Multi-Agent Genetic Algorithm Based on Uniform Design

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Abstract

In this paper, the uniform design and multi-agent genetic algorithm are combined to propose a new uniform crossover operator and population initialization method. The core of the uniform experimental design is the construction of a uniform table, using a well-optimized lattice method to construct a uniform table.

Keywords

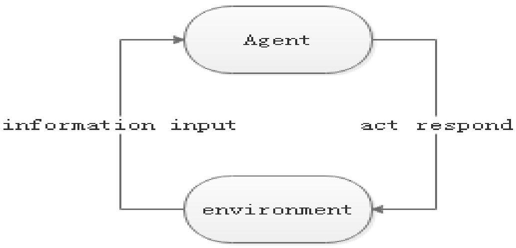
Multi-agent, uniform design, crossover operator.

1. Research Background

Multi-agent system

At first, the concept of Agent was proposed by American Minsky. The agent is a kind of intelligent entity with adaptive ability and self-learning ability. The purpose of proposal of the agent is to identify and simulate various human behaviors. All the behaviors of the agent are composed of the interaction between the agent and the environment, and interaction among the agents.

The definition of agent [1] is an entity; this entity can be physical or can be abstracted by people. It can sense its surroundings for internal and can respond to external stimulus. The figure below is the interaction diagram between the agent and the environment.



The agent has the following characteristics:

Autonomy: the agent is an independent computing entity; there are some states within it. It can control its behavior autonomously in accordance with the state, and operates and performs actions autonomously when no one or other program intervenes.

Sensitivity: the agent can sense its environment, and make timely response to environmental changes.

Initiative: the agent has active behaviors under the guidance of the certain goal, and can choose the appropriate time to take appropriate action. The agent has ability to reason and predict in a rational way based on current knowledge and experience.

Sociality: through some communication language to communicate and cooperate with other each other in the external environment of can

Agent has the ability to interact and cooperate with external environment through some communication language, it can work together and resolve conflicts in many environments, so that it can perform and accomplish some complex tasks that are mutually beneficial and cannot be solved independently.

2. Genetic algorithm

The genetic algorithm [2~3] is proposed based on the genetic crossover, selection and mutation in the natural genetic process. A set of evolutionary solution is reserved in the genetic operations for each time, and choose a certain number of individuals from population in accordance with certain standards, and then carry out selection, crossover and mutation operation for individual according to certain probability. And the population is initialized according to certain rules, so that a new generation of population is produced, and the process above is repeated until the termination condition is reached.

Simple Genetic Algorithms (SGA) can be described as follows:

$$SGA =(C, E, P, M, \Phi, \Gamma, \Psi, T)$$

In the above formula: the coding method of individual is expressed with C; the fitness evaluation function of the individual is expressed with E; initialize population.

The size is expressed with P; the evolutionary population size is expressed with M; selection operator is expressed with Φ; crossover operator is expressed in Γ; mutation operator is expressed with Ψ; the termination conditions of the algorithm are expressed with T.

Next, the basic process of genetic algorithm is summarized as follows, and then expresses it with the algorithm flow chart.

(1) Randomly generate initial population p_0.

(2) Calculate the target value of each individual in the initial population, and then convert it to corresponding fitness function in accordance with certain principle.

Numerical value f(x)

(3) According to the function value of the individual fitness, a selection strategy is adopted, and selects an individual currently conforming to certain conditions as the parent.

(4) The parent individual is paired, and then the parent is intersected by a certain probability according to crossover operator.

(5) The individual produced by step (4) is mutated with a certain probability through the mutation operator.

(6) Judge whether meet the termination condition t or not. If met, the genetic operation ends, and the output result; If not met, go to step (2).

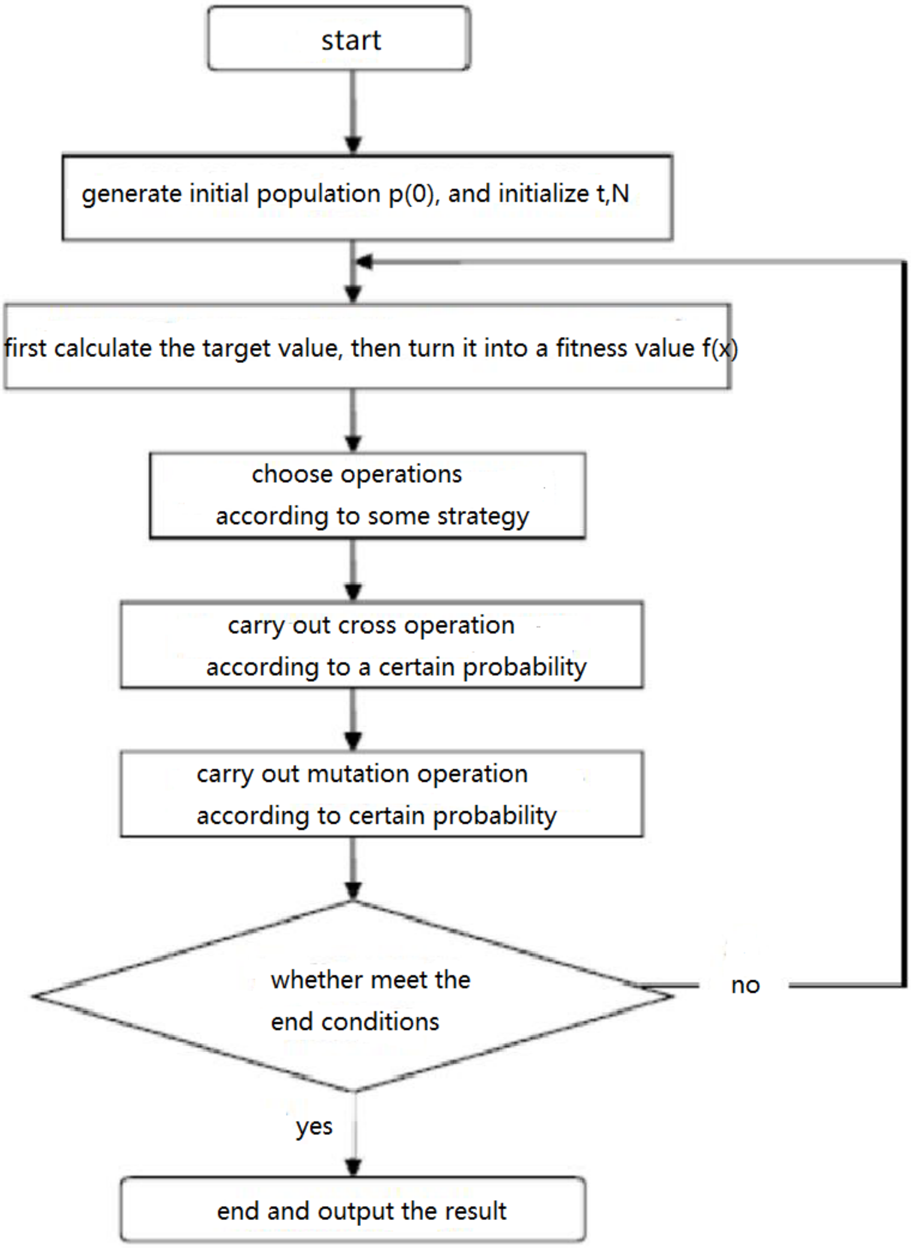
The genetic algorithm flow chart is as follows.

3. Uniform Experimental Design

The uniform experimental design [4-5] was founded by two mathematicians, Fang Kaitai and Wang Yuan in 1978. The uniform design is an experimental design method proposed from the uniformity perspective on the basis that the experimental points are distributed evenly throughout the experimental range.

The principle of experimental design method is to select representative points in the experimental range, and uniform design is the principle. It selects some representative experimental points from the experimental points obtained from the comprehensive experiment, these experimental points are evenly distributed in the experimental range, but can reflect the main characteristics of the experiment. For example, orthogonal experimental design [6] selects representative points based on orthogonality, and it has a characteristic that is symmetrical comparability in choosing the representative points.

The uniform experimental design is to distribute the experimental points uniformly in the experimental range, so that each experimental point can be fully representative. Uniform design varies greatly in the condition range, which can greatly reduce the number of experiment under the condition that a large number of experimental times are needed. It only needs to have the same times of factor number, and achieve the experimental results which orthogonal design can be achieved.



The mathematical principle of uniform experimental design is uniform distribution theory. This method draws on the experience of the research results in the field of "number theory in approximate analysis", and combines the number theory with the multivariate statistics, which belongs to the Quasi-Monte Carlo method. Uniform design only considers the are uniform distribution of experimental points in the experimental range, the starting point of selecting experimental representative point is "uniform distribution", without considering the " symmetrical comparability ", it can ensure that experimental points with statistical characteristics of uniform distribution, can make each level of each factor do one experiment and only one, experimental point of any two factors in the lattice point of plane, each row and column has only one experimental points. It emphatically considers uniform distribution of experimental points within the experimental range to, get the most information by using the least experiment, t Therefore, the number of experiment times is obviously less than that of the orthogonal design, and make the uniform design especially suitable for many factors and multilevel experiments and the system model is completely unknown.

4. Algorithm Design

4.1 Uniform Table Design

The grid method is used to construct a uniform table. The j column of the uniform design table is generated by $u_{ij} = ih_j[mod\, n]$. [mod n] represents the congruence operation. If ih_jexceeds n, then it subtract an appropriate multiple of n, so that the difference is in [1, n].

ih_j can be calculated by the following formula:

$$\begin{cases} u_{\mathrm{ij}} = h_j \\ u_{i+1,j} = u_{ij} + h_j \quad u_{ij} + h_j \le n \\ u_{i+1,j} = u_{ij} + h_j - n \quad u_{ij} + h_j > n \end{cases}$$

4.2 Uniform Population Initialization.

Because all the variable elements in the algorithm, which is any one real number in the continuous domain. But the uniform design must be in the discrete case, so the design of the experimental point should be used in the discrete case. In order to apply uniform design in continuous value condition, first, the continuous domain must be quantized first. If the population size is K, the continuous domain is quantized as a level K. In this way, the feasible solution space of the problems contains n power points of K, according to uniform design table, K points are selected from K^n point, this point constitutes initial population. In order to get a better initial population, the search space can be divided first [l,u]. The specific steps of uniform population initialization are as follows:

Step 1: divide [l, u] into S subspace.

$$\begin{cases} \mathrm{l(k)} = \mathrm{l} + (\mathrm{k}-1)(\frac{u_j - l_j}{S}) \\ u(k) = u - (S-K)(\frac{u_j - l_j}{S})E_j \end{cases} E_j$$

Step 2: according to the calculation method of uniform design table, K feasible solutions are generated.

Step 3: the KxS feasible solution generated from S subspace, choose the K individual with the best quality to form the initial population.

4.3 Neighborhood competition operator

The agent in the field competes with each other, and if the energy of one agent is less than the energy of maximum agent, it will be eliminated. If the energy of the agent $A_{i,\mathrm{j}}$ meets the following relation, then the agent wins. Otherwise, the intelligent body fails to compete and is eliminated.

$$\mathrm{Energy}(A_{i,\mathrm{j}}) > \mathrm{Energy}(Max_{i,\mathrm{j}})$$

If the energy of $A_{i,\mathrm{j}}$ is greater than the maximum, it will survive and participate in the next evolution or be eliminated. This position will produce a new agent $New_{i,\mathrm{j}}$。 by $Max_{i,\mathrm{j}}$ in accordance with certain strategy (I,j).

The strategy is as follows, the probability of U(0,1) is used each time, $Max_{i,\mathrm{j}}$ produce the new agent $New_{i,\mathrm{j}} = (\mathrm{e}_1, \cdots, e_n)$ according to the following methods:, as shown below.

$$e_i = \begin{cases} m_i \\ m_i + U(-1,1) \times (m_i - a_i) \end{cases}$$

If the value of U(0,1) is greater than 0.5, select strategy 1, otherwise, select strategy 2.

5. Uniform Crossover Operator

The two parent agents Agent1 and Agent2, $[l_p, u_p]$ are subspaces of the children.

The children generation space is quantized to M level, and M is also the number of feasible solutions for the parent generation. According to the production rules of uniform design table, the number of experiments must not be less than the number of factors. Because the number of variable elements of complex problems is usually more, in order to reduce the calculation quantity, the variable elements are divided into G group randomly, and produce an integer N. Usually, G is small. Thus, this integer divides the variable elements into the following group, N.

6. Mutation Operator

Each agent will be varied in the following way: create a probability between the U(0, 1), and then it is used to compare with mutation probability, the new agent $New_{i,i} = (e_1, \cdots, e_n)$ is produced by comparing the results.

$$e_i = \begin{cases} k_l & U(0,1) > P_m \\ k_l + \gamma \times U(0,1) & else \end{cases}$$

Among them, $\gamma \in [0.2,0.3]$

7. Self-learning Operator

In order to further improve energy, it is necessary to use existing knowledge for self-learning. Here we only give the best agent of the modern population. Self-learning opportunities, through local search methods, and carry out self-learning.

8. Conclusion

This paper proposes a new method of designing uniform table, and applies this method to multi-agent genetic algorithm. New uniform crossover operator and mutation operator are proposed in the multi-agent genetic algorithm.

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