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The Tribute Algorithm: Calculation of Evolutionary Goal Optimization Considering Cooperative Regional Communities

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Abstract—This paper proposes an evolutionary algorithm for regional communities based on cooperation mechanisms, taking into account the objective evolutionary goals of different countries and regions in historical processes, combined with the complex diplomatic relations and deep trade cooperation needs. We first represent regional cooperation as a complex system based on multiple intelligences; then, to avoid the algorithm from maturing prematurely and falling into local optimal solutions, we introduce an elite exploration mechanism to promote regional development; secondly, we propose a cooperative discriminative mechanism based on trust relationship; finally, we verify the effectiveness of the algorithm using research cases with fast solution speed and high solution accuracy. The experimental results show that, unlike the law of the jungle of the weak and the strong, the mutually beneficial open strategy is more conducive to the co-evolution of regional individuals. This paper can better represent the complex network of relationships among multi-intelligent nodes and provide a reference for intelligent decision-making of complex systems.

Keywords-multi-intelligence; multi-objective optimization; regional cooperation; co-evolution; foreign trade

1. INTRODUCTION

Intelligent systems used for decision support scenarios already possess excellent performance [1]. The black box model in widely used deep neural networks hinders the understanding of the decision process employed when predicting outcomes. Neural networks use irreversible and nonlinear activation functions from one layer to the next to learn features of nonlinear vector spaces which cannot be interpreted during the retrospective computation of results.

This paper is based on evolutionary algorithms that map the features of social ecology, natural selection, natural evolution, and dissimilation, and have good reusability in solving highly complex nonlinear problems and good interpretability in deriving real-world multi-objective, multi-attribute problems, especially when multiple objectives are interacting and conflicting with each other at the same time. Effective algorithms can achieve both an optimization of the overall objective and a combination of conflicting sub-objectives, i.e., tradeoffs among sub-objectives.

This paper proposes "community evolution" as a co-evolutionary approach based on cooperative relationships. Unlike the inspiration from nature, this paper is inspired by the behavior of human societies that adopt different diplomatic and trade cooperation approaches. In the same geopolitical environment, there are competitive and cooperative relationships between different intelligences, as well as the "extinction" and "regeneration" of intelligences. In order to maintain the superiority of their own development, different approaches to development may lead to different results.

In this paper, we use complex systems to model a state-led cooperative development model to solve a multi-objective dynamic optimization problem under spatial-temporal constraints [2]. First, we represent regional cooperation as a complex system based on multiple intelligences [3]; then, to avoid the algorithm from maturing prematurely and falling into local optimal solutions, we introduce an elite exploration mechanism to promote regional development; second, we propose a cooperative discrimination mechanism based on trust relationship; finally, we verify the effectiveness of the algorithm using research cases with fast and accurate solutions. The experimental results show that, unlike the law of the jungle of the weak and the strong, the mutually beneficial open strategy is more conducive to the co-evolution of regional individuals. This paper can better represent the complex network of relationships between multiple intelligent nodes and provide a reference for intelligent decision making of complex systems.

In the previous study, we proposed an evolutionary algorithm of global positional knowledge system based on image interpretation, whose main elements include 1) knowledge discovery evolutionary process: we constructed a dynamic path planning model of a fleet in exploring unknown global geo-data, and proposed a fleet algorithm for multi-objective dynamic optimization for exploration of misty area [4]; 2) knowledge acquisition and processing evolutionary process: we proposed a nautical chart algorithm that takes into account knowledge data production behavior and feedback strategy of the nautical chart algorithm, simulating the behavior of ships exploring geo-data, the conditions of ports acquiring data and the law of their own development, the social mechanism attracting data exchange and sharing, the establishment of data specification standards and the process of common knowledge evolution [5]; 3) knowledge game evolution process: inspired by the global geographic knowledge game in the post-great seafaring era, we completed the data game situation discriminating and using algorithms to deduce the links of knowledge processing, knowledge protection and

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knowledge competition [6]. In this paper, we continue to investigate the logical process of how regional communities learn, evolve and develop in competition and cooperation under spatiotemporal constraints.

The innovations of this paper are: 1) a new method based on historical text research is proposed. Older historical research methods mainly involve documentary evidence and mutual proof of evidence, treating textual historical materials as research evidence; more recent digital humanities research methods mainly rely on computer algorithms, such as LDA and CNN, to perform word frequency statistics and topic mining on texts. In this paper, we propose a research method based on the logic of human behavior, converting the evidence of human behavior into covariates in mathematical descriptions, and converting non-computable historical texts into computable historical data.2) Extracting algorithmic logic from human behavior, discussing the behavior of humans in economic and social complex networks learning to evolve in games, introducing elite exploration mechanism and cooperative discrimination mechanism, and improving multi-objective optimization algorithms to solve specific problems.

The second part of this paper discusses the theoretical basis of small habitat technology and multi-intelligent body idea; the third part performs behavioral abstraction and discusses the algorithm principle; the fourth part provides a mathematical description of the model; the fifth part analyzes the case of Zheng He's visit to the West China Sea; the sixth part concludes the whole paper and proposes future work directions.

2. THEORETICAL BACKGROUND

2.1. Dynamic Niche Introduction Based on Sharing Mechanism

Niche is a concept from biology that refers to the function of an organization in a particular environment, while organizations with common characteristics are called species. In their evolutionary process, organisms generally always live with their own identical species and reproduce together. In response to the shortcomings of the basic genetic algorithm in terms of cross validity and optimization efficiency, the introduction of Niche techniques in genetic algorithms has been proven to be an effective attempt.

In this paper, we refer to the sharing-based Niche technique, which divides the evolutionary population into several Niche. The sharing-based Niche technique was proposed by Goldberg and Richard in 1987 [7]. The method is called the shared genetic algorithm of adaptation (FSGA). They used the sharing function to determine the degree of sharing of each individual in the population. The sharing degree is a function of the closeness of relationship (genotypic similarity or phenotypic similarity) between two individuals. When individuals are more closely related, the sharing function value is larger, and vice versa the sharing function value is smaller.

Dynamic Niche Sharing Algorithm [8] proposed by Miller and Shaw, needs to be implemented to give the radius of Niche in the solution space σ and the number of Niche k . The dynamic habitatlet algorithm takes into account the peak radius information and the number of peaks information and has a strong search capability. The main steps of the algorithm are as follows: (1) Ranking of individuals in descending order according to fitness values; (2) The first individual is designated as being in the first Niche; (3) The following steps are performed sequentially starting from the second individual to the last individual: If the distance between the current individual and the center of all one tripod Niche is greater than σ , and the number of designated Niche is less than k , then a new Niche is formed and the individual becomes the center of the new Niche; If the distance between the center of the current second question and all Niche is greater than σ , and the number of designated Niche is not less than k , then the individual becomes independent; (4) For those individuals belonging to a particular Niche, the number of Niche is the number of individuals in the Niche to which it belongs. For those individuals that are independent, the following formula was used to calculate the number of Niche m :

$$m_i = \sum_{j=1}^{n} sh(d_{ij}) \tag{1}$$

Among them, $i = 1, 2, \ldots, n$. n is the population size. The larger the number of Niche of an individual, the more other individuals surround that individual. $sh(d_{ij})$ is the value of the sharing function, which is calculated as follow:

$$sh(d_{ij}) = \begin{cases} 1 - \left(\frac{d_{ij}}{\sigma}\right)^{\alpha}, & d_{ij} < \sigma \\ 0, & \text{else} \end{cases} \tag{2}$$

(5) Use equation (2) to calculate the fitness value after individual sharing $sh(d_{ij})$; (6) Selection, hybridization and mutation with the shared fitness values are used to generate a new generation of populations.

2.2. Multi-Intelligent Body Evolutionary Ideas

Multi-intelligence social evolutionary algorithm was proposed in 2009 by Pan et al [9]. The algorithm can better solve multi-objective optimization problems and effectively improve the convergence speed of the algorithm. In this paper, we mainly refer to its multi-intelligent evolutionary idea and "relational network" model.

An intelligent agent is a physical or abstract entity that acts and reacts to itself and its environment. agents can be connected to each other to form a "network of acquaintances", and the relationship between acquaintances is measured by "trustworthiness". The trustworthiness of agent a and agent b at time t is $trust(a, b, t)$. Specify $trust(a, b, t) \in$

$[-1, 1]$. The greater the likelihood of successful cooperation between acquaintances with greater trustworthiness.

3. BEHAVIORAL ABSTRACTION

The tribute trade was the main pattern of overseas trade in China in the early Ming Dynasty (1368-1566 AD). At that time, the people along the southeastern coast of China were eager to trade overseas due to the development of the commodity and monetary economy. At the same time, handicraft production in Southeast Asian countries as well as Japan, Ryukyu, and Korea was still relatively backward, and the demand for Chinese industrial products was relatively strong. In order to prevent the forces at home and abroad from threatening their own rule, the Ming rulers had strict control and a monopoly on overseas trade. They implemented an official overseas trade system based on " tribute trade".

The essence of the tribute trade is to buy "tribute" from the tributary countries in the form of " bounties". It is a kind of long-distance trafficking trade between countries, which is a kind of unequal exchange with the feature of buying at a low price and selling at a high price, so that the tributary countries can transport the overseas exotic goods to China as luxury goods, and can transport the Chinese general goods back to their own countries and turn them into luxury goods, so both the Ming government and the overseas tributary countries can get high profits from it [10]. Therefore, the formation of the trade network was the inevitable result of the common development needs of regional countries.

It is important to note that tribute trade was predicated on national diplomatic relations. During the Ming Dynasty of China, Emperor Zhu Di (who reigned from 1402 AD to 1424 AD), at the beginning of his reign, the only countries that established tribute trade relations with China were Ryukyu, Chenla, and Siam, and regional trade was in depression. In order to establish a regional network of tribute trade cooperation, rebuild the trust mechanism of regional cooperation, expand the political influence of the Ming dynasty, and strive for a peaceful and stable international environment, he ordered his official Zheng He to make seven voyages to the Atlantic Ocean based on his advanced shipbuilding industry and navigation technology, which were used to establish and maintain regional diplomatic relations and trade networks.

The beginning and end of Zheng He's voyages to the West marked the rise and fall of the tribute trade. Zheng He made seven voyages to the Western Ocean, visiting more than 30 countries and regions in Asia and Africa, based on his advanced shipbuilding industry and navigation technology [11] which extended the influence of ancient China to overseas places, formed friendly relations with various countries and peoples, and promoted the economic and cultural development of several countries and regions.

3.1. Ocean Exploration Behavior

Zheng He's team made a total of seven voyages, and the countries and regions they passed through along the way are briefly marked as follows [12] :

Table 1. Brief description of the countries and regions of Zheng He's seven voyages

Order	AD Year	Route Countries and Regions
1	1405-1407	Champa, Thailand, Palembang , Melaka, Samalanga, Sri Lanka I , Calicut
2	1408-1409	Champa, Thailand, Boni, Pulau Java, Melaka, Sri Lanka I, Jiayile, Cochin, Calicut
3	1409-1411	Champa, Thailand, Pulau Java, Melaka, Alu, Samalanga, Sri Lanka I, Cape Comorin, Quilon, Cochin, Liushan, Calicut, Qeshm
4	1413-1415	Champa, Pulau Java, Kota Baharu, Pengheng, Melaka, Sri Lanka I, Shaliwanni, Cochin, Calicut, Muqdisho, Qeshm, Kilwa Kisiwani
5	1417-1419	Champa, Boni, Pulau Java, Pengheng, Melaka, Sri Lanka I, Shaliwanni, Cochin, Calicut, Muqdisho, Baraawe, Aden, Ra's Isa, Qeshm
6	1421-1422	Champa, Thailand, Melaka, Bengal, Sri Lanka I, Cochin, Liushan, Calicut, Zufar, Aden, Ra's Isa, Muqdisho, Baraawe, Qeshm
7	1431-1433	Champa, Thailand, Pulau Java, Melaka, Samalanga, Bengal, Sri Lanka I, Quilon, Jiayile, Cochin, Liushan, Cochin, Qeshm, Zufar, Aden, Ra's Isa, Tianfang, Muqdisho, Baraawe, Zhubu

From the historical records, it is clear that Zheng He, through his many voyages, had an increasingly wide range of contacts and visited an increasing number of regions, and that the route of each voyage was built on the basis of the previous voyage, in line with the characteristics of genetic evolution.

3.2. Regional Symbiosis Environment

Placing the locations visited by Zheng He in the GIS, it is obvious that the port locations visited by Zheng He are distributed in different geographical regions, and the distribution of ports in the same region appears to have aggregation characteristics, sharing similar climatic environments and having similar products and trade needs, such as the coastal areas of southeast China, Southeast Asia, South Asia subcontinent, and the coastal areas of East Africa, in line with the small habitat (Niche) technique The typical characteristics of Niche technology.

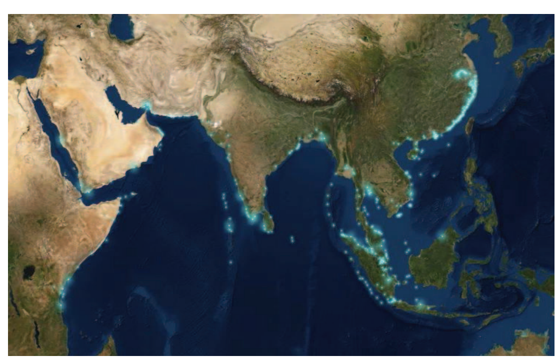

Figure 1. Places visited by Zheng He's fleet

There were both cooperative and competitive relationships between locations in the same region; there was both trade cooperation and war conflict. According to historical records, at the beginning of the 15th century, the period of Zheng He's voyages, there were widespread aggression and bullying of neighboring weak countries by powerful countries in coastal countries of Southeast and South Asia. Zheng He's fleet, backed by the great strength of ancient China, carried out the peaceful diplomatic policy of the early Ming Dynasty overseas. Their arrival caused many weak countries to see opportunities for development and send envoys to the Ming Dynasty to establish diplomatic relations and seek Chinese asylum. The Ming Empire quelled pirates and maneuvered among friendly states, improving regional relations and maintaining regional stability. Through Zheng He's influence, the Ming Empire gained unprecedented prestige among overseas countries and greatly improved its diplomatic level.

3.3. Culture and Trade Development

Zheng He's team had a staff of about 27,500, and each return voyage was severely "attritional". This is because with many voyages, the accompanying personnel would stay in various countries and regions. These residents were generally highly cultured and spread Chinese culture and taught Chinese technology to the local people. Through cultural exchanges, Chinese culture gradually integrated into the local culture and promoted the local cultural level.

In addition, since the opening of the sea route, coastal countries have engaged in government-led maritime trade with China. Chinese silk, porcelain and other products were very popular among overseas countries. At the same time, the coastal countries' products were "purchased at high prices" by China, and some countries even traded with China as a whole, gaining huge economic profits and significantly improving their living standards.

Zheng He demonstrated the art of diplomacy with regional cooperation at its core, promoting regional common development and achieving multilateral win-win results by "propagating the culture of China to all places along the route" and "softening the people". positive results of multilateral win-win situation [13].

3.4. Binding Conditions

With the above background, we find the following typical behaviors extracted from the cooperation-based regional co-development.

- Elite Exploration Behavior: Global elites can search for potential cooperating individuals across Niche. The global elite will explore in the direction of higher developmental level, and if no cooperative individuals are found or the individuals found are of poor developmental level, they are free to explore randomly.
- Relationship Building Behavior: Two individuals will judge whether to engage in trade cooperation between them based on the trust level. If the trade cooperation is successful, the trust level increases; if the trade cooperation fails, the trust level decreases. Initial cooperation is determined by the predominance between individuals.
- Regional Competitive Behavior: Different objects in each region compete with each other. Through competition, the less developed individuals in the population can be eliminated and replaced by individuals with better development level, improving the overall development level of the region.
- Cooperative Developmental Behavior: By cooperating with individuals at a higher level of development, individuals are able to improve their own level of development and accomplish cooperative developmental behavior.
- Autonomous Developmental Behavior: Individuals improve their own development level autonomously through self-reliance.
- Zoning Behavior: Different individuals may be divided into the same region because of the similarity of their living environment, and share the fruits of development with other individuals in the region.

4. Mathematical description of the algorithm

4.1. Building Intelligent Bodies

Intelligent body$a$ denotes a candidate solution of the function to be optimized, and its own development level $performance$ is its fitness value, and its evolutionary goal is to increase its self-development level as much as possible. Order $a = (name, address, body, performance, neighbour, contactList)$, where $name$ denotes the intelligence a ; $address$ denotes the address/label of the intelligence ; $body$ denotes the content of the intelligence a , represented by a code ; $performance$ denotes the development level of the intelligence a, determined by the components in ; $neighbour = (N_1, N_2, \dots, N_n)$, and N_n is other individuals in the same region as the intelligence a, the $neighbour$ is called the neighborhood of the individual. $contactList$ indicates the list of communication with the intelligence a, $contactList = (C_1, C_2, \dots, C_n)$, and C_n is other individuals who have had contact with the intelligence a , which may be individuals in the same region or individuals in different regions.

4.2. Divide the Area

According to the Niche technique, different intelligences are divided into zones based on the distance d_{ij} from each other. The distance can be chosen according to the actual d_{ij} calculation method. Since the resources in the same region are limited and no individual can develop indefinitely, the sharing function value is calculated using equations (1) and (2). The sharing degree of an individual is equal to the sum of the sharing function values between that individual and each other individual in the group. Next, the adaptation value of an individual after sharing is calculated f_i' , where m is the number of divided regions:

$$f_i' = {}^{f_i}/_{m_i} \quad (3)$$

For example, in the case problem, the different ports are located in geographic environments that are natural regional Niche. Based on the historical information and the real environment, the area radius can be given in advance σ and the number of areas k . Therefore, when calculating the distance d_{ij} , the Euclidean distance can be calculated directly from the latitude and longitude of the visited individual:

$$d = \sqrt{\sum_{n}^{i=1} (x_i - y_i)^2} \quad (4)$$

4.3. Elite Exploration

The globally optimal solution or solutions are made elite. The introduction of the elite exploration mechanism, which allows elites to visit other Niche, is to avoid the algorithm from maturing prematurely and falling into local optimal solutions, and can improve the global search effectiveness of the algorithm.

The elite i will always explore in the direction of a higher level of development, and its choice to visit a certain body according to the roulette style j. The probability of $P_{ij}(t)$ can be expressed as:

$$P_{ij}(t) = \begin{cases} \dfrac{\tau_{ij}^{\alpha}(t)\eta_{ij}^{\beta}(t)\gamma_{ij}^{\theta}(t)}{\sum_{s\epsilon \mathrm{allowed}_k} \tau_{ij}^{\alpha}(t)\eta_{ij}^{\beta}(t)\gamma_{ij}^{\theta}(t)}, & s\epsilon allowed_k \\ 0, & else \end{cases} \quad (5)$$

Where $\tau_{ij}^{\alpha}(t)$ denotes the individual j whose attractiveness is proportional to the level of development$performance$ is proportional to the level of development, and α denotes the attractiveness weight. $\eta_{ij}^{\beta}(t)$ denotes the number of current iterations$t$ for the individual at the time of j of the known data volume, and β denotes the known data volume weight. $\gamma_{ij}^{\theta}(t)$ denotes the distance factor, and θ denotes the weight of the distance factor:

$$\gamma_{ij}^{\theta}(t) = \frac{1}{d_{ij}} \quad (6)$$

The individual j who are visited will be added to the address book $contactList$ by the elite i , and individual j will likewise add the elite i to their address book $contactList$.

4.4. Relationship Building

Whether it is competition or cooperation within the region or a visit from outside the region, whenever there is contact between two individuals, it is necessary to determine whether the two bodies cooperate or not and calculate the trustworthiness between the two individuals.

- Trustworthiness: Trustworthiness $trust$ is used to measure the trustworthiness of individuals a and individuals b in time t of the relationship, denoted as $trust(a,\ b,\ t)$ that specifies $trust(a,\ b,\ t) \in [-1, 1]$. The initial time $t = 0$. At the time, the individual a and individual$b$ the trustworthiness between is 0 and $trust(a,\ b,\ 0) = 0$. The likelihood of successful cooperation between acquaintances with larger trustworthiness values is also higher. Meanwhile, trustworthiness $trust$, address book $contactList$ and neighborhood $neighbour$ relationships are consistent with the following conditions: (1) Make Smart Body $a.neighbour = (an_1, an_2, \dots, an_m)$; the $a.contactList = (ac_1, ac_2, \dots, ac_n)$; (2) Make Smart Body $b.neighbour = \left(bn_1, bn_2, \dots, an_p\right)$, the $b.contactList = (bc_1, bc_2, \dots, bc_n)$; (3) a with b after contact (whether or not both are in the same area), the a with b will be added to each other's address book $contactList$ and $a.contactList = (ac_1, ac_2, \dots, ac_n, b)$, and $b.contactList = (bc_1, bc_2, \dots, bc_n, a)$. Initially, the $trust(a, b) = 0$; (4) If $trust(a, b) = 1$, then both can share $contactList$; if there is both $bc_n \in b.contactList$ and $trust(b, bc_n) = 1$, then $trust(a, bc_n) = 1$; but if there is both $bc_n \in b.contactList$ and $trust(b, bc_n) = -1$, then $trust(a, bc_n) = -1$.
- Collaborative Discernment: For the discernment of whether to initiate cooperation, in the cross-regional case, cooperation must occur between the regionally optimal individual and the global elite solution, and the trustworthiness with the regionally optimal individual is greater than the threshold T of individuals is likely to cooperate with the global elite solution; within regions, individuals a actively initiates a judgment on whether an individual b The probability of discriminating whether to cooperate or not P_{co} can be expressed as:

$$P_{co}(a, b) = trust(a, b, t) \times 0.5 + \left(1 - \frac{performance_b}{performance_a}\right) \quad (7)$$

The probability of cooperation is influenced by a combination of trust and risk factors. This is because it is necessary to conform to the risk possibility of cooperation between the weak and the strong in the real world. If the risk of cooperation between the strong and the weak is low, the strong are more likely to offer to cooperate with the weak; while the weak consider cooperating with the strong to improve themselves, they also have to consider the potential dangers of cooperating with the strong.

Whether or not to cooperate is determined by the predominance between individuals[14] If $a \succ b$, then the cooperation is considered successful, otherwise the cooperation fails. If the two cooperate successfully and the trustworthiness of both parties increases, then:

$$trust(a,b) = trust(a,b) + 0.1 \tag{8}$$

If the cooperation between the two fails and the trustworthiness of both parties decreases, then:

$$trust(a,b) = trust(a,b) - 0.2 \tag{9}$$

4.5. Cooperation Development

For two individuals who successfully cooperate, performing a mutually beneficial act [14]. Their $body$ and $performance$ both change. Assuming that $a.body = (a_1, a_2, \dots, a_i)$ that $b.body = (b_1, b_2, \dots, b_i)$, if $a \succ b$, then there is:

$$a_{inew} = a_i + rand[0,1] \times (a_i - M_v \cdot B_1) \tag{10}$$

$$b_{inew} = b_i + rand[0,1] \times (b_i - M_v \cdot B_2) \tag{11}$$

$$M_v = \frac{a_i + b_i}{2} \tag{12}$$

Among them, the a_i and $b_i$are the solution components before the execution of the reciprocal operation; a_{inew} and b_{inew} are the solution components after the execution of the reciprocal operation; B_1 and B_2 are the random numbers in respectively $\{1, 2\}$, denoting the benefit factors in the reciprocal relationship; M_v is the mutual benefit vector of the relationship. If the new solution dominates the original solution, it replaces the original solution to become the new $a.body$; otherwise, it remains $a.body$ unchanged.

4.6. Autonomous Development

For the optimal individual in each region, perform autonomous development operations to enhance their competitiveness. Assume that the region optimal solution is a , such that $a.body = (a_1, a_2, \dots, a_i)$, then the new solution $b.body = (b_1, b_2, \dots, b_i)$ has:

$$b_i = \begin{cases} a_i, & U(0,1) < 1/i \\ a_i + G(0, 1/t), & \text{else} \end{cases} \tag{13}$$

$G(0, 1/t)$ is the Gaussian distributed random number, and t is the evolutionary algebra. If the new solution dominates the original solution, it replaces the original solution to become the new$a.body$; otherwise, keep$a.body$ unchanged.

4.7. Regional Competition

Each individual within the region needs to compete with the $performance$, the highest individual in the region. The competition eliminates the inferior individuals and improves the overall level of the region, and the failed individuals will be replaced by new individuals. Let the individuals in the region $a.body = (a_1, a_2, \dots, a_i)$, compete with the best individual in the region $b.body = (b_1, b_2, \dots, b_i)$, denoted as:

$$a_i = a_i + rand[-1,1] \times |b_i - a_i| \tag{14}$$

$$b_i = b_i + rand[-1,1] \times |b_i - a_i| \tag{15}$$

If the new solution dominates the original solution, it replaces the original solution as the new $body$; otherwise, it remains $body$ unchanged. Compare the new $a.performance$ and $b.performance$, if the new a performs better than the new b, then a replaces b to become the new regional optimal individual; if the new a still performs worse than the new b , then the new b remains the regionally optimal individual and a new individual replaces a . With the substitution probability $poccupy$ to decide in which way to perform the substitution operation, if $rand \leq poccupy$, then generate $child.body$ substitution $a.body$; otherwise, an intelligent body is randomly generated to replace a , where $child.body = (ch_1, ch_2, \dots, ch_i)$.

$$ch_i = a_i + rand[-1,1] \times |b_i - a_i| \tag{16}$$

5. Case Studies

In this paper, we still use Zheng He's voyage to the West as t he study case. To test the effectiveness of the algorithm, we manually extracted ancient place names, present-day place n ames and location latitudes and longitudes of ports in the co untries and regions visited by Zheng He from the New Atlas of Zheng He's Voyages published by the Institute of Marine Surveying and Mapping of the Chinese Navy, and obtained a total of 484 data items [8] (See https://github.com/Science-Art-Demonstration-Research-Lab/Project2301-Zheng-He-s-Navigation-Chart.git). Based on Zheng He's voyage mission (to promote common regional development and maximize t he diplomatic sphere of influence of the Ming Empire), we s et the objective function $F(X)$ was set as:

$$F(X) = max f(a) \tag{17}$$

$$f(a) = \sum_{i \in a.contactList} w_i \times performance(i) \times trust(a,i) \tag{18}$$

Suppose the storage set population is P , the size is M , the area radius is σ , the number of regions is k , and the probability of occupation is $poccupy$. The "Tournament" rule is used to construct the stored population of Pareto solutions. The flowchart with the code is as Figure 1.

According to the above mathematical description and process, using Python 3.11 to program, we input the location coordinates and divide them into 13 regions according to the geographical situation, each region selects the regional local best point, and among all locations selects the global best point, and iterate 100 times to obtain Figure 3. In Figure 3, the horizontal axis indicates the latitude, the vertical axis indicates the longitude, the red points represent the distribution of the global best point, the blue points are the regional best point distribution, and the gray points are all point distributions. The left panel in Figure 3 shows the global optimal solution and the regional optimal solution after 200 iterations, and the right panel shows the distribution of the regional optimal solution for each iteration.

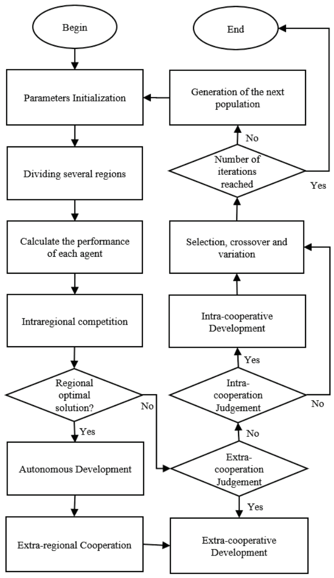

Figure 2. Algorithm flow chart

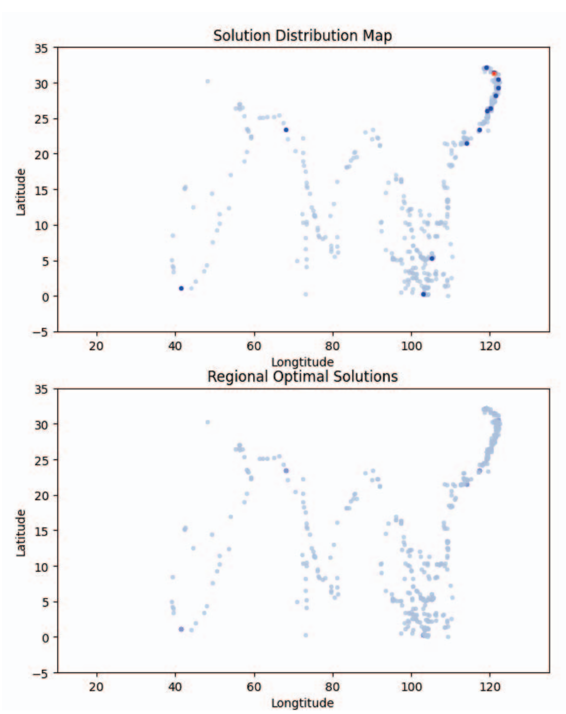

Figure 3. Experimental iteration results

Table 2. Distribution of solutions after 200 iterations

Type	Name	Longitude	Latitude
Global optimal solution	Tai Cang (China)	121.06	31.27
Regional optimal solution	Zhanlongmiao	119.03	32.16
Regional optimal solution	Baimaokou	121.04	31.43
Regional optimal solution	Dajinsha	122.10	30.49
Regional optimal solution	Jiushan	122.11	29.26
Regional optimal solution	Zhigu	121.43	28.23
Regional optimal solution	Dongsang Xisang	120.21	26.42
Regional optimal solution	Fuzhou	119.18	26.05
Regional optimal solution	Dongshan	117.28	23.40
Regional optimal solution	Beijiamdao	114.02	21.53
Regional optimal solution	Teluk Betung	105.16	5.28
Regional optimal solution	Sungai Kampar	103.07	0.28
Regional optimal solution	Pulau Sakijang	103.51	1.13
Regional optimal solution	Bhitiaro Creek	68.02	23.39

Experiments show that the algorithmic model in this paper can effectively simulate the nonlinear relationship between regional trade cooperation, spatial exploration and diplomatic games. We found that: (1) Regional co-evolution dominated by global elites and regional elites is more efficient, and global elites can indirectly act on less adaptive individuals through regional elites, which improves the optimization efficiency; (2) The introduction of the small habitat technique ensures the distributivity of the evolving population, while individuals in different regions share the resources in the region, which inhibits the unlimited growth of individuals; (3) Intra-regional competition and cooperation helps to maintain the diversity and variability of the population and reduce the risk of premature maturation of the algorithm.

6. Conclusion

In this paper, we propose an evolutionary algorithm for cooperation-based regional communities, taking into account the complex network relationships among foreign trade, diplomatic relations and regional development, with the goal of improving the efficiency and equity of multiparty cooperation. To ensure the efficiency of regional competition, we introduce an "elite search" strategy; to ensure the fairness of regional cooperation, we propose "cooperation discrimination" and "trust metric" mechanisms. Our algorithm provides decision support for complex systems of economic and trade relations.

It is worth noting that realistic multi-objective optimization problems are subject to both time and space constraints, and the decision space keeps changing with the passage of time and environment. Therefore, it is an important direction of our future work to simulate the operation of complex systems in more complex time-lapse and geographical environments to improve the modeling and solution accuracy.

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