Jens Gottlieb
Günther R. Raidl (Eds.)

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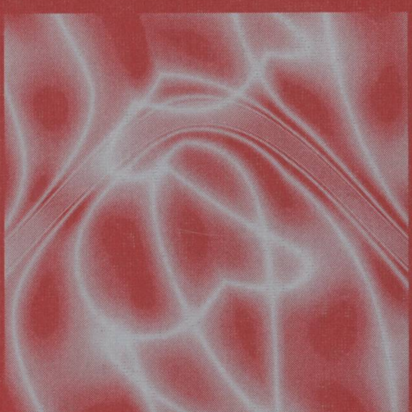
Evolutionary Computation in Combinatorial Optimization

4th European Conference, EvoCOP 2004
Coimbra, Portugal, April 2004
Proceedings



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Evolutionary Computation in Combinatorial Optimization

4th European Conference, EvoCOP 2004
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Preface

Evolutionary Computation (EC) involves the study of problem solving and optimization techniques inspired by principles of natural evolution and genetics. EC has been able to draw the attention of an increasing number of researchers and practitioners in several fields. Evolutionary algorithms have in particular been shown to be effective for difficult combinatorial optimization problems appearing in various industrial, economic, and scientific domains.

This volume contains the proceedings of EvoCOP 2004, the 4th European Conference on Evolutionary Computation in Combinatorial Optimization. It was held in Coimbra, Portugal, on April 5–7, 2004, jointly with EuroGP 2004, the 7th European Conference on Genetic Programming, and EvoWorkshops 2004, which consisted of the following six individual workshops: EvoBIO, the 2nd European Workshop on Evolutionary Bioinformatics; EvoCOMNET, the 1st European Workshop on Evolutionary Computation in Communications, Networks, and Connected Systems; EvoHOT, the 1st European Workshop on Hardware Optimisation; EvoIASP, the 6th European Workshop on Evolutionary Computation in Image Analysis and Signal Processing; EvoMUSART, the 2nd European Workshop on Evolutionary Music and Art; and EvoSTOC, the 1st European Workshop on Evolutionary Algorithms in Stochastic and Dynamic Environments.

EvoNet, the European Network of Excellence in Evolutionary Computing, organized its first events in 1998 as a collection of workshops that dealt with both theoretical and application-oriented aspects of EC. EuroGP, one of these workshops, soon became the main European conference dedicated to Genetic Programming. EvoCOP, held annually as a workshop since 2001, followed EuroGP. Due to its continuous growth in the past, EvoCOP became a conference in 2004, and it is now the premier European event focusing on evolutionary computation in combinatorial optimization. The events gave researchers and practitioners an excellent opportunity to present their latest research and to discuss current developments and applications, besides stimulating closer future interaction between members of this scientific community. Accepted papers of previous EvoCOP events were also published by Springer in the series Lecture Notes in Computer Science (LNCS Volumes 2037, 2279, and 2611).

EvoCOP 2004 covers evolutionary algorithms as well as related metaheuristics like memetic algorithms, ant colony optimization, and scatter search. The papers deal with representations, operators, search spaces, adaptation, comparison of algorithms, hybridization of different methods, and theory. The list of studied combinatorial optimization problems includes on the one hand classical academic problems such as graph coloring, network design, cutting, packing, scheduling, timetabling, the traveling salesperson problem, and vehicle routing, and on the other hand specific real-world applications.

The success of EvoCOP, so far the only international series of events specifically dedicated to the application of evolutionary computation and related methods to combinatorial optimization problems, is documented by a steadily growing number of submissions; see the table below. EvoCOP 2004 is the largest event of its series. A double-blind reviewing process made a strong selection among the submitted papers, resulting in an acceptance rate of 26.7%. All accepted papers were presented orally at the conference and are included in this proceedings volume. We would like to give credit to the members of the program committee, to whom we are very grateful for their quick and thorough work.

EvoCOP	submitted	accepted	acceptance ratio
2001	31	23	74.2%
2002	32	18	56.3%
2003	39	19	48.7%
2004	86	23	26.7%

EvoCOP 2004 was sponsored, for the last time, by EvoNet, whose activity as an EU-funded project has come to an end with the organization of this year's events. However, the figures reported above show that EvoCOP, as well as EuroGP and the EvoWorkshops, have reached a degree of maturity and scientific prestige that will allow the activity promoted by EvoNet during the last six years to go on, and presumably further expand in the years to come.

The organization of the event was made possible thanks to the active participation of several members of EvoNet. In particular, we want to thank Jennifer Willies, EvoNet's administrator, for her tremendous efforts.

April 2004

Jens Gottlieb
Günther R. Raidl

Organization

EvoCOP 2004 was organized jointly with EuroGP 2004 and the EvoWorkshops 2004.

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EvoCOP Contributions

Mutation Multiplicity in a Panmictic Two-Strategy Genetic Algorithm

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Abstract. Fitness based selection procedures leave majority of population individuals idle, that is, they don't take place in any recombination operation although some of them have above average fitness values. Based on this observation, a two-phase two-strategy genetic algorithm using a conventional strategy with multiple mutation operators in the first phase is proposed. In the second phase, those individuals that are not sufficiently recombined in the first phase are reconsidered within a second strategy and recombined using multiple mutation operators only. In the second strategy, mutation operator probabilities are adaptively determined based on the cumulative fitness-gain achieved by each mutation operator over a number of generations. The proposed genetic algorithm paradigm is used for the solution of hard numerical and combinatorial optimization problems. The results demonstrate that the proposed approach performs much better than the conventional implementations in terms of solution quality and the convergence speed.

1 Introduction

Genetic algorithms (GA's) are biologically inspired search procedures that have been used successfully for the solution of hard numerical and combinatorial optimization problems. While successful applications of the standard implementation are presented in many scientific and industrial fields, there also has been a great deal on the derivation of various algorithmic alternatives towards faster and better localization of optimal solutions. In order to determine the most efficient ways of using GA's, many researchers have carried out extensive studies to understand several aspects such as the role and types of selection mechanisms, types of chromosome representations, types and application strategies of the genetic operators, parallel implementations, and hybrid algorithms [1], [2], [3].

This paper introduces a novel genetic algorithms strategy in which a population is evolved using a GA in which two different strategies are implemented in two consecutive phases. In the implementation of the proposed approach, it is implicitly assumed that the population is actually divided into two subpopulations; high fitness individuals that are frequently recombined during the first phase are stored within one subpopulation, whereas the individuals for which

J. Gottlieb and G.R. Raidl (Eds.): EvoCOP 2004, LNCS 3004, pp. 1–10, 2004.

the number of recombinations is below a predefined threshold are members of the second subpopulation. The main motivation and ideas leading the development of the proposed two-phase two-strategy GA are based on the following observation: due to selection procedures favoring individuals with higher survival capacity for recombination, most of the recombined individuals have fitness values above the population average. As it is also illustrated in the next section, only a very small percentage of individuals having below-average fitness enters the mating pool. Hence, the genetic algorithm steps are actually applied on an elite subset of the population, while individuals outside this subset are generated and wasted without being touched. Then, one may simply think of a population as if it is partitioned into two subpopulations implicitly created by fitness-based selection procedures. Since average fitness and ratio of above average individuals change over generations, the sizes of subpopulations are not fixed.The first phase of the proposed approach includes the application of a conventional GA with a single crossover operator and multiple mutation operators on the whole population. Then, the number of recombination operations performed on each parent individual is considered, and elements of the subpopulation to be processed in the second phase are determined. Since the majority of individuals within this subpopulation have below-average fitness and, hence, do not carry good solution properties, crossover operations between them will most probably not result in fitness improvements. However, one can make use of these individuals to provide further genetic diversity within a population by mutating them with multiple mutation operators.

The idea of using multiple mutation operators is an inspiration from nature; it is known that several mutation mechanisms such as point mutations, insertions, deletions, inversion, etc. occur simultaneously in nature [4]. In both phases, selection of mutation operators is based on a performance-directed scheme in which effectiveness of each operator is observed over a number of generations and operators with higher total fitness gain have higher probabilities of being selected. In the first phase, a selected mutation operator generates only one offspring with its associated small mutation probability, whereas, in the second phase, each selected mutation operator is allowed to generate more than one offspring based on its effectiveness. This is because, only mutation operators are used in the second phase. In this respect, currently the most effective mutation operator (the one with highest fitness gain) is applied on a parent for K_m times, where K_m is a predefined integer constant, whereas the least effective one is used to generate a single offspring only. The numbers of applications for the other mutation operators are determined with linear scaling. During the two phases, fitness values of the offspring individuals are computed and the mutation operator probabilities are updated based on these fitness values. A new generation begins with the first phase where the new panmictic population is the combination of individuals within the two offspring subpopulations generated in the current two phases. The implementation details of the proposed two-phase two-strategy GA approach are presented in Section 3.

This paper is organized as follows. The statistical reasoning behind the two-phase approach is introduced in Section 2. Section 3 covers the implementation details of the two-phase two-strategy GA paradigm. Experimental framework and obtained results are demonstrated in Section 4. Finally, conclusions and future research directions are specified.

2 Statistical Reasoning

The roulette-wheel and the tournament selection methods are the two most commonly used selection mechanisms in genetic algorithms. Both of these selection methods are fitness-based and they aim to produce more offspring from individuals having higher survival capacity. However, these selection operators leave a significant number of individuals having close to average fitness value unused in the sense that these individuals don't take part in any recombination operation.

In order to understand the above reasoning more clearly, let's take the minimization problem for the Ackley's function of 20 variables. A genetic algorithm with 200 individuals, uniform crossover with a crossover rate 0.7 and a point-mutation operator with probability 0.1 is considered. Since it is more commonly used, the tournament selection operator is selected for illustration. Statistical data are collected over 1000 generations. First, the ratio of the unused individuals to population size is shown in Figure 1. Obviously, on the average, 67% of the individuals remain unused in all generations, they are simply discarded and replaced by the newly produced offspring. This ratio of unused individuals is independent of the selection and encoding methods used; however, it changes with the population size. For example, this ratio is 56% for 100 individuals and 71% for 400 individuals.

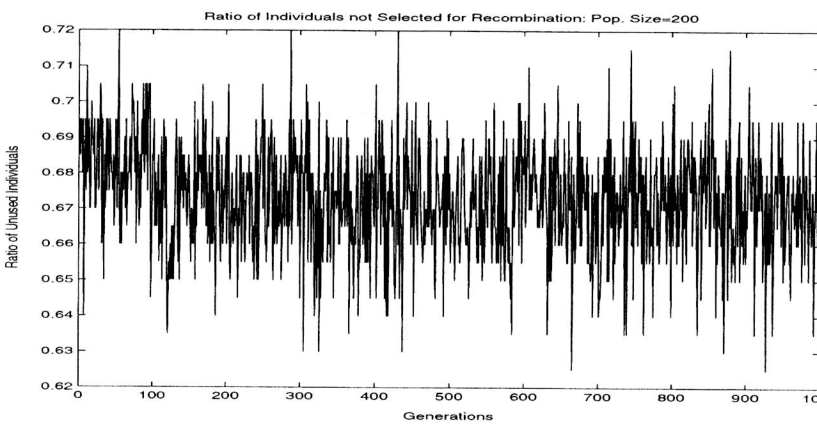

Fig. 1. The ratio of unselected individuals for a population size = 200

A more clear insight can be obtained from the ratio of unused individuals having a fitness value greater than the population's average fitness. As illustrated in Figure 2, on the average, 64% of the individuals having a fitness value above the population average are not used at all in any recombination operation.

Based on the above observations, the proposed approach is based on the following idea: a significant percentage of these idle individuals can be used to extend the genetic variance within the population. That is, when these individuals are mutated with multiple and adaptively selected mutation operators, it is possible to provide additional exploration over the solution space as exemplified and demonstrated by experimental evaluations in Section 4. In addition, while intensification is implemented within a subpopulation of superior individuals, pure diversification is achieved within another subpopulation through multiple adaptively selected mutation operators.

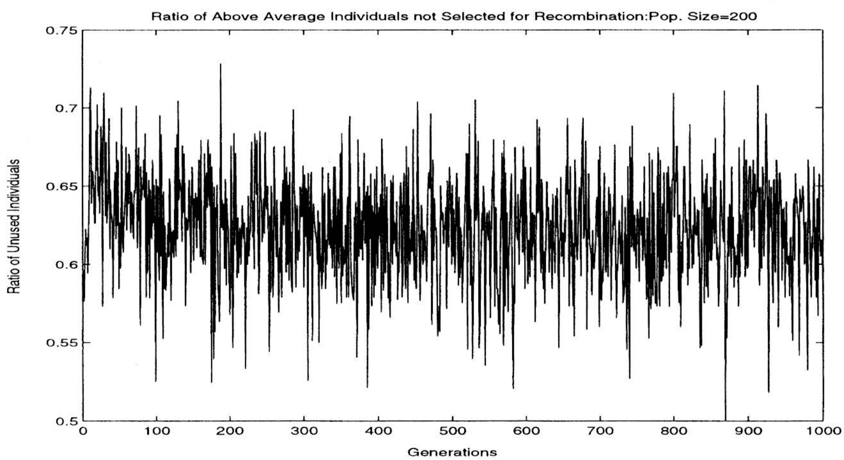

Fig. 2. The ratio of unselected individuals with above average fitness for a population size = 200

3 The Proposed Approach

Let's recall that, the main idea behind the proposed approach is to use two consecutive GA strategies to evolve a population which is implicitly divided into two subpopulations by fitness-based selection procedures. A conventional GA strategy empowered with multiple mutation operators is used to evolve a subpopulation of those individuals which are most frequently selected by a fitness-based selection procedure, whereas the subpopulation containing almost idle individuals is evolved with a mutation-only GA strategy. Mutation operators to be used are predefined and indexed using a mutation operators' index vector ($MOIV$). After initializing the population, $P(0)$, and finding the fitness values of individuals using the fitness function $F(.)$, mutation probabilities to be used in both phases are initialized to $1/|MOIV|$ for all mutation operators. There are