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Chaotic Particle Swarm Optimization in Water Pollution Prevention and Control System Planning

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Abstract: Water resources management is closely related to environmental protection and other disciplines, a large amount of data and various indicators. With the continuous development of Water Pollution (WP) control technology, WP prevention and control is diverse and systematic. However, technical improvement is still needed in terms of expressiveness, integration and authority. In terms of the sustainable development of water resources, it is necessary to make short-term and medium-long term predictions of water resources, and make appropriate improvements to WP control planning technologies such as the optimization of planning schemes. The comprehensive utilization, development and utilization of water resources in river basins can lay a solid foundation for the formulation of national water resources protection policies and implementation plans, and the coordination of national, regional, river basin and department water resources management. Chaotic particle swarm optimization has the advantages of fast convergence, less control, simple implementation, and avoiding local bias. This method can effectively reduce the order and make the model closer to the original system. Through the analysis of experimental data, it was found that the operation efficiency of chaotic particle swarm optimization algorithm was 36.84% higher than that of traditional particle swarm optimization algorithm, and the operation accuracy of chaotic particle swarm optimization algorithm was 10.4% higher than that of traditional particle swarm optimization algorithm.

1. Introduction

In the study of WP prevention and control system, appropriate prevention and control measures are usually taken by monitoring the pollution sources and evaluating the pollution status of water bodies. In the prevention and control of WP, the corresponding data model should be constructed according to the regulations of governments on water quality to determine the factors affecting the maximum discharge of water quality. The prevention and control of WP plays an important role in system planning, and a simple planning system is more efficient for WP prevention and control.

Due to the slow efficiency of traditional particle algorithm in practical application, many experts have made various attempts and studies. Dursun Emre Hasan designed a particle algorithm when studying wind power generation technology. Its research showed that compared with other traditional processes, the process of the invention improved the efficiency of electric extraction [1]. Li Mei proposed a group optimization method with multiple uses, which had good convergence performance and operation speed. This was a very popular intelligent computing. In the optimal operation of the combined production of cold and heat, the integrated scheduling of the two units was realized. The simulation results showed that the scheme had good effects in reducing environmental pollution and energy consumption and improving energy conservation [2]. In order to solve the motion problem of the manipulator, Du Yuxiao adopted polynomial interpolation and local chaos particle swarm optimization methods. On this basis, the local convergence of this optimization method was studied. Through the simulation test on the joint surface, the optimal motion speed and the optimal motion path of each node were obtained, which proved that this algorithm could greatly reduce the working speed of the manipulator and ensure the stability of the manipulator [3]. Particle swarm optimization accelerated the process of WP prediction, and also laid the foundation for the development of WP prevention and treatment technology.

With the further deepening of the economic system, the change of the development mode and the rapid development of science and technology, the rational development and use of water resources would gradually enter the scientific track. Suriadikusumah, Abraham adopted several methods to reduce the pollution of these water sources. The most effective way was to obtain a value through the study of the pollution index to reflect the pollution level of the area, so as to use the pollution index to evaluate its pollution level. The study found that the pollution indicators significantly changed the environmental quality of water bodies [4]. Aziz Zena A proposed an air quality control plan to ensure the balance of nature. Wireless sensor network was a revolutionary system. On this basis, pollution sensors and monitoring systems were studied [5]. Stravs Michael A showed a WP control platform, which could monitor image quality through sample preparation, analysis, automatic data processing, and remote control and monitoring [6]. He, Yuqing summarized the main measures and mechanisms of environmental pollution control in various countries from the perspective of environmental pollution of air, sea, forest, water and solid waste, which was used to explore a complete system of environmental governance and management [7]. Due to the severe water resources situation and environmental threats, the people’s demand for the living environment was increasing. Therefore, all regions should strengthen the protection and supervision of water sources.

The above research only studied the chaos particle swarm optimization algorithm and the WP prevention and control system planning separately but did not combine the two. Although these studies had some reference, they were more or less insufficient to prove the conclusion, which had some room for improvement. In order to solve the application research of chaos particle swarm optimization algorithm in the planning of WP prevention and control system, this paper analyzed the planning of WP prevention and control system, and compared the operational efficiency of traditional particle swarm optimization algorithm and chaos particle swarm optimization algorithm through the analysis of experimental data, which had reference significance for the future research of algorithms in other fields.

2. Planning and Evaluation of WP Prevention and Control System

2.1. Development Status of WP Prevention and Control

At present, Geographic Information System (GIS) is mainly used to carry out pollution source investigation, and divide water environment functional areas. It is also used to calculate water environment capacity, and formulate corresponding countermeasures, so as to achieve the ability of pollution prevention planning and data processing. The data is relatively complex, and the relevant data management can be carried out within a certain limit by using GIS technology; at the same time, it can also share real-time information and resources on WP; the project chart is used to display the plan results, so that it can be retrieved and run directly through the window, thus greatly improving the work efficiency. Relevant scholars introduced the application of various engineering and scientific research, and explained it with high-level complexity and high-level system. Compared with the more precise model, more physical insights can be obtained through the simpler model, thus making it easier to implement the lower level controller [8].

Relevant experts adopted the particle swarm optimization method, and compared it with the two recently improved adaptive evolution of covariance matrix and the scale reduction differential evolution of linear population, which verified the effectiveness of the method [9]. Relevant personnel adopt a method based on mixed mode, which can effectively improve the classification accuracy, and adopt the principal component method to reduce the error rate. The correctness of this method is proved under various load cases [10].

Relevant personnel use the chaos particle swarm optimization method to build the stability benchmark of the robust adaptive system on the test platform, which can effectively solve and adjust the instability of the system. In addition, it is suitable for program-based technology [11]. In addition, chaos adaptive method can also be used for system fault analysis, and adaptive gravity constant attenuation coefficient and hybrid mapping technology can be used to improve the classification effect [12]. The above research shows that chaotic particle swarm can promote the prevention and control of WP. The principle of particle swarm applied to river WP prevention and control is shown in Figure 1.

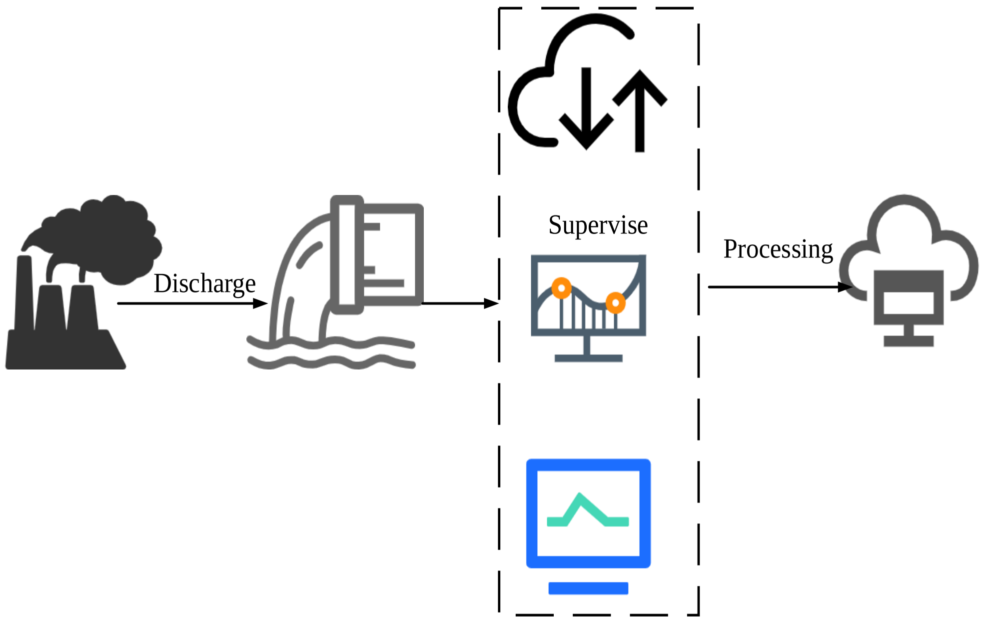


Figure 1. Application of particle swarm to river WP prevention and control principle

2.2. Evaluation of WP Prevention

Water resources are closely related to the economy. The main objectives of economic and social development are the growth of economic growth rate, the output of main products and the income of urban residents. Economic costs and environmental costs are not considered as part of economic accounting. However, poor water quality or insufficient water resources may hinder economic development. In the era of planned economy, the development of some countries conflicts with environmental protection. All kinds of small enterprises have problems such as unreasonable distribution, small scale and low level of production technology, which have caused great damage to the environment and ecology.

Due to the role of climate factors, the water quality problem is more serious, and the control of water supply pollution has brought difficulties. In recent years, the distribution of global temperature, humidity and precipitation has changed greatly. As the temperature rises, the surface runoff decreases, evaporation increases, and the possibility of drought increases, thus resulting in serious precipitation and temperature changes. The reduction of river runoff would reduce its own purification function, resulting in poor water quality. Relevant researchers need to grasp the changes of the natural environment in a timely manner, and recognize the irrational behavior of human beings, so as to grasp its dynamics and lay the foundation for the development of the country and the quality of life of the people.

WP supervision can accurately reflect the water quality and pollution status of water bodies, thus providing the most accurate basic data for the improvement of water quality. If water quality can be quantitatively studied, it can accurately grasp the dynamic changes of water quality, and provide basis for water resource protection, management and WP control, so as to promote people to pay attention to water conservation in daily work and life, and contribute to the construction of an environment-friendly society. Relevant experts analyzed the impact of flood mitigation and water environment improvement in Southeast Asia, and the data obtained from the model and experiment proved that the model can deal with the flood and water environment problems in this region. However, it is difficult to link grey infrastructure, climate change and informal settlements [13].

Therefore, previous scholars developed a pre-determined water supply cycle system to reconstruct existing water resources, and established analytical systems and corresponding numerical models for the data of three observation stations to simulate the groundwater flow in the area. The technical analysis also proves that the proposed scheme is suitable for cities and towns with water shortage [14]. Relevant personnel evaluated the domestic water purification technology and the cost of the UV water purification test plan, and estimated the project cost of the whole region. In terms of project cost, this information can be used to provide financial and administrative support for the water resources storage and disposal plan in the Territory [15]. The influencing factors of river WP are shown in Figure 2.

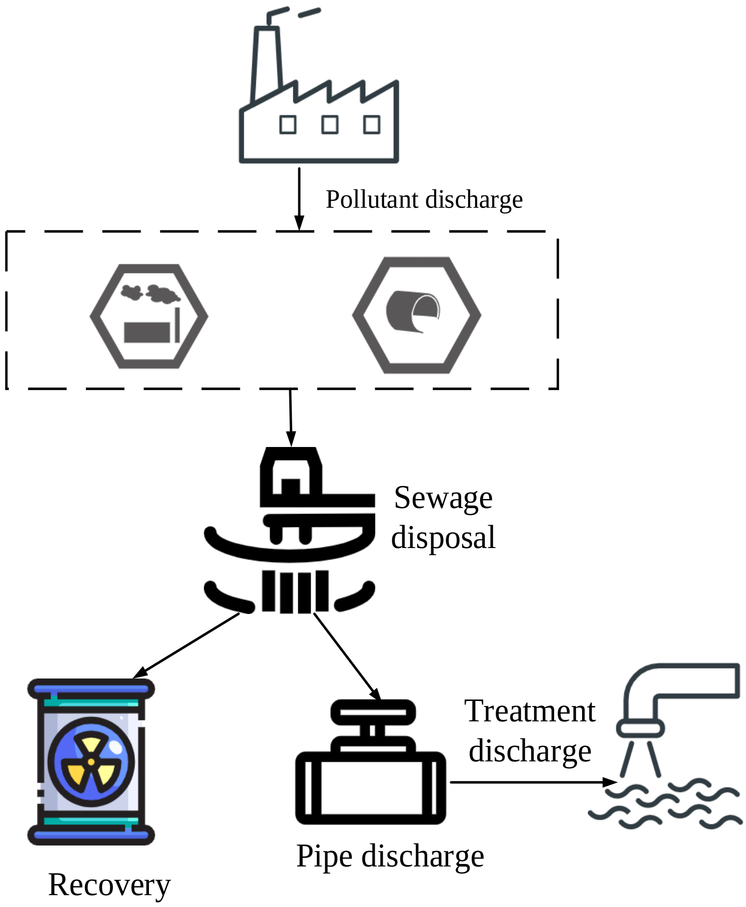


Figure 2. Influential factors of river WP

2.3. Application Value of WP Prevention

In recent years, due to the rapid economic development of countries around the world, the massive discharge of sewage, and the accumulation of pollutants such as soil and water resources, many heavy metals have had a great impact on the ecosystem. Industrial thermal separation has been widely used in mining, building materials, paper, leather, electronics and other industries, while the prevention and control of WP in industrial and rural areas is still very backward, thus resulting in the harm of WP. It has caused great harm to human life and property, which has become an important factor restricting economic development. Relevant personnel discussed the particle swarm optimization method, and reviewed some current fields from three aspects of algorithm, application field, open problem and prospect, so as to highlight the open problems in this field and the future development direction [16].

Relevant personnel analyzed that polymer electrolyte thin film fuel cells are widely used in engineering fields because of their high energy conversion efficiency, high power density and low working environment temperature. Based on this, a new particle swarm optimization method based on chaos is introduced. Three commonly known methods are simulated. The results show that these parameters determine the correctness of the scheme [17]. A variety of heuristic and meta-heuristic solutions can be used to deal with WP problems. Relevant scholars have applied this algorithm to existing problem sets and compared it with other problems, and found that this method has high reliability [18].

According to the characteristics of urban big data, relevant scholars conducted an empirical study of sustainable governance system based on smart cities. Based on the analysis of these data, the combination of sustainable urban technology and smart city is studied. Large-scale data technology based on perception lays the foundation for the development of intelligent and environmentally friendly cities, which is conducive to reducing environmental pollution and improving water quality [19].

Relevant personnel carry out simulation calculation on sustainable water management, which is conducive to selecting the optimal decision for the comprehensive treatment of water resources needs and food resources [20]. The application value of WP control system planning is shown in Figure 3.

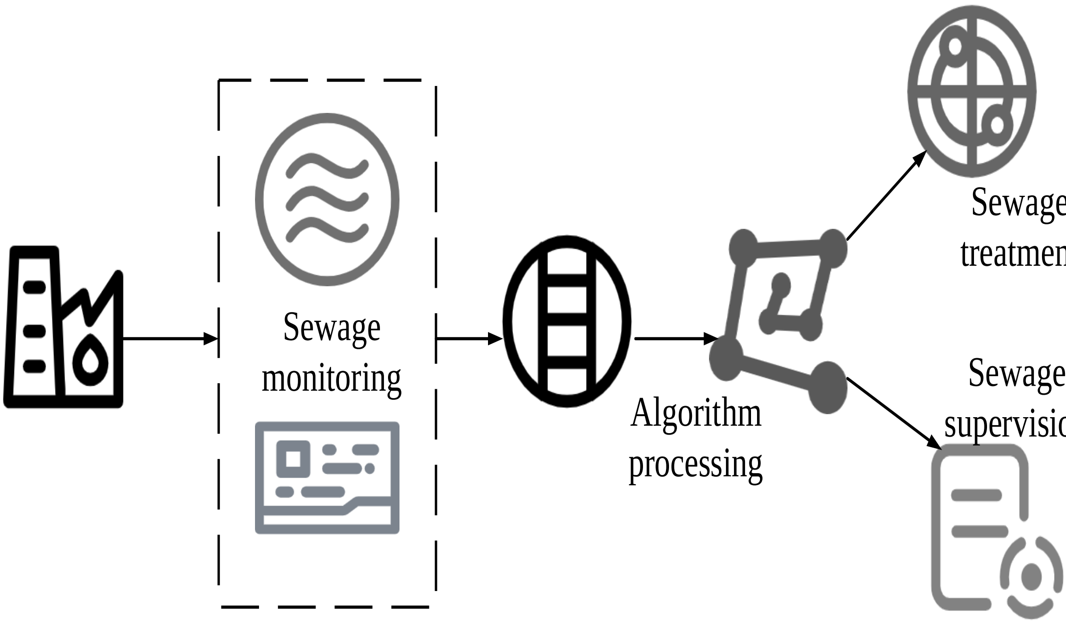


Figure 3. Application value of WP prevention and control system planning

3. Particle Swarm Optimization

Particle Swarm Optimization (PSO) is a method to solve the optimal problem, and it is also the most typical one so far. It has a wide range of applications, including engineering, computer science and behavior management. Its principle is simple and easy to implement, and it has been widely used. Chaotic particle swarm optimization is a new algorithm. Its basic idea is like a nonlinear programming algorithm or called penalty function particle swarm optimization algorithm. Particle swarm optimization algorithm is simple in principle and easy to implement.

3.1. Traditional Particle Swarm Optimization Algorithm

The nonlinear programming problem is as follows:

$$\min f(x)$$
$$s.t.\begin{cases} A_i(x) \le 0, i = 1,2,3,\dots,t \\ B_j(x) = 0, j = 1,2,3,\dots,m \\ x_k \in \{0,1\}, k = 1,2,\dots,n \end{cases} \quad (1)$$

Among them, $f(x)$, $A_i(x), B_j(x)$ are differentiable functions; the number of inequality constraints is t; the number of equality constraints is m; x is an n-dimensional variable; the value is 0 or 1.

The Formula (1) is weighted and converted into the following formula:

$$F(x) = f(x) + w_i \sum_{i=1}^{m} \left(\max A_i(x) + \sum_{j=1}^{m} B_j(x) \right) \tag{2}$$

Among them, w_i is the penalty factor.

3.2. Chaotic Particle Swarm Optimization Algorithm

In the D-dimensional space, x_i and v_i represent the position and velocity of the ith particle, respectively. The Formula (2) is improved, and the rounding method is used to round the position formula. The formula is as follows:

$$x_i(t+1) = \left[x_i(t) + v_i(t+1) \right] \tag{3}$$

It can be seen from Formula (3) that if the method is to converge rapidly, the acceleration constant should be increased. However, such practices are likely to cause “precocious” operations. If the weight of inertia is increased, the “enthusiasm” can be improved, thus preventing the algorithm from entering the optimization state in advance. However, the convergence rate of the algorithm would also be reduced. In some improved methods, in order to balance the convergence and prevent “premature”, a random variable is added to the speed update. Moreover, due to the characteristics of position correction, chaos particle swarm optimization method can better solve this kind of problem.

4. Comparative Experiment before and after WP Control System Planning

4.1. Experimental Method

By selecting WP samples from five regions, the chaotic particle swarm optimization algorithm and traditional particle swarm optimization algorithm were respectively used to plan and analyze the WP prevention and control systems in these five regions, and the data results were compared and recorded.

4.2. Data Evaluation

4.2.1. Operation Rate

Five WP samples were selected and analyzed by using chaos particle swarm optimization algorithm and traditional particle swarm optimization algorithm respectively to compare the operation speed of the system. The results showed that the operation efficiency of the chaotic particle swarm optimization algorithm was 36.84% higher than that of the traditional particle swarm optimization algorithm. The comparison of the operation speed of the traditional particle swarm optimization algorithm and the chaotic particle swarm optimization algorithm was shown in Table 1.

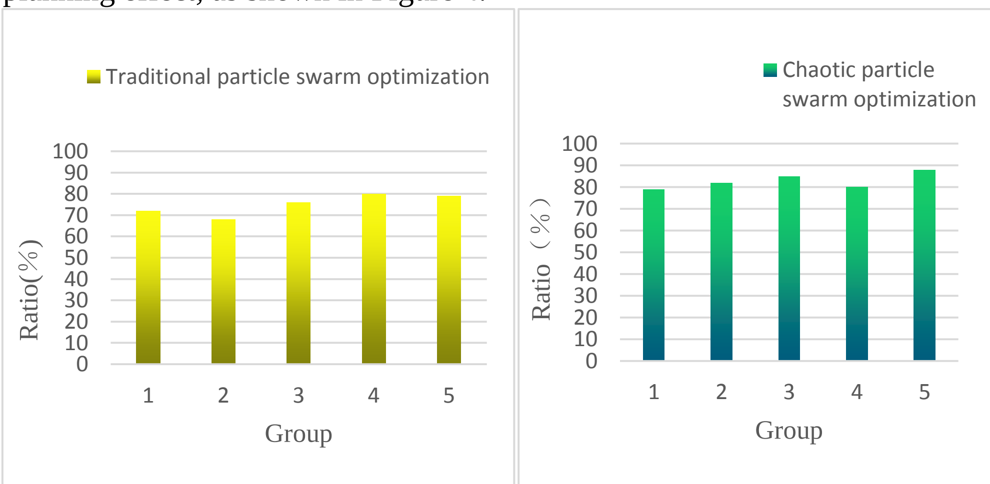
Table 1. Comparison of running speed between traditional particle swarm optimization and chaotic particle swarm optimization

Groups	Sample				
	1	2	3	4	5
Traditional particle swarm optimization	2.3s	1.9s	1.8s	1.4s	2.1s
Chaotic Particle Swarm Optimization	1.5s	1.1s	1.2s	0.9s	1.3s
Increase rate of operation rate	36.84%				

By analyzing the data in the table, the traditional particle swarm optimization algorithm was in the range of 1.4-2.3s, and the average time was 1.9s. The chaotic particle swarm optimization algorithm was in the range of 0.9-1.5s, and the average time was 1.2s. Through comparison, it was found that chaotic particle swarm optimization algorithm had better operation effect and less operation time. Therefore, it could be concluded that chaos particle swarm optimization algorithm was of great significance in WP system planning.

4.2.2. Accuracy Rate

The accuracy of chaotic particle swarm optimization and traditional particle swarm optimization in planning WP prevention and control system was analyzed and compared. The higher the score, the better the planning effect, as shown in Figure 4.



(a)Traditional particle swarm optimization *(b)Chaotic particle swarm optimization*

Figure 4. Comparison of planning accuracy between chaotic particle swarm optimization and traditional particle swarm optimization

It could be seen from Figure 4 that Figure a showed the accuracy score of traditional particle swarm optimization algorithm. Among them, the average score of accuracy using traditional particle swarm optimization algorithm was 75%. The highest value was 80% and the lowest value was 68%. The fluctuation range was large and the effect was poor. Figure b showed the accuracy score of chaotic particle swarm optimization algorithm. It could be clearly seen that the score of chaotic particle swarm optimization was higher than that of traditional particle swarm optimization. The average value of chaos particle swarm optimization was 82.8%, and the score was basically distributed in the range of 79-88%. The fluctuation range was small and the effect was good. The efficiency of chaos particle swarm optimization algorithm was 10.4% higher than that of traditional particle swarm optimization algorithm.

5. Conclusion

In this paper, a new chaotic particle swarm optimization method was adopted, which transformed a class of linear integer programming problems into a class of restricted integer programming problems, and applied it to the initialization of chaotic strategies. This paper analyzed the application of WP prevention and control system planning by analyzing the development status and main problems of WP prevention and control system planning. Compared with traditional particle algorithm, chaotic particle swarm optimization algorithm was found to be more effective in WP system planning. As a simple and effective optimization method, chaotic particle swarm optimization could achieve the optimal solution through continuous iteration through experiments. Chaotic particle swarm optimization had good applications in many aspects, such as power supply, biology, daily life services, etc. However, in some special problems, chaotic particle swarm optimization could not guarantee the quality of its solution. Therefore, the development of chaotic particle swarm optimization was still ongoing, and there were still many unsolved problems, such as the mathematical test of particle swarm optimization, thus hoping to make contributions to the development of particle swarm optimization in the future.

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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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