University of Colorado at Colorado Springs

Home Work Assignment 3: Support Vector Machines

Out 03-19-2025, Due 04-09-2025

Introduction

We are going to learn about Support Vector Machines (SVMs) in this assignment.

The original SVM is a binary classifier, although it has been extended to multiple classes, when it is called multi-class SVM. We are going to work with the binary version of it. In SVMs, we fit a linear function to discriminate between two classes present in a dataset. The linear discriminator (or, separator or classifier) is chosen in such a way as to ensure the widest margin between examples of the two classes. Assume our dataset containing N examples is called **D**. Each example in the dataset **D** is a two-tuple $\langle \vec{x}, y \rangle$ where $\vec{x}^T = [x_1, \cdots, x_n]$ is a vector of n features and y is the class label associated with the example. The values of $y \in \{-1, 1\}$ for binary classification. Assume the parameters of the SVM we fit are given as the vector $\vec{\theta}^T = [\theta_0, \theta_1, \cdots, \theta_n]$, where θ_0 is the bias.

To Do

In this assignment, you will answer a number of questions as well as program the SVM on your own. You will also learn to use SVM using libraries in Python or R. The specifics of what you need to do are given below.

1. Our goal is to find to fit a linear function to separate the examples in the dataset. Discuss the concepts of linear separability, and a linear discriminator for binary classification. Provide the equation for a binary linear discriminator, with any necessary constraints. Use the terminologies given above.
2. In addition, for SVMs, we want the margin of separation between the two classes to be as wide as possible. Discuss the concept of a margin of separation, and how equations can be written for the fences or walls at the margins in a margin-based binary discriminator and the width of the margin.
3. Illustrate, motivate and derive the equation of the regularized loss function for SVMs. Discuss clearly the role of the loss component and the regularization component.
4. Assume you are using stochastic gradient descent for solving the SVM classification problem. Develop the update equation for gradient descent.
5. The UCI Machine Learning Repository contains some datasets for binary classification with all real number attributes. Two of these are: *Skin Segmentation Data Set* and *Planning Relax Data Set*. Download these two datasets so that you can work with them.
6. Program a solution to the SVM loss minimization problem using stochastic gradient descent.
7. Learn to perform SVM classification using libraries in Python or R.

8. Compare results of your own SVM implementation, and library-based implementations of Nearest Neighbor classification, Random Forests, two versions of Boosting Trees—AdaBoost and XGBoost—on these two datasets. Experiment with hyper-parameters that may be available for the classifiers.

What to Hand in

You will submit a 2-4 page paper with a title and your name. Use the AAAI Author style in LaTeX. In the paper, you will have a short section with an appropriate heading for each question asked and any extra work you perform. Please keep to the paper length requested above and use the right format. You may be penalized for writing too little or too much, and for not following the format.

Extra credit may be given for *substantial* additional work. Please read on your own if a topic has not been discussed in class to your satisfaction. *Make sure you have a demo scheduled with the class TA Ali AlShami the week the homework is due.*