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PARISlab

Concrete Strength

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Research goal:

- Use machine learning to predict the compressive strength of concrete
- Design optimal concrete mixtures that minimize cost and embodied CO2 impact while satisfying imposed target strengths.

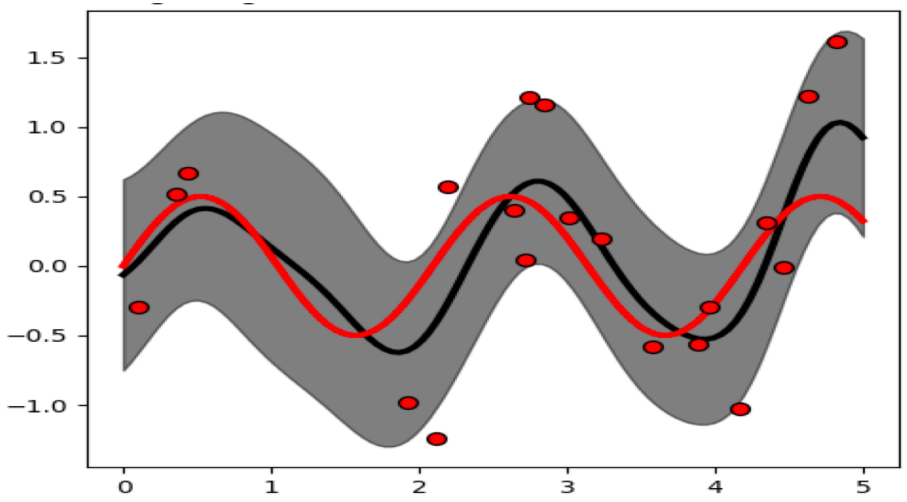
Why important:

- Reducing the labor and time intensity of concrete batching/trial operations
- Physical models that are capable of strength prediction are difficult to construct

Gaussian Process Regression

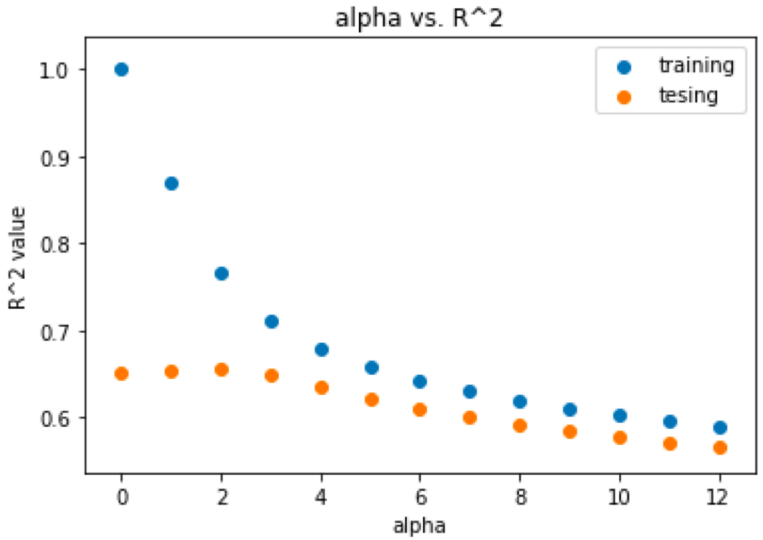
Recap: GPR

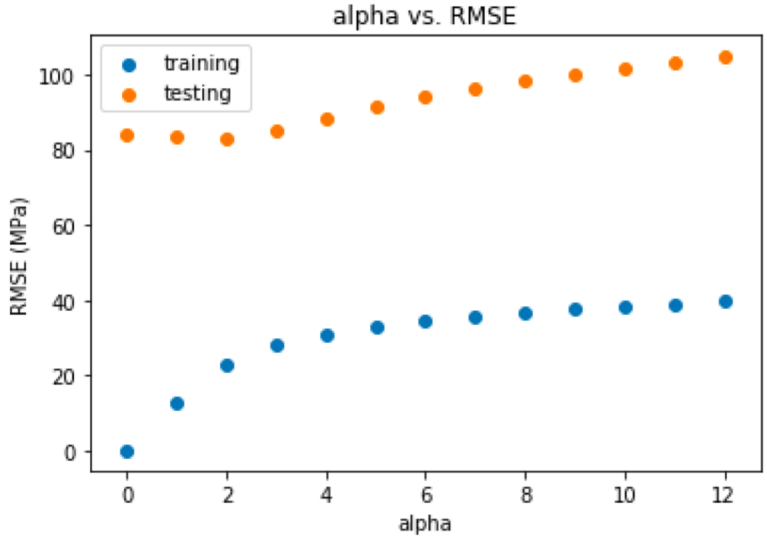
- a generic supervised learning method designed to solve regression and probabilistic classification problems.
- The prediction is probabilistic (Gaussian) so that one can compute empirical confidence intervals and decide based on those if one should refit (online fitting, adaptive fitting) the prediction in some region of interest.



GPR Parameter

- alpha:





Optimization

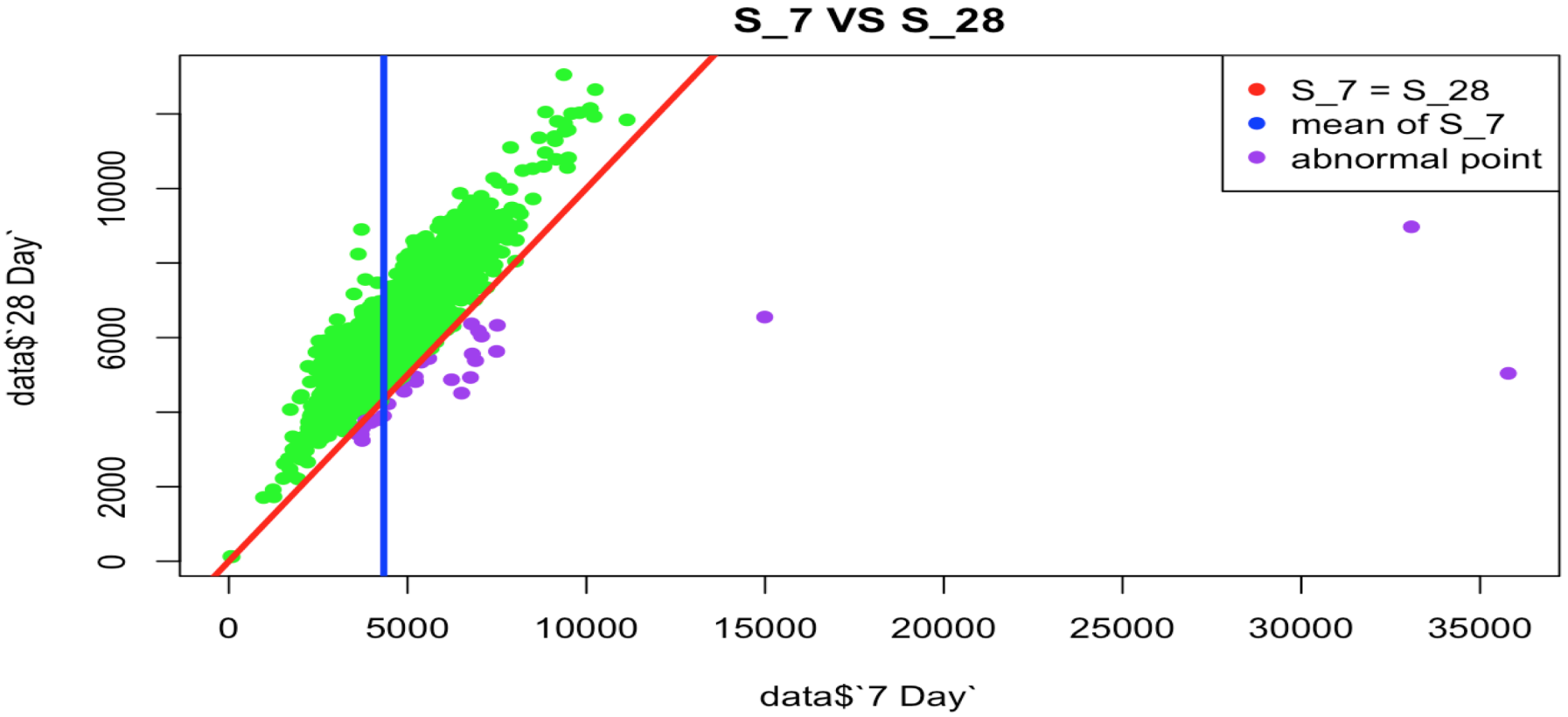
Cement AEA WRA Water/Cementitious
Coarse Aggregate Fine Aggregate Fly Ash

The upper and lower bound constraints placed on the mixture parameters.

Mix parameter	Expression	Lower bound	Upper bound
Cementitious material content	$C_c + C_{fla}$	300 kg/m^3	500 kg/m^3
w/c	$C_w/(C_c + C_{fla})$	0.20	0.60
Fly ash content	C_{fla}	0 kg/m^3	150 kg/m^3
Coarse aggregate content	C_{ca}	500 kg/m^3	1100 kg/m^3
Fine aggregate content	C_{fa}	600 kg/m^3	1200 kg/m^3
Fly ash/total cementitious material ratio	$C_{fla}/(C_c + C_{fla})$	0.00	0.30
Total volume fraction of aggregates	$\frac{C_{fa}}{\rho_{fa}} + \frac{C_{ca}}{\rho_{ca}}$	0.60	0.75
Coarse/fine aggregate ratio	$\frac{C_{fa}}{}$	0.50	1.00

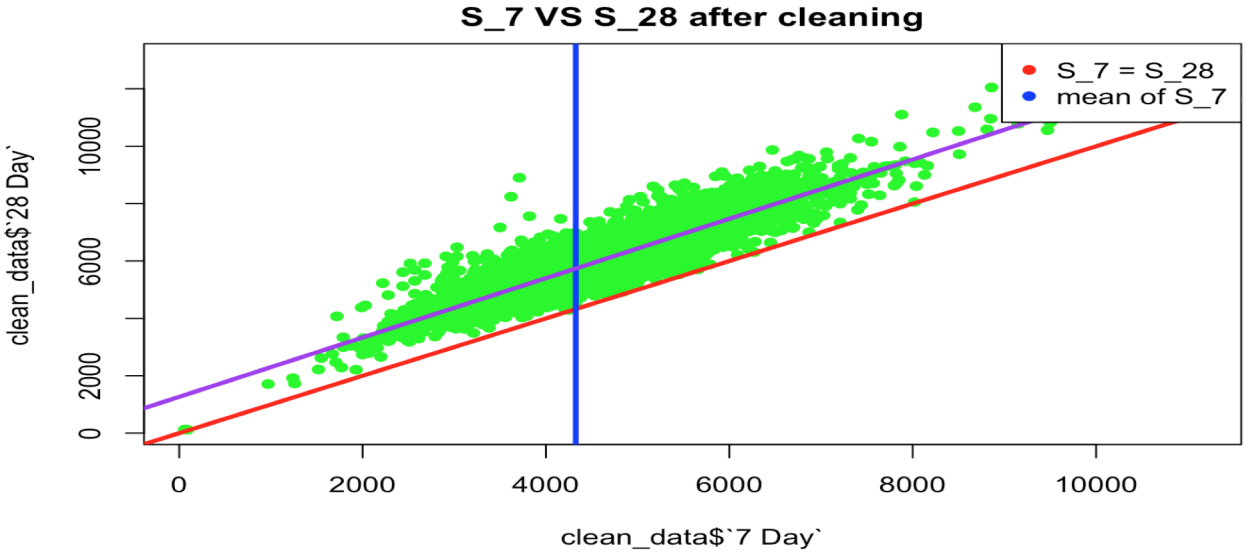
Classification

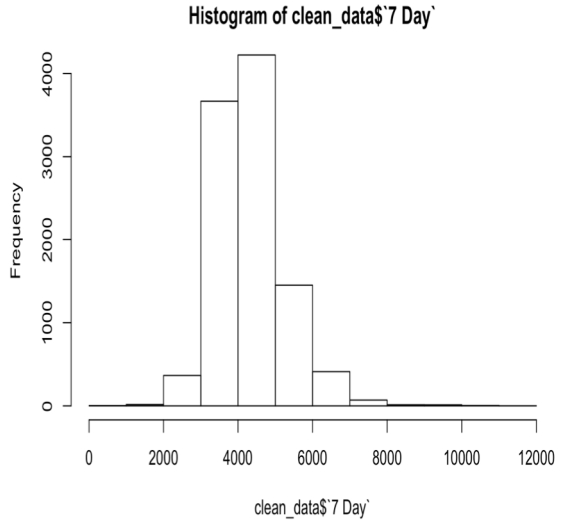
Exploratory Day 7 Data



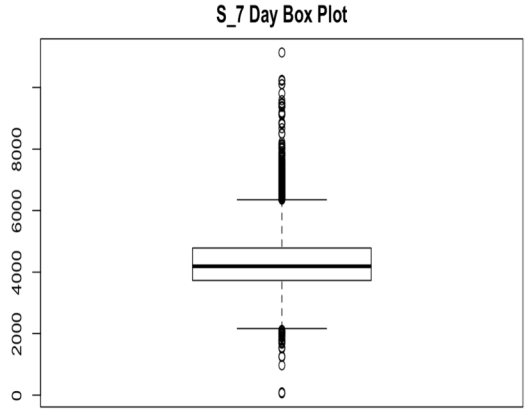
From these plots, we can see there are some abnormal day 7 data points we need to clean before we build model.

After Cleaning Abnormal Data Points

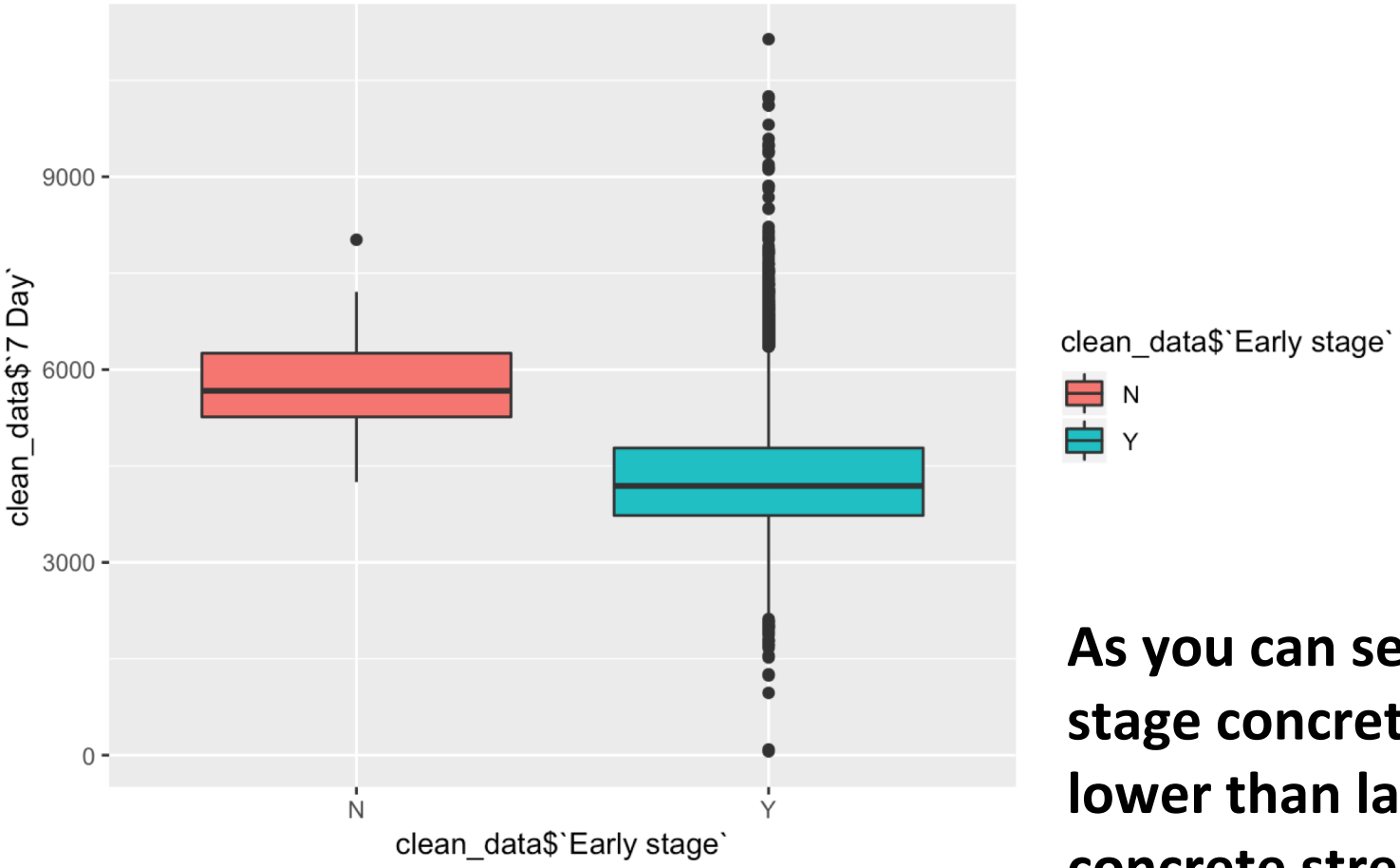




After cleaning abnormal data points, It seems good to build model now.



Early Stage and Late Stage Concrete

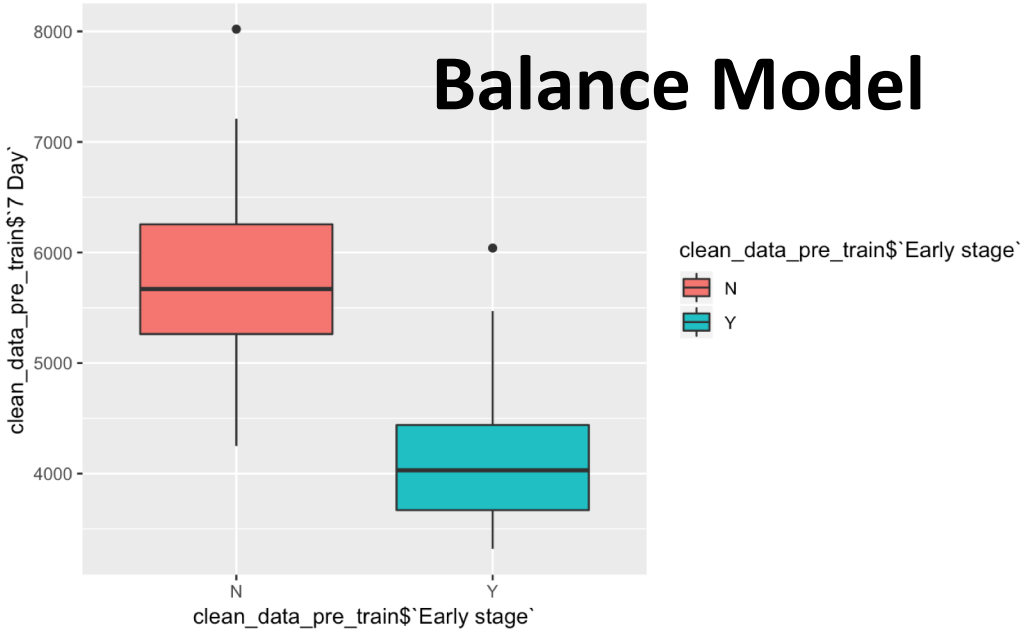


As you can see, the early stage concrete strength is lower than late stage concrete strength.

SVM Model to Distinguish Early Stage and Late Stage

	N	Y
N	10	8
Y	3	13

The accuracy rate is 0.6764706



It seems this variable is very significant in the concrete strength prediction.

Future Direction

- **Strength Prediction:** Solidify current GPR model and use model stacking to maximize the precision
- **Classification:** Add late and early stage variables to the model
- **Optimization:** Use brute force searching to find the most optimal ingredient compositions.
- Will try adopting more advanced searching algorithms to reduce computing time

Thank you!

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Some references:

"Topological Control on the Structural Relaxation of Atomic Networks under Stress"
M. Bauchy *et al.*, Physical Review Letters 119 (2017): 035502

"Nanoengineering of Concrete via Topological Constraint Theory"
M. Bauchy, MRS Bulletin 42 (2017): 50-54

"Mesoscale Texture of Cement Hydrates"
K. Ioannidou *et al.*, PNAS 113 (2016): 2029

"Combinatorial Molecular Optimization of Cement Hydrates"
M.J. Abdolhosseini *et al.*, Nature Communications 5 (2014)

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