Super Learning (SL) and `sl3`

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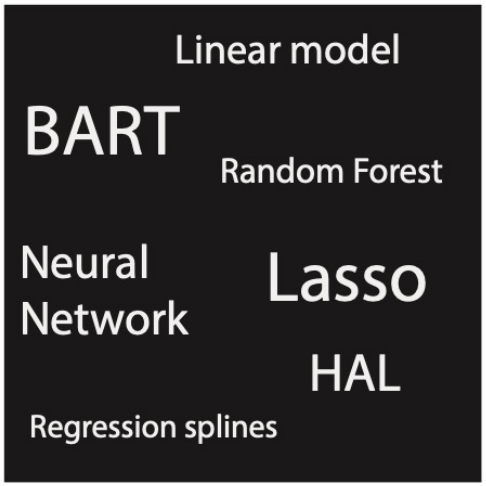
Overview of Super Learner

Super Learner (SL)

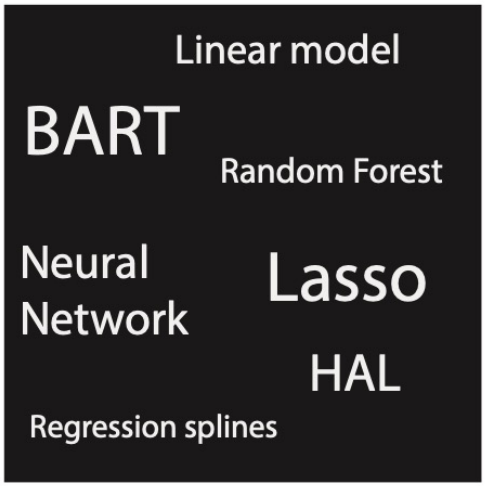
LIBRARY

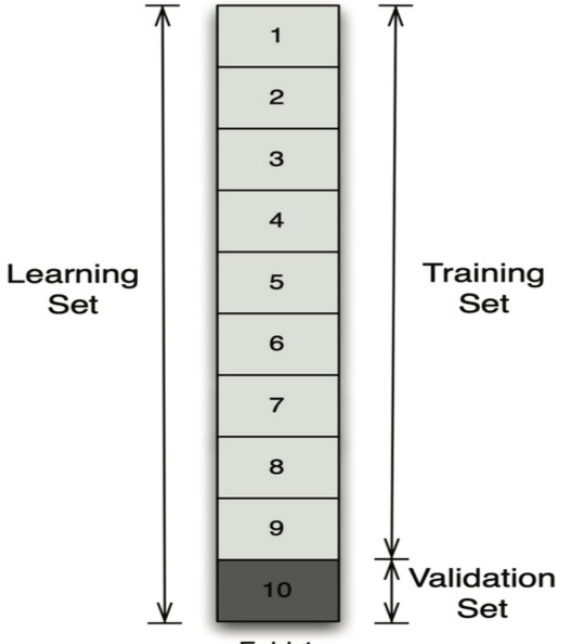


Super Learner (SL)

LIBRARY **COMPETITION**

Cross-validated performance of learners + ensembles





Super Learner (SL)

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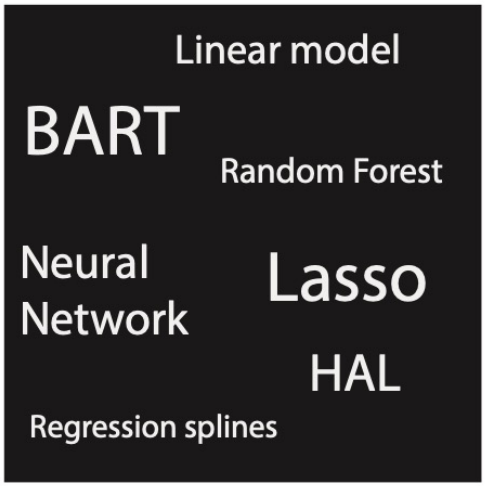

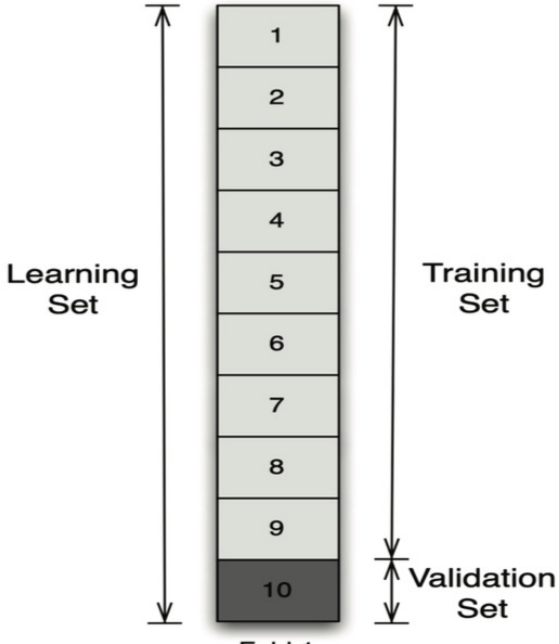

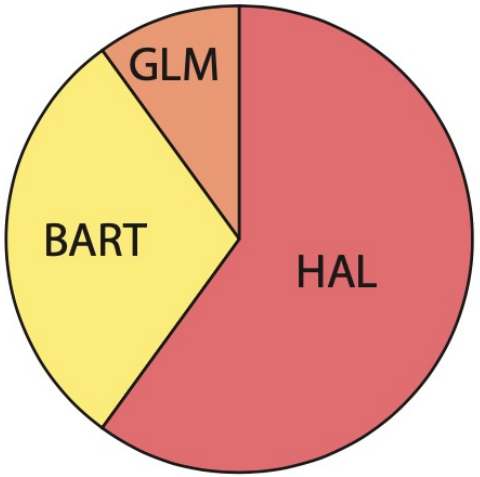

Super Learner (SL)

- Uses a library of algorithms for estimating a prediction function
  - Analyst specifies Alg_1, … Alg_K
  - Create an optimal combination
    - Optimal with respect to V-fold cross-validated (CV) risk
    - Example risk functions: Negative log likelihood, mean squared error, 1-AUC
- SL predicted values, $\hat{Y}_{SL}$, are a combination of $\hat{Y}_{Alg_1}$, …, $\hat{Y}_{Alg_K}$
  - Discrete SL: "winner-take-all", predictions from algorithm with best CV risk
  - Ensemble SL: predictions from multiple algorithms are combined
    - weighted combination
    - some other, possibly complex function of the algorithms' predictions

Defining prediction problem for estimation

Defining prediction problem for estimation

- A performance metric quantifies the success of an estimated prediction function (i.e., a trained algorithm)
  - Expectation of the squared error loss / MSE
  - The area under the ROC curve, AUC

Defining prediction problem for estimation

- A performance metric quantifies the success of an estimated prediction function (i.e., a trained algorithm)
- The chosen metric needs to be optimized (minimized or maximized) by the true prediction function
  - **This guarantees that the evaluation corresponds to the trained algorithm's success in approximating the true prediction function**

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- The chosen metric needs to be optimized (minimized or maximized) by the true prediction function
  - **This guarantees that the evaluation corresponds to the trained algorithm's success in approximating the true prediction function**
- The chosen metric should align with the intended real-world use of the predictions

Why super learner (SL)?

- No need to select the one “right” strategy
- Can consider diverse set
- Grounded in statistical optimality theory
- Pre-specified also flexible
- Mitigate statistical model misspecification
- Asymptotic linearity of an accompanying estimator

What does user specify for SL?

a) Measure of performance
b) Cross-validation scheme
c) Diverse library of candidate learners

Super learner

1. Specify
   a) Measure of performance
   b) Cross-validation scheme
   c) Diverse library of candidate learners

What are you learning from the data? What do you want to optimize for?

Performance measure should be valid (i.e., optimized by underlying target), bounded, corresponds to desired goal

Super learner

1. Specify
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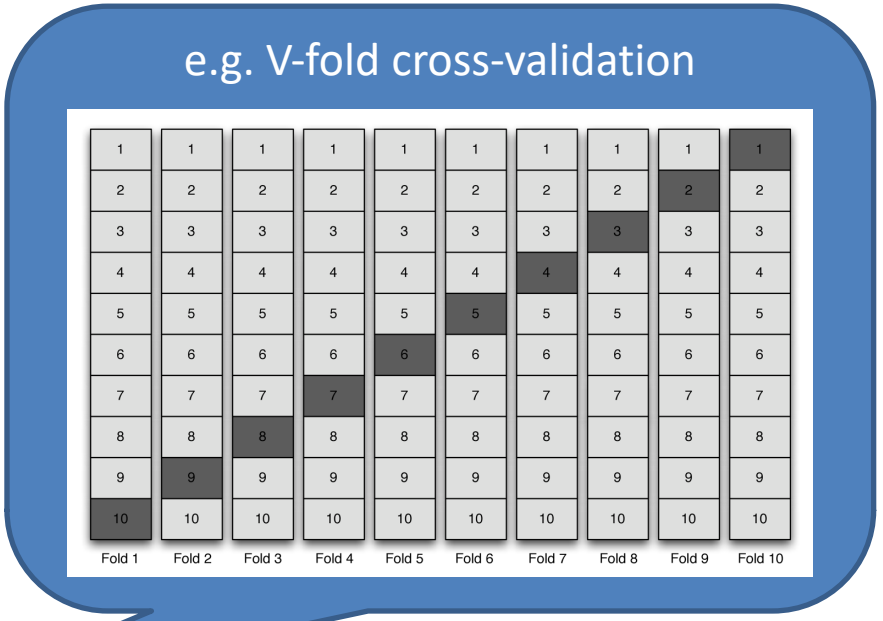

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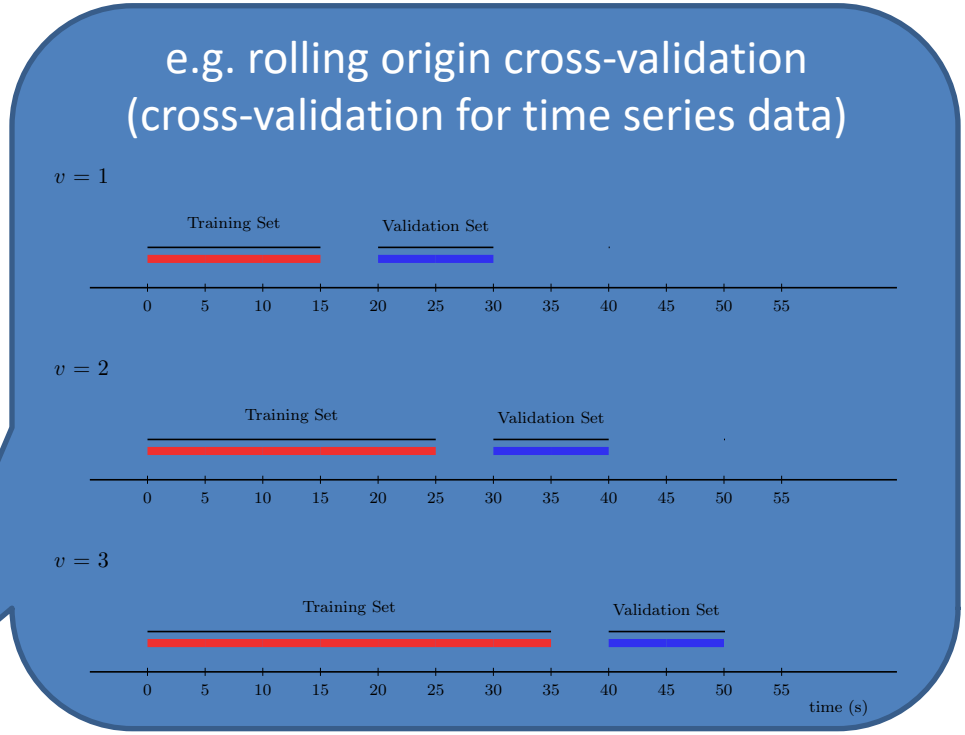
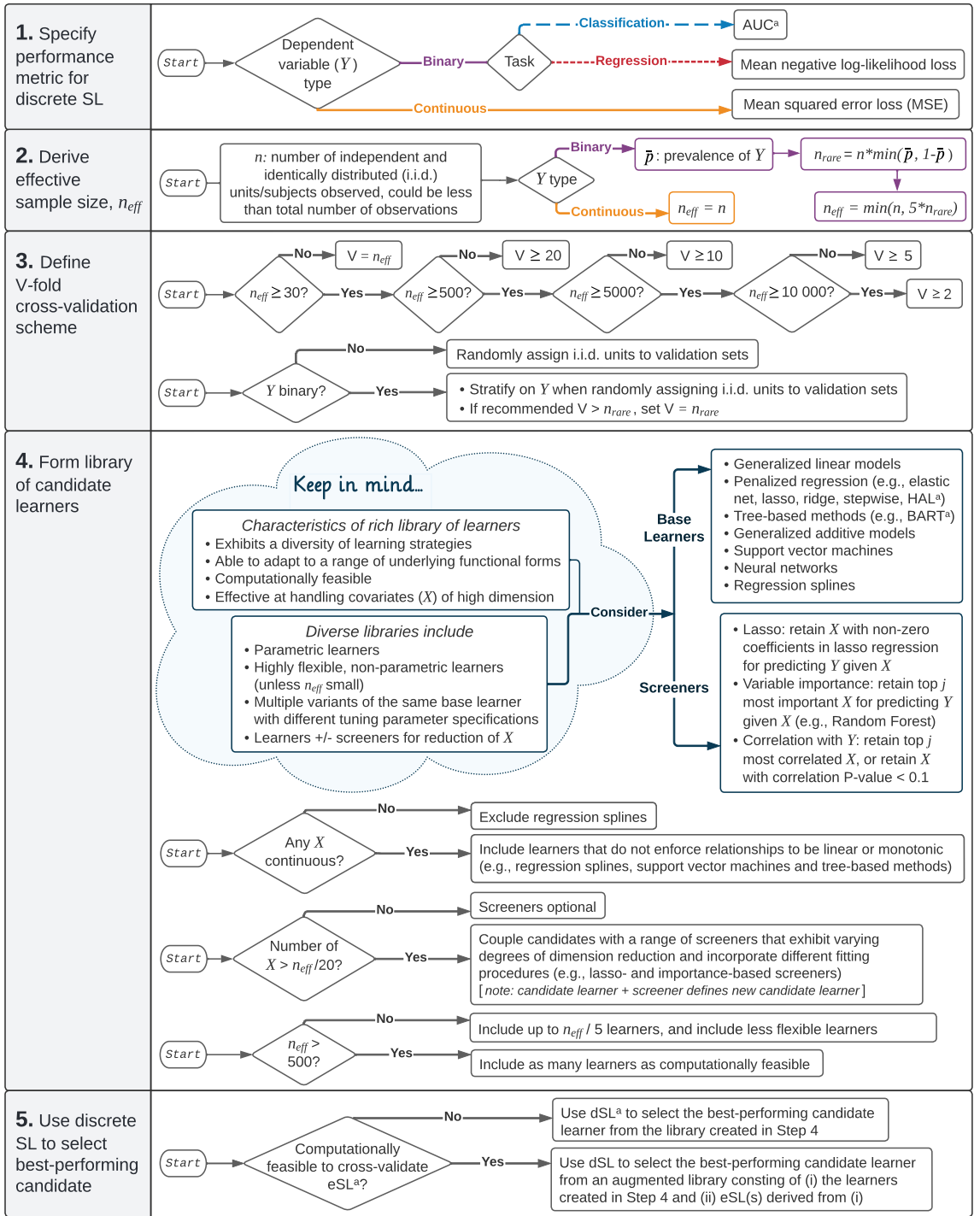


Overview of the algorithm

1. Make metalevel dataset with cross-validated candidate predictions and validation set outcomes
2. Fit meta-learner to the metalevel dataset
3. Full-fit candidates
4. Define the SL

Practical considerations for specifying SL

Rachael V Phillips, Mark J van der Laan, Hana Lee, Susan Gruber,
Practical considerations for specifying a super learner, *International Journal of Epidemiology*, 2023.
https://doi.org/10.1093/ije/dyad023



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sl3

SL software package in tlverse

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Introductory overview of `sl3`

- Task
- Learners
- Functions

Introductory overview of `sl3`

- **Task**
- Learners
- Functions

Tasks in `sl3`

What is the prediction task?

data, covariates, outcome,

weights, id, outcome_type,offset,
drop_missing_outcome, folds

https://tlverse.org/sl3/reference/sl3_Task.html

Introductory overview of `sl3`

- Task
- **Learners**
- Functions

Learners in `sl3`

How to estimate prediction function?

https://tlverse.org/sl3/reference/index.html#sl-learners

Exercise: Training learner with `sl3` wrapper versus package's function

- Prediction tasks in `sl3`
- Comparison of R6 methods and S3 methods
  - `sl3` R package function, `Lrnr_earth`
  - `earth` R package function, `earth`
- Looking up learners, the `sl3` wrapper, and arguments
- Modifying learner parameters

- **Data example**: Collaborative Perinatal Project (CPP) was a multisite prospective cohort study designed to identify the effects of complications during either pregnancy or the perinatal period on birth and child outcomes.

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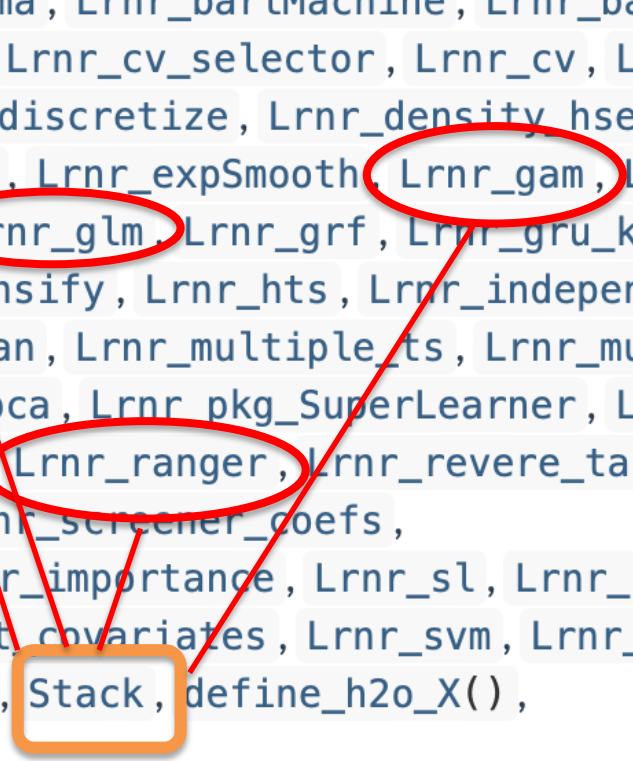

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https://tlverse.org/sl3/reference/index.html#sl-learners

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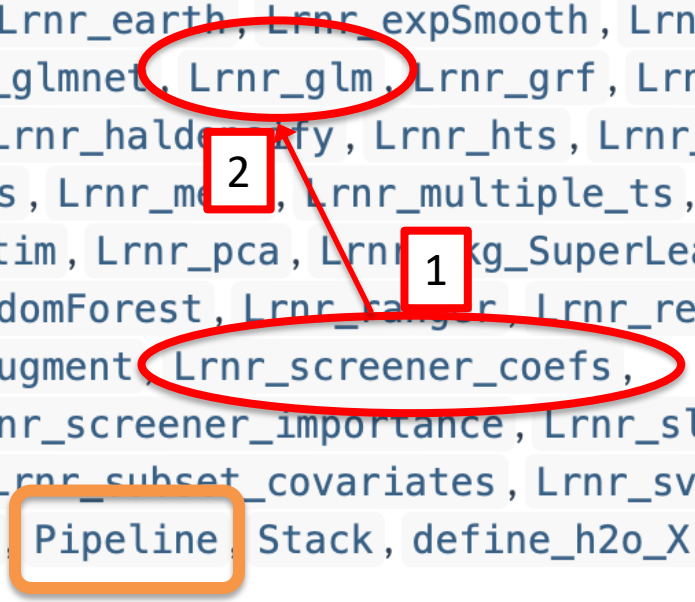

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Introductory overview of `sl3`

- Task
- Learners
- **Other functions**

Other sl3 Functions

- Performance measures:
  - loss functions (e.g., squared error, negative log-likelihood, multinomial log-likelihood)
  - metrics based on `ROCR` software package, like AUC, AUCPR, accuracy, sensitivity, with `custom_ROCR_risk()`
- Variable importance with `importance`
- Table with each candidate learner's cross-validated predictive performance with `cv_risk`
- Cross-validated SL with `cv_sl`

Live coding exercise with sl3 using WASH Benefits data

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WASH Benefits Bangladesh Example Dataset

- Study aiming to understand the effect of water quality, sanitation, hand washing, and nutritional interventions on child development in rural Bangladesh (WASH Benefits Bangladesh): a cluster randomized controlled trial (Tofail et al. 2018).
- Enrolled pregnant women in their first or second trimester from the rural villages of Gazipur, Kishoreganj, Mymensingh, and Tangail districts of central Bangladesh, with an average of 8 women per cluster.

WASH Benefits Bangladesh Example Dataset

- Groups of eight geographically adjacent clusters were block randomized, using a random number generator, into
  - six intervention groups (all received weekly visits from a community health promoter for the first 6 months, and every 2 weeks for next 18 months) and
  - a double-sized control group (no intervention or health promoter visit).

WASH Benefits Bangladesh Example Dataset

- Six intervention groups:
  - chlorinated drinking water;
  - improved sanitation;
  - hand-washing with soap;
  - combined water, sanitation, and hand washing;
  - improved nutrition through counseling and provision of lipid-based nutrient supplements; and
  - combined water, sanitation, handwashing, and nutrition.
- We concentrate on child growth (size for age) as the outcome of interest.

Exercise: Training a super learner with `sl3`

https://tlverse.org/tlverse-handbook/sl3.html

http://tlverse.org/enar2023-workshop/sl3.html