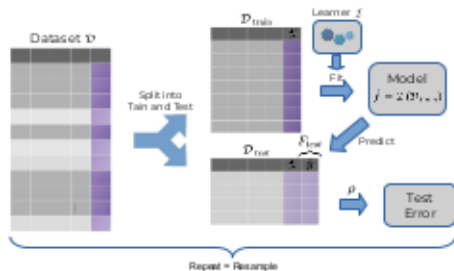


# RESAMPLING

- **Goal:** estimate  $GE(\mathcal{I}, \lambda, n, \rho_L) = \mathbf{E}[L(y, \mathcal{I}(D_{\text{train}}, \lambda)(\mathbf{x}))]$ .
- 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:

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

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



## CROSS-VALIDATION

- 5 or 10 folds are common.
- $k = n$  is known as "leave-one-out" CV (LOO-CV)
- Bias of  $\widehat{GE}$ : The more folds, the smaller. LOO nearly unbiased.
- LOO has high var, better many folds for small data but not LOO
- Repeated CV (avg over high-fold CVs) good for for small data.



# 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

