

An Improved Immune Genetic Algorithm and Its Application in Computer-aided Landscape Design

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Abstract: This paper proposes an improved immune genetic algorithm, and utilizes it in evaluating the results of computer-aided landscape design. After analyzing the related works and the flow chart of the standard immune genetic algorithm, an improved immune genetic algorithm is designed. The main modifications of our proposed immune genetic algorithm lie in the following aspects. 1) We modified the standard immune genetic algorithm using symbolic coding and full binary tree in the chromosomes to describe solutions. 2) The crossover operator with single point is used, and the cross point can be selected from the intermediate nodes and the root nodes. 3) The mutation operator is modified to avoid the dependence of mutation probability on the initial value. 4) The modified immune genetic algorithm not only can keep random global search ability, but also can avoid local premature convergence. Next, the landscape design evaluation results can be obtained by SVM, the parameters of which can be optimized by the proposed modified immune genetic algorithm. Finally, experiments are conducted on three datasets using an index system which is including 17 indexes. Experimental results demonstrate that the proposed scheme can effectively evaluate the quality of computer-aided landscape design.

Keywords: Chromosome, crossover, computer-aided design, immune genetic algorithm, landscape design, mutation.

1. INTRODUCTION

In the different kinds of feature selection algorithms, the genetic algorithm is an effective solution. The genetic algorithm is biologically inspired and has many mechanisms mimicking natural evolution. It has a great deal of potential in scientific and engineering optimization or search problems. Furthermore, genetic algorithm is naturally applicable to feature selection since the problem has an exponential search space. The traditional works demonstrated evidence for the superiority of the genetic algorithm compared to representative classical algorithms. In recent years, many research papers are published, which have shown advantages of the genetic algorithm for feature selection. However, although they presented experimental data supporting the superiority of genetic algorithm, other literatures involving comparative studies did not give satisfactory arguments [1, 2].

In order to extend the performance of the genetic algorithm, immune genetic algorithm is proposed recently. The aim of introducing immune concepts and algorithms into genetic algorithm is theoretically to utilize the local characteristic information for seeking the ways and means of finding the optimal solution when dealing with difficult problems. During the actual operation, Immune genetic algorithm first specifically analyses the pending problem which is regarded as “antigen”, where the basic characteristic information which is regarded as “vaccine” is extracted. Afterwards,

the characteristic information is handled and transformed to be a solution and the set of total results from this solution is called “antibody” based on the vaccine. Finally the solution is transformed to be the immune operator by a certain format to execute the operation [3, 4].

As is illustrated in Wikipedia, Computer-aided design refers to the use of computer systems to assist in the creation, modification, analysis, or optimization of a design. Computer-aided design software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. Computer-aided design output is often in the form of electronic files for print, machining, or other manufacturing operations.

Furthermore, Computer-aided design is an important industrial art extensively used in many applications, such as automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and so on. Computer-aided design is also widely used to produce computer animation for special effects in movies, advertising and technical manuals, often called digital content creation. The modern ubiquity and power of computers means that even perfume bottles and shampoo dispensers are designed using techniques unheard of by engineers of the 1960s. Because of its enormous economic importance, Computer-aided design has been a major driving force for research in computational geometry, computer graphics and discrete differential geometry [5, 6].

As is well known that design is a complex engineering activity, in which computers are more and more involved. The task of design can often be seen as an optimization prob-

lem in which the parameters or the structure describing the best quality design are sought. The Immune genetic algorithm is made up of a class of search algorithms especially suited to solving complex optimization problems. In addition to parameter optimization, immune genetic algorithms are also suggested for solving problems in creative design, such as combining components in a novel, creative mode. Immune genetic algorithms utilize the notions of evolution in nature to computers and then imitate natural evolution. Particularly, this algorithm finds solutions to a problem by maintaining a population of possible solutions according to the ‘survival of the fittest’ principle [7].

Based on the above analysis, we present an improved immune genetic algorithm and then use the proposed algorithm in computer-aided design.

The rest of the paper is organized as the following sections. Section 2 introduces the related works. Section 3 illustrates the improved immune genetic algorithm and its application in computer-aided landscape design evaluation. In section 4, a series of experiments are designed and conducted to make performance evaluation. Finally, we conclude the whole paper in section 5.

2. RELATED WORKS

In this section, the related works of this paper are surveyed. Particularly, some representative works are given as follows.

Diabat *et al.* proposed a multi-echelon reverse logistics network for product returns to minimize the total reverse logistics cost, which consists of renting, inventory carrying, material handling, setup, and shipping costs. Industries need to give more attention to the task of collecting used products from customers and establishing collection facilities. Particularly, a mixed integer non-linear programming (MINLP) model is developed to find out the number and location of initial collection points and centralized return centers required for an effective return and collection system, and also the maximum holding time for aggregation of small volumes of returned products into large shipments [8].

Liang *et al.* proposed a novel system which applies a combination of two methods of artificial immune and genetic algorithm to diagnose the liver disease. The system architecture is based on artificial immune system. The learning procedure of system adopts genetic algorithm to interfere the evolution of antibody population [9].

Li *et al.* utilized immune genetic algorithm for pose optimization in latent space of human motion. Firstly, the authors perform human motion analysis in the learnt latent space of human motion. As the latent space is low dimensional and contains the prior knowledge of human motion, it makes pose analysis more efficient and accurate. Furthermore, IGA is used for pose optimization. Compared with genetic algorithm and other evolutionary methods, its main advantage is the ability to use the prior knowledge of human motion. The authors proposed a sequential IGA(S-IGA) algorithm for motion tracking by incorporating the temporal continuity information into the traditional IGA [10].

Chen *et al.* presented a novel intelligent diagnosis model based on wavelet support vector machine (WSVM) and im-

une genetic algorithm (IGA) for gearbox fault diagnosis. Immune genetic algorithm is developed in this study to determine the optimal parameters for WSVM with the highest accuracy and generalization ability. Moreover, the feature vectors for fault diagnosis are obtained from vibration signal that preprocessed by empirical mode decomposition (EMD)[11].

Tao *et al.* proposed a modified self-adaptive immune genetic algorithm (MSIGA) with two memory bases to improve the searching ability of the algorithm and maintain population diversity. Performance comparisons with other well-known population-based iterative algorithms show that the proposed method converges quickly to the global optimum and overcomes premature problem. This algorithm is applied to optimize a feed forward neural network to measure the content of products in the combustion side reaction of p-xylene oxidation, and satisfactory results are obtained [12].

Arivudainambi *et al.* presented a new efficient immune genetic algorithm (IGA) for broadcast scheduling problem in TDMA Ad hoc network. The proposed algorithm improves the transmission utilization by assigning one transmission time slot to one or more non-conflicting nodes such a way that every node transmits at least once in each TDMA frame. An optimum transmission schedule could minimize the length of a TDMA frame while maximizing the total number of transmissions. The aim of this paper is to increase the number of transmissions in fixed Ad hoc network with time division multiple access (TDMA) method, with in a reduced time slot [13].

Liao *et al.* presented a novel algorithm-Isolation Niche Immune Genetic Algorithm for solving power system Bid-Based Dynamic Economic Dispatch (INIGA-BDED). Economic Dispatch determines the electrical power to be generated by the committed generating units in a power system so that the generation cost can be minimized, while simultaneously satisfying various load demands. Moreover, this paper also proposed the Niche based on the Isolation mechanism which is based on biological possesses. The proposed method effectively ensures diverse group solutions and also has a strong ability to guide evolution. Using the immune genetic algorithm itself is a very good and innovative method for multi-peak model function solutions [14].

Zhou *et al.* proposed an new immune GA (UIGA) based on the clonal selection strategy and UDS. Based on the bias of samples in the uniform design sampling (UDS) point set, the crossover operation in GA is redesigned. Using the concentrations of antibodies in artificial immune system (AIS), the chromosomes concentration in GA is defined and the clonal selection strategy is designed. In order to solve the maximum clique problem (MCP)[15].

Xue *et al.* studied on how to optimize enterprise information system (EIS) structure based on time property. Once the EIS structure is formally represented, the time property corresponding to EIS structure expression can be obtained. Thus, aiming at the minimum time property, the EIS structure can be optimized. Afterwards, the EIS structure model is optimized by the improved immune genetic algorithm (IGA) based on binary tree, niche algorithm and self-adaptive operators, and the steps of the improved IGA are presented in detail as well [16].

Guo *et al.* presented a two-stage damage detection method based on Bayesian theory and immune genetic algorithm (IGA) to solve structural multi-damage identification problem. First, structural modal strain energy and frequency are considered as two kinds of information sources, and Bayesian theory is utilized to integrate the two information sources and preliminarily identify structural damage locations. After the damaged locations are determined, immune genetic algorithm is used to identify structural damage extent [17].

Qian *et al.* designed a novel kinetic model based on the free radical mechanism to simulate the oxidation of p-xylene (PX) in a continuous stirred-tank reactor (CSTR) under industrial operating conditions. Correction coefficients are introduced to accurately evaluate the kinetic parameters based on Adaptive Immune Genetic Algorithm (AIGA) due to the significant difference between the nature of PX oxidation conducted in the laboratory SBR and in the industrial CSTR [18].

Zu *et al.* proposed a multi-user cognitive radio network resource allocation based on the adaptive niche immune genetic algorithm, and then a fitness function is provided. Simulations are conducted using the adaptive niche immune genetic algorithm, the simulated annealing algorithm, the quantum genetic algorithm and the simple genetic algorithm, respectively [19].

Moghaddam *et al.* proposed an Immune-based Genetic algorithm (IGA) and a meta-heuristic approach with a new coding scheme to solve MTSP. Furthermore, to overcome the regeneration phenomena in the proposed GA (generating similar chromosomes) which leads to premature convergence, an affinity based approach inspired from Artificial Immune system is employed which results in better exploration in the searching process [20].

3. THE PROPOSED SCHEME

Immune genetic algorithm is a global search algorithm based on immune system and the standard genetic algorithm. In this optimization approach, variable parameters are coded into a string known as an antibody (individual). Each of these antibodies has a related fitness value, which can be obtained by the objective function to be maximized or minimized. The immune genetic algorithm is implemented by adjusting the concentration of a population, which is made up of different antibodies with different fitness, and then the immune genetic algorithm can efficiently search the new generation with better fitness. Immune genetic algorithm has been tested to have the ability to solve the optimization problem through concentration control and genetic operation applied to antibodies in the population [21-23].

Particularly, immune genetic algorithm is belonged to a kind of improved genetic algorithm based on biology immune mechanism. Particularly, it is one kind of bionic simulated evolutionary algorithm which can imitate and reflect biological immune system, and combined with engineering optimal problems. Based on the original genetic algorithm, immune genetic algorithm could solve the problem of the low searching efficiency, poor individuals variety and premature of genetic algorithm effectively [24], and ensure that algorithm convergence rapidly in globally optimal solution by application of the mechanism of biodiversity maintenance and the mechanism of consistency adjustment of biological immune system [25].

The process of the immune systems construction is shown in Fig. (1). For a given immune system, the antibodies may be a set of thresholds or limitation conditions to the chromosomes, which can be learned from the neighbors by the inference rules. The learning process of antibodies can be calculated as follows.

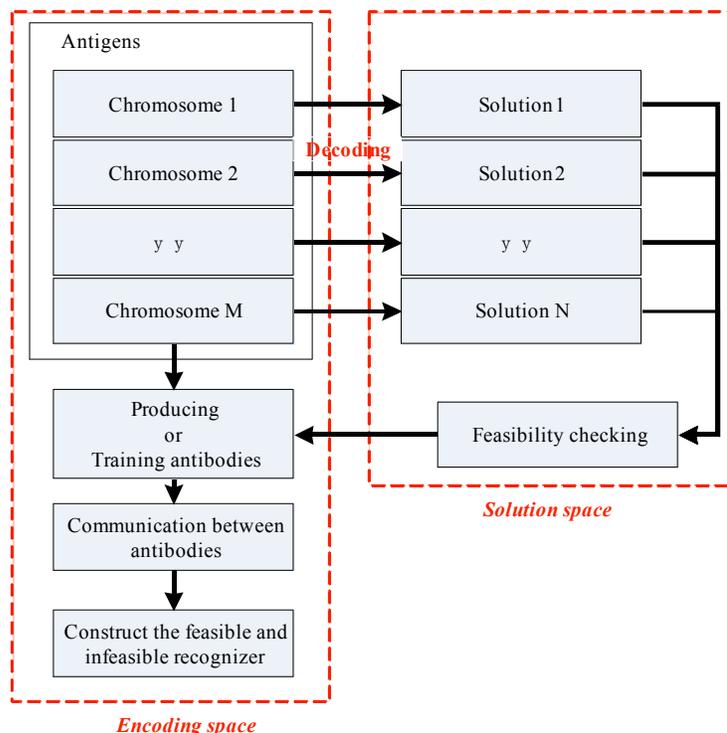


Fig. (1). Process of the immune systems construction.

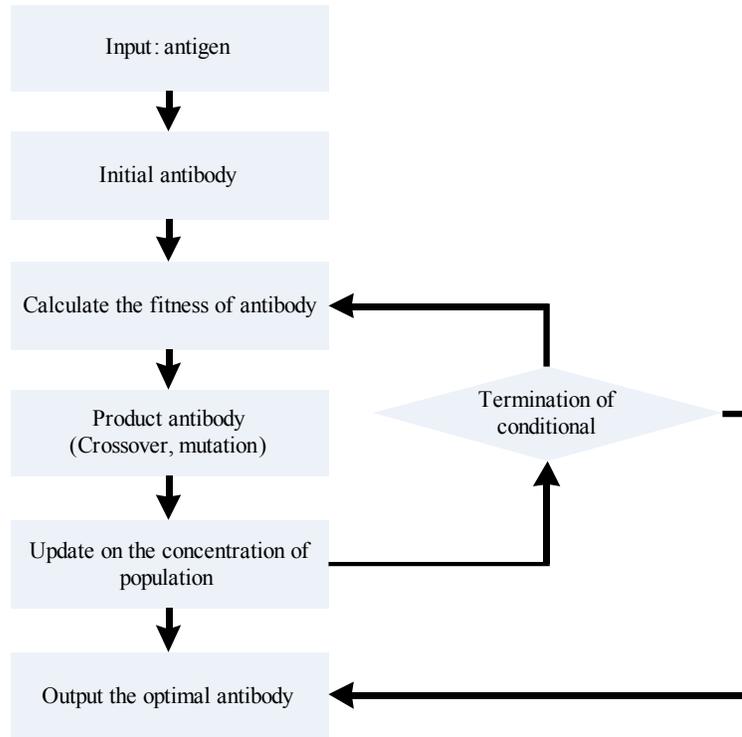


Fig. (2). Flow chart of the standard immune genetic algorithm.

$$Th(i, k) = Th(i, k - 1) + \Delta Rule\{Th(i, k - 1), Th(i - 1, k)\}, \forall i, \forall k \quad (1)$$

where $Th(i, k)$ refers to the threshold of the antibody i after the k^{th} training, and $i - 1$ represents the related antibody which is belonged to its neighbor antibody. $\Delta Rule$ represents the increment based on the rule based learning process.

After the feasible and infeasible recognizer is made, it can be added into the general genetic algorithms to construct a modified immune-genetic algorithm. The process of immune genetic algorithm can be illustrated in Fig. (2). The immune genetic algorithm can be utilized to solve many constrained optimization problems effectively.

In this paper, we modified the standard immune genetic algorithm by utilizing symbolic coding and full binary tree in the chromosomes to describe solutions. Particularly, all the chromosomes' fitness are modified by the following equation.

$$sh(d) = \begin{cases} 1 - \frac{d}{\sigma_{share}}, & d \leq \sigma_{share} \\ 0, & otherwise \end{cases} \quad (2)$$

where σ_{share} refers to the radius of niche and d can be computed by the following equation.

$$d = \frac{H(opi, opj)}{N \cdot k} \quad (3)$$

where $H(opi, opj)$ represents the hamming distance between opi and opj , N denotes the number genes in the chromosome, and k means the number of chromosomes in each

sub-group. Afterwards, the sharing fitness function is represented in Eq.4

$$\varepsilon(\chi_{opi}) = \frac{\varepsilon'(\chi_{opi})}{\sum_{opj=1}^N sh(\chi_{opi}, \chi_{opj})} \quad (4)$$

Particularly, the crossover operator with single point is used in this paper, and the cross point is chosen between the intermediate nodes and the root nodes. Next, we exchange the two nodes chosen in the above process, and then two chromosomes with higher fitness of all the 4 replace the initial two ones.

To avoid the mutation probability's dependence on the initial value, self-adaptive crossover probability is designed as follows.

$$p_c = \begin{cases} p_{c1} - \frac{(p_{c1} - p_{c2}) \cdot (\delta' - \delta_{avg})}{\delta_{max} - \delta_{avg}}, & \delta' \geq \delta_{avg} \\ p_{c1}, & otherwise \end{cases} \quad (5)$$

where δ_{max} refers to the highest fitness in the current population, δ_{avg} represents the average fitness in the current population. Particularly, δ' means the higher fitness of the two crossover individuals, and p_{c1} and p_{c2} means the initial values which can be computed by the self-adaptive crossover probability.

In the proposed immune genetic algorithm, the mutation operator is modified as well to avoid the dependence of mutation probability on the initial value. The self-adaptive mutation probability is obtained by the following equation.

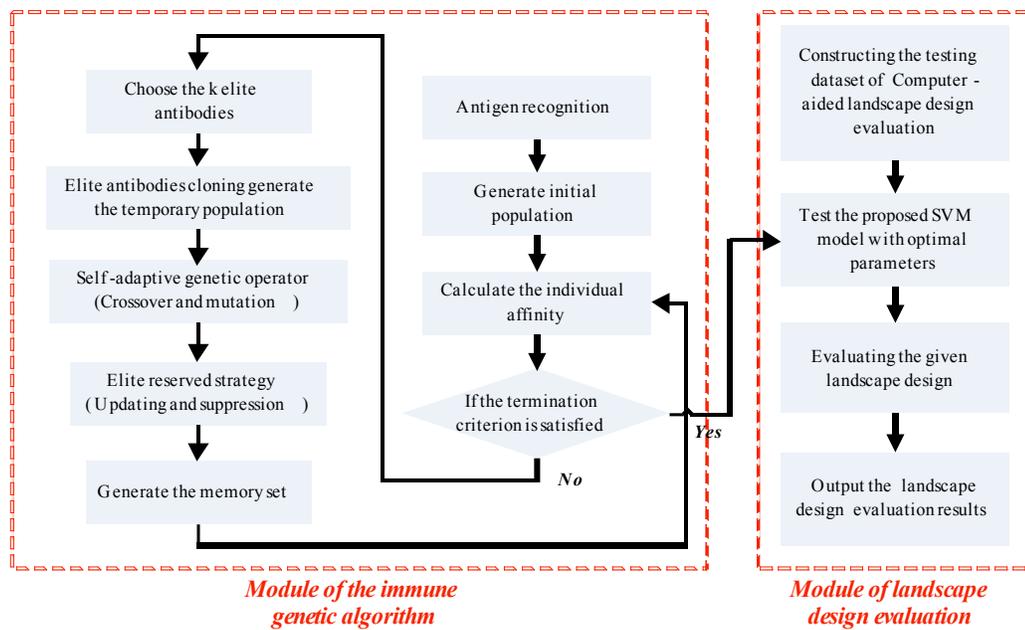


Fig. (3). Process of the proposed improved immune genetic algorithm based computer-aided landscape design evaluation.

$$p_m = \begin{cases} p_{m1} - \frac{(p_{m1} - p_{m2}) \cdot (\delta_{avg} - \delta)}{\delta_{max} - \delta_{avg}}, & \delta \geq \delta_{avg} \\ p_{m1}, & otherwise \end{cases} \quad (6)$$

where δ_{max} refers to the best fitness in the current population, and δ_{avg} means the average fitness in the current population, δ represents the fitness of the mutation individual. p_{m1} , p_{m2} refer to the initial values for computing self-adaptive mutation probability respectively.

After the improved immune genetic algorithm is given, the landscape design evaluation results can be obtained by SVM, the parameters of which can be optimized by the proposed immune genetic algorithm. Next, we will illustrate how to optimize the support vector machine with the proposed immune genetic algorithm.

Using the Morlet wavelet kernel function, the optimal decision function of the SVM can be represented as follows.

$$f(x) = \text{sgn} \left[\sum_{j=1}^n \alpha_j \cdot \prod_{i=1}^d \left[\cos \left(1.75 \cdot \frac{(x_j^i - x_j^i')}{a_j^i} \right) \right] \cdot \exp \left[-\frac{\|x_j^i - x_j^i'\|^2}{2 \cdot a_j^i{}^2} \right] + b \right] \quad (7)$$

where n denotes the training sample number, and x_j^i refers to the i^{th} variable in the j^{th} training sample.

Based on the above optimal decision function, immune selection, immune mutation, immune renewal and the dynamic adjustment strategy can be converted to meet the requirement of large scale optimal computation. On the other hand, the immune memory function is adopted in immune genetic algorithm to improve whole search ability and quicken search speed. Hence, immune genetic algorithm not

only can keep random global search ability, but also avoid local premature convergence, which is more suitable for parameters optimization.

Afterwards, the results of computer-aided landscape design evaluation can be obtained by the above SVM based on training dataset in Fig. (3).

4. EXPERIMENTAL RESULTS

Landscape design refers to an independent profession and a design and art tradition, practised by landscape designers, combining nature and culture. In contemporary practice, landscape design bridges between landscape architecture and garden design. Particularly, landscape design focuses on both the integrated master landscape planning of a property and the specific garden design of landscape elements and plants within it. The practical, aesthetic, horticultural, and environmental sustainability components merit Landscape design inclusion. Landscape designers usually collaborate with related disciplines such as architecture and geography, soils and civil engineering, surveying, landscape contracting, botany, and artisan specialties.

Based on the above illustration of landscape design, how to effectively evaluate the given landscape design is of great importance in the process of landscape design. However, evaluating the landscape design is quite hard. The reasons lie in that when evaluating the landscape design, many factors should be considered, including the aesthetics, practicality, economy, ecology, and so on.

In the following section, we will test the performance of the proposed improved immune genetic algorithm through evaluating landscape design results. Before evaluating the landscape design, the index systems should be determined in advance. The indexes and related weights we used in this experiment are given in Table 1 as follows. Particularly, the index weights are obtained by the Analytic hierarchy process algorithm.

Table 1. The index of landscape design evaluation.

Index category	Index	Weight
Overall	I1: Green rate	0.099
	I2: Surface area ratio	0.073
	I3: road coverage	0.083
	I4: building floor area ratio	0.073
Practicality	I5: garden gate count	0.056
	I6: square number	0.047
	I7: pavilion number	0.050
Layout reasonable	I8: Distance between building and wall	0.044
	I9: Distance between garden gate and parking area	0.048
	I10: Distance between central square and sculpture	0.057
	I11: Distance between iconic architecture and landscape center position	0.060
Appearance	I12: Plant species	0.049
	I13: Ground height difference	0.051
	I14: The number of lake island	0.051
	I15: The number of landscape axis landscape	0.053
	I16: Landscape facade height	0.058
	I17: Types night lighting	0.048

Table 2. Evaluation level for the given fifty testing samples.

Testing Sample	Evaluation Level
S1	Good
S2	Ordinary
S3	Good
S4	Ordinary
S5	Ordinary
S6	Excellent
S7	Excellent
S8	Good
S9	Good
S10	Good
S11	Good
S12	Excellent
S13	Good
S14	Excellent
S15	Excellent

Afterwards, each of the evaluation parameters are used as input data, landscape design evaluation level is regarded as the output by SVM to seek non-linear relationship between them. The evaluation level of training and testing data is defined as “Excellent”, “Good”, and “Ordinary” (in Table.2). For each landscape design evaluation dataset, 240 samples are used as training data, and other 240 are utilized as the testing data. Three datasets for landscape design evaluation are utilized in this experiment. Hence, the problem of landscape design evaluation can be converted as the problem of classification. Next, fifty testing data are given in Table.3 as follows, and the values of all indexes are normalized.

Next, in order to make performance comparison, the proposed modified IGA based landscape design evaluation is compared with the methods based on genetic algorithm (GA) and immune genetic algorithm (IGA). The results are listed in Fig. (4).

Based on the above experimental results, in can be seen that the proposed scheme is effective in computer-aided landscape design evaluation. The reasons lie in the following aspects:

(1) Compared with GA, the standard IGA has the following advantages: a) immune memory function, b) maintaining antibody diversity function, c) self-adjustment function. So IGA has its own unique advantages while maintaining global parallel search.

Table 3. Examples of testing samples.

	I1	I2	I3	I4	I5	I6	I7	I8
S1	0.502	0.692	0.603	0.545	0.601	0.786	0.545	0.589
S2	0.644	0.579	0.466	0.594	0.709	0.627	0.785	0.521
S3	0.449	0.639	0.676	0.458	0.602	0.672	0.689	0.742
S4	0.735	0.649	0.571	0.447	0.498	0.754	0.404	0.694
S5	0.794	0.430	0.431	0.574	0.589	0.529	0.521	0.454
S6	0.739	0.757	0.694	0.535	0.585	0.678	0.447	0.421
S7	0.642	0.505	0.609	0.428	0.573	0.596	0.716	0.727
S8	0.774	0.425	0.642	0.572	0.587	0.590	0.601	0.739
S9	0.681	0.794	0.450	0.479	0.636	0.515	0.434	0.470
S10	0.519	0.411	0.769	0.602	0.608	0.530	0.448	0.558
S11	0.627	0.405	0.568	0.577	0.599	0.655	0.429	0.426
S12	0.706	0.595	0.409	0.791	0.784	0.610	0.764	0.430
S13	0.735	0.667	0.551	0.603	0.790	0.499	0.607	0.779
S14	0.572	0.667	0.794	0.574	0.447	0.598	0.544	0.632
S15	0.646	0.791	0.614	0.706	0.719	0.640	0.630	0.433
	I9	I10	I11	I12	I13	I14	I15	I16
S1	0.617	0.668	0.742	0.755	0.500	0.519	0.553	0.742
S2	0.744	0.531	0.461	0.652	0.452	0.443	0.502	0.402
S3	0.746	0.588	0.549	0.729	0.403	0.708	0.660	0.786
S4	0.619	0.768	0.653	0.654	0.579	0.433	0.480	0.557
S5	0.791	0.705	0.624	0.631	0.441	0.420	0.635	0.588
S6	0.554	0.480	0.419	0.421	0.693	0.512	0.784	0.733
S7	0.432	0.461	0.535	0.554	0.767	0.781	0.542	0.678
S8	0.485	0.691	0.720	0.637	0.703	0.787	0.552	0.440
S9	0.585	0.798	0.490	0.505	0.709	0.629	0.602	0.689
S10	0.607	0.440	0.748	0.441	0.669	0.689	0.768	0.762
S11	0.481	0.688	0.601	0.717	0.711	0.766	0.642	0.465
S12	0.776	0.799	0.624	0.572	0.477	0.799	0.590	0.687
S13	0.650	0.654	0.608	0.652	0.707	0.764	0.467	0.474
S14	0.409	0.629	0.732	0.782	0.576	0.658	0.579	0.678
S15	0.699	0.627	0.439	0.599	0.759	0.680	0.488	0.746

(2) Compared with GA and standard IGA, our modified IGA has the following four advantages:

(a) We modified the standard immune genetic algorithm by utilizing symbolic coding and full binary tree in the chromosomes to describe solutions. Particularly, all the chromosomes' fitness is modified as well.

(b) The crossover operator with single point is used in this paper, and the cross point is chosen between the intermediate nodes and the root nodes.

(c) In the proposed immune genetic algorithm, the mutation operator is modified to avoid the dependence of mutation probability on the initial value.

(d) Our modified immune genetic algorithm not only can keep random global search ability, but also can avoid local premature convergence, which is more suitable for parameter optimization.

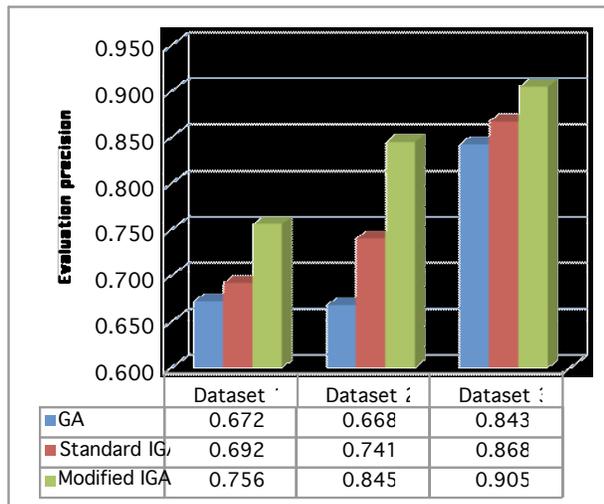


Fig. (4). Performance evaluation for different methods on the three datasets.

5. CONCLUSION

In this paper, we present an improved immune genetic algorithm, and then use this algorithm in evaluating the results of computer-aided landscape design. Firstly, we modified the standard immune genetic algorithm using symbolic coding and full binary tree in the chromosomes to describe solutions. Secondly, the crossover operator with single point is used, and the cross point can be selected from the intermediate nodes and the root nodes. Thirdly, a new mutation operator is designed to avoid the dependence of mutation probability on the initial value. Fourthly, the landscape design evaluation results are obtained by SVM. Particularly, the parameters of SVM classifier are optimized by the proposed modified immune genetic algorithm.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

Declared none.

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Received: September 16, 2014

Revised: December 23, 2014

Accepted: December 31, 2014

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