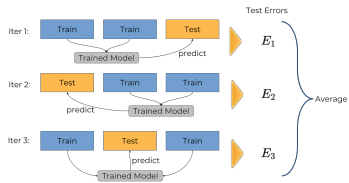


Introduction to Machine Learning

Evaluation Resampling 1

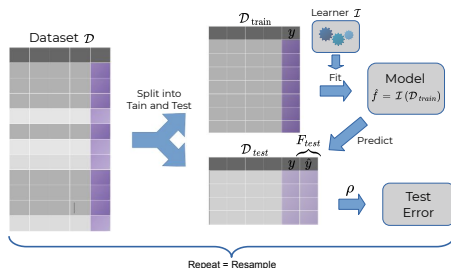
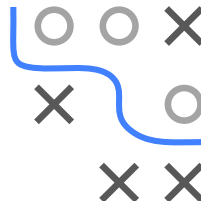


Learning goals

- Understand how resampling techniques extend the idea of simple train-test splits
- Understand the ideas of cross-validation, bootstrap and subsampling

RESAMPLING

- **Goal:** estimate $GE(\mathcal{I}, \lambda, n, \rho_L) = \mathbb{E} [L(y, \mathcal{I}(\mathcal{D}_{\text{train}}, \lambda)(\mathbf{x}))]$.
- Holdout: Small trainset = high pessimistic bias; small testset = high var.
- Resampling: Repeatedly split in train and test, then average results.
- Allows to have large trainsets large (low pessimistic bias) since we use $GE(\mathcal{I}, \lambda, n_{\text{train}}, \rho)$ as a proxy for $GE(\mathcal{I}, \lambda, n, \rho)$
- And reduce var from small testsets via averaging over repetitions.



RESAMPLING STRATEGIES

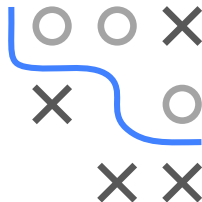
- Represent train and test sets by index vectors::
 $J_{\text{train}} \in \{1, \dots, n\}^{n_{\text{train}}}$ and $J_{\text{test}} \in \{1, \dots, n\}^{n_{\text{test}}}$
- Resampling strategy = collection of splits:

$$\mathcal{J} = ((J_{\text{train},1}, J_{\text{test},1}), \dots, (J_{\text{train},B}, J_{\text{test},B})).$$

- Resampling estimator:

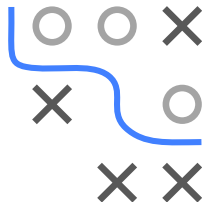
$$\widehat{\text{GE}}(\mathcal{I}, \mathcal{J}, \rho, \boldsymbol{\lambda}) = \text{agr} \left(\rho \left(\mathbf{y}_{\text{test},1}, \mathbf{F}_{\text{test},1, \mathcal{I}(\mathcal{D}_{\text{train},1}, \boldsymbol{\lambda})} \right), \right. \\ \vdots \\ \left. \rho \left(\mathbf{y}_{\text{test},B}, \mathbf{F}_{\text{test},B, \mathcal{I}(\mathcal{D}_{\text{train},B}, \boldsymbol{\lambda})} \right) \right),$$

- Aggregation agr is typically "mean" and $n_{\text{train}} \approx n_{\text{train},1} \approx \dots \approx n_{\text{train},B}$.

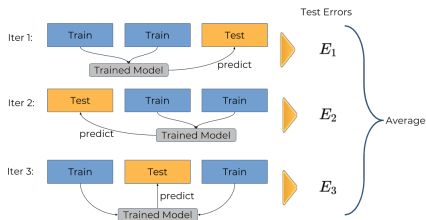


CROSS-VALIDATION

- Split the data into k roughly equally-sized partitions.
- Each part is test set once, join $k - 1$ parts for training.
- Obtain k test errors and average.
- Fraction $(k - 1)/k$ is used for training, so 90% for 10CV
- Each observation is tested exactly once.

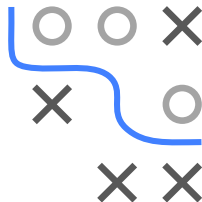


Example: 3-fold CV

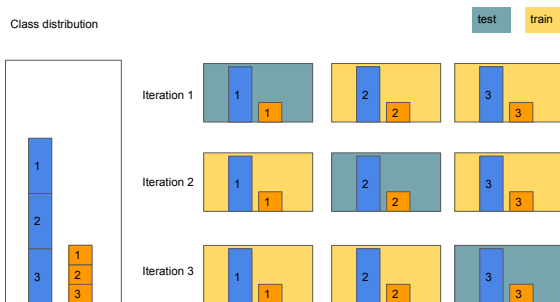


CROSS-VALIDATION - STRATIFICATION

- Used when target classes are very imbalanced
- Then small classes can randomly get very small in samples
- Preserve distrib of target (or any feature) in each fold
- For classes: simply CV-split the class data, then join

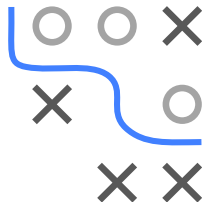
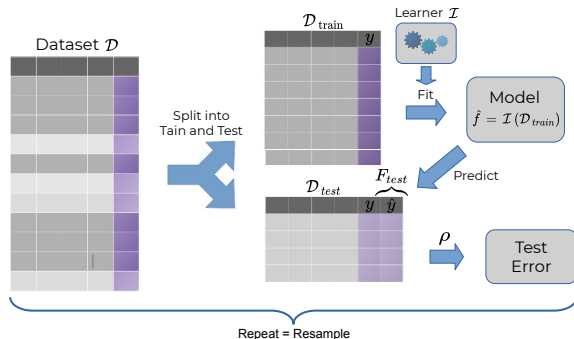


Example: stratified 3-fold cross-validation



SUBSAMPLING

- Repeated hold-out with averaging, a.k.a. Monte Carlo CV.
- Typical choices for splitting: $\frac{4}{5}$ or $\frac{9}{10}$ for training.



- Smaller subsampling rate = larger pessimistic bias
- More reps = smaller var

LEAVE-ONE-OBJECT-OUT

- Used when we have multiple obs from same objects, e.g., persons or hospitals or base images
- Data not i.i.d. any more
- Data from same object should **either** be in train **or** testset
- Otherwise we likely bias \widehat{GE}
- CV on objects, or leave-one-object-out

