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Fuzzy criteria in multi-objective feature selection for unsupervised learning

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Abstract

Feature selection in which most informative variables are selected for model generation is an important step in pattern recognition. Here, one often tries to optimize multiple criteria such as discriminating power of the descriptor, performance of model and cardinality of a subset. In this paper we propose a fuzzy criterion in multi-objective unsupervised feature selection by applying the hybridized filter-wrapper approach (FC-MOFS). These formulations allow for an efficient way to pick features from a pool and to avoid misunderstanding of overlapping features via crisp clustered learning in a conventional multi-objective optimization procedure. Moreover, the optimization problem is solved by using non-dominated sorting genetic algorithm, type two (NSGA-II). The performance of the proposed approach is then examined on six benchmark datasets from multiple disciplines and different numbers of features. Systematic comparisons of the proposed method and representative non-fuzzified approaches are illustrated in this work. The experimental studies show a superior performance of the proposed approach in terms of accuracy and feasibility.

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1. Introduction

Feature selection (FS), in some areas also referred to as dimensionality reduction, deals with selection of one or several optimal sets of attributes that are necessary and/or essential for the recognition process. The challenge of FS is to decide a minimum subset of features with little or no loss of classification/clustering accuracy. This can be formulated as a multi-objective optimization (MOO) problem. The task is the selection of relevant features, elimination of redundant features, and minimization of selected set cardinality. To date, a range of MOO-based FS techniques have been reported[14]. Cross-applications the related FS approaches can be categorized into four groups:

- Filter-supervised, i.e. class-labels known: features are selected based on their discriminating power with respect to the target classes.
- Wrapper-supervised, i.e. class labels known: subsets of features are evaluated from classification, at the point where comparison of resulting labels and actual labels occurs.
- Filter-unsupervised, i.e. class-labels unknown: features are ranked from the performance histogram of all feature dimension vectors and one or several criteria are chosen for deciding a group of features.
- Wrapper-unsupervised, i.e. class-labels unknown: computation of the subset of features is applied in terms of the performance of a clustering algorithm. In this case, tuning of parameters in clustering process will contribute in obtaining an acceptable subset of features.

The search for proper supervised predictors can usually be regarded as a pursuit for optimization, where the number of wrong-predicted operators for a known dataset should be minimized[1]. However, figuring out a similar criterion for validation in unsupervised schemas is a difficult task[2]. It cannot be relied upon that a new-found pattern obtained by optimizations resulting from an unsupervised algorithm, is able to decide if a given pattern is trustful or not. To some extent, the validity of pattern discovery is depended on a priori knowledge and intentions of decision makers. This brings us to the assumption that one often desires to employ unsupervised learning schemas in order to produce several candidate solutions for users. Additionally, some tasks in FS, cover inherent data groups and thereby omit features which might reveal the nature of hidden patterns. Therefore, the unsupervised-based multi-objective heuristic optimization algorithm is becoming an attractive approach, that has been given and increasing attention this decade.

There has been reported on development of evolutionary algorithms for multi-objective (MOEA) for unsupervised feature selection[3]. Oliveira, et al.[4] proposed a Pareto-based approach to generate a so-called Pareto-optimal front in a supervised context. Sensitivity analysis and neural networks (NN) enable to representative evaluation of fitness values. About the same time, Kim, et al.[5], used k-means clustering and Expectation Maximization (EM) as embedded unsupervised approach to evaluate a feature subset encoded in chromosomes. The MOEA employed in this case is called evolutionary local search algorithm (ELSA). With these results as a starting point, research of unsupervised learning in feature selection was expanded. Morita, et al.[6] used the k-means clustering algorithm in a wrapper approach, that encoded with Non-dominated Sorting Genetic Algorithm, type two (NSGA-II). Moreover, two objective functions, i.e. the number of features in a set, and a clustering validation (e.g. Davies-Bouldin (DB)[7]) index are introduced. Handl and Knowles[8] examined different combinations of objective functions and Mierswa[1] investigated different indices, i.e. the normalized DB index. More recent work[9] stated that their multi-objective unsupervised feature selection algorithm (MOUFSA) outperforms several other multi-objective and conventional single-objective methods, by using redundant measurements and negative epsilon-dominance. In addition, three new mutation methods are designed to enhance MOUFSA.

However, the defined criteria in classical objective functions used in unsupervised MOEA, fail to predict the performance of clustering results, i.e. the overlapping information (features) in-between classes which probably highlights the essentials that are shared within these classes. To solve this problem, we employ fuzzy criteria in a hybrid filter-wrapper approach. Pioneered by Zadeh[10], fuzzy logic-based systems have been successfully utilized to various application areas, e.g. control system and pattern classification[11]. The comprehensibility of fuzzy criteria, namely the linguistic interpretability of fuzzy partitions and the simplicity of fuzzy if-then rules[12], makes it a promising method to access qualified optimization in MOEA when employed into unsupervised learning. Although fuzzy criteria are addressed in a supervised manner[13], it rarely has been reported in unsupervised cases, in which the natural patterns are discovered according to fuzzy clustering validity and fuzzy objective functions.

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