The Simulated Annealing Algorithm Implemented by the MATLAB

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Abstract

This paper expounds the basic principle of simulated annealing algorithm which was applied to solve the function optimization problem and the algorithm realization process by using MATLAB language. Through the improvement algorithm results show that the method is able to function for global optimization, effectively overcome the based on the derivative of the optimization algorithm easy to fall into local optimum problems. This method not only can deepen the understanding of the simulated annealing process, but also can achieve the purpose of design intelligent system.

Keywords: *Simulated annealing algorithm; MATLAB; Optimization algorithm; BP neural network*

1. Introduction

In recent years, the BP neural network in the field of artificial intelligence is the most widely used one of the key technologies. It is a kind of multilayer feed forward neural network model, can learn a lot of model mapping relationship, and from the point of view of bionics to simulate human brain intelligent behavior, and is widely used in pattern recognition, classification and prediction and other fields, have strong adaptive ability. However, the BP neural network are also easy to fall into the local minimum value, slow convergence speed and easy to cause defects such as shock. Therefore, based on the research and analysis of the simulated annealing algorithm, this paper will use the selected neural network simulation corresponding function to study weight coefficient to verify the simulated annealing algorithm to improve the results, and complete the MATLAB results analysis. We assume that using simulated annealing algorithm simulation approximation function: ,（-2 2）, and the neural network weight coefficient, valve value for learning and neural network structure is the 1-3-4-3-1. The following is a learning process and improve the results.

2. The simulated annealing algorithm learning method principle and the learning process.

2.1 Learning principle:

Simulated annealing algorithm of the original idea was proposed in 1953, in the Metropolis, Kirkpatrick put it successful application in the combinatorial optimization problems in 1983.

Simulated annealing algorithm from the solid annealing principle, the solid heating to fully high, let its slowly cooling, heating, solid internal particle with temperature rise into disordered shape, internal energy increases, and slowly cooling particles gradually orderly, and in each temperature are to reach an equilibrium state, and the last in the room temperature reaches ground state, internal energy is reduced to the minimum. According to the Metropolis criterion, particle in temperature T when the probability of equilibrium is e-ΔE/(kT), including E for temperature T of internal energy, ΔE for its change quantity, k for Boltzmann constant. With solid annealing simulation combination optimization problem, the internal energy E simulation for the objective function value f, temperature T evolution into control parameter T, namely get solution combination optimization problem of simulated annealing algorithm: the initial solution i and control parameter initial t start, on the current solution repeat "produce data processing to calculate target function difference - to accept or to reject" iteration, and gradually attenuation t value, the algorithm at the end of the current solution is the income approximate optimal solution, this is based on the Montecarlo's iteration method of a kind of heuristic random search process. Annealing process by Cooling Schedule (Cooling Schedule) control, including the control parameters of the initial t and its attenuation factor Δt, every t value the iteration number L and stop condition S.

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2.2 Simulated annealing algorithm basic ideas:

（1）Initialization: initial temperature T (Sufficiently large), initial solution state S (is the starting point of the iterative algorithm), each T value the iteration number L
（2）The k = 1,... , L do the first (3) to step 6.
（3）Produce 'S data processing
（4）Calculation incremental Δt '= C(' S) - C(S), including C(S) as evaluation function
（5）If Δt '< 0 is accepted as a new S' current solution, or otherwise the probability exp(- Δt '/ t) accept S' as a new current solution.
（6）If meet the termination condition is output current solution as the optimal solution, end program. Termination condition usually takes for continuous several data processing are not accepted end algorithm.
（7）T gradually reduce, and T->0, then turn step 2.

2.3 Simulated annealing algorithm of the data processing produce and receive can be divided into below four steps:

The first step is produced by a function from the current solution produce a is located in the solution space express; For convenience of subsequent calculation and accept, reduce algorithm is time-consuming, usually choose from current data processing after simply transformation can produce the data processing methods, such as to constitute the express all or part of the elements to displacement, exchanging, etc., pay attention to produce data processing of transform method determines the current data processing neighborhood structure, and the selection of cooling schedule has certain influence. The second step is to computing and data processing of the corresponding objective function difference. Because of the target function only difference by transform part production, so the objective function calculated according to the difference of the best incremental calculation. In fact, for the majority of applications is concerned, this is the objective function calculated poor fastest way. The third step is to judge whether the data processing is accepted, the basis of judgment is an accepted standards, the most commonly used accept rule is Metropo1is criteria: if Δt '< 0 is accepted as a new' S current solution S, or otherwise the probability exp (- Δt '/ t) accept S' as a new current solution S. The fourth step is when the data processing is determined to accept, the use of data processing to replace the current solution, this just the current solution corresponding to express in produce the transform part to achieve, and at the same time, the objective function value can be modified. At this time, the current solution implements a iteration. Can be based on this began the next round of test. And when the data processing was judged for abandon, is in the original on the basis of the current solution continuing to the next round of test. The simulated annealing algorithm and the initial value has nothing to do, algorithm of the obtained solution and initial solution state S (is the starting point of the iterative algorithm) matter, Simulated annealing algorithm is asymptotic convergence, already in theory was proved to be a probability l converge to the global optimal solution of the global optimization algorithm, Simulated annealing algorithm has parallelism.

2.4 The learning process: specific neural network structure and parameters are shown below chat. As shown in Fig. 1 shows.

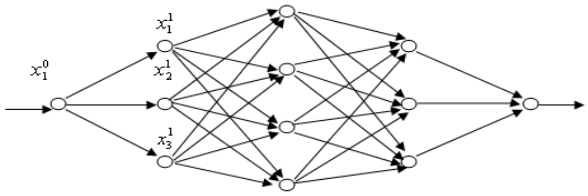

Fig. 1 Specific Neural Network Structure

（1）learning objective:
Simulated annealing algorithm is used to optimize weight coefficient and threshold, so that network approximation function: as Eq. (1)
（2）deviation function
Deviation function using cost function, take as Eq. (2): Among them: $\overline{y}$ is expectations value are for constant; y For the actual output, namely x_1^3 , The S function as Eq. (3) as excitation function.

$$y = 100(x^2 - 1)^2 + (1 - x)^2, \quad (-2 \le x \le 2) \tag{1}$$

$$e = \frac{1}{2}(\overline{y} - y)^2 \tag{2}$$

$$\left(f(x) = \frac{1}{1 + \exp(-n)} \right) \tag{3}$$

（3）Set the initial weight coefficient
Used in [1, 1] interval random decimal for network initial weight coefficient, threshold, initial temperature, end temperature and cooling rate. Using normal distribution function random generation [1, 1] initial weight coefficient, in using MATLAB RANDN function to realize.
（4）Specific learning process is as follows:

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The realization of the simulated annealing algorithm is mainly by the MATLAB software, using the neural network toolbox for programming simulation. The actual learning uniform produce [0, 2π] interval 20 to learning samples, namely function input and output value are as follows Table 1 shows:

Table 1: Input x

1	2	3	4	5
0	0.15708	0.31416	0.47124	0.62832
6	7	8	9	10
0.7854	0.94248	1.0996	1.2566	1.4137
11	12	13	14	15
1.5708	1.7279	1.885	2.042	2.1991
16	17	18	19	20
2.3562	2.5133	2.6704	2.8274	2.9845

Table 2: Output expect Y

1	2	3	4	5
101	95.837	81.705	60.798	36.767
6	7	8	9	10
14.726	1.2518	4.3791	33.606	99.89
11	12	13	14	15
215.65	394.77	652.59	1005.9	1473
16	17	18	19	20
2073.6	2828.9	3761.4	4895.5	6256.5

Table 3: Neural network actual output y

1	2	3	4	5
222.63	222.64	222.68	222.81	223.42
6	7	8	9	10
227.92	298.31	341.05	341.21	341.22
11	12	13	14	15
341.22	341.22	341.22	341.22	341.22
16	17	18	19	20
341.22	341.22	341.22	341.22	341.22

3. Five typical weight coefficient change process curve and primitive function and network output chart is as follows Fig. 2 as shows :

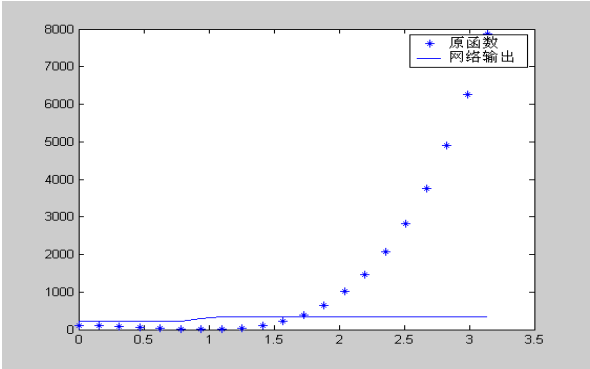

Fig. 2 the Output Chart

4. The results analysis:

The study result, learning curve and the original curve is large, and function convergence slowly, this is because the simulated annealing method of initial parameters (initial temperature t0, end temperature tf, attenuation temperature deltaT and control internal circulation markov chain length L) choice is very important, in order to speed up the convergence, improve the learning efficiency, therefore, need to improve the algorithm to speed up the neural network learning.The advantages and disadvantages of simulated annealing algorithm:

Simulated annealing algorithm is in a certain initial temperature, the temperature parameters with the declining, combined with probability step characteristic in the solution space of random target function of the global optimal solution, namely in the local optimal solution can probabilistic to jump and finally tends to global optimal, avoid the search process into local minimum.

As the expansion of the local search algorithm, simulated annealing algorithm based on a certain probability choice adjacent domain cost value's largest state. Its main advantage is the calculation process is simple, easy to realize general, robust, suitable for parallel processing, can be used to solve complex nonlinear optimization problem. But, in order to find the optimal solution, the algorithm usually require higher initial temperature, slower cooling rate, lower end temperature and the temperature of the sampling enough times, so the simulated annealing algorithm often optimization process

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is long, the convergence speed is slow, this is the biggest drawback SA algorithm.

6. The improved algorithm

According to the optimization of SA process is long, the disadvantages of slow convergence, so SA to improve the main content is the guarantee of optimization based on the quality, improve the searching efficiency of algorithm (time performance), make its can speed up the convergence of function, enabling the network output and the expected value approximation.

Improved SA algorithm is improved annealing feasible scheme including: design appropriate state produce functions; Design efficient annealing process; Avoid state of alternate search; The parallel searching structure; Improvement of temperature control mode; Choose appropriate initial state; Design the suitable algorithm termination criterion. In addition, it also can be by adding some to achieve: such as increasing temperature or heavy heating process; Increase the memory function; Increase added search process; Combined with other search mechanism algorithm, such as genetic algorithm and simulated annealing method combination (GASA), simulated annealing - simplex algorithm (SMSA); Parallel simulated annealing algorithm, etc.

The improved algorithm expected output and the actual output is as follows:

Table 4: Improved algorithm expected output expect Y

1	2	3	4	5
101	95.837	81.705	60.798	36.767
6	7	8	9	10
14.726	1.2518	4.3791	33.606	99.89
11	12	13	14	15
215.65	394.77	652.59	1005.9	1473
16	17	18	19	20
2073.6	2828.9	3761.4	4895.5	6256.5

Table 5: Improved algorithm actual output Y

1	2	3	4	5
96.132	102.8	110.93	120.95	133.48
6	7	8	9	10
149.38	169.93	196.99	233.41	283.62
11	12	13	14	15
354.73	458.4	614.18	855	1235.2
16	17	18	19	20
1836.1	2746.6	3970	5276.9	6281.1

Improved algorithm of object function and the network output chart is as follows Fig. 3 shows:

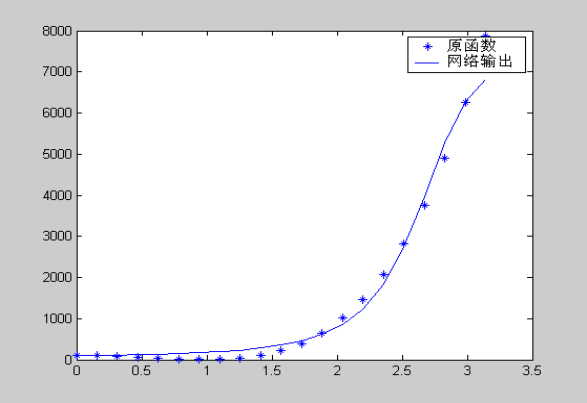

Fig. 3 the Improved Network Output Chart

The results can be seen, the improved algorithm convergence speed, function approximation and precision can reach the expected effect.

References

[1] WenXun punishment, XieJinXing. Modern optimization calculation method [M]. Beijing: tsinghua university press, 1999.

[2] focal LiCheng. Neural network system theory. Xian: xian university of electronic science and technology press, 1996.6.

[3] zhang ying, LiuYanQiu. Soft computing method. Beijing: science press, 2002.

[4] fly thinking science and technology r&d center. MATLAB7 foundation and improve. Beijing: publishing house of electronics industry, 2005.

[5] kang ls, etc. Non-numerical parallel algorithm (volume 1) simulation annealing algorithm. Beijing: science press, 2003.

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