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Social-Spider Optimization-based Support Vector Machines applied for energy theft detection[☆]

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ABSTRACT

The problem of Support Vector Machines (SVM) tuning parameters (i.e., model selection) has been paramount in the last years, mainly because of the high computational burden for SVM training step. In this paper, we address this problem by introducing a recently developed evolutionary-based algorithm called Social-Spider Optimization (SSO), as well as we introduce SSO for feature selection purposes. The model selection task has been handled in three distinct scenarios: (i) feature selection, (ii) tuning parameters and (iii) feature selection+tuning parameters. Such extensive set of experiments against with some state-of-the-art evolutionary optimization techniques (i.e., Particle Swarm Optimization and Novel Global-best Harmony Search) demonstrated SSO is a suitable approach for SVM model selection, since it obtained the top results in 8 out 10 datasets employed in this work (considering all three scenarios). Notice the best scenario seemed to be the combination of both feature selection and SVM tuning parameters. In addition, we validated the proposed approach in the context of theft detection in power distribution systems.

1. Introduction

Machine learning techniques have been actively pursued in the last decades, since to recognize patterns in different applications through a learning process is of great interest. Based on the statistical learning theory, Support Vector Machines (SVM) [1] are based on the maximal margin assumption, which considers a hyperplane that separates the dataset samples in a high dimensional feature space induced by a non-linear mapping using kernel functions. Although SVM have been considered one of the state-of-the-art pattern recognition techniques, they suffer from the high computational burden for training patterns. Some kernel functions are parameterized, which means there is a need for optimization techniques to find out a suitable set of values that are less prone for classification errors over a training/validating set.

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Although the reader can face several works that deal with new approaches for SVM modeling and parameter optimization, in this work we focus on evolutionary strategies for the latter purpose. Friedrichs and Igel [2], for instance, presented an evolutionary-based approach for SVM parameter optimization using the Covariance Matrix Adaptation Evolution Strategy. Howley and Madden [3] proposed a kernel optimization method based on Genetic Programming, and Lessmann et al. [4] employed the well-known Genetic Algorithm for the same task. In regard to Particle Swarm Optimization (PSO)-based SVM training, one can be referred to several works: Liu et al. [5], for instance, proposed an integrated approach that aimed to optimize both features and the parameters of a Support Vector Machines classifier. Melgani and Bazi [6] presented an SVM model selection approach based on PSO for Electrocardiogram signal classification; in this work, only SVM parameters have been optimized. More recently, Pereira et al. [7] introduced the Harmony Search algorithm for training SVM classifiers in the context of theft detection in power distribution systems, and Cawley [8] proposed an approach based on Tabu Search for model selection in SVM classifiers.

Based on the social dynamics of spiders, Cuevas et al. [9] proposed the Social-Spider Optimization (SSO), which considers both male and female spiders as well as their cooperative behavior for solving optimization tasks. Such technique has demonstrated very promising results, being also as efficient as some state-of-the-art evolutionary-based approaches. The main contributions of this paper are two-fold: (i) to extend the work by Pereira et al. [10], which introduced SSO for SVM parameter estimation, and (ii) to apply feature selection by means of SSO together with SVM model selection. The proposed SSO-SVM technique is evaluated in public datasets, as well as in the context of theft detection in power distribution systems for the first time. For this latter purpose, we have employed two private datasets provided by a Brazilian electrical power company, which contain legal and illegal profiles from commercial and industrial consumers.

The remainder of this paper is organized as follows. Sections 2 and 3 present the theory background regarding SSO and the methodology employed in this work, respectively. Experiments are described in Section 4, and the conclusions are stated in Section 5.

2. Social-Spider Optimization

Social-Spider Optimization is based on the cooperative behavior of social-spiders and it was proposed by Cuevas [9]. The algorithm takes into account two genders of search spiders: males and females. Depending on the gender, each agent is conducted by a set of different operators emulating a cooperative behavior in a colony. The search space is assumed as a communal web and a spider's position represents an optimal solution.

An interesting characteristic of social-spiders is the female-biased population. The number of male spiders hardly reaches 30% of the total colony members. The number of females N_f is randomly selected within a range of 65–90% of the entire population N, being calculated as follows:

$$N_f = \lfloor (0.9 - rand * 0.25) * N \rfloor, \tag{1}$$

where *rand* is a random number between [0, 1], thus guaranteeing the aforementioned range considering the number of female spiders. The number of male spiders N_m is given by:

$$N_m = N - N_f. \tag{2}$$

Every spider receives a weight according to the fitness value of the solution:

$$w_i = \frac{fitness_i - worst}{best - worst}, \tag{3}$$

where $fitness_i$ is the fitness value obtained by the evaluation of the *ith* spider's position $i = 1, 2, \ldots, N$. The *worst* and *best* mean the worst fitness value and best fitness value of the entire population, respectively.

The communal web is used as a mechanism to transmit information among the colony members. The information is encoded as small vibrations and depends on the weight and distance of the spider which has generated them:

$$V_{i,j} = w_j * e^{-d^2_{i,j}}, \tag{4}$$

where $d_{i,j}$ is the Euclidean Distance between the spider i and j. We can consider three special relationships:

- Vibrations $V_{i,c}$ are perceived by the spider i as a result of the information transmited by the member c who is the nearest member to i, and possesses a higher weight $w_c > w_i$;
- The vibrations $V_{i,b}$ perceived by the spider i as a result of information transmitted by the spider b holding the best weight of the entire population;
- The vibrations $V_{i,f}$ perceived by the spider i as a result of the information transmitted by the nearest female f.

Social-spiders perform cooperative interaction over other colony members depending on the gender. In order to emulate the cooperative behavior of the female spider, a new operator is defined in Eq. (5). The movement of attraction or repulsion is