Active Accuracy Estimation on Large Datasets

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Outline

1. Goal
2. Background
3. Proposed Solution
4. Results
5. Summary

Goal I

- **Accuracy estimation** : Estimate accuracy of a classifier on a large unlabeled dataset based on a small, possibly unrepresentative, labeled set and a human labeler
  - **Results** : Between 15% and 62% relative reduction in error compared to existing approaches.

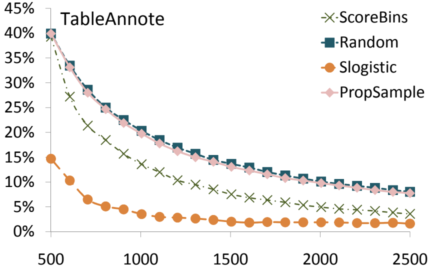

Figure: Absolute error (on the Y axis) of different estimation algorithms against no. of labeled instances (on the X axis)

Goal II

- **Scalable algorithm** : Perform accuracy estimation on unlabeled data so large that it makes even a single sequential scan impractical in an interactive setting
  - **Results** : Able to match within 0.5% of the estimates of methods based on full scan while sampling just 2.5k instances from indexed unlabeled data

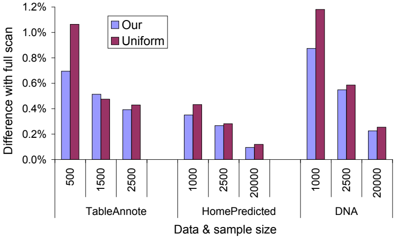

Figure: Comparing methods of sampling from indexed data for estimating bucket weights

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Motivation

- Many applications rely on output of imperfect classifiers deployed on large datasets
  - **Examples**: Web page classification, classifying columns of a table to their semantic types
- **Common characteristics**
  - Large and diverse dataset
  - Labeled data unrepresentative of the entire dataset.
- So Measured accuracy on labeled set $\neq$ True accuracy on data
- Hence need a method that can converge to the true accuracy
  1. An algorithm that returns estimate $\hat{\mu}$ of true accuracy μ of the classifier
  2. *Scalable algorithm* : should work on large datasets where sequential scan not possible & data accessible only via an index

Related Work

- Most existing work on *learning* rather than *evaluating* classifiers
- Existing works on selecting instances for evaluating classifiers:
  - (Sawade et al., 2010) present a new proposal distribution for sampling instances
  - (Bennett and Carvalho, 2010) and (Druck and McCallum, 2011) use stratified sampling. However, both assume that classifier $C(\mathbf{x})$ is probabilistic & base their selection on $\Pr(y|\mathbf{x})$ scores
- Unlike (Bennett and Carvalho, 2010) and (Druck and McCallum, 2011), instead of fixing a stratification, we learn a new one every time more data gets labeled
- None of the existing methods consider cases where the dataset D is too large to even afford a single sequential scan

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Overall Idea

Algorithm 1 Loop for active accuracy estimation

$B = \#\text{buckets}$, $\mathbf{f} = $ feature vector, $\mathbf{w}_{1 \ldots r} = $ hyperplanes
$\hat{\mu}_b, p_b = $ accuracy & weight esimates for bucket b
repeat
    Learn stratification function $h(\mathbf{f}|\mathbf{w}_{1 \ldots r})$
    Stratify L via $h(.)$ & compute $\{\hat{\mu}_b : 1 \leq b \leq B\}$
    Stratify D via $h(.)$ & compute $\{p_b : 1 \leq b \leq B\}$
    Display accuracy estimates: $\hat{\mu}_S = \sum_b p_b \hat{\mu}_b$
    Get stratified sample set L' from D
    For each $\mathbf{x}_i \in L'$, get label y_i, and add $(\mathbf{x}_i, y_i)$ to L
until accuracy $\hat{\mu}_S$ not converged and labeler not bored.
Return $\hat{\mu}_S$

Learning a stratification strategy

- Stratify input space so that instances in each stratum have similar accuracy values
  - *Supervised clustering methods* : Learn a distance function
    Issue : These methods do not scale well
  - **Proposal** : Use Hash codes based on projections on hyperplanes learned over the feature space
- Learning hyperplanes (kindly refer the paper for details)
  - *Smoothing the objective* : Upper-bound with minimum of two convex objectives
  - *Optimizing the smoothed objective* : EM-like algorithm
  - *Ensuring distinct r hyperplanes* : Re-weight instances – ideas from boosting.
- $\hat{\mu}_b = \frac{1}{n_b} \sum_{i \in L_b} a_i$ prone to over-fitting. Smooth based on labeled data in neighbouring buckets
- Method agnostic to the type of classifier under consideration

Scaling up – Instance selection on large amounts of data

- TODO: explain where instance selection is needed
- TODO: describe the idea behind the algorithm to perform accuracy estimation & instance selection on unlabeled data D which can only be accessed via an efficient index partition

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Results I

Dataset	# Features	Size		Accuracy (%)	
		Seed(L)	Unlabeled(D)	Seed(L)	True(D)
TableAnnote	42	541	11,954,983	56.4	16.5
Spam	1000	5000	350,000	86.4	93.2
DNA	800	100,000	50,000,000	72.2	77.9
HomeGround	66	514	1060	50.4	32.8
HomePredicted	66	8658	13,951,053	83.2	93.9

Table: Summary of Datasets

Results II

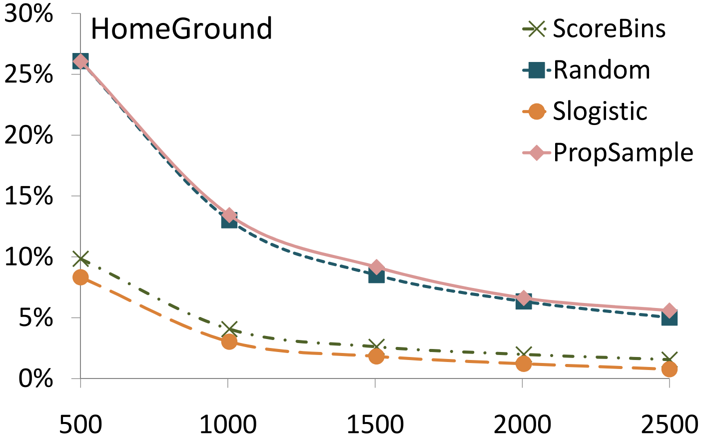

Figure: Homeground data: Absolute error (Y axis) of different estimation algorithms against increasing number of labeled instances (X axis)

Results III

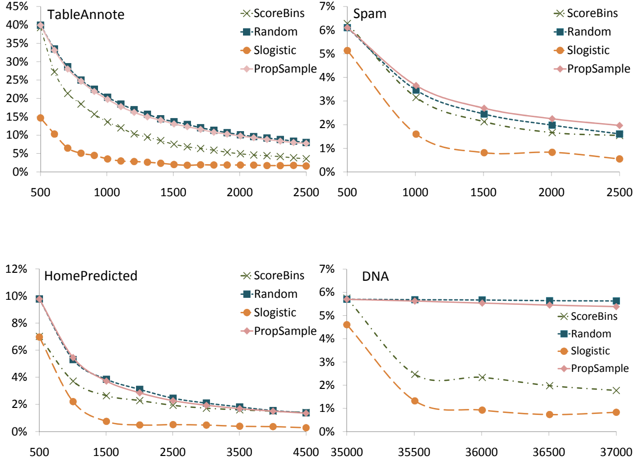

Figure: Absolute error (on the Y axis) of different estimation algorithms against increasing number of labeled instances (on the X axis)

Results IV

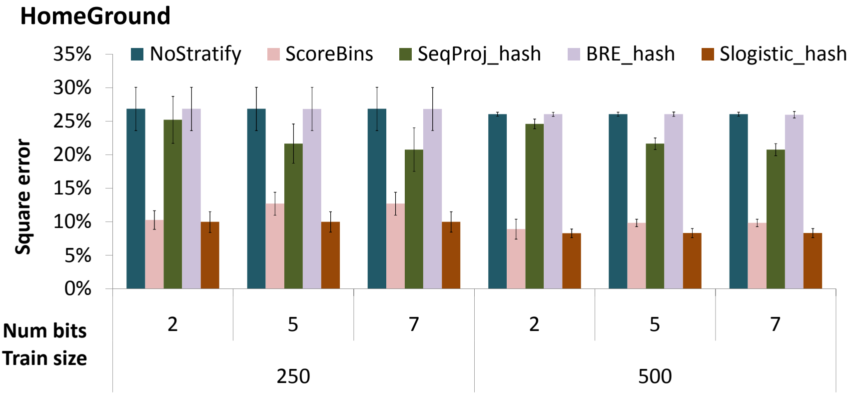

Figure: HomeGround data: Error of different stratification methods against increasing training sizes & for different number of bits

Results V

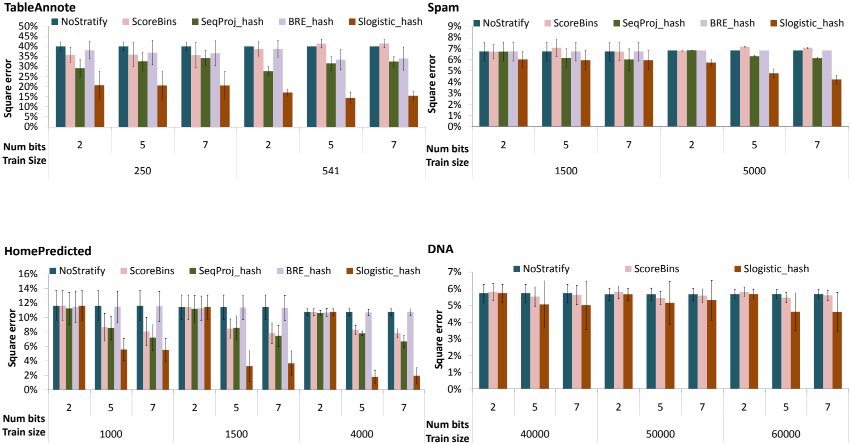

Figure: Error of different stratification methods against increasing training sizes and for different number of bits

Results VI

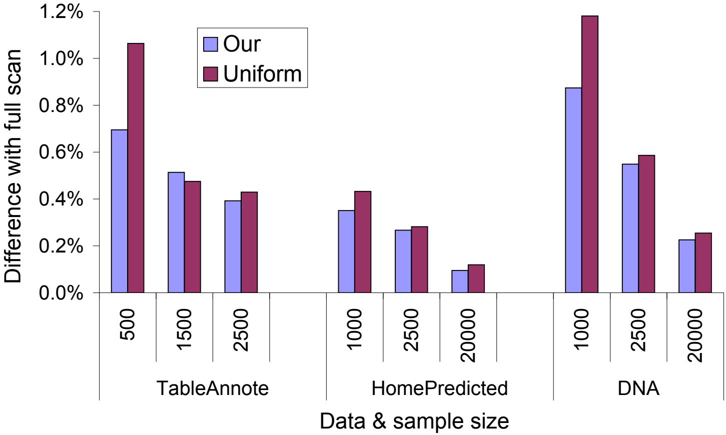

Figure: Comparing methods of sampling from indexed data for estimating bucket weights

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Summary

1. Addressed the challenge of *calibrating a classifier's accuracy on large unlabeled datasets given small amounts of labeled data and a human labeler*
2. Proposed a stratified sampling-based method that provides better estimates than simple averaging & better selection of instances for labeling than random sampling
3. Between 15% and 62% relative reduction achieved in error compared to existing approaches
4. Algorithm made *scalable* by proposing optimal sampling strategies for accessing indexed unlabeled data directly
5. Close to optimal performance while reading three orders of magnitude fewer instances on large datasets

Thank You

References I

Paul N. Bennett and Vitor R. Carvalho. Online stratified sampling: evaluating classifiers at web-scale. In *CIKM*, 2010.

Gregory Druck and Andrew McCallum. Toward interactive training and evaluation. In *CIKM*, 2011.

Christoph Sawade, Niels Landwehr, Steffen Bickel, and Tobias Scheffer. Active risk estimation. In *ICML*, 2010.