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System Parameter Optimization based on Genetic Algorithm

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ABSTRACT

Genetic algorithm is an algorithm based on the coding strategy and propagation principle of biological evolution. It constructs a universal framework suitable for solving complex system optimization problems. The algorithm is unique in its independence for specific application areas and strong adaptability to different problem types, making it able to effectively deal with extremely challenging problems. Genetic algorithm is especially suitable for global optimization problems and has the ability to jump out of the local optimal solution and search for the global optimal solution. In addition, it supports the definition of complex fitness evaluation functions and can impose constraints on the search space of variables.

KEYWORDS

Genetic Algorithm; Genetic Iteration; Parameter Optimization.

1. INTRODUCTION

In the field of genetic algorithms, a pattern can be defined as a template that describes a subset of a population whose bits have the same characteristics at a particular location. The core operation of genetic algorithm involves the processing of these patterns, including passing excellent patterns to the next generation through selection operators, implementing combinations of patterns through crossover operators, and introducing new pattern variations through mutation operators. These operations make the suboptimal model gradually eliminated, while the dominant model is inherited and evolved, thus leading to the optimal solution of the problem[1].

The pattern theorem in genetic algorithms, also known as the fundamental theorem, describes that under the influence of selection, crossover, and mutation operators, those patterns with short definition distances, low order, and average fitness exceeding the population average will grow exponentially in the offspring. The defined distance here refers to the interval between the first and last defined point in the pattern, denoted D(H).

Pattern theorem provides the basis of genetic algorithm theory, reveals the theoretical support of genetic algorithm, explains the law of pattern increase, and provides the direction for the practical application of genetic algorithm. According to the pattern theorem, with the iterative evolution of genetic algorithm, the dominant patterns with short defined distance, few bits and high fitness will gradually accumulate, so that the performance of the final generated bit string will continue to improve and tend to the global optimal solution[2].

2. GENETIC ALGORITHM APPLICATION FIELD

Due to the excellent characteristics of genetic algorithm, its application field is very wide, the main application fields are: function optimization, combinatorial optimization, job scheduling, intelligent control, robotics and so on[3].

(1)Function optimization is the classical application field of genetic algorithm, and the performance of genetic algorithm can be evaluated. To evaluate the performance of genetic algorithm by using geometric functions (continuous function, discrete function, deterministic function, random function, etc.) can better reflect the essential effect of the algorithm.

(2)In combinatorial optimization, the size of combinatorial optimization problems increases, the search space of combinatorial optimization problems expands, and people tend to use genetic algorithms to find satisfactory solutions.

(3)In the field of resource allocation, especially job scheduling, we are mainly faced with the allocation of equipment resources. The core of the problem is to find an optimal arrangement of the workpiece to the equipment so that the job can be completed efficiently. Each job contains several tasks, and each task needs to be performed by a specified device.

(4)The scheduling scheme involves assigning all tasks to devices in a specific order of priority. Because of the many constraints, job scheduling is a difficult combinatorial optimization problem. At present, genetic algorithm has been proved to be an effective method to solve this kind of complex scheduling problem.

(5)The application of genetic algorithms is particularly appropriate for robotics, an artificial system that is complex and difficult to model accurately. The reason is that the genetic algorithm itself is derived from the research of artificial adaptive systems, so robotics naturally becomes a key application field of genetic algorithms.

Genetic algorithm is a kind of algorithm based on the coding strategy and propagation principle of biological evolution. It constructs a universal framework suitable for solving complex system optimization problems. The algorithm is unique in its independence for specific application areas and strong adaptability to different problem types, making it able to effectively deal with extremely challenging problems. Genetic algorithm is especially suitable for global optimization problems and has the ability to jump out of the local optimal solution and search for the global optimal solution. In addition, it supports the definition of complex fitness evaluation functions and can impose constraints on the search space of variables.

In the process of solving optimization problems, many methods based on numerical computation rely on derivative information to guide the search direction, which often leads them to fall into local optimal solutions. In contrast, genetic algorithms only evaluate the value of the function without relying on the continuity of the design space or the differentiability of the function, making them suitable for a wide range of function optimization tasks. Genetic algorithm can search widely in the design space, which increases the possibility of finding the global optimal solution.

The advantages of genetic algorithm are as follows: Firstly, its population-based search mechanism facilitates parallel processing; Secondly, the algorithm adopts heuristic search strategy instead of blind exhaustive method. Third, the fitness of the algorithm does not require the function to have continuity or differentiability, which makes the application field wide. Finally, the implementation of genetic algorithm is relatively simple, for different problems only need to change the gene coding mode, and adjust the fitness function under the premise of keeping the coding method consistent. However, genetic algorithm also has some limitations: on the one hand, its global search ability is limited, it is easy to fall into the local optimal and difficult to jump out; On the other hand, when applied to a specific problem, the algorithm may converge prematurely to a local optimal solution, making it difficult to reach a global optimal.

Compared with traditional optimization methods, the unique advantages of genetic algorithms include the ability to encode parameters, no derivatives or additional information, non-deterministic optimization rules, self-organization, self-adaptation and self-learning. In the process of chromosome crossing, the genetic material of the parents combines, so that the offspring inherits its characteristics; When random variation of chromosomes occurs, the offspring characteristics will be different from those of the parents.

3. THE BASIC FLOW OF GENETIC ALGORITHM

3.1. Application of Genetic Algorithm in the Field of Hydraulic Expansion

Research in the field of hydraulic expansion usually involves complex optimization problems, and genetic algorithm, as a heuristic search method, plays an important role in this field.The operation flow of genetic algorithm includes several key steps: First, the initialization process sets the initial evolutionary algebra to zero, and specifies a maximum evolutionary algebra G. Next, we randomly generate M initial solutions to form the initial population G(0).Secondly, in the individual assessment phase, the fitness of each solution in the population G(g) is calculated. Then, in the selection operation, the solutions in the population are screened based on fitness to retain or generate high-quality solutions and pass them on to the next generation. Crossover operation is the core of genetic algorithm, which involves the application of crossover operators in a population.In the mutation operation, the mutation operator acts on the population to adjust the gene sequence of the individual string. The genetic manipulation process is shown in Figure 1. After selection, crossover and mutation, the population G(g) evolved into a new generation of population G(g+1).Finally, the termination condition is judged based on whether the evolutionary algebra reaches G, if so, the algorithm outputs the best solution and stops the operation[4].

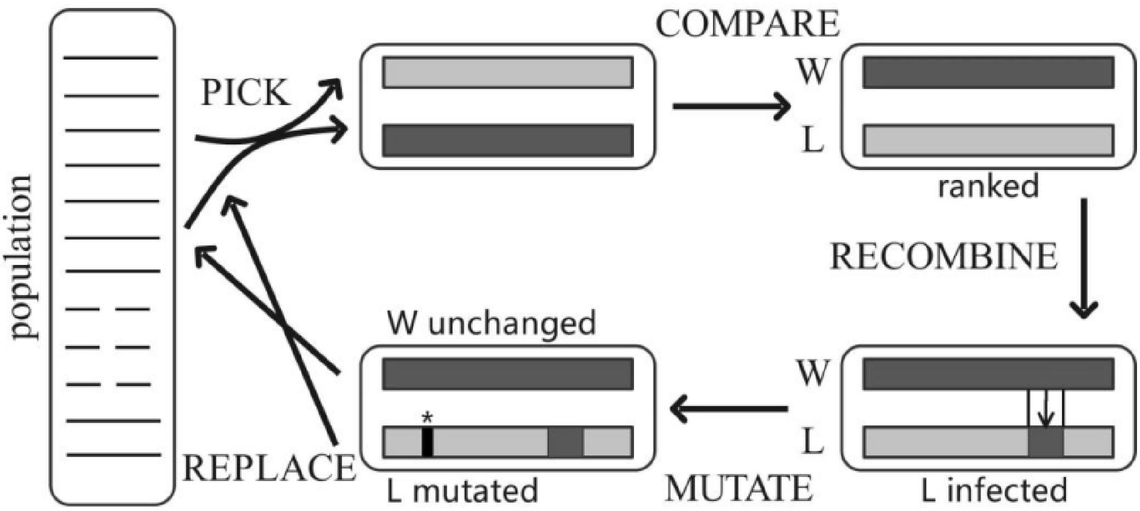

Figure 1. Genetic algorithm process

Genetic algorithm, which can be called evolutionary algorithm, is a heuristic optimization method inspired by Darwinian evolution. The algorithm simulates the mechanism of biological evolution, starting from a group of randomly generated initial populations, and using the fitness function to evaluate each member of the population, that is, "score". According to specific algorithmic rules, population members undergo genetic operations such as selection, crossover, and mutation to produce a new generation of candidate solutions. In this process, candidates with low fitness will be gradually eliminated, while candidates with high fitness will be retained and multiplied. After N generations of iterative evolution, excellent individuals with high fitness are produced.

In the genetic algorithm, it is necessary to encode, decode the problem into the form of a string to use the genetic algorithm, the common encoding way is binary coding, decode the problem into the form of a binary bit array; Interchangeable coding, used to solve sorting problems; Tree coding is used to solve fireworks programming or representation in genetic programming, multiple input and output problems. To make a selection, select some chromosomes to produce the next generation, and the probability of an individual being selected is proportional to its fitness function value. The two selected chromosomes exchange some genes to construct the next generation of two new chromosomes. In the process of reproduction, the genes of the newly generated chromosomes will make mistakes and mutate due to a certain probability.Genetic algorithm program parameters are shown in Table 1.

Table 1. Genetic algorithm program parameters

Program parameter	Symbol	Value
Number of variables	num	3
Number of iterations	ger	50
The length of the coding gene for a single variable	L	10
Crossover probability	pc	0.75
Variation probability	pm	0.1
Self-replication probability	pt	0.2

3.2. Genetic Algorithm Parameter Configuration

In the genetic algorithm, it is necessary to encode, decode the problem into the form of a string to use the genetic algorithm, the common encoding way is binary coding, decode the problem into the form of a binary bit array;Change coding, used to solve the sorting problem; Tree coding is used to solve fireworks programming or representation in genetic programming, multiple input and output problems.To make a selection, select some chromosomes to produce the next generation, and the probability of an individual being selected is proportional to its fitness function value. The two selected chromosomes exchange some genes to construct the next generation of two new chromosomes. In the process of reproduction, the genes of the newly generated chromosomes will make mistakes and mutate due to a certain probability.

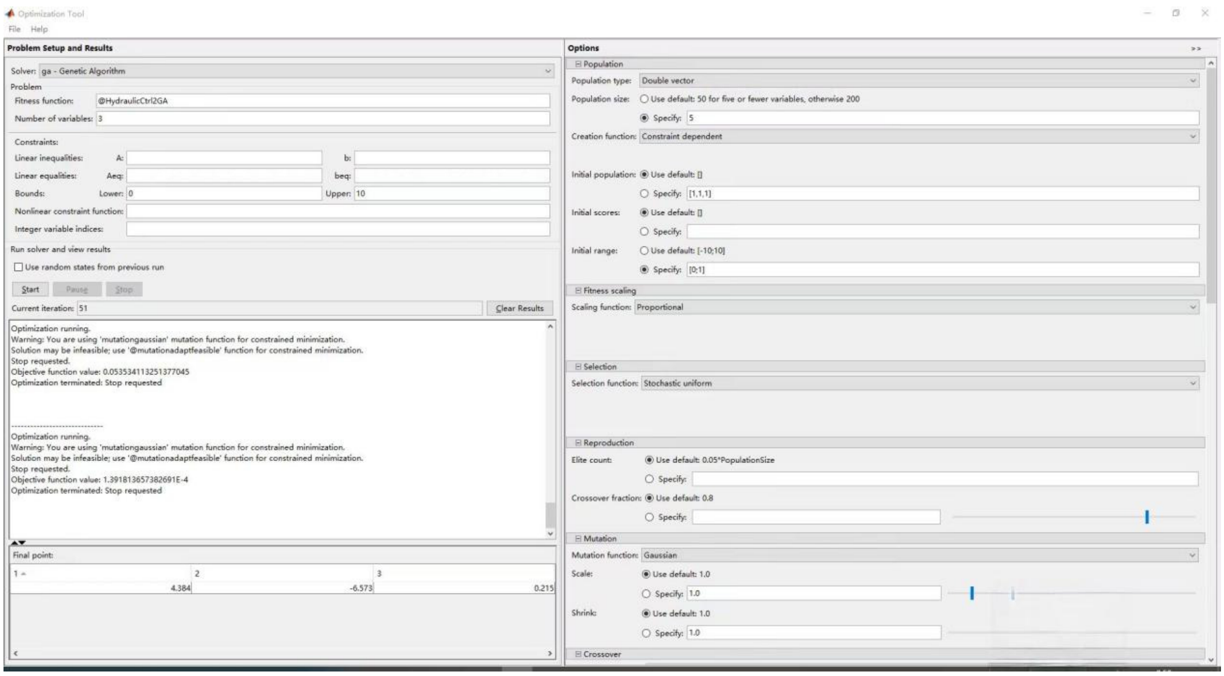

Figure 2. Genetic algorithm parameter configuration

3.3. Iterative Optimization of System Parameters

In this paper, the optimal solution of K_P ,K_I and K_D parameters is obtained by using genetic algorithm. The three parameter values are optimized by programming in Matlab software. The Genetic algorithm is used to perform several iterations on parameters K_P ,K_I and K_D of PID controller in Simulink model of the system, and the optimal solution is obtained. The parameter configuration of the genetic algorithm is shown in Figure 2. The number of variables is set to 3, which corresponds to the three parameters K_P,K_I and K_D in the PID controller. The number of iterations in the genetic algorithm process is 50, the value of the coding gene length of a single variable is 10, the probability of cross operation is 0.75, the probability of mutation operation is 0.1, and the probability of self-replication is 0.2.

After the evaluation function is established, the input parameter values of K_P, K_I and K_D are 1, 0.5 and 0.05, and the three parameter values of the PID controller optimized by Genetic algorithm are 4.38378, 6.57315 and 0.21451, which are brought into the evaluation results obtained by the evaluation function. The evaluation result of manual parameter setting is 0.0066, and the optimized one is 1.3860e-04. Figure 3 shows the results of the genetic algorithm.

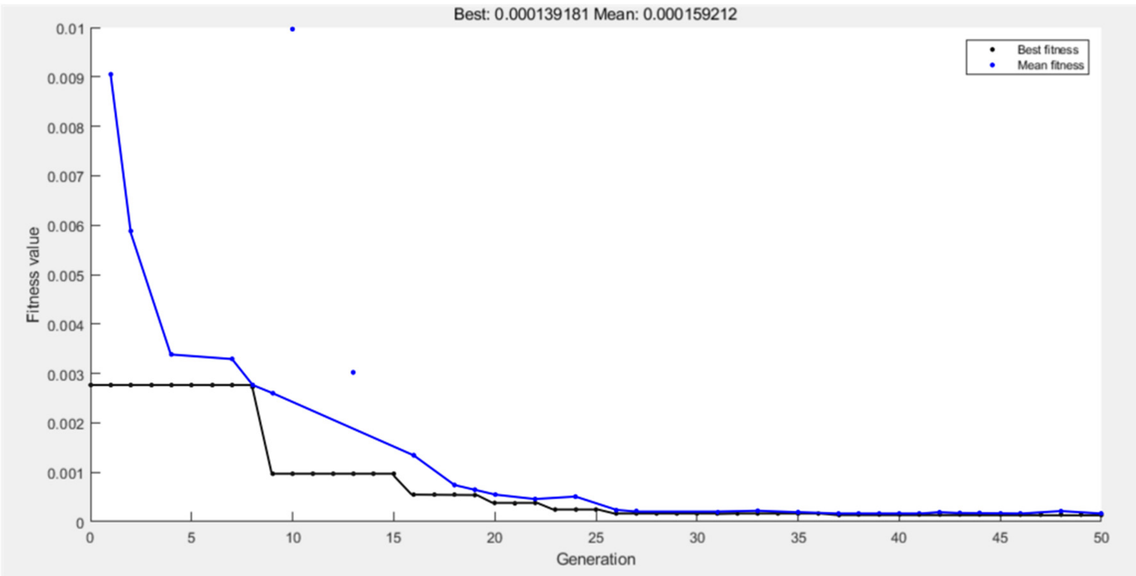

Figure 3. Genetic algorithm result

4. SUMMARY

The optimal solution of K_P, K_I and K_D parameters, whose values are 4.38378, 6.57315 and 0.21451, is obtained by correcting the system parameters through genetic algorithm, and the evaluation results are brought into the evaluation function. The evaluation result of manual parameter setting is 0.0066, and the optimized one is 1.3860e-04. It is found that the control system can meet the technical requirements and has good stability.

5. CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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