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A novel hybrid genetic algorithm with Tabu search for optimizing multi-dimensional functions and point pattern recognition

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ABSTRACT

Hybrid evolutionary algorithms are drawing significant attention in recent time for solving numerous real world problems. This paper presents a new hybrid evolutionary approach for optimizing mathematical functions and Point Pattern Recognition (PPR) problems. The proposed method combines a global search genetic algorithm in a course-to-fine resolution space with a local (Tabu) search algorithm. Such hybridization enhances the power of the search technique by virtue of inducing hill climbing and fast searching capabilities of Tabu search process. The approach can reach the global or near-global optimum for the functions in high dimensional space. Tests have been successfully made on several benchmark functions in up-to 100 dimensions. The performance of the proposed algorithm has been compared with other relevant algorithms using non-parametric statistical approaches like Friedman test, multiple sign-test and contrast estimation. Also, the hybrid method with grid based PPR technique has been applied for solving dot pattern shape matching and object matching represented as edge maps. The performance of proposed method compares favorably with relevant approaches reported in the article.

1. Introduction

Evolutionary Algorithms (EAs) are a class of search and optimization techniques that work on the principle inspired by Darwinian Evolution. EAs are used in solving a wide variety of combinatorial optimization problems in diverse fields as machine vision, astronautics, document processing, biometrics, computational biology and computational chemistry [1,2,19,26].

In recent years the hybrid genetic algorithms have gained significant interest and are being increasingly used in solving various real world problems. It is now well known that *pure* evolutionary algorithms are not suited for a fine tuned search in complex combinatorial spaces. Instead hybridization with other techniques can improve the efficiency of the search process [11]. The combination of *Evolutionary Algorithm* with *Local Search* approach is known as “Memetic” or “Hybrid” algorithm. Memetic or hybrid algorithms are extensions of evolutionary algorithms which apply separate processes of hill climbing to refine individual chromosome.

In recent past, we proposed a CAscaded Genetic Algorithm (CAGA) for optimization problems [7] which is a *coarse-to-fine* search method. The process starts in low resolution over the entire space and in subsequent stages the space is reduced and the resolution is increased. Recently we have upgraded this algorithm by introducing varying degree of search space reduction so that the global solution can be better attained. This approach is described in Section 2.3. However, there have been

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occasions where the global optimum has been missed by CAGA. In this paper CAGA with Tabu search has been explored as a remedy to this problem.

The hybridization overcomes the limitation of the *coarse-to-fine* search based genetic algorithm by reducing the possibility of the search process getting trapped in local optima. Since the search (*coarse-to-fine*) process jumps from one hypercube to another in a multi-dimensional space, there is a possibility of missing the global solution in this movement. The inclusion of a local search process with the Genetic Algorithm (GA) helps to search in the neighborhood of the solution (when the solution is converged in a hypercube in an intermediate stage) when the GA jumps to the new hypercube (see Figs. 1 and 2 and description in Section 2.3). Thus, the hybridization process largely (but not entirely) reduces the possibility of missing the global solution. As a result, the proposed method can work on high dimensional spaces. The user also has the option to control the rate of reduction of search space. The reduction in slower pace may be necessary to reach the global optimum solution. Tests have been made on the benchmark functions in up-to 100 dimensions as described in Section 4.2.

The effective use of genetic algorithm in point pattern recognition is reported in various literatures [10,11,26]. Given two sets of points in *d*-dimensional space, one has to determine whether there is a transformation that maps the first set onto or close to the second set of points. In general, pattern matching can be of two categories namely, *complete matching* and *approximate matching*. Complete matching usually occurs in an idealistic situation while in practice there exist spurious or lost points due to image degradation and binarization error, so that exact match is not possible. Depending on additional information of an image (such as color, intensity etc.) other than pixel coordinates, the point pattern recognition can be done on labeled points or unlabeled points [26]. The unlabeled point matching is more difficult than its labeled counterpart but such a situation is encountered more often.

Among other hybrid approaches, in [20] the GA is combined with two neural networks namely, a feature extraction network and a neural classifier. The hybrid GA is used to select the receptive field parameters to improve the classification performance and is applied for handwritten digit classification and face recognition. Another genetic approach hybridized with fuzzy logic has been proposed by Ishibuchi et al. [14] for designing fuzzy rule based systems for pattern classification. Also, the memetic evolutionary method with Tabu search has been used for cell image segmentation [16].

Among the different approaches proposed for point pattern matching, a heuristic algorithm has been used by Denton and Beveridge [4] to minimize the effect of spurious points for matching two point patterns. A meta-heuristic particle swarm optimization algorithm [25] has also been proposed in the recent past. Zhang et al. [26] employed genetic algorithm for point pattern recognition. They used the reference triplet points as the chromosome representation in order to reduce the search space significantly. In a noise-free environment Caetano et al. [1] proposed point pattern matching as a weighted graph matching problem where the weights correspond to Euclidean distance between nodes. Carcassoni and Hancock [2] have applied the spectral graph theory to compute the point pattern correspondence. Li et al. [19] used the point pattern matching method in palm pattern recognition. The matching is performed in two-phases based on the local structure of the minutiaes and the global feature.

Usually, GAs require a large number of iterations in order to converge to a solution. In pattern recognition or similar problems, generally one starts with chromosome length dependent on the accuracy of the required solution. The length then

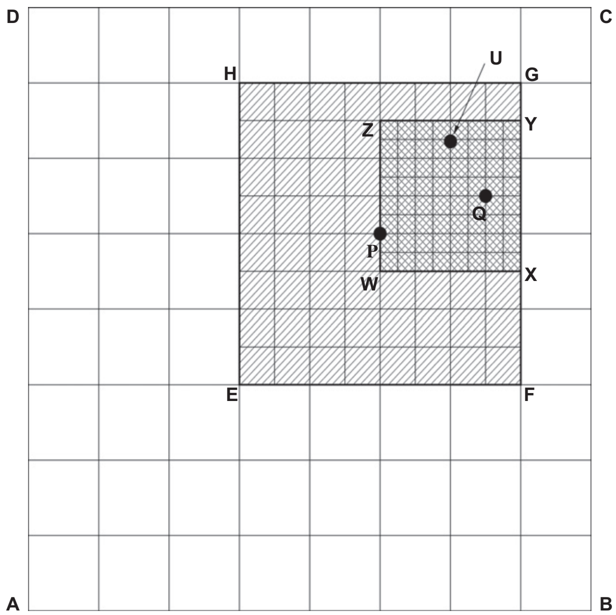

Fig. 1. Transfer of GA search in three stages in 2-D space with fast partitioning process.