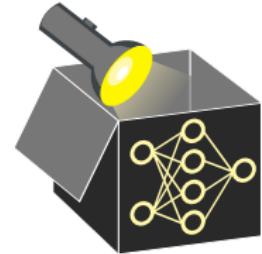
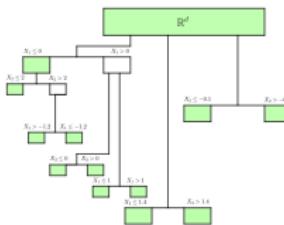


# Interpretable Machine Learning



## 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)

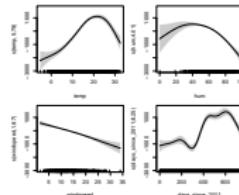
► "Hiabu et al." 2023

**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)

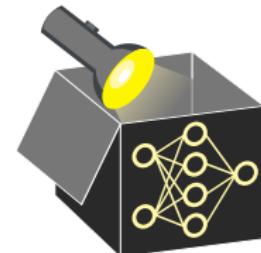
$$\hat{f}(x) = \theta_0 + f_1(x_1) + f_2(x_2) + \dots + f_p(x_p) + f_{1,2}(x_1, x_2) + \dots + f_{1,p}(x_1, x_p) + \dots + f_{p-1,p}(x_{p-1}, x_p),$$

$\rightsquigarrow$  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?

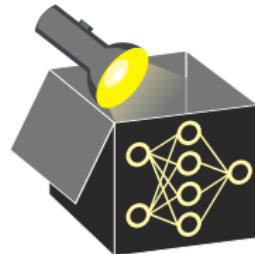
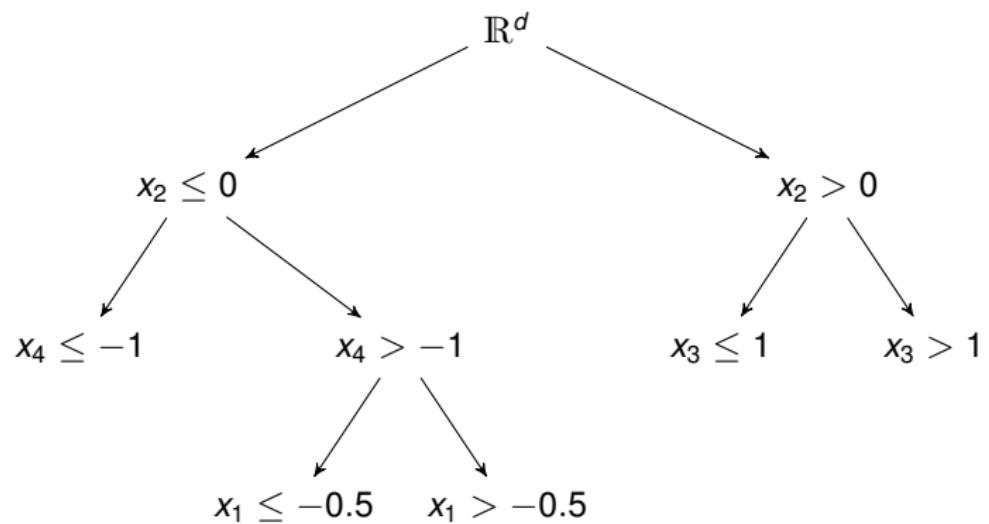
**Solution:** Easy to determine for trees / tree ensembles!



# RPF: DETERMINE INTERACTION TYPE IN TREES

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

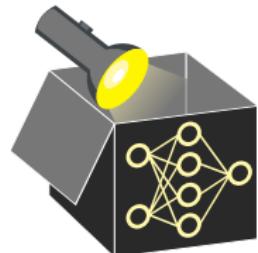
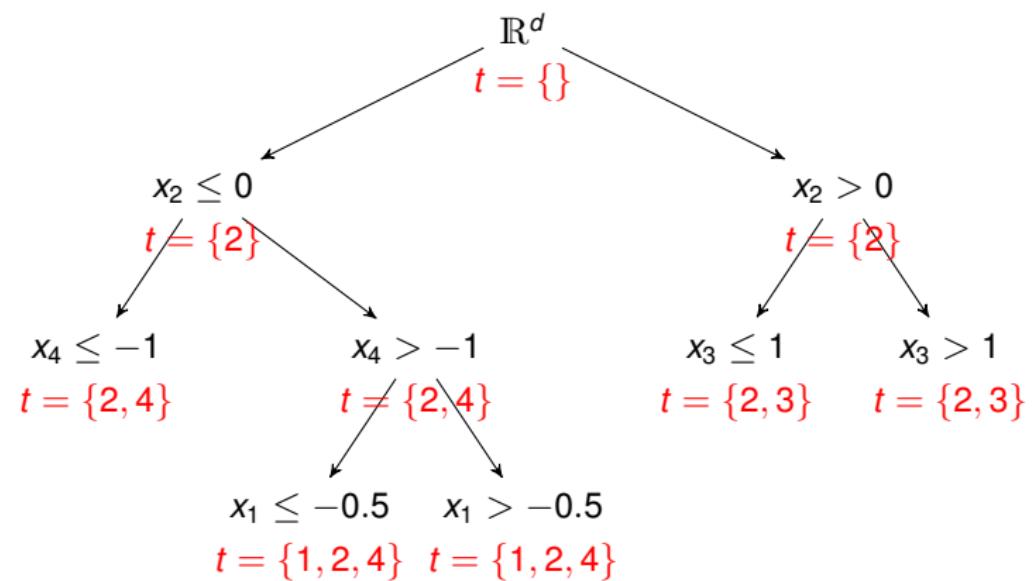
**Example:**



# 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:**



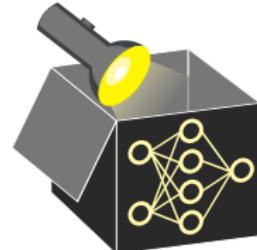
⇒ Degree of interaction in each node is  $|t|$ .

# 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 ⇒ When max. number of features reached, no new features are allowed



**Problem:** For small interaction order, single trees quickly limited

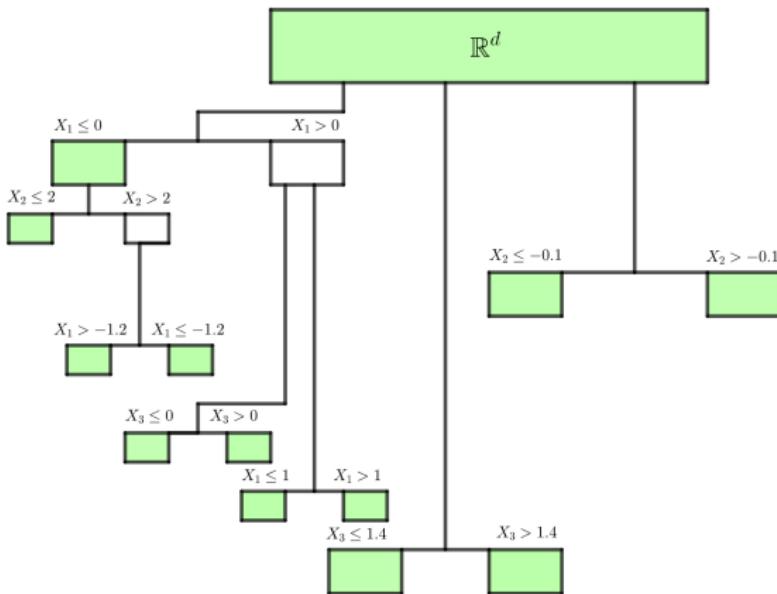
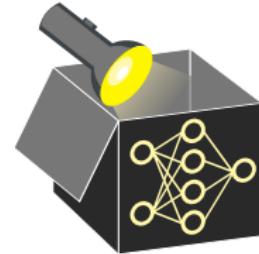
- E.g. interaction order 1: Every tree only one feature
- ⇒ Many trees needed for more complex model

**Idea:** Allow inner nodes to split again

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

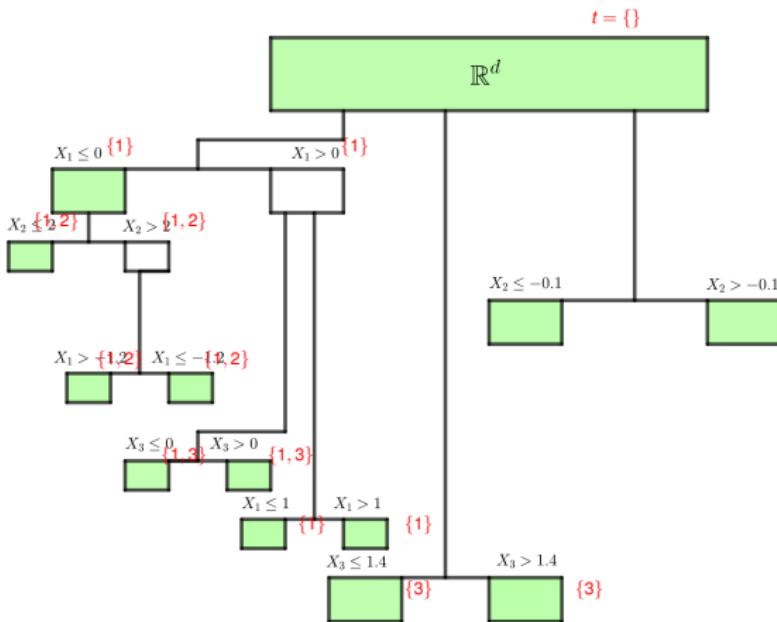
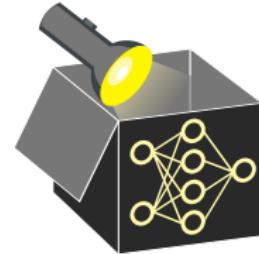
- Add prediction to final output
- Can be split again ⇒ several splits possible

# RPF: EXAMPLE



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

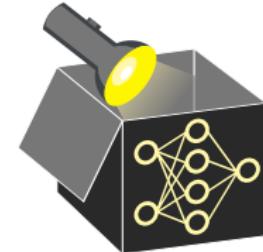
# RPF: EXAMPLE



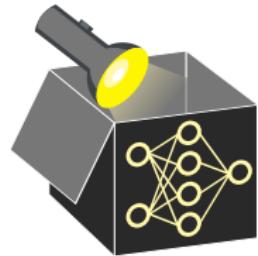
**Figure:** Example of a single fully grown planted tree, green nodes: “leaves”

# 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

