

Rules-Based Prediction Models: Training an Entire Accuracy-Complexity Tradeoff Frontier

From Knowledge to Competitiveness

Portugal-US Partnerships 2026 Summit

MIT Portugal Program

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Interpretable Machine Learning: Sum-of-Rules Model

Artificial Intelligence

Interpretable Model for Regression/Classification

Sum-of-Rules
(3 rules)

Rule
(2 splits)

Split
(Yes/no question)

Rule/Condition	Prediction
Baseline	→ +14.1
[age > 14]	→ +19.5
[cement > 355]	→ +13.7
[cement > 212.57] & [water ≤ 183.8]	→ +15.0

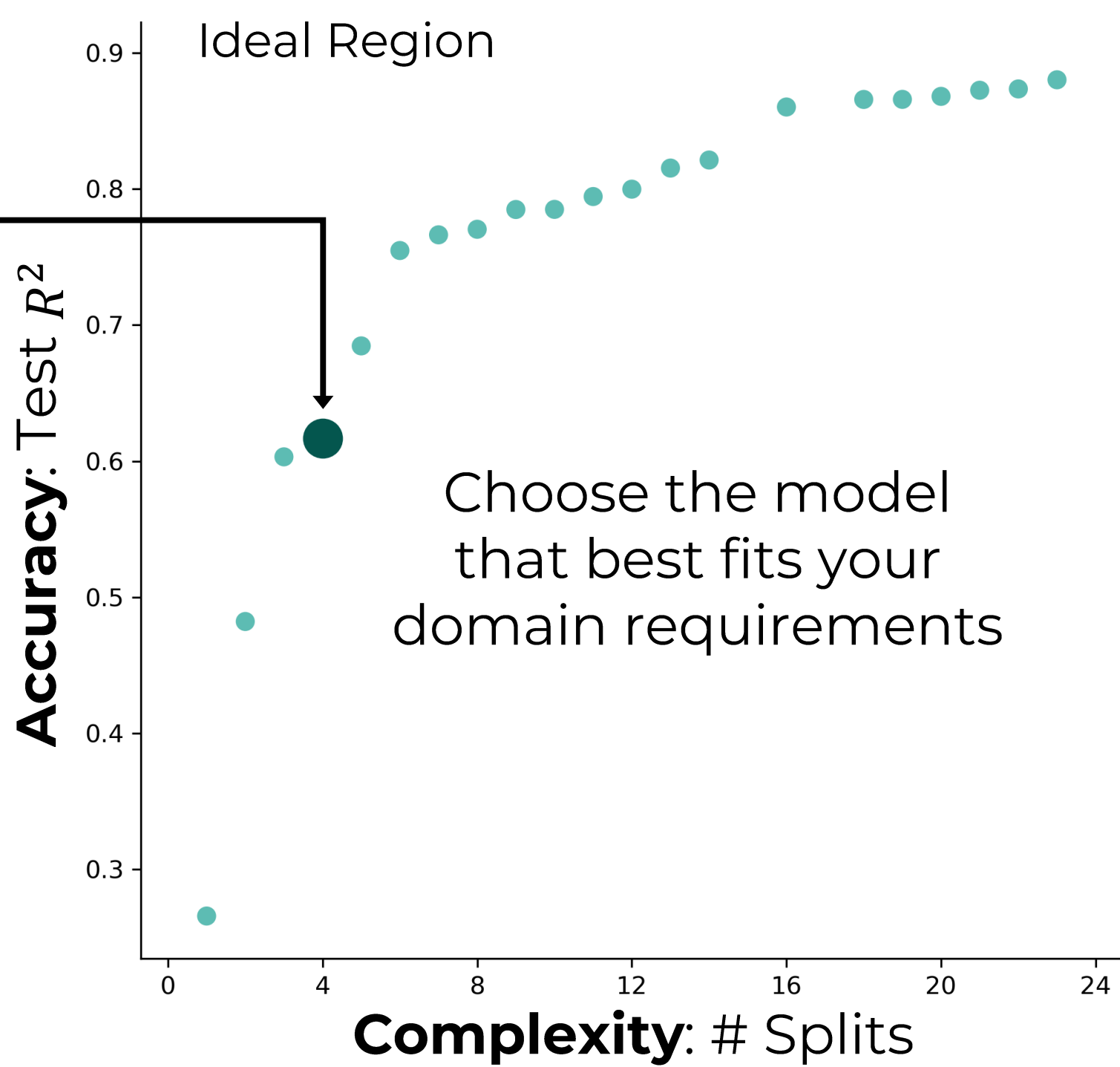
[cement > 212.57] & [water ≤ 183.8]

+15.0

Effect

[cement > 212.57]

Accuracy-Complexity Tradeoff



High-accuracy models are more complex to interpret.

We optimize both accuracy and complexity (number of rules/splits/features, etc.).

Interpretable models are essential when decisions must be auditable (healthcare, public policy, manufacturing, etc.).

Training an Entire Pareto Frontier

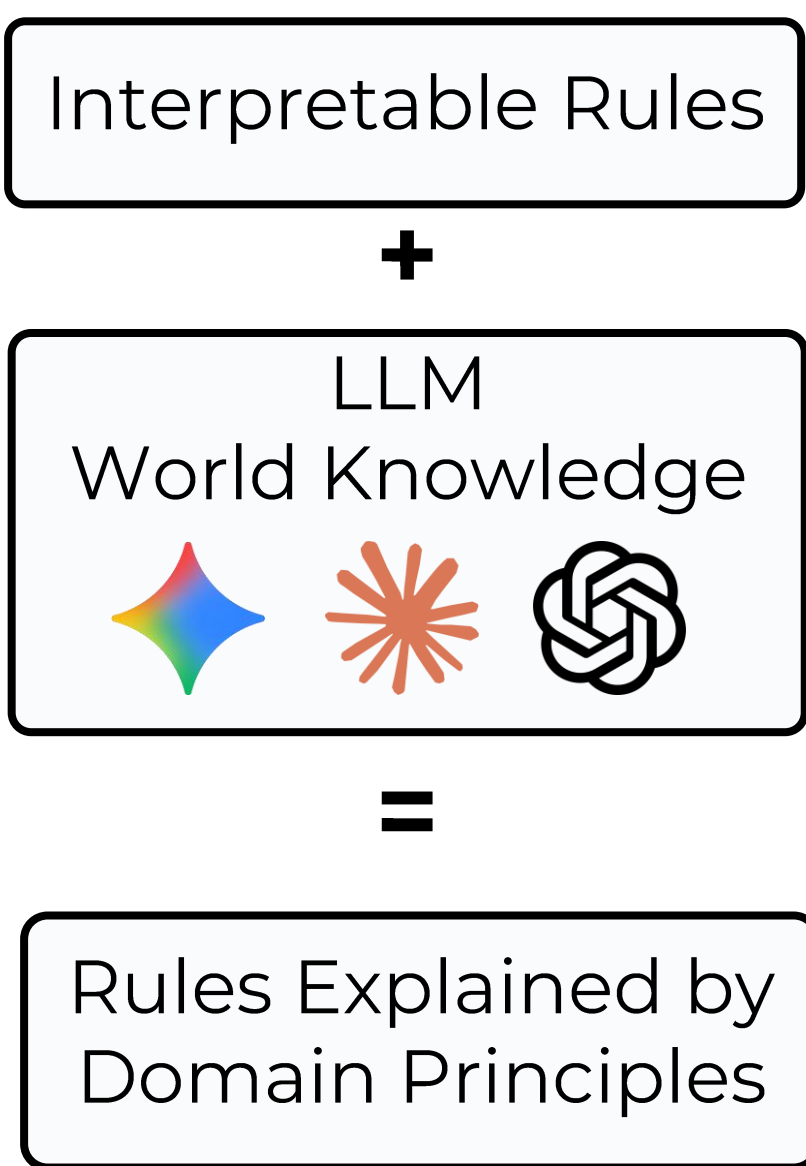
Main Contributions

- Simultaneously optimize accuracy and complexity.
- Train the entire Pareto frontier in one execution.
- Combine guarantees from mathematical optimization with multiobjective search from evolutionary methods.
- Construct models from scratch (no distillation).

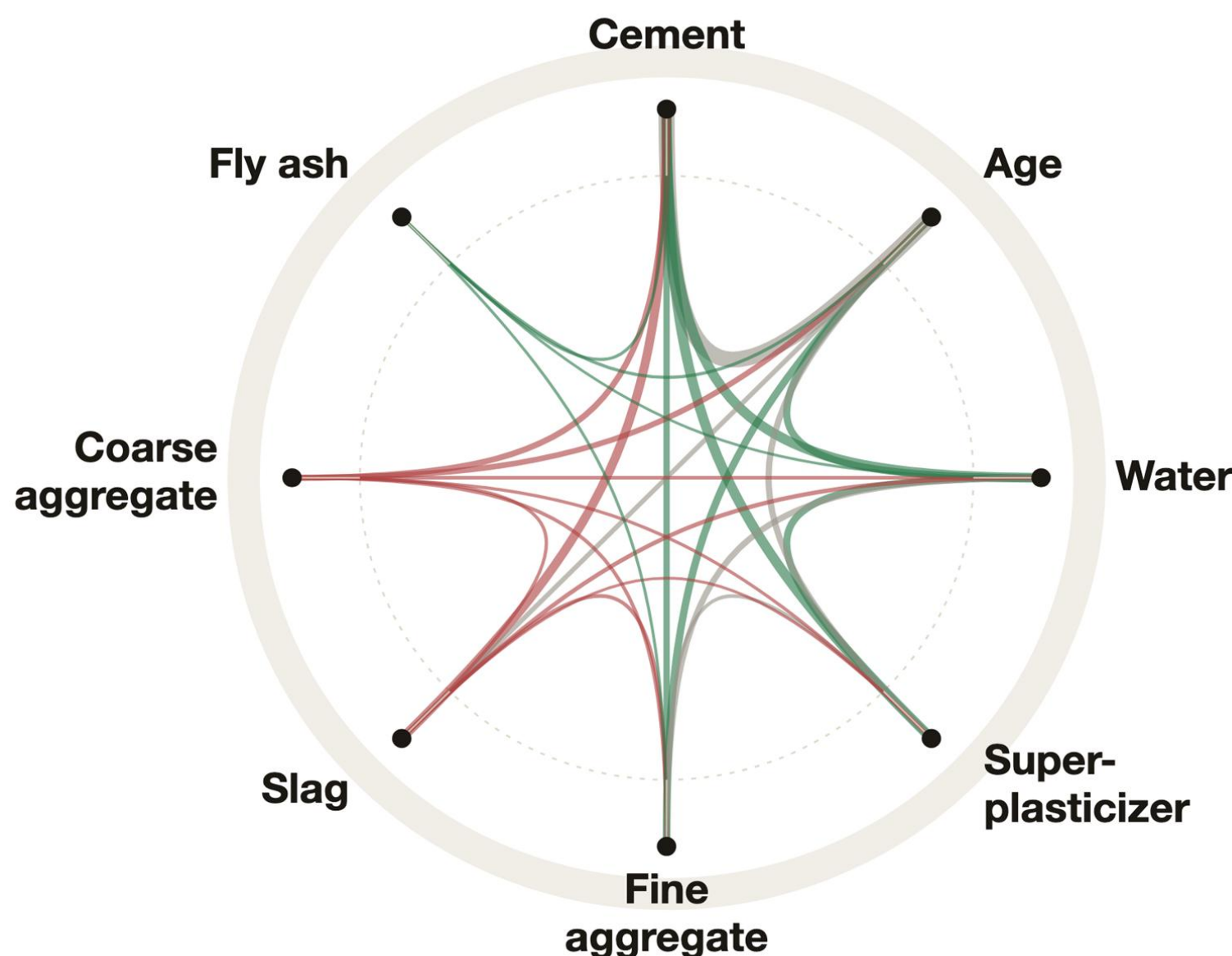
Optimization Framework

$$\min_{\beta, b: \|\beta\|_0 \leq B} \underbrace{\mathcal{L}(\beta, b)}_{\text{Loss}} + \sum_k \lambda_k \underbrace{\mathbf{1}[\beta_j \neq 0] f_k(R_j)}_{\text{Complexity}}$$

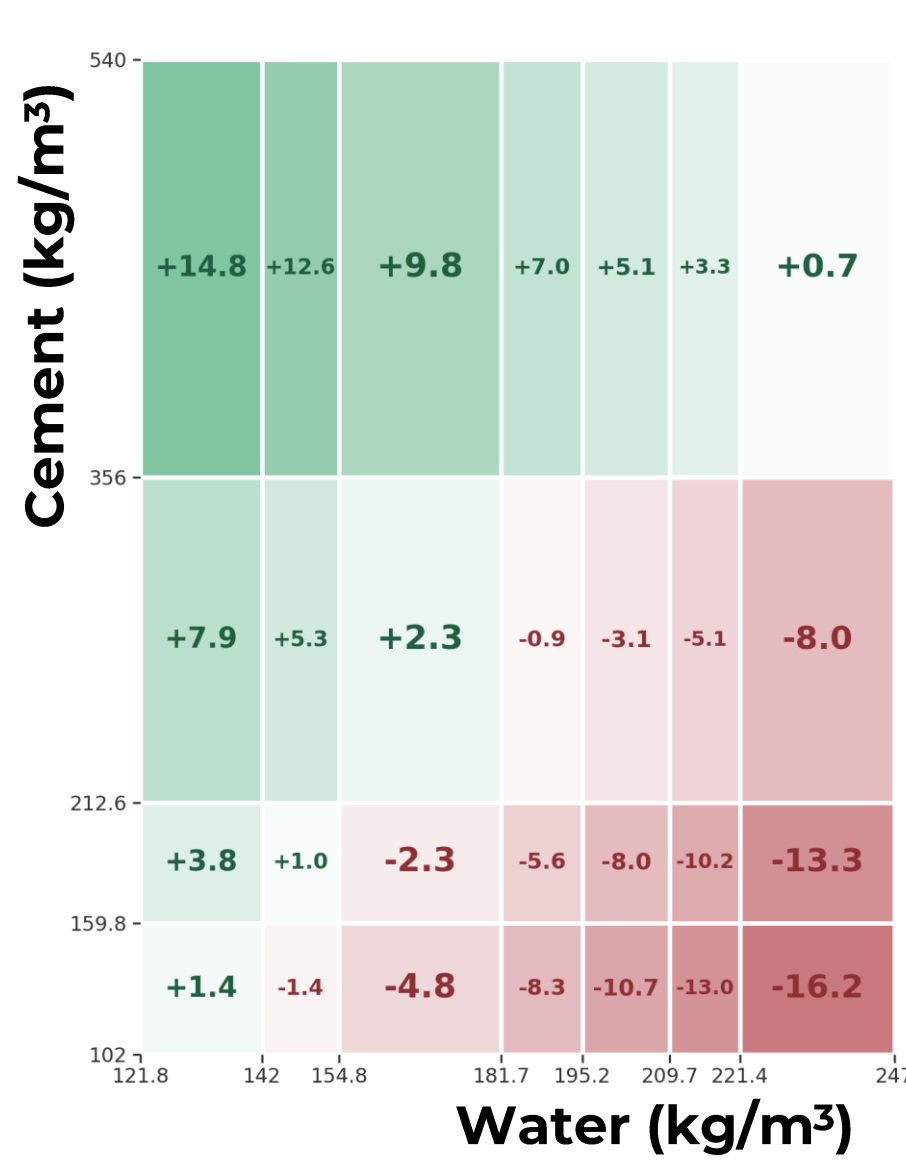
Actionable Insights



Importance of Features, Interactions



Sensitivity Analysis

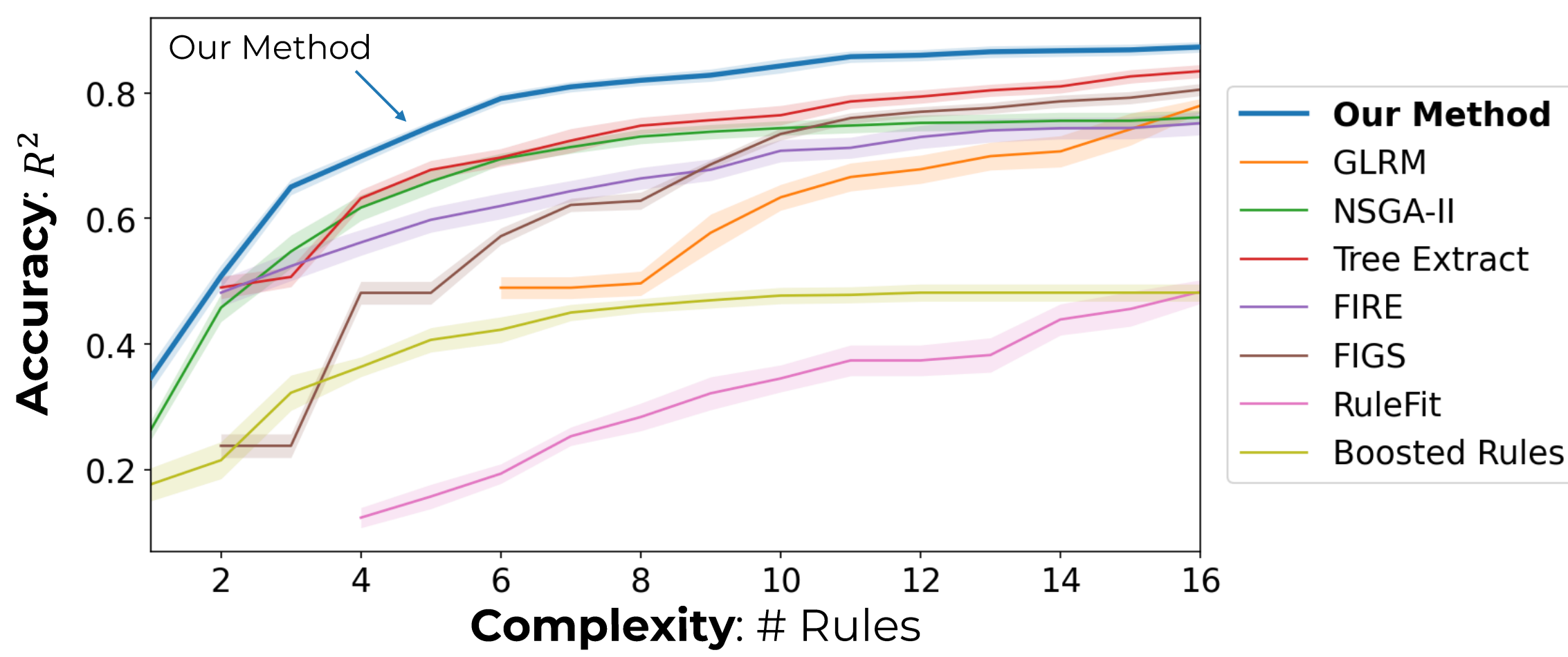


Benchmark

Higher Accuracy at the Same Complexity

In 43 of 44 datasets, our method has the largest area under the frontier.

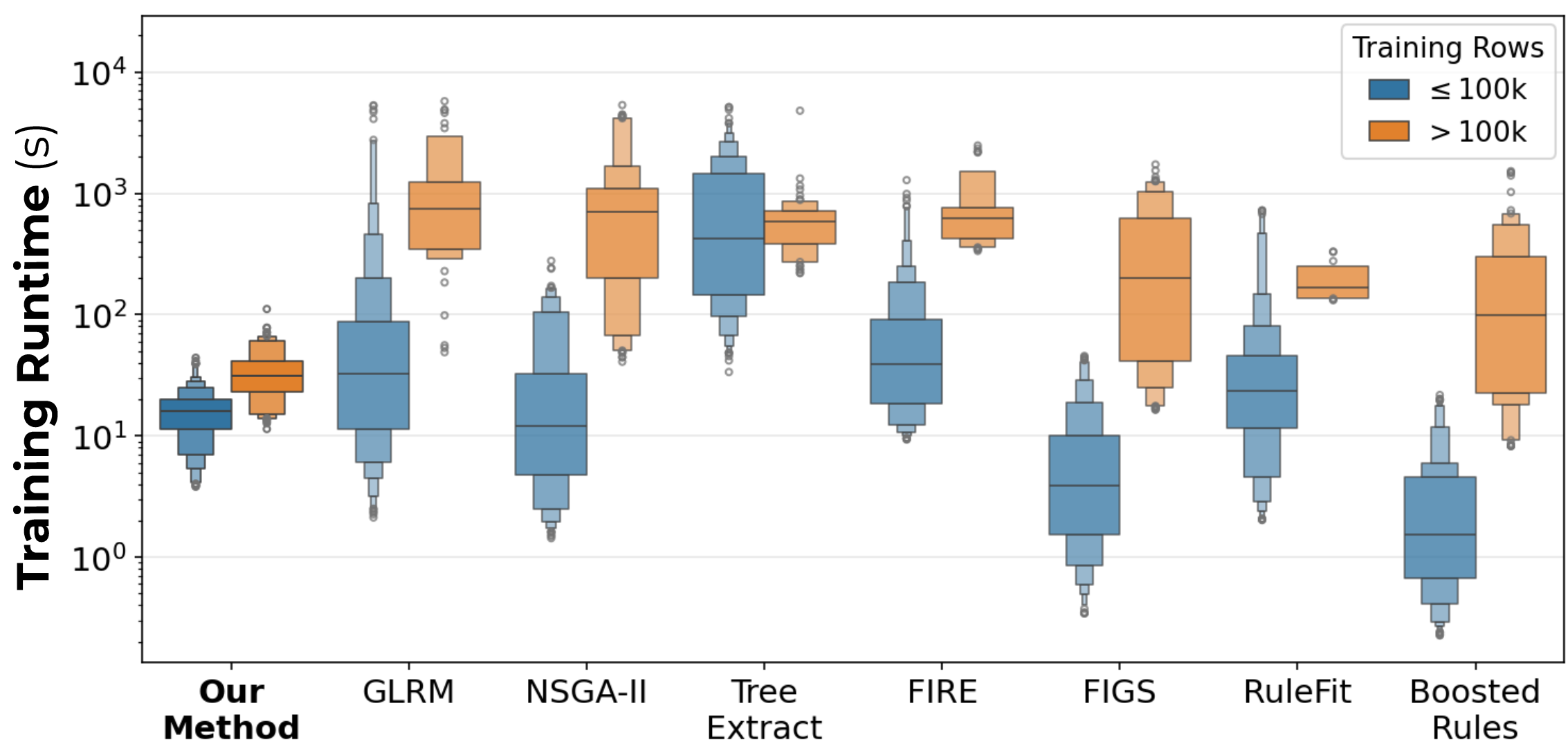
In 9 datasets, our accuracy dominates all others at all complexities.



Substantially Faster

Our method is >5x faster than others on datasets with >100k rows.

We train the entire frontier at once. Others train one model at a time.



Computational Challenges

Training one rule is NP-Hard.

We seek a frontier of Sum-of-Rules models.

Popular distillation-based methods are suboptimal.

