Optimizing Allocation of Sea Area Utilization Based on Genetic Algorithm

Xiaowen Wang and Minjie Kang*
School of Economics and Management, Dalian University, Liaoning, China

*Corresponding author email: kangminjie@sina.com

Abstract. Optimal allocation of sea area utilization solves the problem of quantity allocation and spatial distribution of sea area used by various departments. It is a necessary method to coordinate the conflicts between different departments and realize the dual goals of development and ecological protection. This paper presents an optimal allocation method of sea area utilization based on genetic algorithm. The basic principle and solving process of optimal allocation of sea area utilization based on genetic algorithm are described. The fitness evaluation model, genetic operator and constraint conditions are designed.

Keywords: Allocation of Sea Area Utilization, Marine spatial planning, marine zoning.

1. Introduction
In order to accelerate the process of industrialization and urbanization, coastal areas have a rising rigid demand for sea area resources. Facing the dual contradiction of development and ecological protection, and sea use conflicts among departments [1-2], the scarcity of sea area space resources is becoming increasingly prominent. Optimizing the allocation of sea area space resources is a necessary method to coordinate the conflicts among departments and achieve the dual goals of development and ecological protection.

The research methods on optimal allocation of land use provide references for the optimal allocation of sea area utilization. In recent years, the combination of multi-agent model and optimization algorithm, and the combination of multi-objective decision model and CLUE-S model have become the research hotspots of optimal allocation of land use. However, there are qualitative differences between sea area space resources and land resources in physical form and utilization mode, therefore the existing land use optimization allocation model is difficult to be applied to the sea use optimization allocation issues directly. Genetic algorithm provides a general framework for solving complex optimization problems, which has a wide range of applicability and flexibility. And the research results of optimal allocation of land use have shown that genetic algorithm can solve the problems of quantitative structure optimization and spatial distribution of space resources simultaneously. This paper proposes an optimal allocation method of sea area utilization based on genetic algorithm, aiming at applying the intelligent optimization algorithm to the optimal allocation of sea area space resources issues, providing references and supports for issues of sea area development and ecological protection contradictions, sea utilization conflicts among departments, and marine zoning and planning technology.

2. Fundamental Principle of Optimal Allocation of Sea Area Utilization based on Genetic Algorithm

The optimal allocation of sea area utilization is to generate the optimal sea area utilization scheme...
from various initial sea area utilization schemes. Based on the fundamental principle of genetic algorithm, sea area utilization scheme corresponds to the concept of individual in genetic algorithm, and the collection of multiple schemes corresponds to the concept of population in genetic algorithm. Initial sea area utilization schemes become the initial population. Chromosomes encode individual characteristics into a string of gene values, and realize the optimization process based on the string operation (Figure 1). Sea area utilization scheme is the spatial distribution of sea area utilization types. From the individual perspective, the key feature is the utilization type at each sea area location. Therefore, individual characteristics of a sea area utilization scheme can be encoded on the basis of a sea area unit. The sea area unit corresponds to the concept of gene in genetic algorithm, and the utilization type of sea area unit corresponds to gene value. After the sea area utilization type is encoded as a numerical value, the sequence of values of all sea area units within the study scope constitutes the chromosomes of the sea area utilization scheme. Genetic algorithm evaluates the fitness of individuals by fitness function. In order to maximize the comprehensive benefits of sea area utilization, the optimal allocation of sea area utilization constructs the fitness objective function to evaluate the fitness of sea area utilization schemes. In the process of genetic evolution, through selection, crossover and mutation operation, the utilization types of each sea area unit are constantly changed to form chromosomes with higher fitness, which are finally decoded into the optimized sea area utilization scheme.

**Figure 1.** The corresponding relationship between sea area utilization scheme and genetic algorithm

### 3. Solution Process of Optimal Allocation of Sea Area Utilization based on Genetic Algorithm

The solution process of sea area utilization optimization scheme starts by initializing the population and then enters into the iterative process of continuous evaluation and evolution. To maximize the comprehensive benefits of sea area utilization, under the operation of selection operator, crossover operator and mutation operator, the process of evolution generates optimization schemes continuously and eliminates schemes with low comprehensive benefits (figure 2).
Figure 2. The solution process of optimal allocation of sea area utilization based on genetic algorithm

The initial population of optimal allocation of sea area utilization takes into account the current situation of sea area utilization and the sea use demand in the planning of different departments. The sea use demand of each department is drawn up from the interests of the department, and there is often a conflict in sea use space when they are summarized together. As sea use demand increases, so does the sea use conflict. The multi-scheme optimization process based on the needs of different departments can implement the sea use demand of departments, and coordinate the sea use conflict with the goal of comprehensive benefits maximization.

Fitness evaluation is the basis of the genetic operator operating. Different from the simple genetic algorithm process, the genetic algorithm of the optimal allocation of sea area utilization needs to take fitness assessment on individual schemes of a population before the selection, crossover and mutation. This can ensure that the sea use scale and comprehensive benefits of each utilization type get calculated timely after the changes of utilization types of each sea area unit.

Selection operators guide the evolutionary process to realize the survival of the fittest in a population. The selection operator adopts the roulette selection method. According to the fitness ratio of individuals in the population, the higher the fitness of individuals, the greater the probability of being selected and individual genes being passed on to the next generation.

The crossover operator crosses the alleles of the parents selected by the selection operator to produce offspring. The good genes from both parents can be passed on to their offspring to produce individuals with higher fitness, thus achieving optimization. The general genetic algorithm adopts random single point or multiple point crossover to pass the parental genes to the offspring, but this method is not suitable for the optimal allocation of sea area utilization, which will lead to the random dispersion of sea area utilization in the offspring scheme. Even if the contiguous constraint is adopted, the efficiency is too low to produce ideal results. In the design of optimal allocation crossover operator of sea area utilization, randomness should be reduced, and the optimal alleles of the parents should be directly passed on to the offspring, that is, the types with higher benefits in the parental scheme should be assigned to each sea area unit. The crossover process itself reduces the randomness, and its result is derived from the optimal utilization combination of parents, which is more efficient. The crossover results may lead to the increase of the utilization scale of some types of descendant schemes, and some oversized utilization units need to be eliminated according to the scale constraints. Based on the comprehensive benefits, these types are sorted by units, then eliminated the end, and set the oversized ones to 0 to indicate undeveloped.
4. Fitness Evaluation Model for Optimal Allocation of Sea Area Utilization

The fitness of optimal allocation of sea area utilization seeks for higher comprehensive benefits of sea area utilization, including economic benefits and ecological value (equation (1)). The comprehensive benefits of sea area utilization is the economic benefit and ecological value after development and utilization minus the ecological value without development and utilization.

\[ F_{(i,t)} = M_{(i,t)} + E_{(i,t)} - V_{(i,t)} \]  

Here, \( F_{(i,t)} \) represents the comprehensive benefits of sea area unit \( i \) under the sea area utilization type \( t \) scenario, \( M_{(i,t)} \) represents the economic benefits of sea area unit, \( V_{(i,t)} \) represents the ecological value when the sea area unit is not developed and utilized (equation (2)), and \( E_{(i,t)} \) represents the ecological value after the development and utilization of sea area unit (equation (6)).

The ecological value of the sea area unit can be calculated according to the location weight of the sea area unit (equation (4)) and the ecosystem service value of the entire ecological area under the sea area utilization \( t \) scenario (equation (2)). The ecosystem service value of the whole ecological area is estimated according to the proportion of economic benefits of sea area utilization in the ecosystem service value (equation (3)).

\[ V_{(i,t)} = w_i \cdot ESV_t \]  
\[ ESV_t = M_t \cdot R \]  
\[ w_i = E_{di}/\sum_{i=1}^{n} E_{di} \]  

Here, \( V_{(i,t)} \) represents the ecological value of sea area unit \( i \) under the sea area utilization type \( t \) scenario without development and utilization. \( w_i \) represents the ecological value weight of sea area unit, \( ESV_t \) represents the ecosystem service value within the scope of the study under the sea area utilization type \( t \) scenario. \( M_t \) represents the economic benefits generated under the scenario \( t \) for all sea area units within the scope of study, and \( R \) represents the proportion of economic benefits of sea area utilization in the value of marine ecosystem services; \( E_{di} \) represents the influence degree of ecological value of sea area unit \( i \), and \( n \) represents the number of sea area units. Assuming that the ecological value of sea use units in the whole study scope decreases from the ecological core area to the periphery in spatial distribution, the influence of the ecological core area on the ecological value of sea area units can be simulated by distance attenuation model (equation (5)).

\[ E_d = (1 + d_i/d_{max})^{-k} \]  

Here, \( E_d \) represents the influence degree of ecological core area on the ecological value of sea area unit; \( d_i \) represents the distance between sea area unit \( i \) and the ecological core area; \( d_{max} \) represents the maximum distance affected by the ecological core area; \( k \) is the distance attenuation coefficient.

The ecological value after development and utilization is calculated according to the ecological loss coefficient of various types of sea utilization:

\[ E_{(i,t)} = (1 - l_t) \cdot V_{(i,t)} \]  

Here, \( E_{(i,t)} \) represents the ecological value after the development and utilization of sea area units, and \( l_t \) is the ecological loss coefficient of sea area utilization type \( t \). It is assumed that the degree of ecological loss caused by the same sea area utilization type of different sea area units is consistent.

5. Constraint Conditions

The constraint conditions of optimal allocation of sea area utilization can limit the development and utilization scale and layout of the optimal scheme, which can avoid the occurrence of "disorderly and unrestrained" optimization results of sea area utilization. Constraint conditions include scale constraints and conditional constraints.

The scale constraints include the constraints of the overall development and utilization area of each sea area utilization type and the individual sea area of each sea area utilization project. The scale
constraints of each utilization type are set according to various sea use demands or sea area management requirements. The maximum area of each type of sea area in each scheme of the initial population can represent the total scale of all types of sea use demand. The constraints on the area of each sea use project can ensure that the sea use project generated by the neighborhood multi-point variation can meet the needs of the sea use project or not violate the regional sea area management requirements.

6. Conclusion
This paper proposes an optimal allocation method of sea area utilization based on the genetic algorithm, describes its fundamental principle and solution process, and designs its fitness evaluation model, genetic operator and constraint conditions. This optimal allocation method of sea area utilization based on the genetic algorithm can produce the optimal scheme with higher comprehensive benefits and lower ecological losses on the basis of initial scheme. Under the guidance of constraint conditions, the sea use conflict among different departments can be solved by optimizing the layout to fully meet the sea use demand of each department. Under the same sea area utilization structure, optimization alternatives with different spatial layout can be generated to provide more options for sea area management requirements.

Compared with the general spatial superposition method based on GIS, the optimal allocation method based on genetic algorithm can obtain the optimal allocation scheme only by setting relevant parameters required for optimization. Without specialized spatial analysis operation technology and complex analysis process, this method can quickly obtain the optimal results that meet the target requirements. Facing with the complicated and changeable sea use demand of different departments, just the initial population scheme needs to be changed. This method can be used as a reference to solve the problems of sea area development, ecological protection and multisector sea use conflict, and provide support for marine zoning and planning technology.

Acknowledgement
This research is financially supported by the National Natural Science Foundation of China (NO. 41601591).

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