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Automatic clustering algorithm based on multi-objective Immunized PSO to classify actions of 3D human models

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ABSTRACT

Multi-objective clustering algorithms are preferred over its conventional single objective counterparts as they incorporate additional knowledge on properties of data in the from of objectives to extract the underlying clusters present in many datasets. Researchers have recently proposed some standardized multi-objective evolutionary clustering algorithms based on genetic operations, particle swarm optimization, clonal selection principles, differential evolution and simulated annealing, etc. In many cases it is observed that hybrid evolutionary algorithms provide improved performance compared to that of individual algorithm. In this paper an automatic clustering algorithm MOIMPSO (Multi-objective Immunized Particle Swarm Optimization) is proposed, which is based on a recently developed hybrid evolutionary algorithm Immunized PSO. The proposed algorithm provides suitable Pareto optimal archive for unsupervised problems by automatically evolving the cluster centers and simultaneously optimizing two objective functions. In addition the algorithm provides a single best solution from the Pareto optimal archive which mostly satisfy the users' requirement. Rigorous simulation studies on 11 benchmark datasets demonstrate the superior performance of the proposed algorithm compared to that of the standardized automatic clustering algorithms such as MOCK, MOPSO and MOCLONAL. An interesting application of the proposed algorithm has also been demonstrated to classify the normal and aggressive actions of 3D human models.

1. Introduction

The success of a clustering method mainly depends on the separation potentiality (defined in the form of an objective function to be optimized) of the data in a multi-dimensional space. Conventionally most clustering methods use a single optimization criteria which at times are not able to identify the underlying clusters present in the dataset and hence leads to poor accuracy. Therefore the clustering task is formulated as a multi-objective problem in which multiple optimization criteria can be set and evaluated simultaneously. The solution of a multi-objective problem is composed of a set of solutions obtained by trading off between different objectives (known as Pareto optimal). All the solutions in the Pareto optimal are significant for the user (provides flexibility to select based upon the requirement) and are better than the solution obtained from single objective formulation.

Recently published review paper by Bong and Rajeswari (2011) reports that the algorithm design, development and applications of multi-objective nature-inspired clustering and classification algorithms have exponentially increased during year 2006–2010. Research in this area has been strengthened and become popular after the work by Handl & Knowles on MOCK (Multi-objective clustering with automatic K determination) published in 2007. Prior to that the efforts on the development of PESA-II (Pareto Envelope-based Selection Algorithm) (Corne et al., 2001), VIENNA (Voronoi Initialised Evolutionary Nearest-Neighbor Algorithm) (Handl et al., 2004) and the initialization of MOCK (Handl and Knowles, 2004, 2005) are worth mentioning. Inspired by MOCK, Saha and Bandyopadhyay (2009, 2010) have developed simulated annealing based multi-objective clustering algorithm that uses symmetry distance. The improved and generalized learning strategies for dynamically fast and statistically robust evolutionary algorithms are developed by Dashora et al. (2008). Recently Ma et al. (2009) have proposed an immunodominance and clonal selection inspired multi-objective clustering. The real life applications developed based on multi-objective clustering includes: classification of remote sensing images using NSGA II (Bandyopadhyay et al., 2007), clustering of hyperspectral images based on multi-objective particle swarm optimization (Paoli et al., 2009), electrical power dispatch based on MOPSO with fuzzy clustering Agrawal et al. (2008) and classification of micro-array data using multi-objective differential evolution based clustering algorithm (Suresh et al., 2009).

Hybrid evolutionary algorithms are developed by suitably combining the good features of two parent evolutionary processes and in general provide better solutions than the individual process. A hybrid

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evolutionary algorithm known as Immunized PSO was proposed by Nanda et al. (2009, 2010) by combining the good features of PSO and clonal selection theory of AIS. This proposed algorithm has been applied to develop a supervised learning model to train the weights of Functional Link Artificial Neural Network (FLANN) structure for complex identification of Hammerstein plant, and has been shown to provide superior performance compared to that offered by PSO, Clonal and GA based learning algorithm. Recently a single objective clustering algorithm based on IPSO has been proposed (Nanda and Panda, 2012) and has been reported that it provides improved performance than the standardized K-means (Nazeer and Sebastian, 2009), correlation based (Nanda et al., in press), single objective PSO (Paterlini and Krink, 2006) and single objective clonal (Liu et al., 2008) based clustering algorithms.

Being inspired by the diversified applications of multi-objective algorithms and their superior performance in clustering in this paper we have under taken the problem of an automatic multi-objective clustering algorithm based on a simple but effective IPSO algorithm. One of the good features of the proposed technique is that it automatically evolves the number of clusters present in the dataset. Given a completely unsupervised problem the proposed algorithm provides suitable Pareto optimal front by simultaneously optimizing two objective functions. However if the problem is semi-supervised (a portion of solution is known a priori), then the algorithm also provides a single best solution from the Pareto optimal front which is suitable for the users. The performance evaluation of the proposed approach is carried out using four benchmarked measures and the results are compared with that achieved by standard MOCK, MOCLONAL and MOPSO algorithms.

Recently, modeling of human action recognition and to classify physical activity pattern has been addressed by Theodoridis et al. (2008, 2010). They have developed an experimental setup in the Robotic Arena Hall (University of Essex), using 3D tracker (Vicon system) to record the 3D environment human physical activities. The objective is to develop an off-line processing system which is able to distinguish the normal and aggressive actions of human beings. The classification task in this environment is challenging due to the higher number of samples (≈ 3000 per person for a physical activity) along with high dimensionality (27 dimension for each activity) of the dataset. Theodoridis et al. (2008) have formulated it as an supervised classification problem and have solved it using Dynamic ANN and Genetic Programming based classifiers. In this paper we have formulated the classification task of this complex high dimensional dataset as an unsupervised learning problem and effectively solved it by the proposed automatic clustering algorithm MOIMPSO (Multi-objective Immunized Particle Swarm Optimization).

The paper is organized as follows. Section 2 deals with the development of proposed automatic clustering algorithm MOIMPSO. The benchmark datasets used for experimentation, simulation environment, parameter setting and cluster performance evaluation are dealt in Section 3. The comparative results obtained by the proposed algorithm along with MOCK, MOPSO and MOCLONAL algorithms are presented in Section 4. The application of the proposed algorithm to classify the actions of 3D human model is presented in Section 5. Finally the concluding remarks of the investigation are outlined in Section 6.

2. Proposed automatic clustering algorithm based on multi-objective Immunized PSO

2.1. Problem formulation

The clustering task can be formulated as an multi-objective optimization problem by simultaneously minimizing M different criterion function

$$\underset{z \in Z}{Minimize}\ \mathbf{F}(z) = \min[f_1(z), f_2(z), \ldots, f_M(z)] \tag{1}$$

where z is clustering of given dataset E and Z is the set of feasible cluster. The Pareto optimality is achieved by tradeoff between solutions obtained from the M objectives. Consider two solutions $z_1, z_2 \in Z$. The solution z_1 is said to dominate z_2 (i.e. $z_1 < z_2$) if

$$f_i(z_1) \le f_i(z_2) \quad \forall i,\ i \in 1,2,..,M \tag{2}$$

and

$$\exists j : f_j(z_1) < f_j(z_2), \quad j \in 1,2,..,M \tag{3}$$

If none of the solution dominates z_1 then it is a non-dominated solution. The Pareto optimal solutions is comprised of the set of all non-dominated solutions given by

$$p^* := \{z \in Z : \neg\exists z' \in Z : z' < Z\} \tag{4}$$

The Pareto front is the image of this set in the objective space and is represented by

$$fp^* := \{[f_1(z), f_2(z), .., f_M(z)] : z \in p^*\} \tag{5}$$

2.2. Key features of proposed algorithm

The hybrid Immunized PSO algorithm combines the good features of clonal selection principle (Charsto and de Zuben, 2002; Khilwani et al., 2008; Prakash et al., 2008; Nanda, 2009) and the particle swarm optimization (Kennedy and Eberhart, 1995; Clerc and Kennedy, 2002). For development of automatic clustering algorithm inspired by IPSO the definitions of Pareto optimality described in Section 2.1 is followed. The algorithm can automatically evolve the number of clusters present in the dataset (a priori knowledge on number of clusters present in the dataset is not required). The proposed algorithm provides suitable Pareto optimal fronts for cluster analysis. In addition it provides a single best solution from the Pareto optimal front which mostly satisfy the user requirement (a similar concept proposed for simulated annealing based clustering by Saha and Bandyopadhyay, 2009). Furthermore, a K-means based clustering algorithm is incorporated at the beginning to provide effective initial solutions which are then guided by the IPSO algorithm.

2.3. Details of the proposed algorithm

The steps of IPSO based multi-objective clustering algorithm are outlined in sequel:

- Step 1. K-means based initialization

A swarm S is initialized as follows:

Swarm   Elements of swarm   Number of clusters K-means based initialization

$$S_{1\times N} = \begin{vmatrix} \vec{s}_1 \\ \vec{s}_2 \\ :: \\ \vec{s}_i \\ :: \\ \vec{s}_I \end{vmatrix} = \begin{vmatrix} 2 \\ 3 \\ : \\ Z \\ 2 \\ : \end{vmatrix} = \begin{vmatrix} 1 & 1 & .. & 2 & 2 \\ 1 & 2 & .. & 3 & 3 \\ : & : & :: & : & : \\ 1 & 2 & .. & Z-1 & Z \\ 1 & 1 & .. & 2 & 2 \\ : & : & .. & : & : \end{vmatrix}$$

where I is the number of particles. The length of each particle is