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A Review of Particle Swarm Optimization: Feature Selection, Classification and Hybridizations

Madan Madhaw Shrivas
Research Scholar, Department of CSIT
Guru Ghasidas Vishwavidyalaya
Bilaspur, India
Madhaw_m@yahoo.com

Amit Saxena
Professor, Department of CSIT
Guru Ghasidas Vishwavidyalaya
Bilaspur, India
amitsaxena65@rediffmail.com

Leeladhar Kumar Gavel
Research Scholar, Department of CSIT
Guru Ghasidas Vishwavidyalaya
Bilaspur, India
lk.gavel@yahoo.in

Abstract: Particle swarm optimization (PSO) is a recently grown, popular, evolutionary and conceptually simple but efficient algorithm which belongs to swarm intelligence category. This paper outlines basic concepts and reviews PSO based techniques with their applications to classification and feature selection along with some of the hybridized applications of PSO with similar other techniques.

Keywords: *Swarm Intelligence, Classification, Feature selection, Hybridization.*

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I. INTRODUCTION

The Particle Swarm Optimization (PSO) is a Meta - heuristic search technique, biologically inspired from the nature's social behavior, dynamic movements and communications of insects, birds and fish. It was introduced by American social psychologist James Kennedy and electrical Engineer Dr. Russell Eberhart in 1995[1, 2] and is often considered under the category of Swarm-intelligence (SI) [3]. It is a population based stochastic global optimization technique evolved to study the social behavior of insects, birds or fish as why they move in a group searching for food randomly in some area, knowing only the distance from the food [4]. A PSO system combines local search methods (through self experience) with global search methods (through neighboring experience), attempting to balance exploration and exploitation [5]. PSO has been successfully applied to various areas including Prediction analysis [6], Multi-model Optimization[7], Feature Selection [8], Association rule mining [9], Text clustering [10], Pattern Recognition [11], Clustering[12], Classification [13], Data mining[14], Image Processing [15], Rule extractor[16] etc. Often, to achieve better performance, a PSO is combined with soft computing techniques to form a hybridized model discussed later in this paper.

The rest of the paper is organized as follows. In the Section II, we present the basic concepts of the PSO and its algorithm. In section III, Literature Review on development of PSO is presented. In Section IV, a literature Review on PSO based Classification and Feature Selection is provided. Section V presents PSO hybridization and applications followed by the conclusions in Section VI.

II. BASIC CONCEPTS AND ALGORITHM

PSO relates to Artificial Life, bird flocks, fish schools and swarm theory in particular. PSO is also associated with Evolutionary Computing based techniques namely Genetic Algorithms (GAs) [17] and Evolutionary Programming [18] PSO is endowed with a flexible and well-balanced mechanism to enhance the global and local exploration capabilities [19].

Similar to other population-based evolutionary algorithms, PSO also initializes with the random population of particles (like chromosomes in GA). Each particles flies through a multidimensional search space with a velocity that is dynamically and iteratively adjusted for the optimal solution by updating the position of each particle based on its own experience or that of its neighboring particles. A complete description of PSO can be found in [1], however the pseudo code a flowchart and of PSO are provided for ready reference in Figure 1[20] and Figure 2[21] respectively.

The process for implementing the global version of PSO algorithm is as follows [22]:

1) Initialize a population (array) of particles with random positions and velocities on d dimensions in the problem space.
2) For each particle, evaluate the desired optimization fitness function in d variables.
3) Compare particle's fitness evaluation with particle's p_{best}. If current value is better then p_{best}, then set p_{best} value equal to the current location in d-dimensional space.
4) Compare fitness evaluation with the population's overall previous best. If current value is better then g_{best}, then reset g_{best} to the current particle's array index and value.
5) Change the velocity and position of the particle according to equation (1) and (2) respectively.

$$v_{id} = v_{id} + c1 * rand\ () * (p_{id} - x_{id}) \ldots + c2 * Rand\ () * (p_{gd} - x_{id}) \quad (1)$$

$$x_{id} = x_{id} + v_{id} \quad (2)$$

6) Loop to step 2) until a criterion is met, usually a sufficiently good fitness or a maximum number of iterations (generations).

Pseudo code for PSO:
For each particle
Initialize particle
END
Do
For each particle
Calculate fitness value
If the fitness value is better than the best fitness value (P_{best}) in history
Set current value as the new P_{best}
End
Choose the particle with the best fitness value of all the Particles as the g_{best}
For each particle
Calculate particle velocity according equation (1)
Update particle position according equation (2)
End
while maximum iterations or minimum error criteria are not attained.

Figure 1. Pseudo code of PSO algorithm[20].

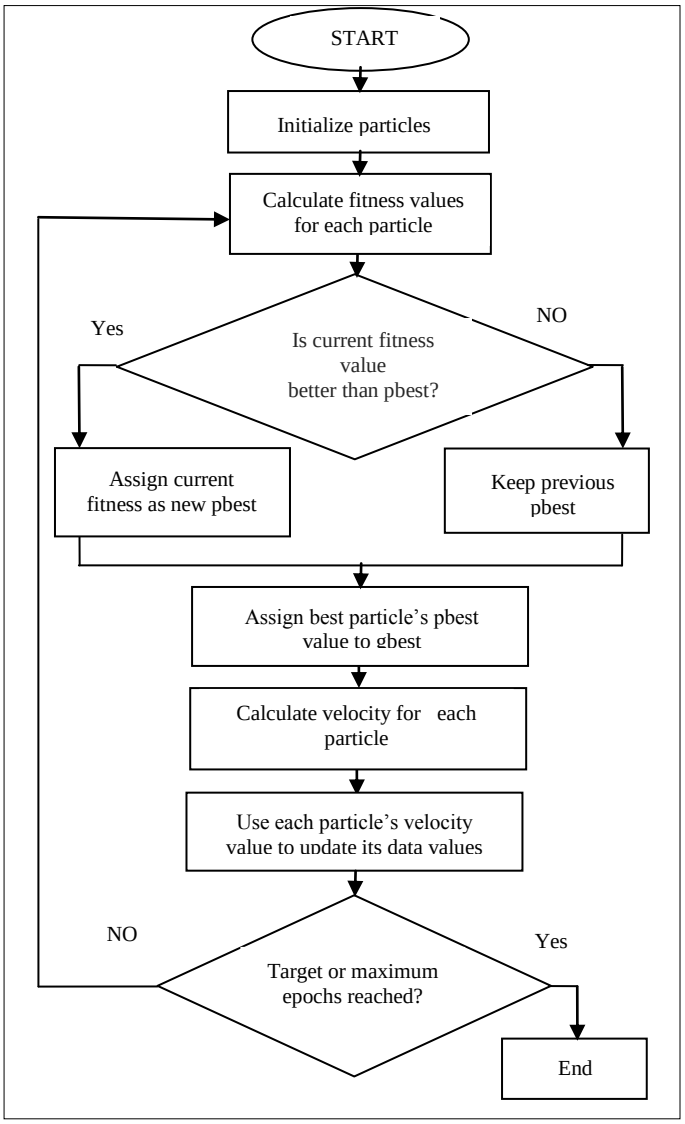

Figure 2. Flow diagram illustrating the PSO algorithm [21].

III. LITERATURE REVIEW FOR PSO

A reasonably good amount of work has been reported in the area of PSO. Kennedy and Eberhart, introduced the concept of PSO based optimization methodology for continuous nonlinear functions [1]. The duo introduced an enhancement of the algorithm to operate on discrete binary variables [23]. Shi and Eberhart introduced inertia weight as a new parameter into the original particle swarm optimizer [24]. Angeline [25] described an evolutionary optimization algorithm based on hybrid model. Shi and Eberhart [26] studied the performance of the PSO with linearly decreasing inertia weight. Eberhart and hu [27] proposed a new technique based on PSO and ANN to classified human tremor (Parkinson's) disease. Løvbjerg et al. [28] introduced two hybrids PSO based on evolutionary algorithms (GA and PSO) to combine the traditional velocity and position update rules with the ideas of breeding and subpopulations. Parsopoulos et. al [29] proposed a Stretching technique by combining. Stretching with the PSO, this was capable of escaping from local minima and effectively locates the global ones. Fourie and Groenwold [30] introduced two new operators in the PSO, namely the elite velocity and the elite particle, which is used for the shape and size optimization problems in structural design. Abido [31] presented the PSO algorithm to solve the optimal power flow (OPF) problem. Salman et al. [32] proposed the PSO algorithm for the task assignment problem for homogeneous distributed computing systems. Saxena and Vora[33] discussed the small world theory of PSO.

IV. FEATURE SELECTION AND CLASSIFICATION USING PSO

Elimination of irrelevant, harmful, redundant and noisy features from the datasets to increase the classification accuracy is termed as feature selection. Classification is the process of organizing data into suitable categories on the basis of some criteria. When the set of possible categories is known in advance, classification under this situation is called supervised classification while the situation when possible classes are not known in advance is called unsupervised classification. Looking to their extensive applications in various data processing techniques, Feature selection and Classification have been studied widely. A numerous successful implementations of feature selection and classification to various applications are summarized in Table I.

TABLE I.

FEATURE SELECTION AND CLASSIFICATION USING PSO

Purpose*: C-Classification, F-Feature Selection

S. N./year	*Authors*	*Purpose**	*Tools*	*Description*
1/2004	Tiago Sousa et. al [13]	C	GA and Tree Induction Algorithm and J48—a Java implementation of C4.5	Proposed particle Swarm Optimizer as a new tool for Data Mining algorithm for classification tasks or rule discovery.
2./2007	De Falco et al. [34]	C	ANN	Proposed Particle Swarm Optimization to face the problem of classification of instances in databases.

3/2007	Qi Shen et al. [35]	C	Support Vector machine (SVM)	Proposed discrete particle swarm optimization (PSO) with support vector machines (SVM) for tumor classification.
4/2008	Qi Shen et al. [36]	C	Pure Tabu search (TS) and hybrid PSO	Proposed a hybrid PSO and TS (HPSOTS) approach for gene selection for tumor classification.
5/2008	Li-Yeh Chuang et al. [37]	F	Binary PSO, K-NN, BPNN and PNN	Proposed binary particle swarm optimization with K-NN method for gene expression data classification problems.
6 /2010	Alper Unler ,Alper Murat [38]	F	logistic regression	Proposed modified discrete particle swarm optimization (PSO) algorithm for investigates the feature subset selection problem for the binary classification problem using logistic regression model.
7/2011	Alper Unler et.al.[39]	F	SVM	Proposed a hybrid filter wrapper feature subset selection algorithm based on PSO and SVM.
8/2012	Pei-Chann Chang et al [40]	C, F	Case base reasoning(CBR)	Proposed integrating a case-based reasoning and particle swarm optimization based hybrid model for medical data classification.
9/2013	Abdulha mit Subasi [41]	C	SVM, PSO ,K-NN	Proposed A novel PSO-SVM model that has been hybridized the PSO and SVM to improve the EMG signal classification accuracy.
10/2014	Bing Xue, et. al [42]	F,C	LDA, KNN, PSO	Proposed a PSO based feature selection approach to selecting a smaller number of features for better classification performance.
11/2014	H. Hannah Inbarani et al. [43]	F	Naïve Bayes, Rough set and PSO	Introduced hybridized approach for the diseases diagnosis.
12/2015	Subhajit Kar et al. [44]	C	PSO, KNN ,SVM	Proposed a PSO–adaptive K-nearest neighborhood (KNN) based gene selection method for proper classification of microarray data.
13/2015	Yong Zhang	F	PSO, 1 - NN	Proposed binary BPSO method to find optimal
	Dunwei Gong et.al.[45]			feature subset.

V. PSO BASED HYBRIDIZATION AND APPLICATIONS

PSO has been combined with several other standard and popular techniques to form a hybrid. The benefit of forming a hybrid is that when a single algorithm (say PSO) finds some limitation on a particular point, then some other technique (say X) can overcome that limitation and both techniques can complement each other's weaknesses and jointly produce better results. Some of the hybridizations of PSO are presented in following section. Later we outline some of the applications of PSO although there have been many but it is not possible to cover all at one place.

A. PSO based Hybridization

Hybridization is a process of combining various established or efficient techniques such that the overall performance of the combination of the algorithm is improved. PSO can be hybridized with other techniques to enhance the overall performance and hence results. Some of the hybridizations of PSO with other techniques are as follows:

Hybridization of PSO with Genetic Algorithm (GA): GA [17] is a very powerful optimization technique. PSO can work together with GA to outperform results as obtained by individually by either PSO or GA.

Hybridization of PSO with Ant Colony Optimization (ACO): The structure of ACO [46] is naturally suited for solving discrete problems. In ACO, the movement of ants is studied similar to birds in PSO. PSO and ACO combination is favored for solving discrete optimization problems like scheduling. Hybrid version PSO and ACO applied for the application of engineering design [47] etc.

Hybridization of PSO with Differential Evolution (DE): DE[48] uses the same evolutionary operators (selection, crossover and mutation) as that of GA but its working are distinct from GA. PSO and DE is used for the application of Medical image processing[49] etc.

Hybridization of PSO with other Algorithms: PSO can be hybridized with other well established techniques including: Fuzzy Logic [50], Rough Set [51], Neural Network [52] etc.

B. Other applications Of PSO

In PSO, each particle can be treated as a multidimensional vector and the particle moves alone in the swarm as a prospective solution to the fitness function. PSO algorithm has been successfully applied in several fields, listing a few are optimal capacitor placement in Distribution systems [53], Peer-to-peer networks [54], nonlinear resource allocation problem [55] and others.

VI. CONCLUSION

This paper presents an overview of PSO and PSO based algorithms. PSO has been applied to extensive areas of research and industrial applications. Like evolutionary computing based

algorithms GAs, it starts with particles (like chromosomes in GA) flying with an initial random velocities in various directions (locations). Both locations and velocities are updated with iterations until a satisfactory solution is reached. The applications of PSO to feature selection and classification have been widely published and briefly presented in this paper. PSO with GA and other techniques when hybridized together can produce better results compared to technique applied alone. Such hybridizations on few areas have been provided in this paper. It can be concluded that slowly but constantly PSO is also going to become an essential tool for optimization problems and that will be a challenging task for researchers.

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