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Online Paper Generating and Testing System of CET-4 Based on Invasive Weed Optimization

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Abstract. *With the aim to better help students train and prepare for College English Test Band 4 (CET-4), a study is conducted on CET-4 intelligent paper generating and online testing system. Firstly, based on thorough analysis of test characteristics and requirements, a simplified paper generating model is proposed. Then, in order to enhance quality of paper generating, the invasive weed optimization (IWO) algorithm is improved by introducing the operation of uniformly spreading weed groups in solution space and randomly spreading them with certain probability, so as to increase its optimizing speed and avoid local optimization. Thus, the improved invasive weed optimization (IIWO) algorithm is applied in intelligent paper generating. Next, based on system framework of Spring+Spring MVC+MyBatis and Bootstrap and MySQL database, an online testing system is established. In paper generating experiments, results of convergence curve of average fitness indicate that spatial distribution of IIWO algorithm population group is more uniform so that IIWO algorithm can find the optimal solution more easily. Similarly, the relationship curve between fitness and group size indicates that with the group size increasing, IIWO algorithm can avoid premature convergence and speed up convergence; the relationship curve between group size and working time show that IIWO has certain advantages in time-saving. The above test results indicate that IIWO algorithm is more efficient in paper generating. In addition, the test results of paper generating error also show that the studied IIWO algorithm has higher paper generating quality. Finally, the black-box test method is chosen to test the five modules in the testing system. The test results indicate that all functional indicators can live up to expected targets, which proves that the system can generate CET-4 paper intelligently with good quality.*
Keywords: Intelligent paper generating, Testing system, Invasive weed optimization algorithm, CET-4

1. **Introduction.** With the development of network technology, technological means and testing platforms are undergoing profound changes [1-5]. With advantages of high degree inclusiveness, wide distribution and superb computing power, network online paper generating and testing can break the limitation of time and space and analyze test results in a much easier and faster way [6, 7]. Therefore, internet-based testing system has become a focus in academic research.

For example, Nguyen et al. [8] studied a parallel paper generating system and took test users' special demands for paper into account, so as to meet various needs of different users. Yang et al. [9] proposed an online intelligent paper generating system by using particle swarm optimization algorithm and solved the objective function of paper generation with this algorithm, so that users could choose questions intelligently from the test bank as required and generate an online paper. When random function is used to select test questions, the speed is slow, and teachers feel difficult to evaluate students' mastery of knowledge points. Therefore, based on traditional network test, a random code was put forward to classify and select test questions from a test bank according to test characteristics, which could greatly improve paper generating efficiency and rapidly make a comprehensive analysis of test results [10]. Based on B/S structure and Java software, an automatic paper-generating management system is designed, consisting of User Management sub-system, Subject Management sub-system, Question Management sub-system and Paper Generation sub-system. An efficient algorithm was used in the Paper Generation system, with success rate increasing greatly [11]. Abd El Rahman and Zolait [12] studied an automatic paper-generating teaching system based on computer technology, using shuffling algorithm to design various test sets and intelligent agent technologies to effectively avoid duplication of questions, reduce paper generation time and improve efficiency. For automatic multi-objective optimized paper generation, a study was made on a parallel paper generating system, proposing a self-adaption memetic algorithm according to multiple users' assessment standards, discussing sub-modular properties of collective objective function and designing greedy max's algorithm in order to improve comprehensive properties of the paper generating system [13]. Li et al. [14] analyzed the mechanism of some common paper generating algorithms, such as random selection, genetic algorithm and backtracking heuristic method. In view of long average test time and high repetition rate of the backtracking heuristic method, he improved the mechanism twice and thus enhanced stability of online paper generating system. Li developed a paper generating system to build an engineering-graphics test bank. This system can meet the requirements of both manual and automatic paper generating for engineering graphics, make the test bank suitable for in-class test, practice and self-test, online test and other purposes to meet requirements of online and mobile testing [15]. By combining students' individual information and knowledge acquisition with the crossing procedure and objective function of genetic generation algorithm, an individual genetic generation algorithm was proposed to provide students at different levels with papers of proper constraints on difficulty, differentiation and number of questions [16]. For deeply analyzing basic features of science and engineering test questions, a question bank management and paper generation system based on Excel and LaTaX was developed, with which teachers could flexibly make online management of questions bank with Excel [17]. Dong et al. [18] designed an advanced unsupervised algorithm to built paper-geneating system. Xu [19] built a test bank and on this basis, computer simulation was used to conduct paper generation through designed genetic algorithm. Spider monkey optimization algorithm designed by shaik had great global searching ability and was suitable for paper-generating work [20].

From what are mentioned above, we can discover that some scholars have made some studies on online intelligent paper generating and testing. What is noteworthy is that introduction of genetic algorithm can enable teachers to automatically select papers that meet requirements from test bank. Genetic algorithm is quite superb at multi-objective optimization of intelligent paper generating, but it tends to fall into local optimization and low convergence rate, so there is still a large room for further study [21-23]. Meanwhile, along with increasing international communication, many countries have set up English

courses in colleges and conducted national college English tests [24-26]. At present, traditional manual paper generating is still a dominate way in college English tests, which has the disadvantages of slow speed and low efficiency. Therefore, in order to avoid defects of genetic algorithm, this paper introduces the invasive weed optimization (IWO) algorithm into the study on online intelligent paper generating and testing system of CET-4. This paper is organized as follows. In the forthcoming section, a simplified paper generating model of CET-4 is built. Next, IIWO algorithm is designed and on this basis, the CET-4 online paper generating and testing system is established. Subsequently, paper generating tests and system tests are conducted, with results being analyzed as well. In the final section, conclusions are drawn.

2. **Analysis and Modeling of Online Intelligent Paper Generating of CET-4.** At present, in China, College English test is a national test, with an aim to comprehensively, objectively and exactly check college students' English proficiency and performing of English teaching syllabus. With gradual popularization of computers and network technologies, an increasing number of college students across the world choose to review and simulate tests via computer terminals to prepare for tests. A typical CET-4 paper consist of the following tasks: writing, listening comprehension, reading comprehension and translation. Prior to an online simulation test, an online CET-4 paper should be firstly generated intelligently.

The attributes of a college English test paper are mainly question type, difficulty, reliability, ability differentiation, knowledge points, testing time, question exposure degree, etc. In this way, a paper model containing n questions can be expressed by the following objective matrix:

$$\mathbf{S}(a_{r,k}) = \begin{cases} a_{1,1} & a_{1,2} & \cdots & a_{1,7} \\ a_{2,1} & a_{2,2} & \cdots & a_{2,7} \\ \vdots & \vdots & \vdots & \vdots \\ a_{N,1} & a_{N,2} & \cdots & a_{N,7} \end{cases} \tag{1}$$

In this matrix, each column represents an attribute, and each line represents a question with seven attributes, all together N questions. Thus, matrix $\mathbf{S}$ forms the target state matrix of the paper generating method in this study. Thus, the paper generating task is then transformed into solution of matrix $\mathbf{S}$ with multi-objective constraints by mathematical model. Optimize and solve each parameter in the paper-generating model and then design multi-objective generating algorithm for CET-4 test. Constraints of college English test are mainly as follows:

1) Question type and mark share:

$$\sum_{r=1}^{N} x_1 a_{r1} = g_k \tag{2}$$

Where, k means question type; gk means the mark share of type k, such as writing, listening comprehension, reading comprehension and translation. In CET-4 tests,

$$x_1 = \begin{cases} = 1 & (a_{r1} = k) \\ = 0 & (a_{r1} \neq k) \end{cases}$$

2)Difficulty coefficient:

$$\text{avg} \sum_{r=1}^{N} x_2 a_{r2} = b_k \tag{3}$$

Where, b_k is the evaluation difficulty coefficient of type k, $x_2 = \begin{cases} = 1 & (a_{r2} = k) \\ = 0 & (a_{r2} \neq k) \end{cases}$.

3) Total mark:

$$\sum_{r=1}^{N} a_{r3} = h \tag{4}$$

Where, h is the total score, which is generally 710 in CET-4 tests

4) Question exposure:

$$\sum_{r=1}^{N} a_{r4} = f \tag{5}$$

Where, f is degree of question exposure, which should be as small as possible.

5) Knowledge points:

$$\sum_{r=1}^{N} a_{r5} = x \tag{6}$$

Where, x is number of knowledge points in a paper, which should be as large as possible.

6) Paper differentiation:

$$\sum_{r=1}^{N} a_{r6}/N = y \tag{7}$$

Where, y is paper differentiation degree, which is a sign of paper discriminating power to differentiate CET-4 test takers with different abilities. The larger the value is, the higher the paper differentiation degree is.

7) Testing time:

$$\sum_{r=1}^{N} a_{r7} = u \tag{8}$$

Where, u is set value of total testing time, which is 130 minutes for CET-4 takers.

In actual process of paper generating, the fitness indicator of the entire paper is set as F to truthfully reflect the above seven indicators. F can be obtained through absolute value of error required by users multiplying different weight coefficients, which is shown in Equation (9).

$$F = \sum_{r=1}^{r=7} F_r \beta_r \tag{9}$$

Where, F is fitness of the entire paper; Fr is corresponding error between the r^{th} index and users' requirements; β_r is weight coefficient of the r^{th} index. The smaller value F has, the higher paper quality is.

3. **Study on Online Intelligent Paper Generating and Testing System.**

3.1. **Invasive weed optimization algorithm-based paper generation.**

Invasive weed optimization (IWO) algorithm is proposed by Mehrabian et al. in 2006, which has the advantages of strong robustness, being easy to understand and easy to implement. However, it also has drawbacks of being easy to fall into local optimization and low searching rate [27,28]. Therefore, the basic IWO algorithm is improved in this paper, making it more suitable for CET-4 paper retrieval. The improvements are realized as follows:

(1) In order to increase searching speed and prevent local optimization, we equally divide the solution space into n' sub-spaces and simultaneously produce invasive weeds of n' small groups. Then, we distribute n' small groups into n' sub-spaces for initialization so as to ensure all weeds are equally distributed into solution space and avoid local optimization. Moreover, we use n' small groups to search in solution space simultaneously in order to increase searching speed.

(2) To prevent local optimization, at the stage of space distribution of weeds, we apply random distribution with certain probability. In paper generating based on IWO algorithm, first the "weeds" are encoded (in a binary coding mode in this paper). That is, assume there are i' questions in CET-4 test bank, and call them $y_1, y_2, \ldots y_{i'}$ respectively. Then, select n questions from these i' questions to generate an effective paper and minimize its fitness coefficient F. Hence, we use all binary strings with i' bit, $l_1 l_2 l_3 \ldots l_{i'}$, to express the solution space, in which, $l_{i'} = 0$ or $1 (i = 1 \ldots i')$. If $l_{j'}$ is 1, the question is selected; otherwise, the question is considered being not selected.

Steps of paper generation based on IIWO algorithm are presented as follows:

Step 1: Initialize groups' parameters, such as group number n', group size m', maximum iterations number, maximum seeds number, minimum seeds number, minimum and maximum value of initial search space of independent variable, nonlinear index, initial standard deviation, final standard deviation, and variation probability α, etc.

Step 2: Equally divide the paper solution space into n' sub-spaces and randomly distribute m' weeds into each sub-space.

Step 3: The number of produced seeds during the growth and propagation of each weed ω_n is:

$$\omega_n = \frac{F - F_{\min}}{F_{\max} - F_{\min}} (s_{\max} - s_{\min}) + s_{\min} \tag{10}$$

Where, F is the fitness of current weeds; F_{max} and F_{min} refer to maximum and minimum fitness value respectively; S_{max} and S_{min}, maximum and minimum number of seeds produced by a weed, respectively.

Step 4: Distribution of paper solution space: If mean value of seeds produced by a random number of weeds $Rand() \geq \alpha$ is 0, normal distribution of standard deviation σ is around the weeds, and produced seeds can be obtained by adding D to each dimension. Standard deviation of $D \in [-\sigma, \sigma]$ changes according to Equation (11) with increase of evolution algebra:

$$\sigma_{\text{cur}} = \frac{(iter_{\max} - iter)^{n'}}{(iter_{\max})^{n'}} (\sigma_{\text{init}} - \sigma_{\text{final}}) \tag{11}$$

Where, σ_{cur} is current standard deviation; $iter$ and $itermax$ are current and maximum number of iterations, respectively; σ_{init} and σ_{final} are the initial and final value of standard deviation, respectively; n' is the nonlinear harmonic factor. If the random number $Rand() < \alpha$, it is the weed seeds.

Step 5: Determine whether the maximum group is reached; otherwise, repeat Step 4.

Step 6: Abide by competitive survival rule: After several generations of algorithm evolution, the number of weed seeds may reach the preset maximum group size P_{max}. Rank group weeds and seeds according to paper fitness, take the former P_{max} ones and eliminate the rest.

Step 7: When the algorithm reaches the iterations maximum, the generated paper is the optimal solution; otherwise, repeat Step 3- Step 6.

The flow chat of IIWO algorithm is shown in Figure 1.

3.2. **Realization of online paper generating and testing system.** The background program of this online paper generating and testing system is structured with powerful Spring+Spring MVC+MyBatis system, while its foreground processing is supported by Bootstrap structure on the basis of HTML, CSS and JavaScript. The system enjoys the advantages of simplicity, intuitiveness and faster Web development. Data storage is carried out through MySQL database system with powerful commanding functions, which can not only operate test questions in the database flexibly and accurately, but also can help users visit CET-4 paper generating system easily and effectively so that success rate

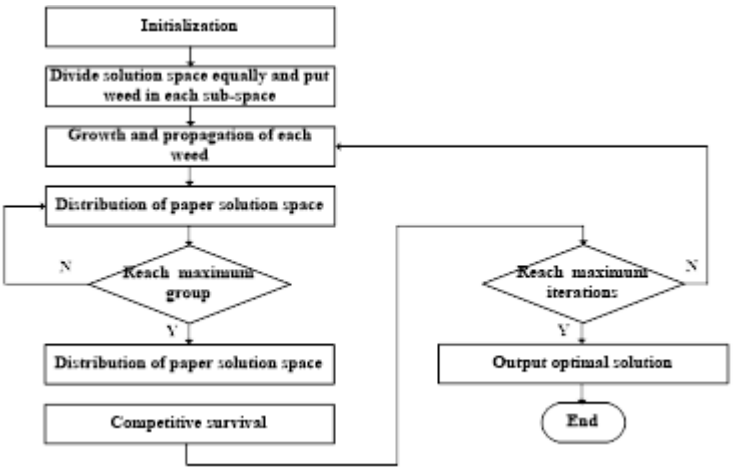

Figure 1. Flow chat of IIWO algorithm

of paper generating can be guaranteed greatly. The CET-4 online paper generating and testing system consists of five modules, user Registration, user Login, Online testing, Paper management and Online marking. Its function module is shown in Figure 2. In

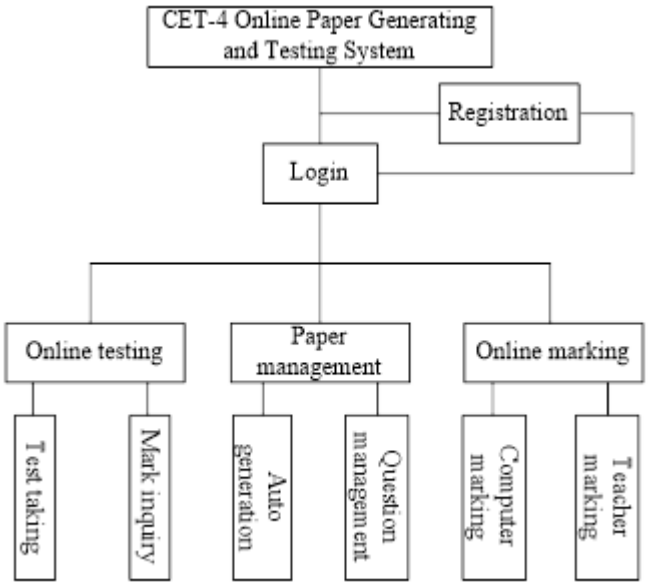

Figure 2. Function modules

Registration and Login module, users are divided into students and teachers, who log in with their own student number or working number after registration. Students can use Online testing module for test taking, mark inquiry, error analysis and error correction, etc. Paper management module is set for teacher users to conduct paper setting and question management, including adding new questions, editing questions, deleting questions, inputting questions in bulk and other functions. "Inputting questions in bulk" means bulk inputting questions from Excel spreadsheet that meet certain requirements, which can greatly improve efficiency of question selection. Online marking module is also set for teacher users. CET-4 questions consist of objective questions and subjective questions. Objective questions are listening comprehension and reading comprehension

(multiple-choice based questions). Subjective questions are writing and translation. Objective questions are automatically marked by computers, while subjective questions are co-marked by machines and teachers. Figure 3 is the mark statistics interface of Online marking module, and Figure 4 is the online marking interface.

Figure 3. Mark statistics interface

Figure 4. Online marking interface

4. **Paper Generating and System Test.**

4.1. **Paper generating test.** Simulation tests for CET-4 paper generation, with IWO algorithm and the IIWO algorithm are carried out respectively based on standard question bank. The question banks are writing question bank, listening comprehension question bank, reading comprehension question bank and translation question bank, etc. Each sub-bank has 6,000 questions. A generated paper includes the following tasks: writing (1 task), listening comprehension (25 tasks), reading comprehension (30 tasks) and translation (1 task). Question types and mark share are as shown in Table 1.

Table 1. Question type and mark share in a paper.

Question type	Mean	Std
Writing	1	106.5
Listening comprehension	25	248.5
Reading comprehension	30	248.5
Translation	1	106.5

In the two algorithms, the fixed group size is 100 individuals, evolution algebra is the average fitness of 150th generation and convergence curve is shown in Figure 5. From Figure 5, it can be drawn that at the beginning of iteration, average fitness coefficient of IIWO algorithm is higher than that of basic IWO due to random factors. However, because the spatial distribution of IIWO group is more uniform and scientific, it can find the optimal solution easily with faster searching speed, reaching the optimal value 0.1806 at the 24th iteration. By contrast, the basic IWO algorithm reaches the optimal value 0.1904 at the 68th iteration. Besides, optimization accuracy of IIWO is 5.14% higher than that of IWO. After the same constraint conditions are set, the relation between group size

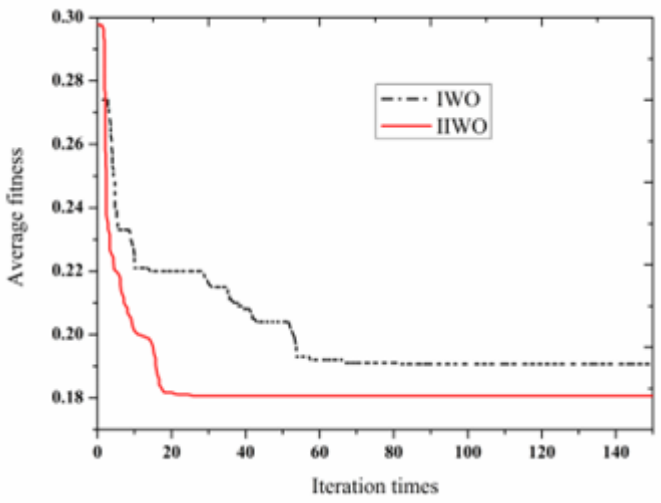

Figure 5. Average fitness and convergence curve

and fitness of the two algorithms is shown in Figure 6. Figure 6 indicates that when the group size is small, the contrast between the two algorithms is not obvious. However, with the group size increasing, the group distribution of IIWO algorithm is more uniform and scientific in the solution space, and it can continue to search the optimal value to avoid premature convergence and speed up convergence. After the same constraint conditions are set, the relation between group size and working time of the two algorithms is shown in Figure 7. With groups changing, IIWO algorithm always spends less working time than basic IWO algorithm, showing certain advantages in time-saving. Based on above analysis, IIWO algorithm has stronger comprehensive capacity and higher efficiency than IWO algorithm in paper generating. In addition, a key index to assess paper quality is the error, i.e. errors of target values of paper generating parameters against their actual values. To examine quality of automatic paper generating of IIWO, 20 papers were automatically generated with this algorithm for error comparison. Target values of each paper are like this: difficulty coefficient, 0.55, differentiation coefficient, 0.5, and testing time, 130 minutes. The test results are shown in Table 2, which suggests that all

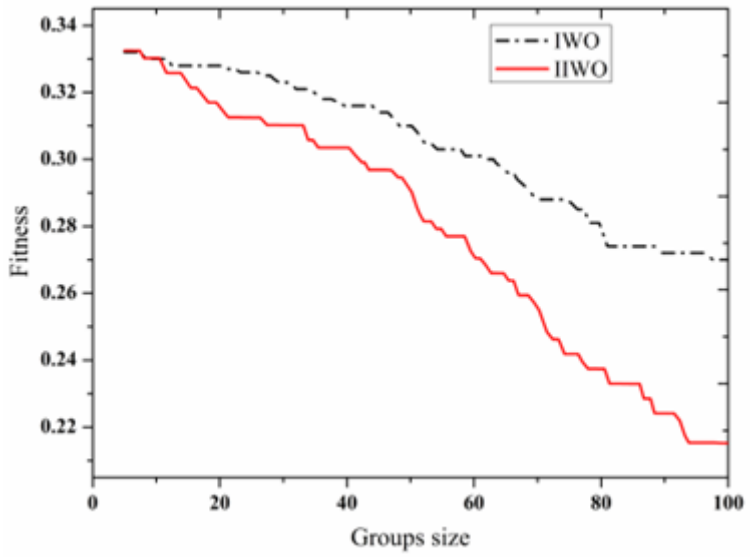

Figure 6. Relation curves of group size and fitness

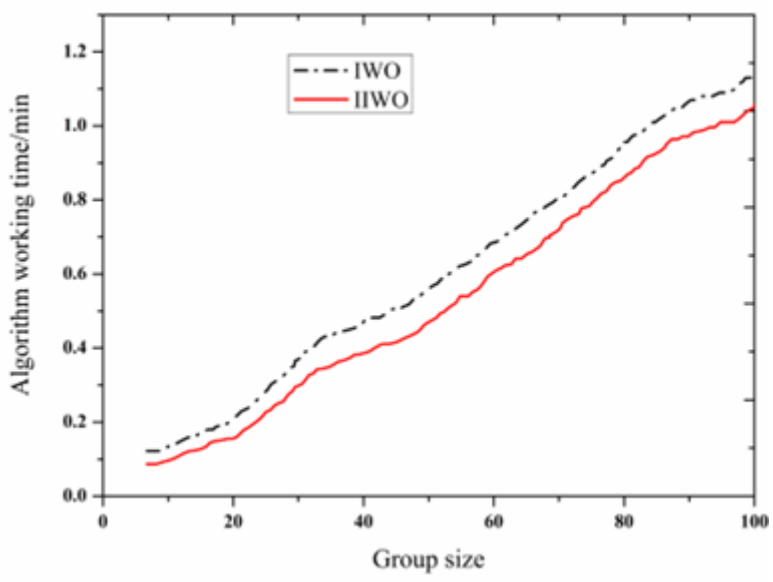

Figure 7. Relation curves of group size and working time

targets of these 20 papers automatically generated with IIWO algorithm are within the error margin. Based on experts' assessment, the 20 test papers are reliable and applicable in real use.

Table 2. Error test results of paper generation.

	Total time	Difficulty	Testing time	Differentiation
Target value	130min	0.55	130min	0.50
Maximum value	130min	0.28	134min	0.54
Minimum value	130min	0.53	127min	0.47
Average value	130min	0.54	131min	0.49

4.2. **System test.** As is well-known that system effectiveness and reliability can be verified through a system test. To ensure effectiveness and reliability of the developed testing system in practical use, a strict test for this system is needed to verify its function and performance. According to software testing theory, black-box and white-box testing methods are typical for system testing. Therefore, this paper applies the black-box testing method. The black-box testing is carried out by taking a function module as a black box, laying emphasis on input and output outside the box and focusing on whether a function can be accurately implemented as defined by requirements analysis and whether different input data can get the due output data. Black-box testing is carried out in the following five modules: user Registration, user Login, Paper management, Online testing and Online marking. Table 3 lists some important test cases at users' side, and records test results of each case.

To sum up, a function test is conducted for this online paper generating and testing system and Table 3 shows that all function parameters of the system can reach their expected targets with easy operation and eye-pleasing system interface.

Table 3. Test table of intelligent paper generating and testing syste.

Case No.	Function unit	Function testing	Function description	Test result	Function unit
1	Registration module	Adding student users	Adding student users and initial password	Successfully added	Registration module
2	Login module	Login authentication	Verifying administrator identity	Successfully verified	Login module
3	Paper management module	Adding questions	Adding new questions	Successfully added	Paper management module
4		Setting paper generating parameters	Setting parameters for paper generation	A paper successfully generated	
5	Online testing module	Answer saving	Real-time answers saving	Successfully saved	Online testing module
6		Mark inquiry	Inquiring a student's mark	Inquiry completed	
7	Online marking module	Marking by a computer	Marking paper by a computer	Successfully marked	Online marking module
8		Mark output	Outputting mark to EXCEL	Successfully output	

5. **Conclusion.** The development of network technology provides a powerful technical support for online college English tests. With the aim to enhance quality and efficiency of CET-4 paper generating, this study proposes a simplified paper generating model. Then, the basic IWO algorithm is improved by introducing the operation of uniformly spreading weed groups in solution space and randomly spreading them with certain probability, so as to increase its optimizing speed and avoid local optimization. Thus, the improved invasive weed optimization algorithm is used in paper generating. The test results of average fitness, algorithm working time and paper errors show that IIWO algorithm has higher efficiency and quality in paper generating. On this basis, this paper develops an online testing system for CET-4 and the black-box testing shows that all function parameters of this system have reached their expected targets and can meet the demand of online college English test.

The online paper generating and testing system designed in this paper combines network platforms and computers or mobile phones so that students can take exams with no geographical restrictions. It is very conductive to enhance students' learning efficiency and create learning convenience, saving much educational source. However, it needs

to be further verified whether IIWO algorithm is suitable for other paper-generation systems, like CET-6, TEM-4 and TEM-8. As a result, 0ur future work should explore the application of IIWO algorithm in other testing systems to reduce teachers' burden of paper generating and provide effective learning for test takers.

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