Selected Topics in Applied Machine Learning: An integrating view on data analysis and learning algorithms

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Practical methods for feature selection

- Filters and wrappers
- Variable importance produced by ensembles
- Feature selection by Lasso
- SVM-RFE – Recursive Feature Elimination
Variable importance (AdaBoost) – cry
**Algorithm 2** Recursive feature elimination using the SVM learner with cross-validated optimization of the SVM parameter cost in each iteration step.

**Input:** Training data set and the initial feature set

**Output:** The best SVM classifier $M_{\text{max}}$ and the corresponding feature subset $S_{\text{max}}$

1: $K \leftarrow \text{the initial feature set size}$
2: $S_K \leftarrow \text{the initial feature set}$
3: **for** $k \leftarrow K$ **down to** 1 **do**
4: \hspace{1em} learn a linear SVM model using the feature set $S_k$ and tune its parameter cost
5: \hspace{1em} $M_k \leftarrow \text{the best tuned linear SVM model using the feature set } S_k$
6: \hspace{1em} $f_{\text{worst}} \leftarrow \text{the least useful feature in the model } M_k$
7: \hspace{1em} $S_{k-1} \leftarrow S_k \setminus \{f_{\text{worst}}\}$
8: **end for**
9: $M_{\text{max}} \leftarrow \text{choose the best model from } \{M_i\}_{i=1}^K$
10: $S_{\text{max}} \leftarrow \text{the best feature subset corresponding to the best model } M_{\text{max}}$
Goal

A complex comparison of competing models trained for the VPR task

- **Model** = method + set of features + learning parameters
  - feature set may be considered as a parameter of the model (!)

- Model flexibility is model’s ability to fit the data well

- Higher flexibility implies higher complexity **but not vice versa**
Outline

• Concluding remarks on methods for reducing the variance
  – ensembles vs. feature selection vs. regularization

• The “Bayes classifier” – the limit of the test error

• A bootstrap method for estimating the generalization error

• More complex comparison of the developed VPR classifiers
  – confidence intervals, an indicator of the model variance

• Concluding remarks & concluding questions
Model assessment and model selection

Assessment – a dictionary definition

- Assessment means the evaluation or estimation of the nature, quality, or ability of someone or something.
Model assessment and model selection

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- Model assessment
  – the process of evaluating a model’s performance

- Model selection
  – the process of selecting the proper level of flexibility
Model assessment and model selection

Finding a model that minimizes generalization error
In a linguistic research, we are also interested in the interpretability of the model, namely in

- recognizing/discovering important features
- error analysis
Leo Breiman: “Instability (of base learners) is an essential ingredient for bagging or arcing to improve accuracy.”
Unstable classifiers and ensembles

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“Instability (of base learners) is an essential ingredient for bagging or arcing to improve accuracy.”

- Unstable classifiers are characterized by high variance
- Decision trees are especially suitable for building ensembles because
  - they are extremely flexible to fit "any data", i.e. they can have very low bias
  - they are unstable, i.e. they have high variance
Ensembles and feature selection and regularization

How and why do the techniques for decreasing variance work?
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- feature selection and regularization decrease model complexity
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- bagging-based ensembles average a large set of low correlated results
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- feature selection and regularization decrease model complexity
- bagging-based ensembles average a large set of low correlated results
- AdaBoost decreases bias in the early iterations
  – it decreases variance as well, namely in later iterations
**Bayes classifier** assigns each example to the most likely class, given its feature values

\[
\hat{y} = \max_y \Pr(y \mid x)
\]

The Bayes classifier produces the lowest possible test error rate, so called **Bayes error rate**

\[
1 - \mathbb{E} \left( \max_y \Pr(y \mid x) \right)
\]
What is the lowest possible error rate

Identical feature vectors?
What is the lowest possible error rate

Identical feature vectors?

- Get the same feature vectors
- How many of them have the same target value?
What is the lowest possible error rate

\[ \hat{y}_i = h^*(x_i) \]
Competing models for VPR

- Confidence intervals
Generalization error estimation by bootstrapping

- Suppose a development data of $n$ examples
- Train a model on the data
- Test the model on the data
- Get training error = optimistic error $e_l$
- Repeat 200 times
  - Randomly select $n$ examples with replacement and train a model on average, 63.2% of the original sample
  - Test the model on the examples not used in the training on average, 36.8% of the original sample
  - Get test error
- Get mean test error = pessimistic error $e_o$
- **generalization error estimation** $= 0.368 \times e_l + 0.632 \times e_o$
Overview of all models developed
It’s Friday afternoon! No more slides, no more lectures!
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- It was a pleasure for us to be here with you.
- We are glad that we could teach you something.
- You were the bright audience.

Thank you!