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Efficient Memetic Continuous Optimization in Agent-based Computing

Wojciech Korczynski[1], Aleksander Byrski[1], and Marek Kisiel-Dorohinicki[1]

AGH University of Science and Technology, Department of Computer Science, Krakow, Poland
{wojciech.korczynski,olekb,doroh}@agh.edu.pl

Abstract
This paper deals with a concept of memetic search in agent-based evolutionary computation. In the presented approach, local search is applied during mutation of an agent. Using memetic algorithms causes increased demand on the computing power as the number of fitness function calls increases, therefore careful planning of the fitness computing (through the proposed local search mechanism based on caching parts of the fitness function) leads to significant lowering of this demand. Moreover, applying local search with care, can lead to gradual improvement of the whole population. In the paper the results obtained for selected high-dimensional (5000 dimensions) benchmark functions are presented. Results obtained by the evolutionary and memetic multi-agent systems are compared with classic evolutionary algorithm.

Keywords: evolutionary algorithms, Evolutionary Multi-Agent System, memetic algorithms

1 Introduction

Some problems are very difficult for common optimization methods as their search space is too big or too complex to be explored efficiently. Such 'black-box' problems [9] may be solved using a general-purpose algorithms, e.g. meta-heuristics, which provide good enough solutions in reasonable time, taking into consideration little information from the problem domain.

For a long time meta-heuristics were not fully understood, until Davis [6] and Moscato [18] conducted successful experimental research and managed to discover the need for adjusting the solver to the problem characteristics. These practical observations were backed up in the so-called 'no-free-lunch' theorem [12, 23], according to which it is not possible to find a meta-heuristic method that will be an ultimate solution for all problems, no matter how excellent it works for a certain problem. Therefore, it is still necessary to look for novel meta-heuristics, adjusted to given problems and often inspired by the various domains of life, such as biology, evolution or genetics.

In 1996 Krzysztof Cetnarowicz [4] introduced a notion of agency to evolutionary algorithms and proposed Evolutionary Multi-Agent System (EMAS), an effective implementation of distributed problem solving. In agent-based systems the main task is decomposed into sub-tasks

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entrusted to agents—intelligent objects which are able to interact one with another, as well as with the environment, and make decisions autonomously. In numerous researches EMAS proved to be an efficient method for solving different problems—classic benchmarks [1], inverse problems [24] and other optimization tasks [7, 8]. Moreover, many modifications and extensions of EMAS have been proposed. Compared to classic evolutionary algorithm, EMAS provides satisfactory results in less computation time, requiring less evaluations.

This paper concerns the idea of hybridization of EMAS with local search algorithms, inspired by the meme theory. Memetic algorithms (MAs) [19, 16, 20] join ideas from the popular metaheuristics and blend together local search with population-based search engine. MAs, initially popularized e.g. by Radcliffe and Surry [21], were proven to provide remarkable success [13]. However, memetic algorithms are very computationally demanding, therefore following [11] of caching partially the fitness results, a similar method is followed in continuous optimization, in order to efficiently realize the local search in the solution space.

Section 2 describes EMAS, along with its main assumptions, in detail. In Section 3 EMAS hybridization with local search memetic algorithms is introduced. Preliminary experiments and their results are presented in Section 4. Section 5 concludes this paper and discusses possible future work.

2 From evolutionary algorithms to Evolutionary Multi-Agent Systems

Evolutionary algorithms [17] belong to population-based metaheuristics. In the most popular variant called a genetic algorithm, solutions are encoded into genotypes owned by individuals. These individuals form populations—groups of potential solutions, which are evaluated based on the fitness function. Poor solutions are eliminated in the process of selection and the remaining ones create a mating pool. Subsequent population is created based on that mating pool, using variation operators, such as crossover or mutation. The whole process continues until some stop condition is reached (e.g.: predefined number of iterations or reaching good enough solution).

The key issue in practical applications of evolutionary algorithms is the diversity of solutions in the population. To preserve this diversity during the search several techniques may be applied. Following the idea of allopatric speciation, individuals may be distributed among evolutionary islands, which allows for parallelizing the algorithm [3]. Figure 1(a) schematically illustrates parallel evolutionary algorithm (PEA) used as a reference in this paper.

Agency brings to the world of evolutionary metaheuristics decentralization of selection and autonomy of the individuals. Thus the natural process of evolution is mimicked better, and in this way the author of EMAS Krzysztof Cetnarowicz [4], and his followers [2, 7] tend to introduce a new quality into metaheuristics, achieving effective results consisting e.g. in decreasing the computation cost computed as the number of fitness function calls [1].

In EMAS phenomena of inheritance and selection—the main components of evolutionary processes—are modelled via agent actions of death and reproduction (Figure 1(b)). As in the case of classic evolutionary algorithms, inheritance is accomplished by an appropriate definition of reproduction. Core properties of the agent are encoded in its genotype and inherited from its parent(s) with the use of variation operators (mutation and recombination). Moreover, an agent may possess some knowledge acquired during its life, which is not inherited. Both inherited and acquired information (phenotype) determines the behaviour of an agent. It is noteworthy that it is easy to add mechanisms of diversity enhancement, such as allopatric speciation (cf. [3]) to EMAS. It consists in introducing population decomposition and a new action of the agent