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Preface

The focus of the Asian Applied Computing Conference (AACC) is primarily to bring the research in computer science closer to practical applications. The conference is aimed primarily at topics that have immediate practical benefits. By hosting the conference in the developing nations in Asia we aim to provide a forum for engaging both the academic and the commercial sectors in that region. The first conference "Information Technology Prospects and Challenges" was held in May 2003 in Kathmandu, Nepal. This year the conference name was changed to "Asian Applied Computing Conference" to reflect both the regional- and the application-oriented nature of the conference.

AACC is planned to be a themed conference with a primary focus on a small set of topics although other relevant applied topics will be considered. The theme in AACC 2004 was on the following topics: *systems and architectures*, *mobile and ubiquitous computing*, *soft computing*, *man machine interfaces*, and *innovative applications for the developing world*.

AACC 2004 attracted 184 paper submissions from around the world, making the reviewing and the selection process tough and time consuming. The selected papers covered a wide range of topics: genetic algorithms and soft computing; scheduling, optimization and constraint solving; neural networks and support vector machines; natural language processing and information retrieval; speech and signal processing; networks and mobile computing; parallel, grid and high-performance computing; innovative applications for the developing world; cryptography and security; and machine learning. Papers were primarily judged on originality, presentation, relevance and quality of work. Papers that had clearly demonstrated results were given preference.

AACC 2004 not only consisted of the technical program covered in this proceedings but also included a workshop program, a tutorial program, and demo sessions. Special thanks are due to the general chair, Lalit Patnaik for the overall organization of the conference both in 2003 and 2004. Thanks are due to the tutorial chair Rajeev Kumar for looking after the tutorial program. The conference would not have been possible without the local organization efforts of Deepak Bhattarai and Sudan Jha. Thanks are due to Thimal Jayasooriya for help with the proofreading.

We would like to thank the program committee members for their efforts, and our reviewers for completing a big reviewing task in a short amount of time. Finally, we would like to thank all the authors who submitted papers to AACC 2004 and made possible a high-quality technical programme.

August, 2004

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Effective Evolutionary Multimodal Optimization by Multiobjective Reformulation Without Explicit Niching/Sharing

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Abstract. In this paper, we revisit a general class of multimodal function optimizations using Evolutionary Algorithms (EAs) and, in particular, study a reformulation of multimodal optimization into a multiobjective framework. For both multimodal and multiobjective problems, most implementations need niching/sharing to promote diversity in order to obtain multiple (near-) optimal solutions. Such techniques work best when one has *a priori* knowledge of the problem - for most real problems, however, this is not the case. In this paper, we solve multimodal optimizations reformulated into multiobjective problems using a steady-state multiobjective genetic algorithm which preserves diversity without niching. We find diverse solutions in objective space for two multimodal functions and compare these with previously published work. The algorithm without any *explicit* diversity-preserving operator is found to produce diverse sampling of the Pareto-front with significantly lower computational effort.

1 Introduction

Evolutionary Algorithms (EAs) search a solution space from a set of points and are, therefore, attractive compared to traditional single-point based methods for those optimization domains which require multiple (near-) optimal solutions. Multimodal optimization (MMO) and multiobjective optimization (MOO) are two classes of optimizations belonging to this category. Having found multiple optimal or near-optimal solutions, a user selects a single solution or a subset of solutions based on some criterion. The problem solving strategy, therefore, should provide as many diverse solutions as possible.

In this context, niching/sharing techniques have been commonly employed to find a diverse set of solutions although such techniques work best when one has *a priori* knowledge of the problem. If the number of niches, a sharing function employing user-defined parameters computes the extent of sharing and may produce multiple (near-) optimal solutions. The technique has been employed by many researchers in the past, *e.g.*, [1-6] on many multimodal problems represented by analytic functions whose multimodality was known. However, in most real-world problems the analytical form is unknown, prior visualization of the solution set is not possible and the proper selection of niche formation parameters is problematic. Knowing the number of niches beforehand is a paradox since this implies one has *a priori* knowledge of the solution set. In actuality, most of the work related to multimodal optimization using

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EAs has been done to *test* the efficacy of EAs in solving *known* problems rather than solving *unknown* problems. The niching/sharing strategy cannot be used reliably to solve multimodal problems where the solution is unknown due to the paradox mentioned above. Additionally, species formation in high-dimensional domains does not scale well and is a computationally-intensive task.

Much work has been done on locating multiple optimal values using niching algorithms – see Mahfoud [7] and Watson [8] for critical reviews of the approaches, testing functions and the performance measures and the relative merits/de-merits of each approach. Watson considered many test functions of varying complexity for a variety of performance measures and concluded that sharing-based GAs often perform *worse* than random search from the standpoint of the *sensitivity* of the user-selected sharing parameters. He further remarked that it is questionable whether niching-based GAs are really useful for identifying multiple fitness peaks of the MMOs.

The commonly used techniques for preventing genetic drift and promoting diversity are: sharing, mating restrictions, density count (crowding) and pre-selection operators. These approaches can be grouped into two classes: parameter-based sharing and parameter-less sharing. The pioneering sharing scheme of Goldberg and Richardson [1] needs a niching parameter, σ_{share} and is thus a parameter-based technique. Other sharing-based approaches, for example, the adaptive clustering algorithm [5] and the co-evolutionary sharing scheme [6] attempt to avoid σ_{share} directly; the clustering technique, is based on *K*-means clustering and requires an estimate of the initial number of clusters although the deterministic crowding [3] scheme does not need any niching parameters. Starting with the original work of Goldberg & Richardson [1], many other schemes have been proposed over the years and together with these, many studies have been done to measure the effectiveness and sensitivity of the values of the selected parameters on a wide-range of problems. For example, Watson [8] performed an extensive empirical analysis to find-out the effectiveness of niching-based GAs and remarked that it is debatable whether these are really very useful for identifying the multiple fitness peaks in MMOs. Many more studies, *e.g.*, [23-24] are available in literature.

In the absence of *a priori* knowledge of the multimodal function, some work has been done on parameter-less MMO. Mahfoud [3] developed a parameter-less method in the form of crowding which does not need *a priori* knowledge of the solution space. Hocaoglu & Sanderson [9] adopted a clustering technique to hypothesize-and-test the species formation for finding multiple paths for a mobile robot.

By analogy, finding multiple (near-) optimal solutions for a multimodal problem is identical to finding multiple (near-) optimal solutions for a multiobjective problem in the sense that in both types of problem-domain need to find all the possible diverse solutions which span the solution space. (For multimodal problems, the diversity of solutions is desired across the space of the variable(s) while for multiobjective problems diversity is required in objective space. In the multiobjective domain, the set of diverse solutions which are non-dominated form a (near-) optimal front known as (near-) Pareto-front.) For both problem domains, the most commonly used approach for preserving diversity is niching/sharing: see [8] for a review of the multimodal domain and [10-11] for reviews of multiobjective genetic optimization. Apart from the heuristic nature of sharing, the selection of the domain in which to perform sharing: variable (genotype) or objective (phenotype) is also open to debate. Some other recent studies have been done on combining convergence with diversity. Laumanns et al. [14] proposed an ε-dominance for getting ε-approximate Pareto-front for problems whose optimal Pareto set is *known*. Kumar & Rockett [15-16] proposed the use of rank-histograms for monitoring convergence of a Pareto front while maintaining diversity without any *explicit* diversity-preserving operator. Their algorithm was demonstrated to work for problems for which the solution was not known *a priori*. Secondly, assessing convergence does not need any prior knowledge for monitoring movement towards the Pareto front using rank-histograms. This approach has been found to significantly reduce computational effort.

Deb [17] retargeted single-variable multimodal problems into two-variable, two-objective problems and studied niching/sharing techniques for finding diverse solutions for some standard test functions [17]. While presenting his results, Deb observed that variable-space sharing is more effective than objective space sharing (p 19, [17]) however we believe that this interpretation cannot be generalized across all problem-domains. Interestingly, in a recent study, Purshouse & Fleming [18] studied the effect of sharing on a wide-range of MOO two-criteria benchmark problems using a range of performance measures and concluded that sharing can be beneficial, but can also prove surprisingly ineffective if the parameters are not properly tuned. They statistically observed that parameter-less sharing is more robust than parameter-based equivalents (including those with automatic fine-tuning during program execution).

In this context, we have revisited MMO using EAs and attempted to solve MMO problems without any problem-dependent parameters using the same reformulation of multimodal optimization into a multiobjective framework [17]. We have used PCGA [16], a steady-state algorithm [19] and we have used two benchmark problems which have been considered previously. The key result of this paper is that we demonstrate that diversity in objective space can be achieved without any *explicit diversity-preserving* operator.

2 Test Functions and Results

We have tested the PCGA algorithm on two multimodal functions which were considered by earlier researchers using multiobjective formulations. For fair comparison, we have used exactly the same formulation, coding, identifiers and parameters, as far as is known. We repeated the experiments many hundreds of times, each with a different initial population to check the consistency of the results. Typical results selected on the basis of their *average* performance are presented in the following subsections.

2.1 Function F1

First, we considered a bi-modal function $g(x_2)$ given by

$$g(x_2) = 2.0 - \exp\left\{-\left(\frac{x_2 - 0.2}{0.004}\right)^2\right\} - 0.8\exp\left\{-\left(\frac{x_2 - 0.6}{0.4}\right)^2\right\}; \quad g(x_2) > 0$$

For, $(0 < x_2 < 1)$, $g(x_2)$ is a function with a broad local minima at $x_2 = 0.6$, and a spike-like global minima at $x_2 = 0.2$ (Figure 1). Retargeting this single-objective problem to a multiobjective one, the corresponding, two-objective problem having two variables x_1 (>0) and x_2 is:

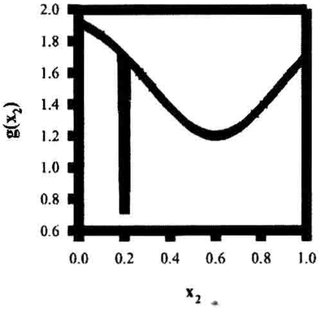

Fig. 1. Bi-modal function F1

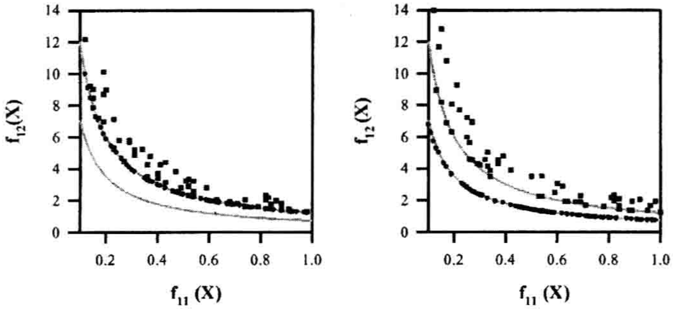

Fig. 2. Function **F1** – Two sets of population, one each converging to (a) local minima ($x_2 = 0.6$), and (b) global minima ($x_2 = 0.2$)

$$\textit{Minimize} \quad f_{11}(x_1, x_2) = x_1$$

$$\textit{Minimize} \quad f_{12}(x_1, x_2) = \frac{g(x_2)}{x_1}$$

For a fixed value of $g(x_2)$, each $f_{11} - f_{12}$ plot is a hyperbola. (See [17] for function characteristics and a related theorem.) For each local and global minimum solution we get one local and global Pareto front, respectively; each of the optimal-fronts are shown by gray-colored curves in Figures 2. We generated many hundreds of random initial populations and observed that, with a population size of 60, most of the individuals were close to the *local* Pareto front but barely one was close to the to the *global* Pareto front. For each of the many runs, we got the whole population of sixty individuals converged within a range of 12 to 41 epochs, with an average of 23.8 epochs per run. (We were able to stop further population evolution by monitoring the advancement of the population to the Pareto front using rank-histograms [16].) Results from two typical runs are shown in Figure 2. The initial population is shown with open squares and the final converged population with filled circles in Figure 2; Figure 2(a) shows the convergence to the local front while Figure 2(b) shows the global front. For some solutions, the population gets trapped in the local Pareto front. We were able to locate the global Pareto front in 36 – 44% of the independently initialized runs, an observation identical to Deb's. The fact that we had a similar success rate to Deb's NSGA in finding the local-to-global Pareto front suggests that this ratio