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Construction of Mixed Covering Arrays Using a Combination of Simulated Annealing and Variable Neighborhood Search

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Abstract

The construction of Mixed Covering Arrays (MCA) with the minimum number of rows has been a problem faced in different ways. This paper aims to construct near optimal MCAs through a novel approach based on Simulated Annealing (SA) and Variable Neighborhood Search (VNS). The solution quality of the proposed algorithm was measured by solving two benchmarks and the obtained results show a significant quality improvement over the results of previously reported metaheuristics.

Keywords: Mixed Covering Arrays, Simulated Annealing, Variable Neighborhood Search

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1 Introduction

The Mixed Covering Arrays (MCAs) are combinatorial structures that have been applied successfully for designing test suites for software *interaction testing* [11]. The problem of constructing MCAs with arbitrary numbers of features (columns) and the minimum number of required tests (rows) is very important. An MCA denoted by $MCA(N; t, k, v_0 v_1 \dots v_{k-1})$ is an $N \times k$ array, where the values for the i-th column comes from an alphabet of size v_i where $0 \leq i \leq k-1$, and must satisfy that all column combinations of size t contains at least the elements of the set: $\{v_{i_0} \times v_{i_1}, ..., \times v_{i_{t-1}}\}$. A short notation for an MCA can be given using the exponential notation writing $v_0^{u_0} v_1^{u_1} \dots v_{i-1}^{u_i - 1}$ to indicate that there are u_i columns with cardinality v_i. An example of an $MCA(6; 2, 4, 3^1 2^3)$ in its transposed form is shown in Figure 1.

0	1	1	0	0	1
0	1	0	1	1	0
0	1	0	1	0	1
0	0	1	1	2	2

Fig. 1. Transposed matrix of an $MCA(6; 2, 4, 3^1 2^3)$.

It is not known if the Covering Array Construction (CAC) problem is NP-complete [12], however some related problems are NP-complete [4]. Also, there is only some special cases for which exists polynomial time algorithms to construct Covering Arrays [4].

The proposed algorithm combines the foundations and advantages of Simulated Annealing (SA) and Variable Neighborhood Search (VNS), we have called the algorithm as SAVNS. The motivation of the SAVNS algorithm comes out from the many papers that reported the success of using SA and VNS independently, and hybrid implementations of VNS [14,3].

2 Proposed Approach

This section presents the proposed SAVNS algorithm, SAVNS comprehends: an initial solution; an evaluation function; a set of neighborhood functions; a cooling schedule; and a combination of SA and VNS.

The **initial solution** is a matrix $\mathcal{M}$ obtained by adding random generated rows with maximum Hamming distance as stated in [1].