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CS/CNS/EE 156a: Learning Systems (Fall 2023)

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**Homework 8**

|  |  |
| --- | --- |
| **Problem** | **Answer** |
| 1 |  |
| 2 |  |
| 3 |  |
| 4 |  |
| 5 |  |
| 6 |  |
| 7 |  |
| 8 |  |
| 9 |  |
| 10 |  |

**Primal Versus Dual Problem**

1. Recall that is the size of the data set and is the dimensionality of the input space. The original formulation of the hard-margin SVM problem (minimize subject to the inequality constants), without going through the Lagrangian dual problem, is

**Answer: [d] a quadratic programming problem with variables**

In the hard-margin SVM problem, we minimize using the constraint . Since the only unknowns in the constraint are and , which have dimensions of and 1, respectively, the hard-margin SVM problem is a quadratic programming problem with variables.

**SVM with Soft Margins**

*Notice: The following problems deal with a real-life data set. In addition, the computational packages you use may employ different heuristics and require different tweaks. This is a typical situation that a machine learning (ML) practitioner faces. There are uncertainties, and the answers may or may not match our expectations. Although this situation is not as “sanitized” as other homework problems, it is important to go through it as part of the learning experience.*

In the rest of the problems of this homework set, we apply soft-margin SVM to the handwritten digits from the processed U.S. Postal Service Zip Code data set. Download the data (extracted features of intensity and symmetry) for training and testing:

<http://www.amlbook.com/data/zip/features.train>

<http://www.amlbook.com/data/zip/features.test>

(The format of each row is: **digit, intensity, symmetry**.) We will train two types of binary classifiers; one-versus-one (one digit is class +1 and another digit is class , with the rest of the digits disregarded), and one-versus-all (one digit is class +1 and the rest of the digits are class ).

The data set has thousands of points, and some quadratic programming packages cannot handle this size. You may need stronger SVM packages such as **fitcsvm** in MATLAB or the free **libsvm**.

Implement SVM with soft margins on the above zip code data set by solving

When evaluating and of the resulting classifier, use binary classification error. is estimated using the test set.

Practical remarks:

1. For this homework, do not scale the data when you use libsvm or other packages or you may inadvertently change the (effective) kernel and get different results.
2. In some packages, you need to specify double precision.
3. In 10-fold cross validation, if the data size is not a multiple of 10, the sizes of the 10 subsets may be off by 1 data point.
4. Some packages have software parameters whose values affect the outcome. ML practitioners must deal with this kind of added uncertainty.

**Polynomial Kernels**

Consider the polynomial kernel , where is the degree of polynomial.

1. With and , which of the following classifiers has the highest ?

**Answer:**

1. With and , which of the following classifiers has the lowest ?

**Answer:**

1. Comparing the two selected classifiers from Problems 2 and 3, which of the following values is the closest to the difference between the number of support vectors of these two classifiers?

**Answer:**

1. Consider the 1 versus 5 classifier with and . Which of the following statements is correct? Going up or down means strictly so.

**Answer:**

1. In the 1 versus 5 classifier, comparing with , which of the following statements is correct?

**Answer:**

**Cross Validation**

In the next two problems, we will experiment with 10-fold cross validation for the polynomial kernel. Because is a random variable that depends on the random partition of the data, we will try 100 runs with different partitions and base our answer on how many runs lead to a particular choice.

1. Consider the 1 versus 5 classifier with . We use to select . If there is a tie in , select the smaller . Within the 100 random runs, which of the following statements is correct?

**Answer:**

1. Again, consider the 1 versus 5 classifier with . For the overall winning selection in the previous problem, the average value of over the 100 runs is closest to

**Answer:**

**RBF Kernel**

Consider the radial basis function (RBF) kernel in the soft-margin SVM approach. Focus on the 1 versus 5 classifier.

1. Which of the following values of results in the lowest ?

**Answer:**

1. Which of the following values of results in the lowest ?

**Answer:**