety of scale formats and coordinate systems to ensure the efficient transformation of spatial data and standardize the data. GIS technology can build a variety of spatial patterns and ensure information sharing by establishing a good interconnection mechanism [14]. In the application of GIS technology, the established model must be analyzed accordingly, and a series of preparations must be made for data input so as to uniformly process the data [15]. GIS application fields mainly include forestry, agriculture, land resources, ecological environment, environmental resources, disaster warning, etc., as shown in Figure 1.

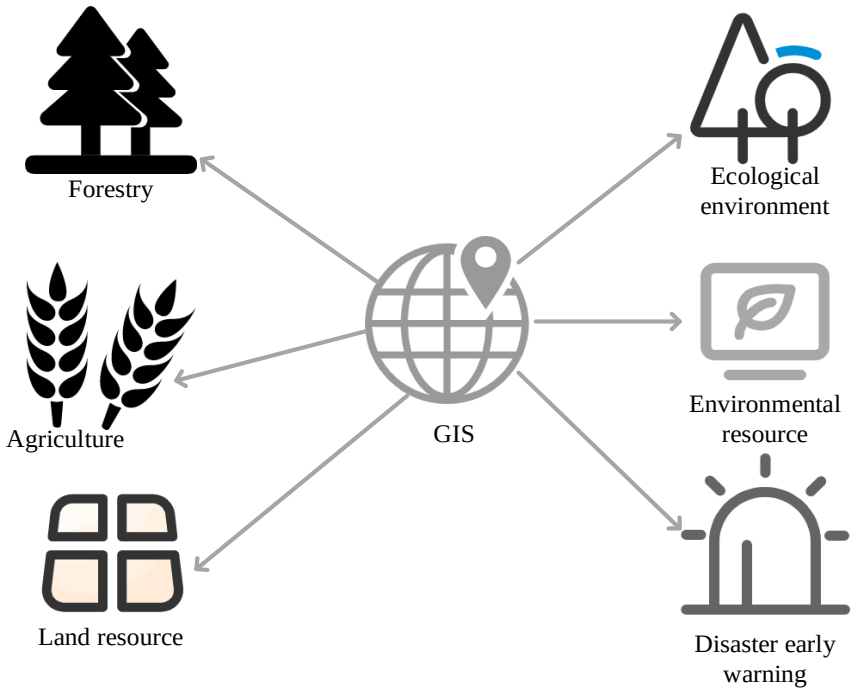



*Figure 1. Application fields of geographic information system (GIS) technology*

The visibility feature of GIS technology is to analyze the structure it simulates in time, so that users can intuitively understand the relevant information [16]. There are special graphics in GIS, which can make the simulation data more intuitive and efficient, and also enable relevant departments to grasp information in time, so as to make more scientific decisions [17]. After obtaining the report, the staff adopted various methods to simulate the contents of the report, making the contents of the report more intuitive, providing sufficient basis for the study of hydrological and water resources, and improving the work efficiency.

## 2.2. Application of GIS in the Field of Water Conservancy and Hydropower

(1) Spatial management and decision-making of water resources

On the premise of ensuring the distribution and spatial change of water resources, appropriate database format should be selected according to the characteristics of water resources to ensure the distribution and spatial change of water resources [18]. Establish a sound water resources management decision-making system to continuously improve the management level of water resources. At present, some cities have established a relatively complete water conservancy decision support system, which fully relies on GIS technology, but in practical application, due to lack of sufficient funds, it is difficult to ensure further improvement of its functions. Therefore, it should strengthen policy support to ensure the effective development of the system in terms of funds and talents, and strengthen the training and introduction of talents to improve their ability in the development of decision-making systems.

(2) Flood information collection and disaster prevention and mitigation

The application of GIS technology has laid a solid foundation for the development of flood control and disaster reduction. Use the GIS internal management platform to carry out drought assessment, risk analysis, flood control, etc., to minimize the impact of drought on regional development. The spatial information of hydrological and water resources collected and described by the GIS system lays the foundation for the establishment of the decision support platform of the flood forecasting system. At the same time, the spatial analysis function of GIS can also reflect the disaster prevention and reduction needs of regional hydrological and water resources, and optimize various parameters to achieve the visual goal of flood control and disaster reduction decision.

(3) Application in groundwater exploration

Accurate geological survey is an important means to improve the management level of mineral resources. Among them, the distribution law of underground flow, geological conditions, connectivity degree and boundary between underground rock mass and rock mass are the key points of its exploration. Using GIS technology and GIS technology, the source and reserves of groundwater can be accurately obtained. Through the analysis of different spatial data, the corresponding spatial model is established to make the actual distribution of surface water more intuitive and detailed.

(4) Application in water resources management

The application of GIS technology in WP control can quickly collect water quality related data and facilitate relevant departments to obtain accurate water quality data through graphic display, formulate effective control measures and reduce environmental pollution. At the same time, in order to further determine the control objectives, relevant departments can use GIS technology to carry out relevant work, establish databases, models and improve work, so as to better manage and control local WP.

At the same time, GIS technology also plays an important role in the prevention and control of WP. Using this technology, water quality simulation technology and network analysis function can be organically combined to better simulate the pollution situation of sudden environmental events [19]. So that relevant departments can understand its causes and objectives in the shortest time and develop a set of scientific and reasonable emergency plans.

## 2.3. Development Trend of Water Conservancy and Hydropower in GIS Technology

GIS is a dynamic and long-term process. In the application of GIS technology, the following development trends must be followed. First, it should formulate GIS technical specifications and related standards, formulate more scientific and unified GIS technical management standards, and actively learn the experience of GIS technology development to ensure the application of GIS in

GIS system, so that there are laws to follow and the law enforcement must be strict. Second, establish a database to ensure the standardization and normalization of the database and lay a solid theoretical foundation for future research work. For example, according to the regional climate and environmental characteristics, a characteristic database of water and rain information is built, which provides a special theoretical basis for the evaluation of regional drought and flood disasters. Thirdly, construct the spatial decision support system of hydrology and water resources to provide sufficient human and material resources for its further improvement and optimization. Fourth, it should accelerate the integration of GIS technology and professional models. Relevant departments should strengthen the research on the spatial data management function of GIS, constantly improve and perfect its distribution mode, so as to ensure the high-quality integration of GIS technology and improve its professional level.

## 3. Common Improved Genetic Algorithms

### 3.1. Genetic Algorithm

GA is a kind of possibility search to operate a series of sequences with specific coding technology. Its basic idea is to imitate the evolution of individuals composed of sequences. In each era, new sequences are generated from the better fragments in the previous generation; In order to improve the quality of the solution, it is sometimes necessary to introduce some new bits and segments into the sequence to replace some new GA [20]. Similar to natural evolution, GA can find the right chromosome by influencing the genes on the chromosome to solve the problem. Like natural phenomena, GA does not know how to solve this problem. It only needs to evaluate each chromosome generated by the algorithm and adjust them according to their fitness value, so as to increase the number of suitable chromosomes.

### 3.2. Features of GA

GA is a stochastic optimization method that simulates the law of biological evolution (survival of the fittest). The optimization methods of the three conventional GA: analytical method, enumeration method and random method, as shown in Figure 2.

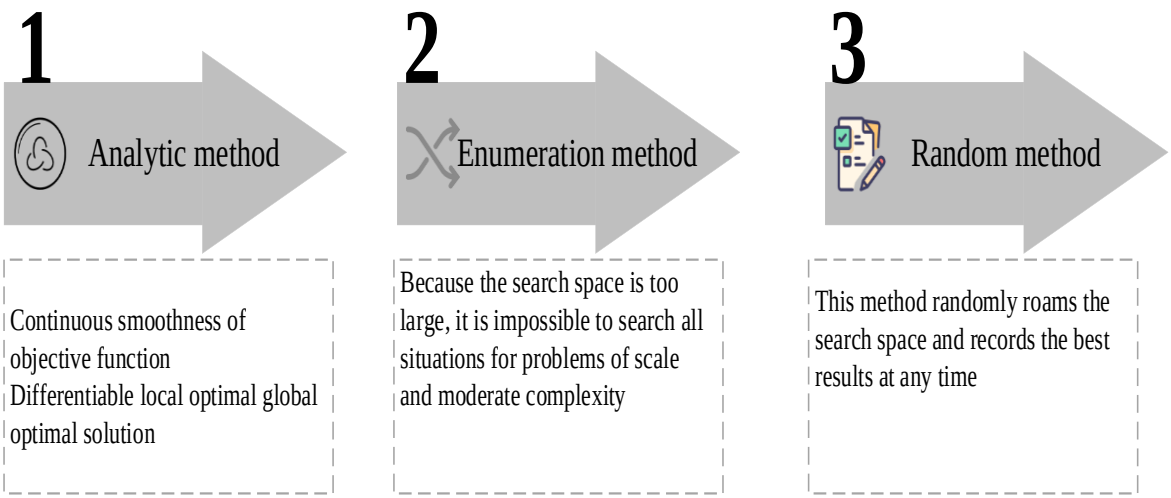



*Figure 2. Optimization methods in three conventional GA*

In the case of fast, simple and fault-tolerant computing of class structure objects, GA shows

obvious advantages in the process of solving. Compared with traditional retrieval, its features are shown in Figure 3.

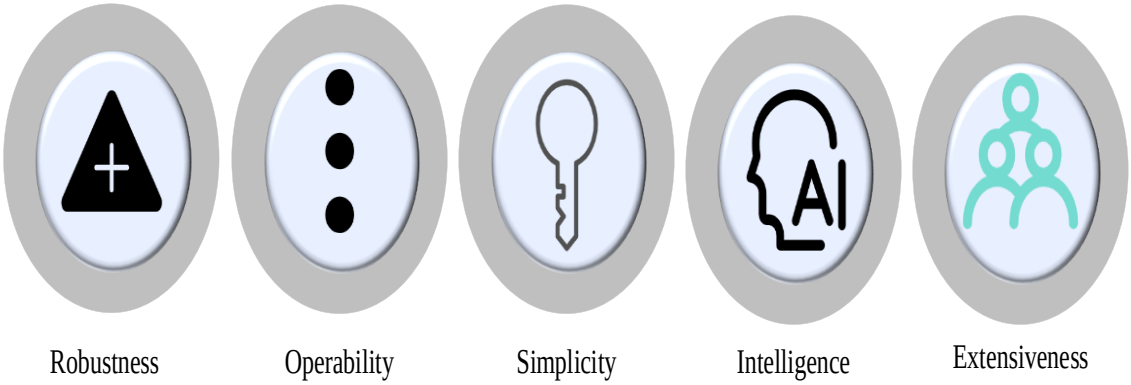



*Figure 3. Main characteristics of GA*

### 3.3. Improved Genetic Algorithm

GA is an optimal method for global parallel search, which has been widely used in many fields. The main feature of this method is global optimization. It guides the existing fitness value, rather than blindly searching for the optimal solution. Due to its own characteristics, some problems are often encountered in the solution process, such as slow convergence rate and local optimization. Many scholars have adopted methods such as increasing the number of population, improving genetic operators, and adopting hybrid algorithms to improve the convergence and global optimization of the algorithm. The advantages of the improved GA are shown in Table 1.

*Table 1. Advantages of three improved GA*

| GA | Advantages after improvement |
|---|---|
| Adaptive GA | Increase individual fitness difference<br>Improve the convergence accuracy of GA<br>Faster convergence |
| Hybrid GA | Faster<br>Higher accuracy |
| Parallel GA | Overcoming premature convergence of standard GA<br>Strong global search capability |

(1) Adaptive GA

Adaptive GA is a new GA, which can improve convergence by adjusting genetic parameters. Adaptability function is an assessment of environmental adaptability and a common selection method. Its selection or not would have a great impact on the performance of GA. At the initial stage, the fitness values vary greatly. In order to avoid some individuals with weak adaptability losing their adaptability at the beginning, they can maintain their existence by changing the fitness function. Moreover, when the population is close to convergence, the difference in fitness is very small, so in the process of fitness change, the difference in fitness would become larger and larger, so that the best results can be obtained quickly.

(2) Hybrid GA

Hybrid GA is an efficient method to find the optimal solution through GA and other efficient optimization methods. Therefore, this method can be applied to solve complex practical problems. Hybrid GA is a hybrid optimization method that combines two different optimization methods. The

working process of this method is as follows: First, GA is used to generate a group of initial solutions in the original solution space; Secondly, according to the given evolution strategy, a new solution is formed from this group of initial solutions; The second is to use the improved method to improve the previous solution and obtain a good result. The comprehensive results show that the method can solve multiple optimization problems, improve the search efficiency and improve the search accuracy. Therefore, in GA, hybrid GA would be used more and more widely.

(3) Parallel GA

Parallel GA (parallel design) is a GA used to solve complex optimization problems of parallel evolution of multiple populations. This method can effectively solve the premature problem of traditional GA, and has great advantages in global search. This paper proposes a GA based on parallelism, that is, by changing its structure to make it have better parallelism, so as to make it have parallelism. It can not only accelerate the speed of solution, but also enrich and maintain its diversity through the number of expansion and the separation of each subgroup, reducing the possibility of premature convergence, thus improving the quality of solution.

## 4. Build Water Pollution Control Model Based on Genetic Algorithm of GIS

In the urban WP prevention and control plan, the focus is on sewage discharge and upstream pollution, without considering the prevention and control of the pollution source itself, the cost of sewage transmission pipeline and the resulting pollution. This system must ensure that the downstream water quality would not be polluted.

Set $g_o(i)$ as the fitness function of point i at point o, and $g_{con}(i)$ as the weight constraint fitness function of the objective function under the GA. Assuming that there are k WP constraints, $g_o(i)$ can be expressed as

$$g_o(i) = 1 - \frac{|f_o(i)|}{f_{\max}(i)} \tag{1}$$

$g_{con}(i)$ can be expressed as

$$g_{con}(i) = \sum w_i g_o(i) \sum_{i=1}^{k} w_i \tag{2}$$

$f_o(i)$ is the inequality constraint condition of the WP control model, and $w_i$ is the equality constraint condition of the WP control model.

Through the simulation of GA based on GIS, the analytical formula of WP control model is obtained as follows:

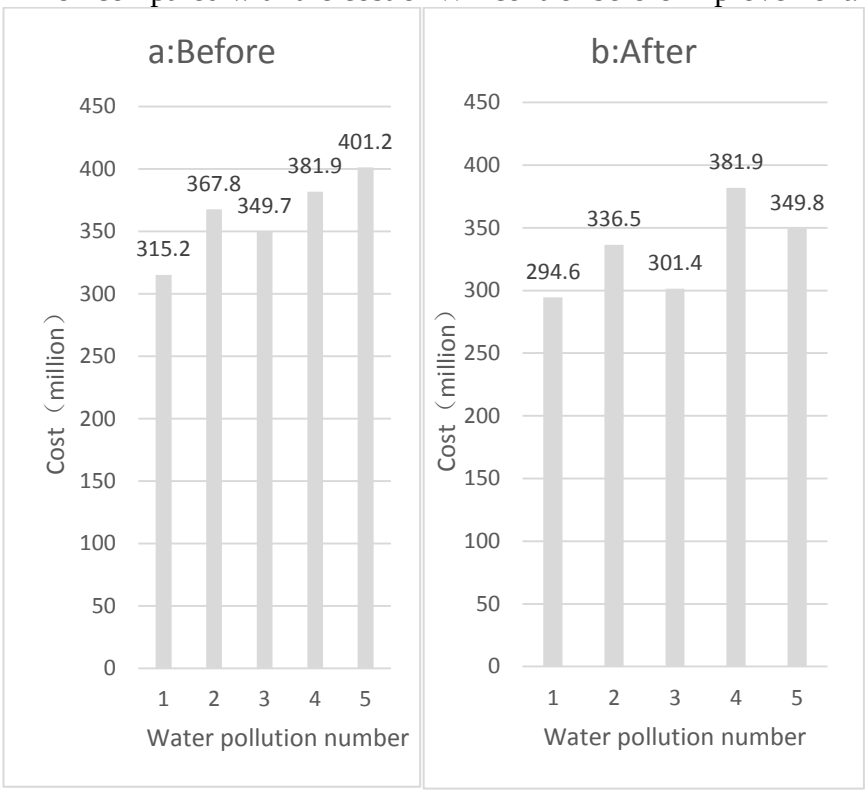
$$W_l = Lo(i) \sum_{i=1}^{k} \exp(Z) p_i \tag{3}$$

$Z$ is the WP treatment cost of a certain area, $p_i$ is the sewage treatment efficiency of a certain area, and $Lo(i)$ is the water quality constraint condition of a certain area.

## 5. Result of Improved Genetic Algorithm

The improved GA of GIS is applied to the field of WP control system planning, and the results

are satisfactory. In this paper, five groups of WP areas were randomly selected and applied to the improved GIS GA in the field of WP control system planning. The comparison of WP control costs before and after the improvement is shown in Figure 4. Figure 4a shows the WP control costs before the improvement, and Figure 4b shows the WP control costs under the improved GIS-based GA. The study found that the average cost of WP control system based on GA based on GIS was reduced by 30.32 million compared with the cost of WP control before improvement.




*a. Before improvement* *b. After improvement*

*Figure 4. Comparison of WP control cost before and after improvement*

## 5. Conclusion

Water pollution control planning is to obtain the maximum discharge of each pollutant by monitoring and evaluating the pollution source and establishing the corresponding mathematical model, and then determine its consumption according to the pollution load of the planning year. Based on the results of WP prevention and control planning, this paper combines GIS technology with GA to significantly improve the data processing capacity and planning level of urban WP prevention and control planning. In short, in modern society, applying GIS technology and GA to all aspects of hydrology and water resources is a necessary means for water resources research and protection. With the continuous improvement of social scientific and technological level and the continuous change of social needs, GIS technology and GA are applied to practical applications to solve the problems existing in the traditional hydrological and water resources research, improve the accuracy of its processing and analysis, and obtain various kinds of information in a timely manner, thus improving the protection effect of water resources.

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## Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

## Conflict of Interest

The author states that this article has no conflict of interest.

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