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ROBUST SUPPORT VECTOR MACHINES WITH LOW TEST TIME

YAHYA FORGHANI,[1] AND HADI SADOGHI YAZDI[2]

[1]*Computer Department, Ferdowsi University of Mashhad, Iran*
[2]*Computer Department, Center of Excellence on Soft Computing and Intelligent Information Processing, Ferdowsi University of Mashhad, Iran*

The robust support vector machines (RoSVM) for ellipsoidal data is difficult to solve. To overcome this difficulty, its primal form has been approximated with a second-order cone programming (SOCP) called approximate primal RoSVM.

In this article, we show that the primal RoSVM is equivalent to an SOCP and name it accurate primal RoSVM. The optimal weight vector of this model is not sparse necessarily. The sparser the weight vector, the less time the test phase takes. Hence, to reduce the test time, first, we obtain its dual form and then prove the sparsity of its optimal solution. Second, we show that some parts of the optimal decision function can be computed in the training phase instead of the test phase. This can decrease the test time further. However, training time of the dual model is more than that of the primal model, but the test time is often more critical than the training time because the training is often an off-line procedure while the test procedure is performed online.

Experimental results on benchmark data sets show the superiority of the proposed models.

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1. INTRODUCTION

On the basis of the idea of structural risk minimization in statistical learning theory, the support vector machines (SVM; Vapnik 1995, 1998) have been shown to provide higher performance in pattern recognition and function regression than traditional learning machines (Burges 1998). The SVM assumes that training data are known precisely. However, data uncertainty is inevitable in practical classification problems where data cannot be observed precisely, because of sampling errors, modeling errors, and/or measurement errors. Recent studies have shown that robust SVM (RoSVM), which explicitly handles the data uncertainties, can improve the performance of the traditional SVM (Bhattacharyya, Grate, et al. 2004a; Bhattacharyya, Shivaswamy, et al. 2004b; Shivaswamy, Bhattacharyya, and Smola 2006; Trafalis and Gilbert 2006, 2007; Bhadra et al. 2009; Xu 2009; Xu, Caramanis, and Mannor 2009; Ben-Tal et al. 2011; Huang et al. 2012).

The RoSVM is a complex model and difficult to solve. To overcome this difficulty, the primal form of RoSVM for hyperbox data in the input space was transformed into a linear model (Bhadra et al. 2009; Ben-Tal et al. 2011), but it was not extended to a high-dimensional feature space. Hence, this model can be used only for linear data classification. This model was utilized for interval-valued data classification and also for handling missing data (Bhadra et al. 2009; Ben-Tal et al. 2011).

The primal RoSVM for spherical data in feature space was simplified to a second-order cone programming (SOCP; Boyd 2004; Trafalis and Gilbert 2006, 2007; Xu 2009; Xu, Caramanis, and Mannor 2009). Then, it was used for robust classification of noisy data.

The primal RoSVM for ellipsoidal data in the input space was also simplified to an SOCP (Bhattacharyya, Grate, et al. 2004a; Bhattacharyya, Shivaswamy, et al. 2004b), and then it was used for classifying uncertain molecular profiling data and missing data. After

Address correspondence to Yahya Forghani, Computer Department Ferdowsi University of Mashhad, Iran; e-mail: ya_fo365@stu.um.ac.ir