Multiple Test Forms Construction based on Bees Algorithm

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Abstract. This paper proposes a new construction method of multiple test forms that applies a Bees Algorithm and a parallel computation technique to improve the computational costs of the traditional methods.

1 Introduction

Educational assessments occasionally need “multiple test forms” in which each form consists of a different set of items but still has qualities that are equivalent to the others. In order to construct multiple test forms, e-testing, which accomplishes automated test construction, has recently become popular in research areas involving educational measurement. In order to construct multiple test forms, several methods have been proposed to construct all forms of a test to satisfy the same test constraints to ensure that all forms have equivalent qualities. However, the main problem with traditional methods of constructing multiple test forms to maximize the equivalent between test forms is the trade-off between the fitting errors to test constraints and computational costs. The main purpose of the research discussed in this paper is to solve this problem.

2 Method of Constructing Multiple Test Forms Based on Bees Algorithm in Parallel Computing

The main idea behind this research is to alleviate the trade-off by applying a parallel-computing technique that divided the computational costs between multiple processors without increasing the differences in fitting errors.
It is possible to effectively install a parallel-computing technique into random-search methods. Several studies have used random-search methods in parallel computing to solve optimization problems [1] [2].
Furthermore, some studies have compared the efficiencies of random-search algorithms [3] [4]. The results of these studies revealed Bees Algorithm (BA) performed the high performances in searching for optimal solutions. Moreover, the problems in [3] [4] and the multiple test construction are combinatorial optimization problems which are classified as NP-hard as the multiple test construction. Therefore, we propose a method of constructing multiple test forms based on BA in parallel computing to alleviate the trade-off between computational costs and differences in fitting errors. This method constructs multiple equivalent test forms by minimizing the difference in fitting errors between test forms.
The construction of multiple test forms has a time complexity of $O(c \cdot m! \cdot 2^{f})$, where c is the number of test constraints, m is the number of items in an item bank, and f is the number of constructed test forms that satisfy all test constraints. To reduce the computational time, we divided the construction of test forms into two steps:
Step A: Construct test forms only to minimize the fitting errors of each form to test constraints without taking into consideration the equivalence of test forms. Therefore, the

time complexity of this step is $O(c \cdot m!)$. Here, the constructed test forms are still not equivalent.
Step B: Extract the most equivalent set of test forms from the constructed test forms in Step A that minimizes the difference in fitting errors between test forms. The time complexity in this step is $O(2^f)$.
The time complexity for constructing test forms is reduced from $O(c \cdot m! \cdot 2^f)$ to $O(c \cdot m! + 2^f)$. The BA is applied as a search algorithm to both steps.

3 Evaluation

We compared the proposed method (BA) with the Big-Shadows Test (BST) method [5] and a genetic algorithm for multiple test construction (GA) to demonstrate its accuracy and speed in constructing multiple test forms. BA, BST, and GA construct multiple test forms to minimize the fitting errors indicted by the differences between the expected test information function and the test information function of the constructed test forms at five levels of abilities and to minimize the difference in the fitting errors. Before constructing test forms, we define the target values of the expected test information function. We used three actual item banks from the Japan Information Technology Engineers' Examination that had total numbers of items of 517, 978, and 2385.The total numbers of test constraints corresponding to each item bank were 32, 57, and 112 and the total numbers of test items were 20, 50, and 80. The results obtained from this experiment indicate that the proposed method improves the traditional construction of multiple test forms.

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