CM146, Fall 2019
Problem Set 4: Learning Theory, Boosting, Multi-class Classification
Due December 8, 2019, 11:59pm

Submission instructions

- Submit your solutions electronically on the course Gradescope site as PDF files.
- If you plan to typeset your solutions, please use the LaTeX solution template. If you must submit scanned handwritten solutions, please use a black pen on blank white paper and a high-quality scanner app.

1 PAC Learning [25 pts]

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i (1)	Label (2)	Hypothesis 1 (1st iteration)				Hypothesis 2 (2nd iteration)			
		D_0 (3)	$f_1 \equiv [x >\_\,]$ (4)	$f_2 \equiv [y >\_\,]$ (5)	$h_1 \equiv [\,\_\_\_\_\_\,]$ (6)	D_1 (7)	$f_1 \equiv [x >\_\,]$ (8)	$f_2 \equiv [y >\_\,]$ (9)	$h_2 \equiv [\,\_\_\_\_\_\,]$ (10)
1	−								
2	−								
3	+								
4	−								
5	−								
6	−								
7	+								
8	−								
9	+								
10	+								

Table 1: Table for Boosting results

2 VC Dimension [15 pts]

3 Boosting [40 pts]

i	x	y	Label
1	0	8	−
2	1	4	−
3	3	7	+
4	-2	1	−
5	-1	13	−
6	9	11	−
7	12	7	+
8	-7	-1	−
9	-3	12	+
10	5	9	+

4 Multi-class classification [60 pts]

Consider a multi-class classification problem with k class labels $\{1, 2, \ldots k\}$. Assume that we are given m examples, labeled with one of the k class labels. Assume, for simplicity, that we have m/k examples of each type.

Assume that you have a learning algorithm L that can be used to learn Boolean functions. (E.g., think about L as the Perceptron algorithm). We would like to explore several ways to develop learning algorithms for the multi-class classification problem.

There are two schemes to use the algorithm L on the given data set, and produce a multi-class classification:

- **One vs. All:** For every label $i \in [1, k]$, a classifier is learned over the following data set: the examples labeled with the label i are considered "positive", and examples labeled with any other class $j \in [1, k], j \neq i$ are considered "negative".
- **All vs. All:** For every pair of labels $\langle i, j \rangle$, a classifier is learned over the following data set: the examples labeled with one class $i \in [1, k]$ are considered "positive", and those labeled with the other class $j \in [1, k], j \neq i$ are considered "negative".