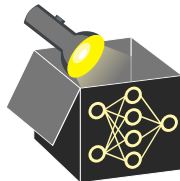
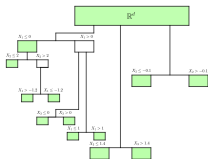


Interpretable Machine Learning



Interpretable Models 2

Random Planted Forests



Learning goals

- Motivation for RPFs
- Understand node types and restricting interactions in decision trees
- Understand planted trees: non-binary decision trees and inner leaves

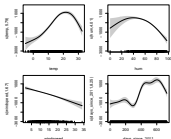
RANDOM PLANTED FORESTS (RPF) ▶ “Hiabu et al.” 2023

Goal: Create a powerful tree ensemble, but still interpretable

Idea:

- GAMs easily interpretable, because no interaction \rightsquigarrow Plot 1D functions

$$\hat{f}(x) = \theta_0 + f_1(x_1) + f_2(x_2) + \dots + f_p(x_p),$$



- Same for function containing interactions between max. 2 features
 \rightsquigarrow function of 2 features, Plot 2D functions (i.e. 3D plot)

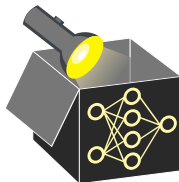
$$\hat{f}(x) = \theta_0 + f_1(x_1) + f_2(x_2) + \dots + f_p(x_p) + f_{1,2}(x_1, x_2) + \dots + f_{1,p}(x_1, x_p) + \dots + f_{p-1,p}(x_{p-1}, x_p),$$

\rightsquigarrow Visualize single functions $f_1, f_2, f_{1,2}(x_1, x_2), f_{1,3}(x_1, x_3) \dots$

\Rightarrow Interpretability possible via restricting degree of interactions

Problem: How to know degree of interactions?

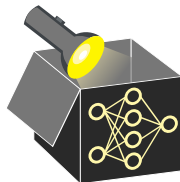
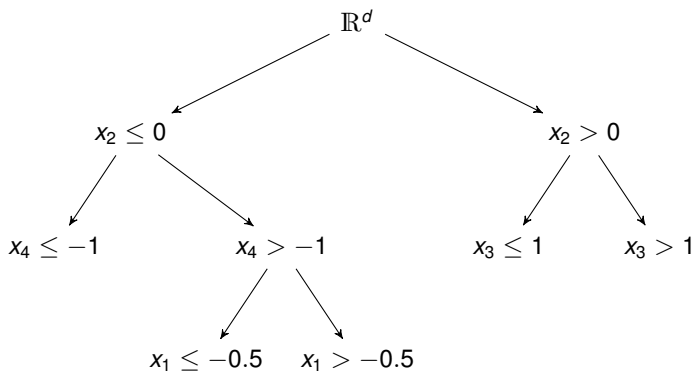
Solution: Easy to determine for trees / tree ensembles!



RPF: DETERMINE INTERACTION TYPE IN TREES

Define the *interaction type* t of a node as the subset of features involved in constructing this node.

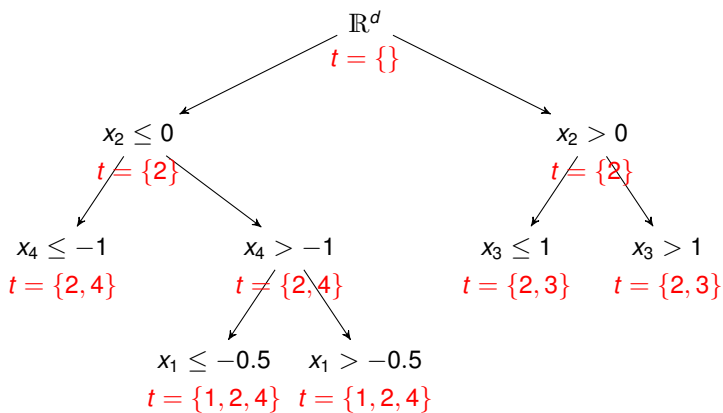
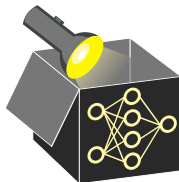
Example:



RPF: DETERMINE INTERACTION TYPE IN TREES

Define the *interaction type* t of a node as the subset of features involved in constructing this node.

Example:



\Rightarrow Degree of interaction in each node is $|t|$.

RPF: BOUNDED INTERACTION ORDER + PLANTED TREES

Goal: restrict this interaction degree

↪ In RPFs:

- Always keep track of interaction type in each node
- For each new split, make sure max. degree of interactions is not exceeded \Rightarrow When max. number of feat reached, no new feat are allowed

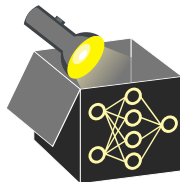
Problem: For small interaction order, single trees quickly limited

- E.g. interaction order 1: Every tree only one feature
- \Rightarrow Many trees needed for more complex model

Idea: Allow inner nodes to split again

Define *Planted Trees*: Decision trees where each inner nodes can be *leaves*:

- Add prediction to final output
- Can be split again \Rightarrow several splits possible



RPF: EXAMPLE

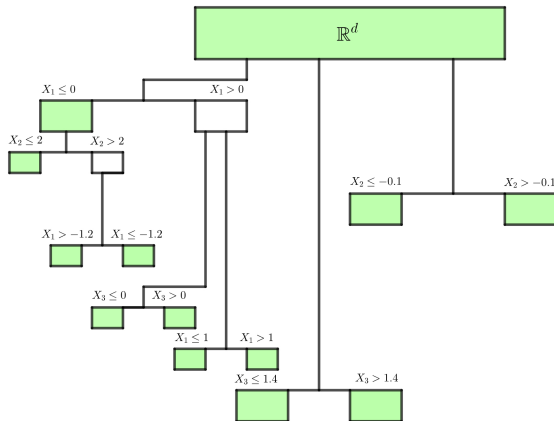
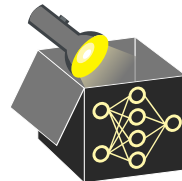


Figure: Example of a single fully grown planted tree, green nodes: “leaves”

RPF: EXAMPLE

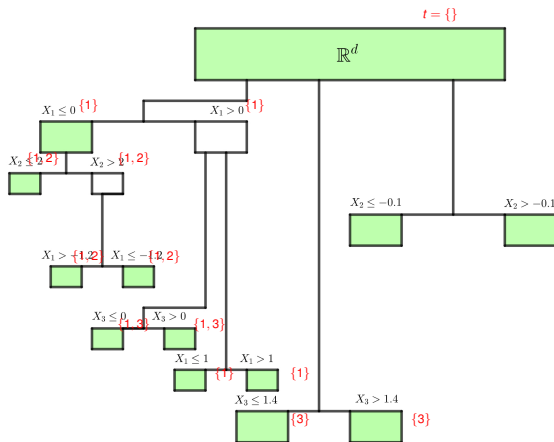
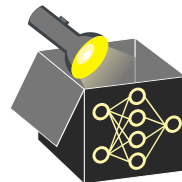
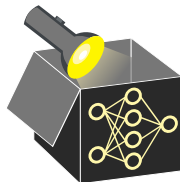


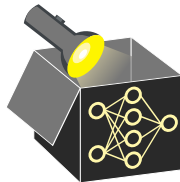
Figure: Example of a single fully grown planted tree, green nodes: “leaves”

RPF: ALGO

- Max. interaction degree is a hyperparameter
- Total number of trees is a hyperparameter
- End growing tree after max. total number of splits instead of max. depth (min. number of samples also possible, but then higher nodes would split too often)
- Randomization as in Random Forests:
 - Only optimize over subset of features, randomly chosen
 - Only optimize over subset of possible split values
- Make an inner leaf an inner node (i.e. delete “leaf” property), if it has children with the same type



RPF: EXAMPLE RESULTS AND INTERPRETATION



RPF: CONCLUSION

