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Region-based memetic algorithm with archive for multimodal optimisation

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ABSTRACT

In this paper we propose a specially designed memetic algorithm for multimodal optimisation problems. The proposal uses a niching strategy, called region-based niching strategy, that divides the search space in predefined and indexable hypercubes with decreasing size, called regions. This niching technique allows our proposal to keep high diversity in the population, and to keep the most promising regions in an external archive. The most promising solutions are improved with a local search method and also stored in the archive. The archive is used as an index to effiently prevent further exploration of these areas with the evolutionary algorithm. The resulting algorithm, called Region-based Memetic Algorithm with Archive, is tested on the benchmark proposed in the special session and competition on niching methods for multimodal function optimisation of the Congress on Evolutionary Computation in 2013. The results obtained show that the region-based niching strategy is more efficient than the classical niching strategy called clearing and that the use of the archive as restrictive index significantly improves the exploration efficiency of the algorithm. The proposal achieves better exploration and accuracy than other existing techniques.

1. Introduction

Many real world problems offer various solutions considered as global optima. The identification of multiple solution has thus gained popularity in the research community. It is referred to as multimodal optimisation as the objective is to retrieve more than one optima. While classical evolutionary algorithms (EA) were designed to identify a single optimum, some modifications have to be applied to identify multiple optima, preventing their premature convergence and maintaining the diversity in their population to ensure the exploration of distinct areas of the fitness landscape. Such techniques, known as niching strategies [6], are meant to stay in the population subgroups of individuals, or *niches*, in different parts of the search domain.

Most existing techniques' efficiency relies on two problem dependent parameters, the niche radius and the population size [7,16,42]. The first one should be defined according to the distance between optima in the fitness landscape and the second one according to the number of optima to locate. Both data are however usually unknown in real world problems. Nowadays, research interest focuses on designing EA which are less dependent on those parameters.

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The main challenge when designing an EA for multimodal optimisation is to create an algorithm capable of approximating with the highest level of accuracy the different global optima.

Memetic algorithms (MA) [35] are the hybridisation between EA and local search methods (LS) combining in one model the exploration power of the former and the exploitation capacity of the latter. This hybridisation can achieve a good trade-off between the exploration of the domain search and the exploitation of found solutions, so it is important to obtain good results in EAs [59], and it also offers interesting properties when applying them to multimodal optimisation problems from the multimodal optimisation point of view. Indeed, as we said before, niching techniques used with classical EA forms sub-populations destined to explore and optimise different areas of the search space with the same mechanism. MA separate these efforts, leaving the exploration task to the EA and the refinement of the most promising regions identified by the EA to the LS method.

In a previous work [21], we designed a MA for global continuous optimisation problems called region based memetic algorithm with local search chaining (RMA-LSCh). It proposed a novel niching strategy, the originality of which lies in the definition of a niche. While traditionally the niche surrounding a solution is defined by the radius around it, the proposed niching technique partitions the search into equal hypercubes called regions. The dependency to the niche size (defined by the number of divisions of the search space) is reduced by increasing the number of divisions during the search. In this work we propose a new algorithm specially designed for continuous multimodal optimisation, Region-based Memetic Algorithm with Archive (RMAwA). Although RMAwA maintains the same definition of a niche and alternatively applies the EA and the LS, the memetic scheme is modified and a novel archive is implemented to match the requirements of multimodal optimisation. First, while RMA-LSCh uses LS Chaining [32,33] and thus limites the number of fitness evaluation per LS application, RMAwA applies the LS until it has reached a local or global optimum. Most importantly, regions intensively explored by LS are discarded by the proposal from further exploration. RMAwA contains an indexed archive with these regions to reduce the search domain in a very efficient way. Also, because the identified optima are stored into the archive and not into the population, the number of optima that RMAwA can identify is not limited by the population size [12, [63], 64].

RMAwA is tested using a specific benchmark for multimodal optimisation. The experiments carried out show that the use of the region based niching strategy coupled with an archive provides interesting improvements to the memetic framework, and that the RMAwA is a very competitive algorithm against existing ones.

This paper is organised as follows. In Section 2, we present a quick introduction on methods previously proposed to tackle multimodal problem optimisation. In Section 3, we present the RMAwA and detail each component. In Section 4, we explain the experimental framework used and the parameter setting of the algorithm. In Section 5, several comparisons are carried out to study the influence of the different components of the algorithm and our proposal is compared with other algorithms in the literature. Finally, In Section 6 some concluding remarks are pointed out.

2. Background

In order to identify multiple optima of a fitness landscape several techniques have been proposed. In this section, we give a brief overview of techniques that have been proposed to maintain the diversity in the population in order to prevent its convergence towards a single optimum. Such techniques are commonly called niching strategies and refer to the technique used for the discovery and preservation of distinct niches. This term is a reference to the ecological concept of niches referring to the formation of distinct species exploiting different niches (resources) in an ecosystem.

The main challenge in multimodal optimisation is the unknown nature and characteristics of the objective function, specifically the number of global optima and their repartition on the search domain. The main goal of the proposals presented in this section is to tackle these issues. Alternatively, [55] proposes a preprocessing tool to estimate the number of basins of attraction in the fitness landscape.

We have classified the methods proposed to tackle multimodal optimisation into two categories. The first one lists the classical niching strategies which mainly affect the replacement criterion of the EA they are applied to. The second one works with the idea of creating subgroups of solutions in different area of the search space by limiting the cooperation of each individual to its nearest neighbours. We refer to them as neighbourhood based techniques.

In this section, we first describe the different elements composing those two categories by giving a general overview of the proposal making use of such techniques. In a third section, we briefly introduce proposals combining those techniques with MA which demonstrate that the use of a refinement method improves the performance of EAs for multimodal optimisation.

2.1. Classical niching techniques

The first niching techniques consist in limiting the presence of multiple solutions within the same niche in order to keep the population highly diverse. When included in a classical EA, those mechanisms are mainly replacement strategies designed to remove solutions present in the same vicinity. We describe here the four main methods to achieve this objective: crowding, clearing, fitness sharing, and speciation.