Solving Multimodal Combinatorial Puzzles with Edge-Based Estimation of Distribution Algorithm

Warin Wattanapornprom
Department of Computer Engineering,
Faculty of Engineering
Chulalongkorn University, Bangkok, Thailand
+66-(0)80-935-6789
yongkrub@gmail.com

Prabhas Chongstitvatana
Department of Computer Engineering,
Faculty of Engineering
Chulalongkorn University, Bangkok, Thailand
+66-(0)85-144-2579
Prabhas.C@chula.ac.th

ABSTRACT

This article compares two edge-based Estimation of Distribution Algorithms named Edge Histogram Based Sampling Algorithm (EHBSA) and Coincidence Algorithm (COIN) in multimodal combinatorial puzzles benchmarks. Both EHBSA and COIN make use of joint probability matrix of adjacent events (edge) derived from the population of candidate solutions. These algorithms are expected to be competitive in solving problems where relative relation between two nodes is significant. The experiment results imply that EHBSAs are better in convergence to a single optima point, while COINs are better in maintaining the diversity among the population and are better in preventing the premature convergence.

Categories and Subject Descriptors

[Evolutionary Combinatorial Optimization and Metaheuristics] [Estimation of Distribution Algorithm]

General Terms

Combinatorial Optimization, Multimodal Combinatorial Problem, N-Queens Puzzle, Knight's Tour Puzzle, Magic Square

Keywords

Combinatorial Optimization, Multimodal Combinatorial Problem, N-Queens Puzzle, Knight's Tour Puzzle, Magic Square, Edge Histogram Based Sampling Algorithm, Coincidence Algorithm and Negative Correlation Learning

1. INTRODUCTION

Recently, there has been a growing interest in developing evolutionary algorithms based on probabilistic models called Estimation of distribution Algorithms (EDAs). In this scheme, the candidate solutions are generated according to the estimated probabilistic model of the previous selected solutions instead of using tradition recombination and mutation operators. The outstanding algorithms used to solve the problem in permutation representation domains are Edge histogram based sampling Algorithms (EHBSAs) [1] and Node histogram based sampling Algorithms (NHBSAs) [2] proposed by Tsutsui.

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Previously, we propose a novel evolutionary algorithm based on probabilistic model named Coincidence Algorithms (COINs) [3] which utilize the undesired solutions incorporate with the traditional desired solutions in order to construct a probabilistic model based on edge representation. The proposed algorithms have been successfully applied to many real world applications including travelling salesperson problems (TSP), multi-objective scheduling, sequencing, and worker allocation problems [4].

In this article, we compare EHBSA and COIN in several combinatorial puzzles without using a problem specific heuristics or bias in order to show some properties of COINs in solving multimodal and multi-objective problems.

2. EDGE HISTOGRAM BASED SAMPLING ALGORITHMS

Edge Histogram Based Sampling Algorithms (EHBSAs) was proposed by Tsutsui in 2002. EHBSAs were designed to solve combinatorial problems and have shown the competitive performance in solving many real world applications including traveling salesman problems (TSP), flow shop scheduling problems and capacitated vehicle routing problems. In permutation scheme, the models of solutions can be represented as a graph of nodes connected by edges. EHBSAs utilize Edge Histogram Matrix (EHM) to learn the mutual information of edges contained in the selected solutions and then construct new solutions by sampling from it. The idea of EHBSA is to use the edge recombination (ER) in genetic algorithms with the whole selected population instead of tradition two-parent recombination.

3. COINCIDENCE ALGORITHMS

Coincidence algorithms (COIN) can be considered as an incremental version of edge histogram based sampling algorithm (EHBSA). However, the extended idea of COIN is to allow learning from the below average solutions as well as the traditional learning from the good solutions. The coincidences (refer to as edge in EHBSA) found in a situation should be able to statistically describe the chance of the situation to be happening whether the situation is good or bad. Thus the learning of the coincidence found in the bad solutions should be used to avoid the bad situation as well.

4. EMPIRICAL STUDY

4.1 Test Suite and Performance measure

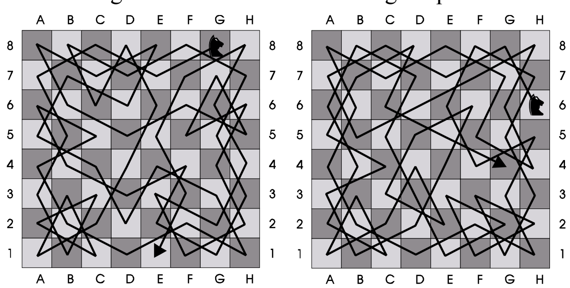
The steps of both algorithms are similar to standard EDAs except for the step of COIN which need to select two groups of candidates, good and not-good, in order to update the joint probability matrix.

We compare EHBSA and COIN with two classes of combinatorial problems that are permutation and combination. The permutation problems include 8-Queens puzzles, 3x3 magic square, 4x4 magic square and knight's tour problems while the combination problems include 8-Queens, 8-rooks, 14-bishops and 32-knights puzzles. Figure 1 shows the sample solutions.

2	7	6
9	5	1
4	3	8

12	6	15	1
13	3	10	8
2	16	5	11
7	9	4	14

(a) A sample of magic squares solutions
Left is the solution of 3x3 magic square
Right is the solution of 4x4 magic square



(b) Two of the solutions generated by the coincidence algorithm.
Left is the first open tour.
Right is the first closed tour.

Figure 1. Sample solutions of the permutation problems.

We apply different configuration of population size and number of generation which total number of evaluation is smaller than the solution/space ratio. The bias ratio B_{ratio} of EHBSA is 0.005 were used in all experiments while the learning rate k of COIN is set to be 0.05. The selection pressure of EHBSA is 50% of the whole population, while COIN uses 25% for both reward and punishment. We evaluate the algorithm by measuring their ANE (average number of evaluations to find the first global optimum) #SOL (average number of solution found within the given number of evaluations) and #DSOL (average number of distinct solution found within the given number of evaluations)

4.2 Empirical Analysis of Results

Summary results of all benchmarks are shown in Table 1. The behaviors of each algorithm in knights puzzles are shown in figure 2. From the overall perspective, EHBSA seems to outperform COIN in the combination problems as EHBSA can converge to the solution faster than COIN. However COIN can find more distinct solutions than EHBSA because COIN tries to maintain all of the possible substructures in order to compose them. COIN performs better than EHBSA in magic square problems, as COIN also learn the negative correlation of the bad solutions.

Table 1. Performance of EHBSA vs. COIN in Combinatorial Puzzles

Problem	Algorithm					
	EHBSA			COIN		
	ANE	#SOL	#DSOL	ANE	#SOL	#DSOL
8 Queens-P	8	25	4	8	21	13
8 Queens-C	1821	78	4	3651	10	9
8 Rooks	25	2457	495	454	4	4
14 Bishops	419	408	4	1070	45	8
32 Knights	N/A	0	0	N/A	0	0
Knight's Tour	N/A	0	0	154	2816	2759
3x3 Magic Square	N/A	0	0	35	40	2
4x4 Magic Square	N/A	0	0	N/A*	0	0

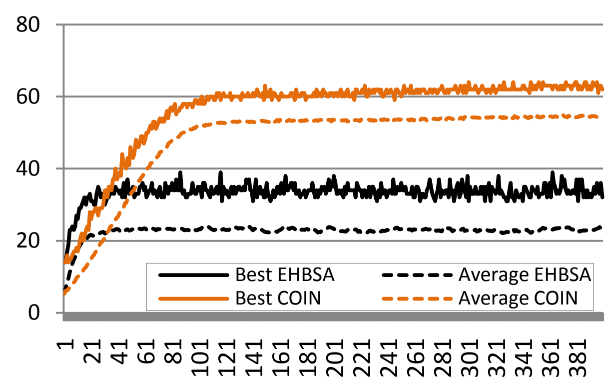


Figure 2. Performance of EHBSA vs. COIN in Knight's Tour problem

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