15-859(A) Machine Learning Theory

Homework # 2 **Due: January 29, 2004**

Groundrules: Same as before. You should work on the exercises by yourself but may work with others on the problems (just write down who you worked with). Also if you use material from outside sources, say where you got it.

Exercises:

1. **Weighted-majority.** For this problem you may use either the deterministic or randomized weighted-majority algorithm.

   (a) Suppose we have some initial belief about which expert is likely to be the best one. In that case, a natural modification to the Weighted-Majority algorithm is that instead of initializing all the weights to 1, we instead initialize $w_i = p_i$, where p_i is our initial belief that expert i is going to be best ($\sum_{i=1}^{n} p_i = 1$). Show how this results in a bound where the $\ln n$ term is replaced with $\ln(1/p_i)$. For example, if you pick the randomized algorithm, you should get a statement that for all i,

   $$M \leq \frac{1}{\epsilon}\left[m_i \ln(1/(1-\epsilon)) + \ln(1/p_i)\right],$$

   where m_i is the number of mistakes of expert i. So, this bound is better if our prior beliefs turn out to be reasonable.[1]

   (b) What if we have infinitely many experts? Use your answer to part (a) to show how you can replace $\ln n$ with $O(\log i)$ in comparing our performance to that of the ith expert.

2. **A bad modification to Winnow.** Suppose that we modify Winnow so that it doubles its weights on positive examples even when it did *not* make a mistake. Show how this can cause the algorithm to make an unbounded number of mistakes, even if all examples *are* consistent with some disjunction.

Problems:

3. **Tracking a moving target.** Here is a variation on the deterministic Weighted-Majority algorithm, designed to make it more adaptive.

   (a) Each expert begins with weight 1 (as before).

   (b) We predict the result of a weighted-majority vote of the experts (as before).

   (c) If an expert makes a mistake, we penalize it by dividing its weight by 2, but *only* if its weight was at least 1/4 of the average weight of experts.

[1] Notice that in this analysis we are *not* assuming that the best expert is actually picked from our prior. We simply are producing a bound that depends on what our beliefs were.

Prove that in any contiguous block of trials (e.g., the 51st example through the 77th example), the number of mistakes made by the algorithm is at most $O(m + \log n)$, where m is the number of mistakes made by the best expert *in that block*, and n is the total number of experts.

(If you get stuck, there is a proof in the Littlestone-Warmuth paper, but my guess is that it is easier to prove it yourself. If you do read their proof, you must still prove it in your own words.)