Leverage based sampling for classification

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Abstract

We validate the results of leverage based sampling for Least-squares regression, shown by Ma et al. [1]. We explore the possibility of using the leverage based sampling distribution from LS-regression on 2 class classification, and introduce a new approach for sampling from an leverage distribution (important points).

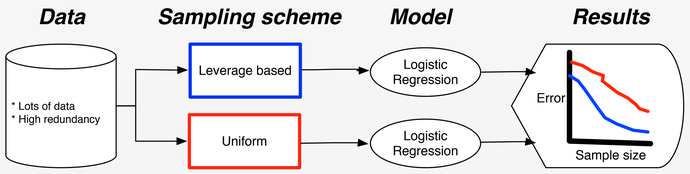
Motivation

For video the importance of sampling methods is initiated by very large and high-dimensional datasets where

- It is not feasible to use all of the available data.
- There is a high redundancy between datapoints (25 fps).
- Time taken in fitting a model is rarely linear to the input.

We therefore want to explore alternative sampling methods, and try to identify which datapoints are important when fitting a model.

Concept



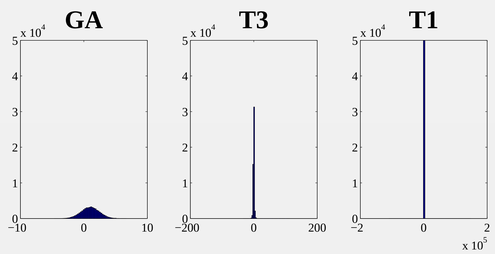
Research Questions

- Can we validate the results for least-squares regression shown by Ma et al. ?
- Will a linear regression based sampling distribution improve our performance in classification?
- Can leverage based sampling be generalized and used for classification?

Datasets

These datasets are drawn from distributions defined in Ma et al. [1] and characterised by

- GA: Nearly uniform leverage-scores
- T3: Mildly non-uniform leverage-scores
- T1: Very non-uniform leverage-scores



Figur 2: The three distributions considered.

Leveraging for least-squares regression

When fitting a model, we know that some datapoints are more important that others, leveraging is based on the idea that we can determine the importance of these point beforehand.

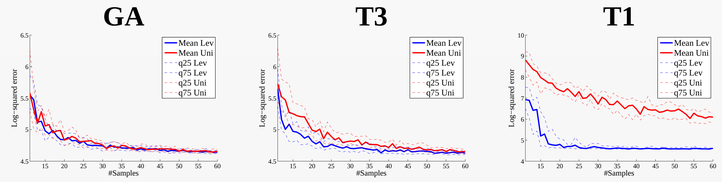
1. A leverage-score is calculated for each datapoint (its importance).
2. These scores are normalised into a distribution $\mathbf{H}$to sample from.

Ma. et al. [1] show that the leverage-scores for least-square regression is the diagonal elements of $\mathbf{H}$

$$\mathbf{H} = (\mathbf{X}^T\mathbf{X})^{-1}\mathbf{y} \tag{1}$$

Validation of the results Ma et al.

We have empirically tested and validated the results shown by Ma et al. [1].



Figur 3: Comparison of uniform vs. leverage based sampling schemes for least-squares regression. $N = 1000$, $d = 10$.

- GA: The leverage score are approximately uniform, and thus there is no significant difference between the two sampling schemes.
- T3: Leveraging consistently provides slightly better results compared to uniform sampling.
- T1: With *very non-uniform* leverage-scores, leveraging clearly outperforms uniform sampling.

There results are consistent when varying N and d, although the level of improvement using leveraging compared to uniform varies.

LS-based Distribution

We want to generalise the leveraging concept, that is to find the effect that a datapoints class has on the predicted class for that datapoint:

$$\frac{\delta\hat{\mathbf{y}}_n}{\delta\mathbf{y}_n} \tag{2}$$

There is a closed form solution which is linear in y

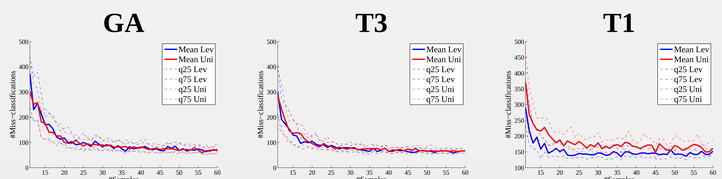
$$\hat{\beta}_{OLS} = \left(\mathbf{X}^T\mathbf{X}\right)^{-1}\mathbf{X}^T\mathbf{y} \quad \text{where} \quad \hat{\mathbf{y}}_n = \mathbf{X}_n * \hat{\beta}$$

Therefore the leverage-score (2) is the coefficient

$$\frac{\delta\hat{\mathbf{y}}_n}{\delta\mathbf{y}_n} = \mathbf{X}\left(\mathbf{X}^T\mathbf{X}\right)^{-1}\mathbf{X}^T$$

Test Results

We compared logistic regression when sampling from a LS-distribution (blue) vs. a uniform-distribution (red). The mean, 25th and 75th quantile are plotted.



Figur 4: LS- vs. uniform-distribution based sampling for logistic regression.

- A LS-distribution sample scheme is no better that uniform sampling on datasets of type GA and T3.
- With very non-uniform leverage scores, T1, the LS-distribution slightly outperforms uniform sampling.

The results shown are for dimension $p = 10$ and $N = 1000$ datapoints, but it is consistent when varying p and N.

Sensitivity Based Distribution

Vi generalisere til noget andet, og derfor kan WLS ikke bruges, s**r**a vi laver bare LS. The target is again (2)

$$\hat{\mathbf{y}}_n = p(y|\bar{\mathbf{x}_n}, \bar{\mathbf{w}}) \quad \bar{\mathbf{w}} \text{ s.t. } \frac{\delta L}{\delta\bar{\mathbf{w}}} = 0$$

Since depends both directly and indirectly on y we see that

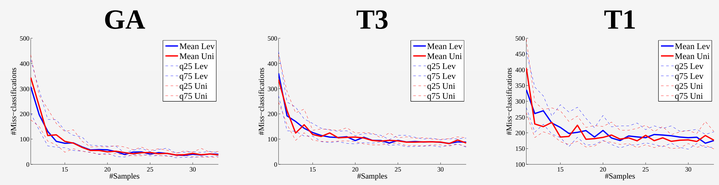
$$\frac{\delta}{\delta\mathbf{y}}\frac{\delta\mathcal{L}}{\delta\bar{\mathbf{w}}} = 0$$
$$\Downarrow$$
$$\frac{\delta^2\mathcal{L}}{\delta\mathbf{y}\delta\bar{\mathbf{w}}} + \frac{\delta^2\mathcal{L}}{\delta\bar{\mathbf{w}}\delta\bar{\mathbf{w}}^T}\frac{\delta\bar{\mathbf{w}}}{\delta\mathbf{y}} = 0$$

and from this we can get our leverage-score (2)

$$\frac{\delta\hat{\mathbf{y}}_n}{\delta\mathbf{y}_n} = \frac{\delta p(y|\bar{\mathbf{x}}_n, \bar{\mathbf{w}})}{\delta\bar{\mathbf{w}}^T}\frac{\delta\bar{\mathbf{w}}}{\delta\mathbf{y}} = -\frac{\delta p(y|\bar{\mathbf{x}}_n, \bar{\mathbf{w}})}{\delta\bar{\mathbf{w}}^T}\left[\frac{\delta^2\mathcal{L}}{\delta\bar{\mathbf{w}}\delta\bar{\mathbf{w}}^T}\right]^{-1}\frac{\delta^2\mathcal{L}}{\delta\mathbf{y}\delta\bar{\mathbf{w}}}$$

When evaluating this model, weights trained on a small training-set is used. This is expected to be better than LS-based sampling since it introduces dependence on class information.

Test results



Figur 5: Comparison of sensitivity vs. uniform -based sampling for logistic regression.

New questions??????

From our work several new question arise.

- How large show the initial sampling size be for sensitivity-based sampling?
- Should all points be sampled from the initial weights found, or should the process be iterative?

Conclusion

In the case of linear regression, leverage-based sampling provides a improvement over uniform sampling when the leverage-scores are mildly or very non-uniform.
Using the LS-based sampling for classification shows know improvement on datasets *GA* and *T3*, but for *T1* with very non-uniform leverage-scores, the approach is slightly better.
We have generalised the concept of leverage-based scores to classification, but for logistic regression it has not led to improvements.

References

Litteratur

[1] Ma et al. A statistical perspective on algorithmic leveraging. *arXiv:1306.5362v1 [stat.ME]*, June 2013.