Active Learning Recitation

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Outline

● Review Active Learning Model
● Active Learning Algorithms
● Active Learning Practice Problems
Active Learning

- Supervised Learning: training set contains labeled examples

Massive amounts of data, could be costly or time-consuming to label

- Active Learning: Do we need to have labels for every datapoint?
Batch Active Learning

- Learner can choose specific examples to be labeled.
- Goal: use fewer labeled examples [pick informative examples to be labeled].
Motivating Example

- Threshold functions on the real line: \( h_w = 1(x > w) \)

Active algorithm: Get \( N \) unlabeled examples

- *Binary search* to find the correct threshold. \( O(\log n) \) labels

Passive supervised learning: \( N \) labels to find OPT, \( \Omega(1/\varepsilon) \) to get \( \varepsilon \) error

Active Learning: \( O(\log n) \) labels to find OPT, \( O(\log 1/\varepsilon) \) to get \( \varepsilon \) error
Active SVM seems to be quite useful in practice.

[Tong & Koller, ICML 2000; Jain, Vijayanarasimhan & Grauman, NIPS 2010]

Algorithm (batch version)

Input $S_u = \{x_1, ..., x_m\}$ drawn i.i.d from the underlying source $D$

Start: query for the labels of a few random $x_i$s.

For $t = 1, ...,$

- Find $w_t$ the max-margin separator of all labeled points so far.

- Request the label of the example closest to the current separator: minimizing $|x_i \cdot w_t|$.

(highest uncertainty)
Active Learning in Practice

One caveat: sampling bias

- Bias created because of querying strategy
- As time goes on, the sample is less and less representative of the true source
- Sampling bias is observed in practice
Disagreement Based Active Learning \textsuperscript{[CAL92]}

Algorithm:

Query for the labels of a few random $x_i$s.

Let $H_1$ be the current version space.

For $t = 1, \ldots,$

Pick a few points at random from the current region of disagreement $\text{DIS}(H_t)$ and query their labels.

Let $H_{t+1}$ be the new version space.
Region of uncertainty [CAL92]

- Current version space: part of $C$ consistent with labels so far.
- "Region of uncertainty" = part of data space about which there is still some uncertainty (i.e. disagreement within version space)
Practice Questions

In this problem you will design an active learning algorithm for finding a consistent linear separator passing through the origin when the data is on the unit circle in 2 dimensions. That is, given a dataset \( S = \{x_1, \ldots, x_n\} \) with \( \|x_i\| = 1 \) for all \( i = 1, \ldots, n \), your goal is to find a consistent classifier of the form \( h(x) = \text{sign}(w^T x) \). Assume we are in the realizable setting.

(a) [8 pts.] First, suppose that our data lies only on the top half of the circle (e.g., see Figure 3a). In 1–2 sentences, describe an algorithm for finding a consistent linear separator passing through the origin using \( O(\log n) \) label queries. Hint: this problem is very similar to learning a consistent threshold function for data on the real line.

(b) [Extra Credit 4 pts.] Describe in 1–3 sentences how to extend your algorithm from part (a) so that it works for data anywhere on the circle. See Figure 3b for an example dataset. Hint: use the fact that for any point \( v \) \( \text{sign}(w^* (v)) = -\text{sign}(w^*(v)) \) (where \( w^* \) is the target weight vector) to try to reduce this case to the case studied in part (a).
Practice Questions

● Assume the data lies in one dimension, and your goal is to find a consistent interval classifier of the form $h_{[a,b]} = 1(a < x < b)$? Assume we are in the realizable setting. What is the smallest label complexity you can have?

● Assume the data lies in two dimensions, and your goal is to find a consistent two-dimensional threshold classifier of the form $h_{a,b} = 1(x_1 > a, x_2 > b)$? Assume we are in the realizable setting. What is the minimum label complexity you can have?
Practice Questions

- Now suppose we want to learn a class of rectangles in 2-D. A rectangle predicts positive on points inside and negative on points outside. Assume we are in the realizable setting.

- What is the version space?
- What is the region of disagreement?
- Can we imply other labels?
Questions?