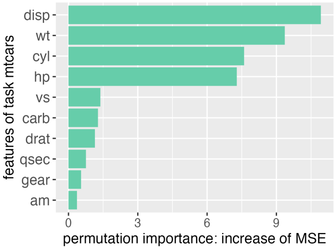
Introduction to Machine Learning

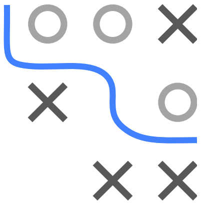
Random Forest
Feature Importance



Learning goals

- Understand that the goal of feature importance is to enhance interpretability of RF
- Understand FI based on feature permutation
- Understand FI based on improvement in splits

PERMUTATION FEATURE IMPORTANCE

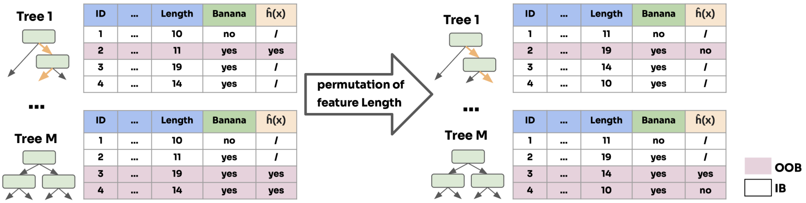


RFs improve accuracy by aggregating multiple decision trees but **lose interpretability** compared to a single tree. **Feature importance** mitigates this problem.

- How much does performance *decrease*, if feature is removed / rendered useless?
- We permute values of considered feature
- Removes association between feature and target, keeps marginal distribution
- Can obtain $\widehat{\mathrm{GE}}$ of RF (without and with permuted features) by predicting OOB data, to **efficiently compute FI during training**
- Avoids not only new models (if feature would be removed) but can already use “OOB test data” during training

ID	Color	Form	Origin	~~Length~~	Banana
1	yellow	round	domestic	~~10~~	no
2	brown	oblong	imported	~~11~~	yes
3	green	oblong	imported	~~19~~	yes
4	yellow	oblong	domestic	~~14~~	yes

PERMUTATION IMPORTANCE



Tree 1 (before permutation):

ID	...	Length	Banana	$\hat{h}(x)$
1	...	10	no	/
2	...	11	yes	yes
3	...	19	yes	/
4	...	14	yes	/

Tree M (before permutation):

ID	...	Length	Banana	$\hat{h}(x)$
1	...	10	no	/
2	...	11	yes	/
3	...	19	yes	yes
4	...	14	yes	yes

Tree 1 (after permutation):

ID	...	Length	Banana	$\hat{h}(x)$
1	...	11	no	/
2	...	19	yes	no
3	...	14	yes	/
4	...	10	yes	/

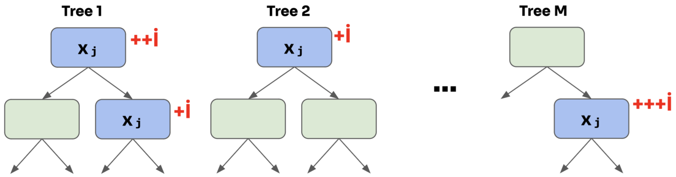
Tree M (after permutation):

ID	...	Length	Banana	$\hat{h}(x)$
1	...	11	no	/
2	...	19	yes	/
3	...	14	yes	yes
4	...	10	yes	no

Calculate $\widehat{\mathrm{GE}}_{\mathrm{OOB}}$ using set-based metric ρ
for features x_j, $j = 1 \to p$ **do**
    for Some statistical repetitions **do**
        Distort feature-target relation: permute x_j with ψ_j
        Compute all n OOB-predictions for permuted feature data, obtain all $\hat{f}^{(i)}_{\mathrm{OOB},\psi_j}$
        Arrange predictions in $\hat{\boldsymbol{F}}_{\mathrm{OOB},\psi_j}$; Compute $\widehat{\mathrm{GE}}_{\mathrm{OOB},j} = \rho(\mathbf{y}, \hat{\boldsymbol{F}}_{\mathrm{OOB},\psi_j})$
        Estimate importance of j-th feature: $\widehat{\mathrm{FI}}_j = \widehat{\mathrm{GE}}_{\mathrm{OOB},j} - \widehat{\mathrm{GE}}_{\mathrm{OOB}}$
    end for
    Average obtained $\widehat{\mathrm{FI}}_j$ values over reps
end for

IMPURITY IMPORTANCE

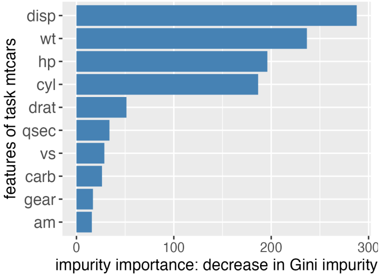
Alternative: Add up all *improvements* in splits where feature x_j is used.

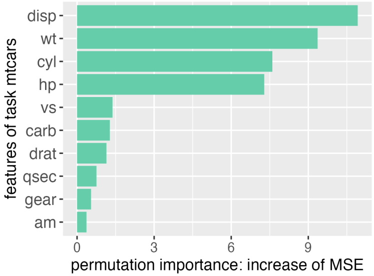


for features x_j, $j = 1 \to p$ **do**
    for all models $\hat{b}^{[m]}$, $m = 1 \to M$ **do**
        Find all splits in $\hat{b}^{[m]}$ on x_j
        Extract improvement / risk reduction for these splits
        Sum them up
    end for
    Add up improvements over all trees for FI of x_j
end for

IN PRACTICE / OUTLOOK

Let's compare both FI variants on `mtcars`:





- Both methods are **biased toward features with more levels** (i.e., continuous or categoricals with many categories) ▸ Strobl et al. 2007
- More advanced versions exist
- PFI and FI have been generalized, see our lecture on IML!