MATHEMATICAL PROGRAMMING APPLICATIONS IN MACHINE LEARNING

by

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Submitted

in fulfillment of the requirements of the degree

of

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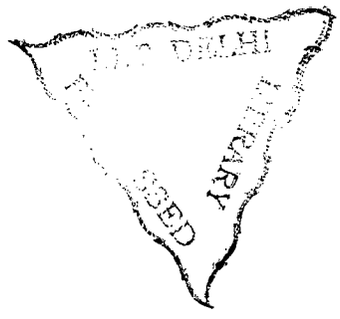
Dedicated to

My Family and God



Certificate

This is to certify that the thesis entitled **Mathematical Programming Applications in Machine Learning**, which is being submitted by **Reshma Khemchandani** for the award of the degree of **Doctor of Philosophy in Mathematics** to the **Indian Institute of Technology Delhi**, is a bona fide research work done under our guidance and supervision.

The thesis has reached the standard fulfilling the requirements of the regulations relating to the degree. The results obtained in the thesis have not been submitted to any other University or Institute for the award of any degree or diploma.

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Abstract

This thesis deals with the development of novel algorithms for the problems of binary classification and regression. These algorithms are in the support vector machines framework, which consists of constructing a separating surface that can discriminate between points of one class from the other, or a regressor which tries to fit the given data. These algorithms are generally very efficient and robust. All the proposed formulations result into the mathematical programming problems such as linear programming, quadratic programming or certain specialized convex programming problems e.g., semi-definite programming and second order cone programming.

A novel idea is the introduction of Twin Support Vector Machines (TWSVMs) for handling large datasets. Twin support vector machines aim at generating two non-parallel planes, such that each plane is closer to one of the two classes and is as far as possible from the other. In TWSVMs, we solve a pair of quadratic programming problems (QPPs), whereas in Support Vector Machines (SVMs), we solve a single QPP. Thus, TWSVM is almost four times faster as compared to conventional SVMs. Incremental TWSVMs have been proposed for reducing memory and time requirements of the learning algorithm when dealing with large datasets. Further, fuzzy membership is introduced in Incremental TWSVM which allows us to improve the overall error rate, since each of the two problems being solved can be associated with a different set of fuzzy memberships, thereby

improving the accuracy of each problem independent of the other. Another significant idea is to introduce expert knowledge along with the data for the development of Knowledge Based Support Vector Machines. The tricky problem of choosing the optimal kernel for two classification problems is formulated in terms of a Second Order Cone Programming (SOCP), which are solved by interior point methods.

In the area of regression, a Regularized Least Squares SVR (RLSSVR) is introduced for simultaneous learning of a function and its derivative. A fuzzy version of RLSSVR is also introduced and its application in the financial time series forecasting is demonstrated. We have also shown, possibly for the first time in the literature, how the partition method for computing the inverse of a matrix can be used for efficiently solving least squares SVM formulations.

Contents