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A new isotropic locality improved kernel for pattern classifications in remote sensing imagery

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ABSTRACT

Kernel based learning algorithms are sensitive to the choice of appropriate kernel function and parameter setting. Classification accuracies yielded by the kernel based classifiers may show variation depending on the choice of the kernel and its associated parameters. Suggesting an efficient kernel function and effective setting of kernel parameters are thus important problems for kernel based classifiers. In this article, we have investigated the performance of the existing kernel functions with our proposed kernel using support vector machines (SVMs). Linear, polynomial, sigmoid, radial basis function (RBF) and the proposed kernel are applied for the classification of the ten real life data sets having features and classes ranging from 4 to 19 and 2 to 5 respectively. The performance of different kernels is also demonstrated on two multispectral and two hyperspectral images. Experimental results on these data sets show the effectiveness of the proposed kernel on several data distributions.

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1. Introduction

Data mining is formally defined as the process of discovering interesting, previously unknown and potentially useful patterns from large amount of data (Maulik et al., 2005). These techniques include classification, clustering, regression, sequence analysis (i.e., analysis of DNA or protein sequence), link analysis and dependency modeling. Data mining tasks can be grouped into two categories: descriptive and predictive. Classification is a predictive data mining technique that learns from the current data in order to make predictions about the behavior of new data set. A typical supervised pattern recognition system consists of data acquisition, feature extraction and classification (Maulik et al., 2005; Bandyopadhyay et al., 2007).

Thus it attempts to label every sample in the entire feature space to one of the possible classes. Popular pattern classification techniques include decision trees, k-NN, neural networks and Bayesian learning. One important kernel based machine learning technique developed in 1995 is the Support Vector Machines (SVMs) (Vapnik, 1995). The SVM formulation is based on the principle of structural risk minimization, instead of the empirical risk. Based on the training samples, the SVM attempts to minimize a bound on the generalization error. As an effect, SVM tends to accomplish well when applied to data which are not in the training set. An excellent literature on SVM is available in Vapnik (1995).

Designing kernel function for kernel based classifiers including SVMs is an important research area. The biggest limitation of the support vector approach lies in the choice of the kernel. Once the kernel is fixed, the parameter(s) of the kernel in use are tuned to provide the best classification performance. Some works on kernel selection / design using prior knowledge are available in the literature, however the best choice of kernel for a given problem is still a research issue. A family of kernels have been proposed in Vishwanathan et al. (2007) based on Binet–Cauchy theorem and they are used in dynamic systems. In this article, we propose a kernel function whose associated parameters are tuned using the standard grid search technique. A new parameter r is incorporated into the proposed kernel. In the first part of the experiment, the proposed and other state-of-the-art kernel functions (linear, polynomial, sigmoid and RBF kernels) are successfully applied on 10 benchmark data sets. The empirical success of the proposed kernel on these data sets has motivated us to apply it on two multispectral and two hyperspectral images. Overall, the experimental results show that the SVM classifier designed using this kernel offers good empirical performance on these data sets.

The rest of the articles have been organized as follows. A brief literature on SVM algorithm is presented in Section 2. Section 3 describes model selection and training procedure of SVM along with standard kernels and the proposed one. Data sets and experimental results are provided in Section 5. Finally, conclusion is drawn in Section 6.

2. Support vector machines

A two-class SVM classifier is based on the hyperplanes that maximize the separating margin between the two classes (Burges, 1998). SVM technique was originally developed as a two-class pattern recognition problem which has been extended to the multi-class problem later. The basic concept of SVM is discussed as follows:

The general formulation of binary classification is as follows. Let

$$S = (\mathbf{x}_1, y_1), (\mathbf{x}_2, y_2), \ldots, (\mathbf{x}_l, y_l) \tag{1}$$

be the set of training examples, where $y_i \in \{\pm 1\}$ is the label associated with input pattern $\mathbf{x}_i$. Given a nonlinear mapping $\phi(\cdot)$, the SVM classifier minimizes:

$$J(\mathbf{w}, \xi) = \frac{1}{2}\|\mathbf{w}\|^2 + C\sum_{i=1}^{l} \xi_i \tag{2}$$

constrained to:

$$y_i(\phi(\mathbf{x}_i) \cdot \mathbf{w} + b) \geq 1 - \xi_i, \quad \xi_i \geq 0; \; i = 1, 2, \ldots, l \tag{3}$$

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