A Novel Min-max Approach to Select Features in Nonlinear SVM Classification

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Aim

Design a **Mathematical Optimization** approach for **feature selection** in **nonlinear Support Vector Machine** classification.

Literature Review

- Do not take into account classifier.
- Number of selected features is prefixed.
- Tedious ad-hoc approaches. Tune several hyperparameters

Our contributions

- Method which simultaneously selects features and classify.
- # selected features is not fixed, but provided by our approach.
- No ad-hoc strategies. Off-the-shelf solvers.

Problem Formulation

Anisotropic Gaussian kernel

$$K(x_i, x_\ell) = \exp\left(-\sum_{j=1}^{M} \gamma_j (x_{ij} - x_{\ell j})^2\right)$$

$$\begin{cases} \min\limits_{\gamma \geq 0} \left[C_2 \|\gamma\|_p^p + (1 - C_2) \max\limits_{\alpha} \sum\limits_{i \in S} \alpha_i - \frac{1}{2} \sum\limits_{i,\ell \in S} \alpha_i \alpha_\ell y_i y_\ell K_\gamma(x_i, x_\ell) \right] \\ \text{s.t.} \sum\limits_{i \in S} \alpha_i y_i = 0 \\ 0 \leq \alpha_i \leq C, \forall i \end{cases}$$

Model complexity

Classification accuracy

Trade-off

Problem Reformulation

- Strong duality. Single level equivalent reformulation.
- Off-the-shelf solvers.

Summary of the results

- Similar or better accuracy results.
- When similar results our approach provides less features.

Further info

A novel embedded min-max approach for feature selection in nonlinear Support Vector Machine classification

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Abstract

In recent years, feature selection has become a challenging problem in several machine learning fields, particularly in classification problems. Support Vector Machine (SVM) is a well-known technique applied in (nonlinear) classification. Various methodologies have been proposed in the literature to select the most relevant features in SVM. Unfortunately, all of them either deal with the feature selection problem in the linear classification setting or propose ad-hoc approaches that are difficult to implement in practice. In contrast, we propose an embedded feature selection method based on a min-max optimization problem, where a trade-off between model complexity and classification accuracy is sought. By leveraging duality theory, we equivalently reformulate the min-max problem and solve it without further ado using off-the-shelf software for nonlinear optimization. The efficiency and usefulness of our approach are tested on several benchmark data sets in terms of accuracy, number of selected features and interpretability.

Keywords: Machine learning, min-max optimization, duality theory, feature selection, nonlinear Support Vector Machine classification

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Conclusions

- Min-max optimization problem for SVM classification and feature selection.
- Single-level reformulation based on strong duality.
- Simple but efficient solving strategy. No ad-hoc.
- Competitive with existing literature results.

Future Research

- Extension to regression or clustering.
- Include physical information.

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Thank you very much for your attention!

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