Ensemble methods: stacking

By Marios Michailidis

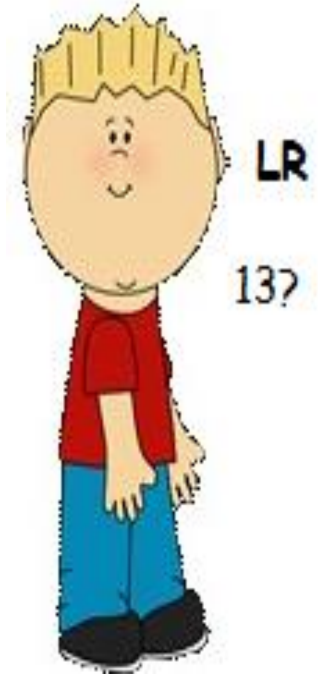
Examined ensemble methods

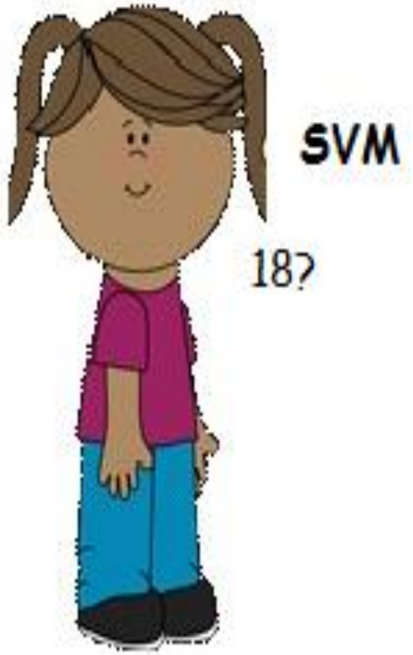
- Averaging (or blending)
- Weighted averaging
- Conditional averaging
- Bagging
- Boosting
- Stacking
- StackNet

What is Stacking

Means making predictions of a number of models in a hold-out set and then using a different (Meta) model to train on these predictions.

Naïve example





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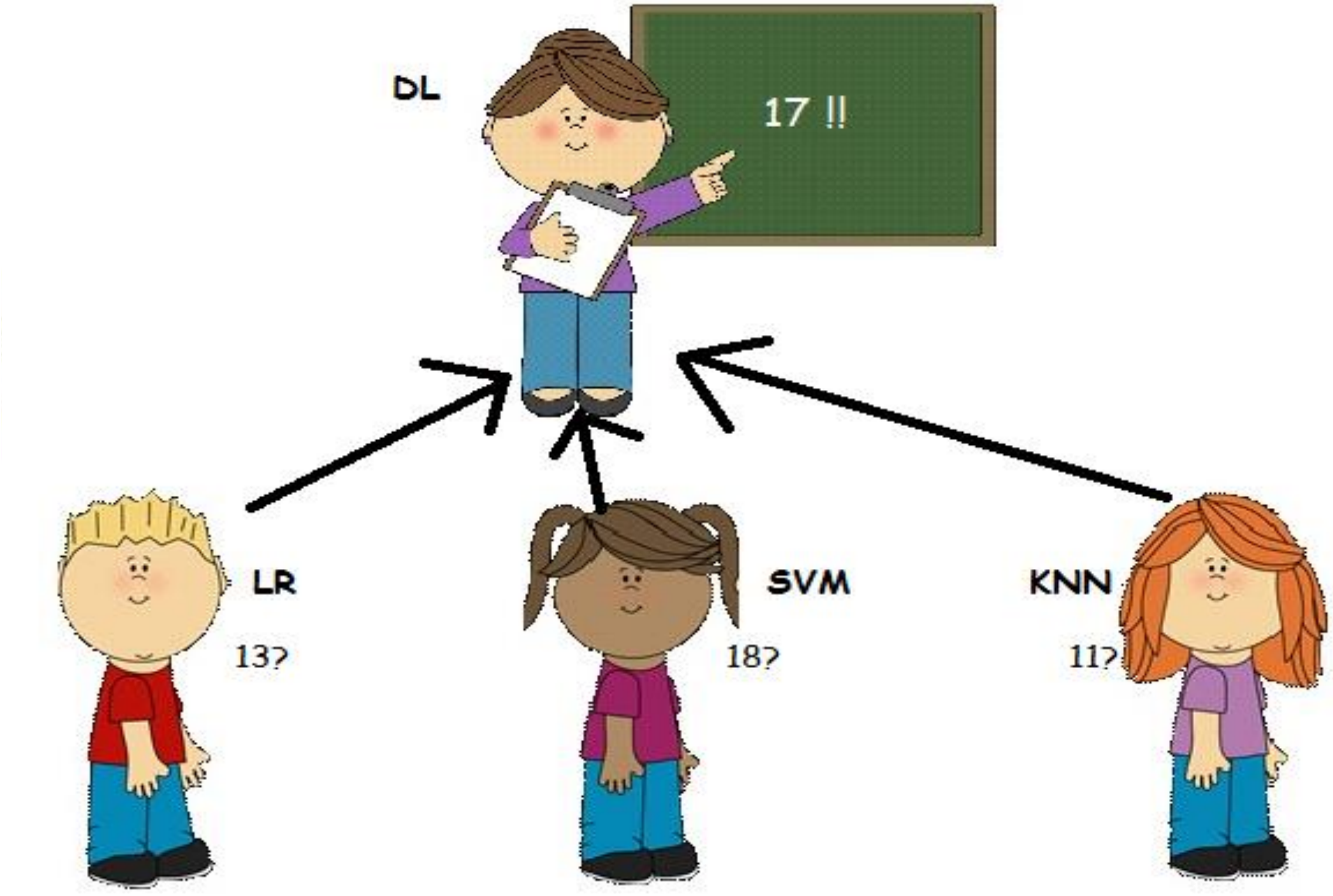


Methodology

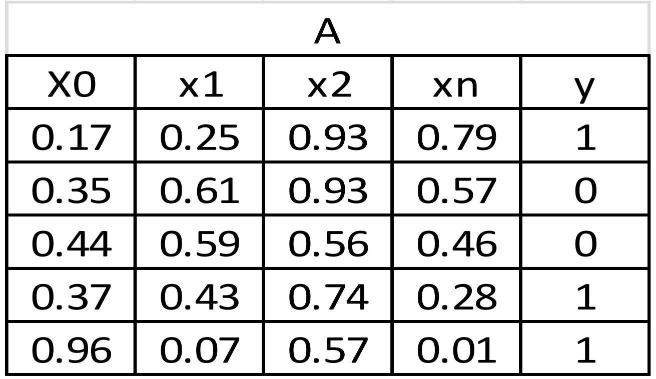
- Wolpert in 1992 introduced stacking. It involves:

1. **Splitting** the train set into two disjoint sets.
2. **Train** several base learners on the first part.
3. **Make predictions** with the base learners on the second (validation) part.
4. Using the **predictions** from (3) **as the inputs** to train a higher level learner.

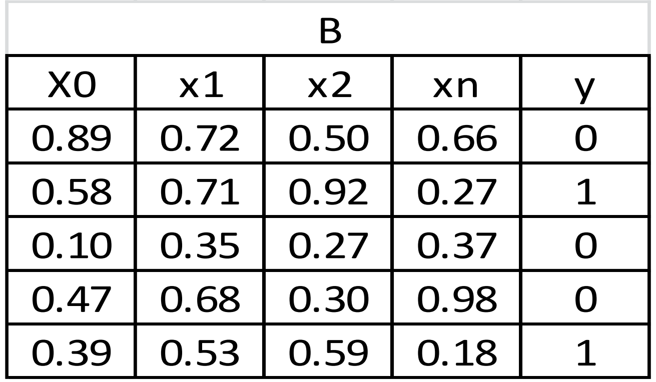
Still confused about Stacking?

Consider datasets A,B,C. Target variable (y) is known for A,B

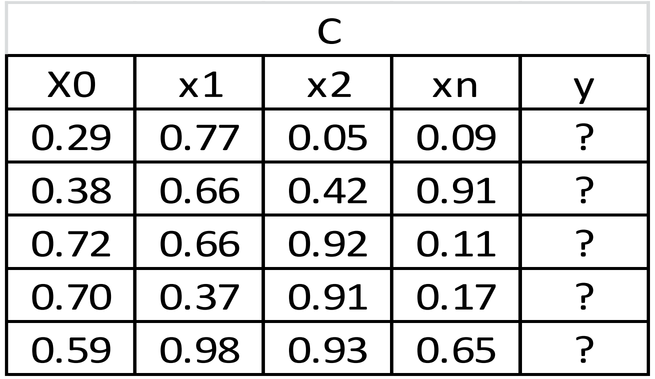
Still confused about Stacking?



A				
X0	x1	x2	xn	y
0.17	0.25	0.93	0.79	1
0.35	0.61	0.93	0.57	0
0.44	0.59	0.56	0.46	0
0.37	0.43	0.74	0.28	1
0.96	0.07	0.57	0.01	1



B				
X0	x1	x2	xn	y
0.89	0.72	0.50	0.66	0
0.58	0.71	0.92	0.27	1
0.10	0.35	0.27	0.37	0
0.47	0.68	0.30	0.98	0
0.39	0.53	0.59	0.18	1



C				
X0	x1	x2	xn	y
0.29	0.77	0.05	0.09	?
0.38	0.66	0.42	0.91	?
0.72	0.66	0.92	0.11	?
0.70	0.37	0.91	0.17	?
0.59	0.98	0.93	0.65	?

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0.59	0.98	0.93	0.65	?

Train algorithm **0** on A and make predictions for B and C and save to **B1**, **C1**

B1
pred0
0.24
0.95
0.64
0.89
0.11

C1
pred0
0.50
0.62
0.22
0.90
0.20

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0.59	0.98	0.93	0.65	?

Train algorithm **0** on A and make predictions for B and C and save to **B1**, **C1**

Train algorithm **1** on A and make predictions for B and C and save to **B1**, **C1**

B1	
pred0	pred1
0.24	0.72
0.95	0.25
0.64	0.80
0.89	0.58
0.11	0.20

C1	
pred0	pred1
0.50	0.50
0.62	0.59
0.22	0.31
0.90	0.47
0.20	0.09

Still confused about Stacking?

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X0	x1	x2	xn	y
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0.38	0.66	0.42	0.91	?
0.72	0.66	0.92	0.11	?
0.70	0.37	0.91	0.17	?
0.59	0.98	0.93	0.65	?

Train algorithm **0** on A and make predictions for B and C and save to **B1**, **C1**

Train algorithm **1** on A and make predictions for B and C and save to **B1**, **C1**

Train algorithm **2** on A and make predictions for B and C and save to **B1**, **C1**

B1			
pred0	pred1	pred2	y
0.24	0.72	0.70	0
0.95	0.25	0.22	1
0.64	0.80	0.96	0
0.89	0.58	0.52	0
0.11	0.20	0.93	1

C1			
pred0	pred1	pred2	y
0.50	0.50	0.39	?
0.62	0.59	0.46	?
0.22	0.31	0.54	?
0.90	0.47	0.09	?
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0.11	0.20	0.93	1

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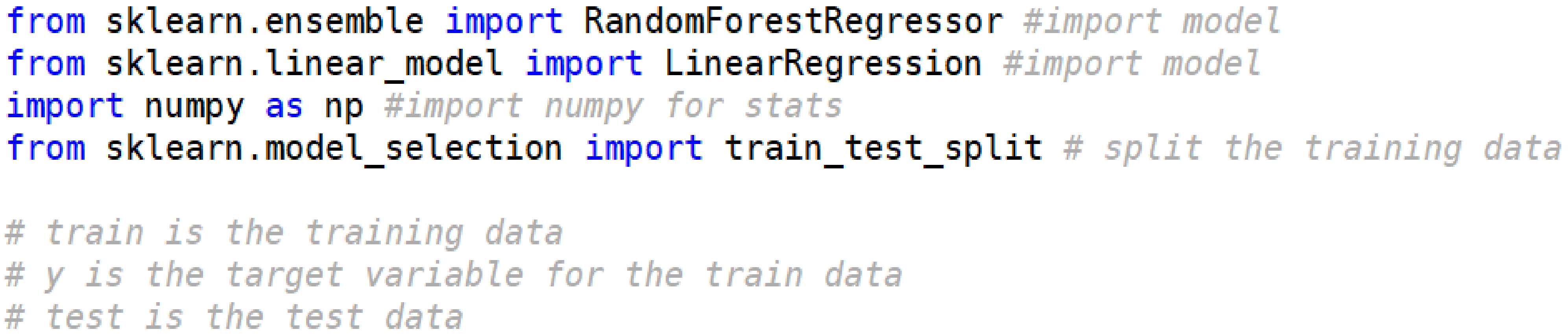
0.50	0.50	0.39	?
0.62	0.59	0.46	?
0.22	0.31	0.54	?
0.90	0.47	0.09	?
0.20	0.09	0.61	?

Preds3
0.45
0.23
0.99
0.34
0.05

Train algorithm **3** on B1 and make predictions for C1

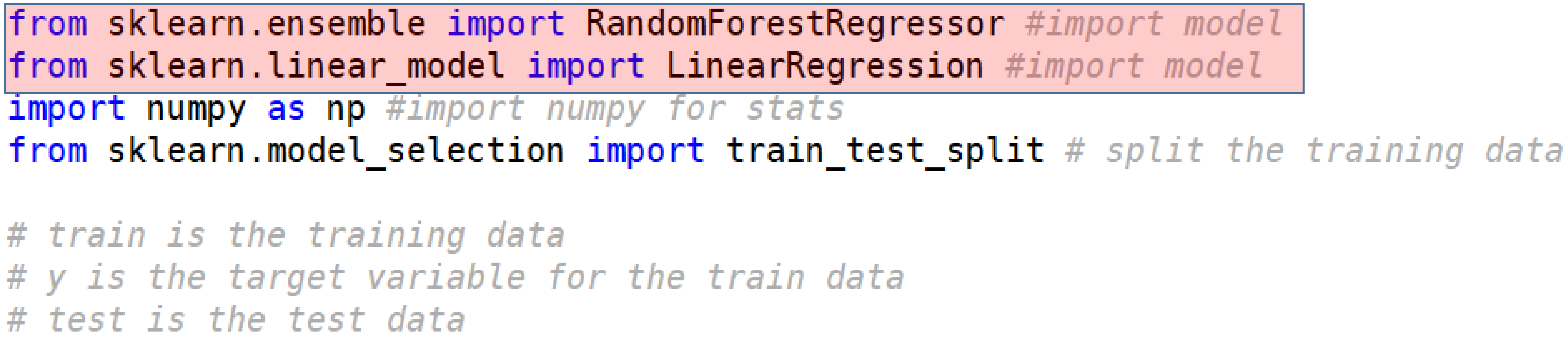
Stacking example



```python
from sklearn.ensemble import RandomForestRegressor #import model
from sklearn.linear_model import LinearRegression #import model
import numpy as np #import numpy for stats
from sklearn.model_selection import train_test_split # split the training data

# train is the training data
# y is the target variable for the train data
# test is the test data
```

Stacking example



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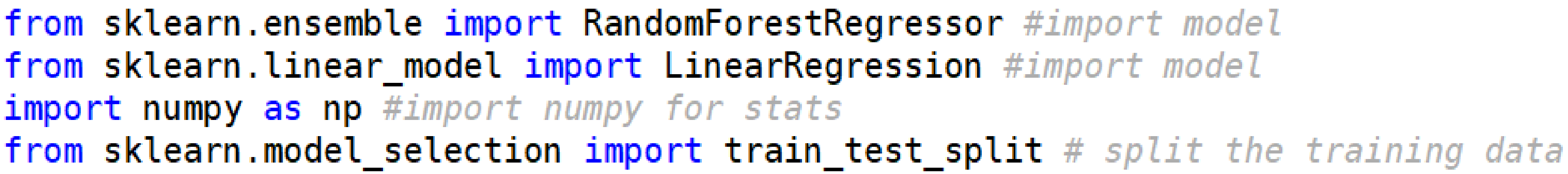

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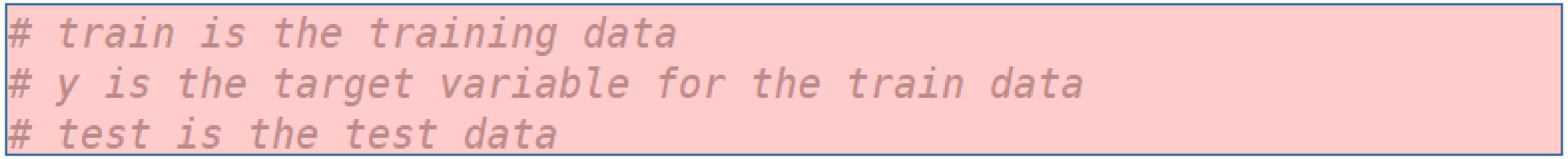

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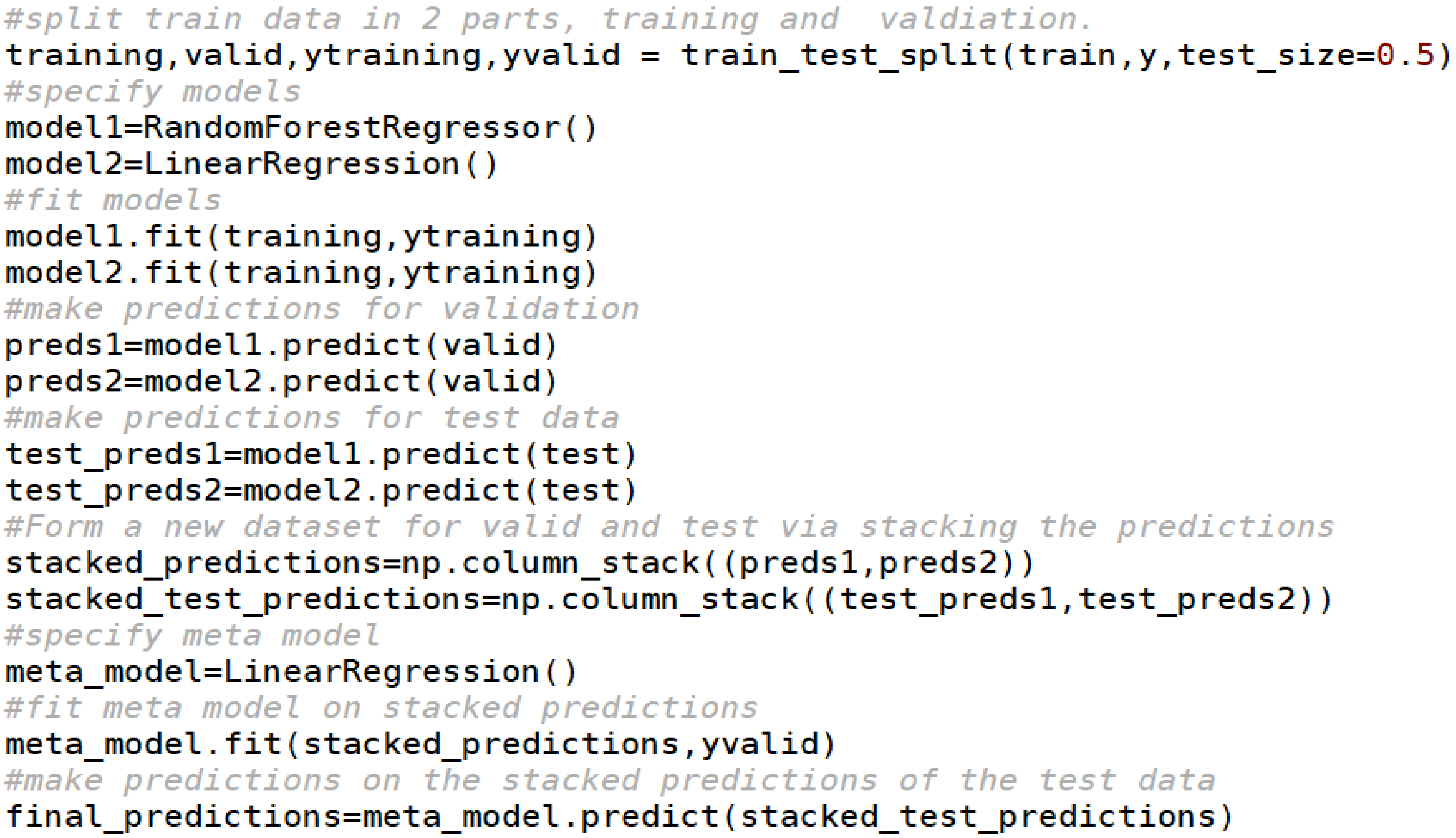

```
#split train data in 2 parts, training and  valdiation.
training,valid,ytraining,yvalid = train_test_split(train,y,test_size=0.5)
#specify models
model1=RandomForestRegressor()
model2=LinearRegression()
#fit models
model1.fit(training,ytraining)
model2.fit(training,ytraining)
#make predictions for validation
preds1=model1.predict(valid)
preds2=model2.predict(valid)
#make predictions for test data
test_preds1=model1.predict(test)
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#Form a new dataset for valid and test via stacking the predictions
stacked_predictions=np.column_stack((preds1,preds2))
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#specify meta model
meta_model=LinearRegression()
#fit meta model on stacked predictions
meta_model.fit(stacked_predictions,yvalid)
#make predictions on the stacked predictions of the test data
final_predictions=meta_model.predict(stacked_test_predictions)
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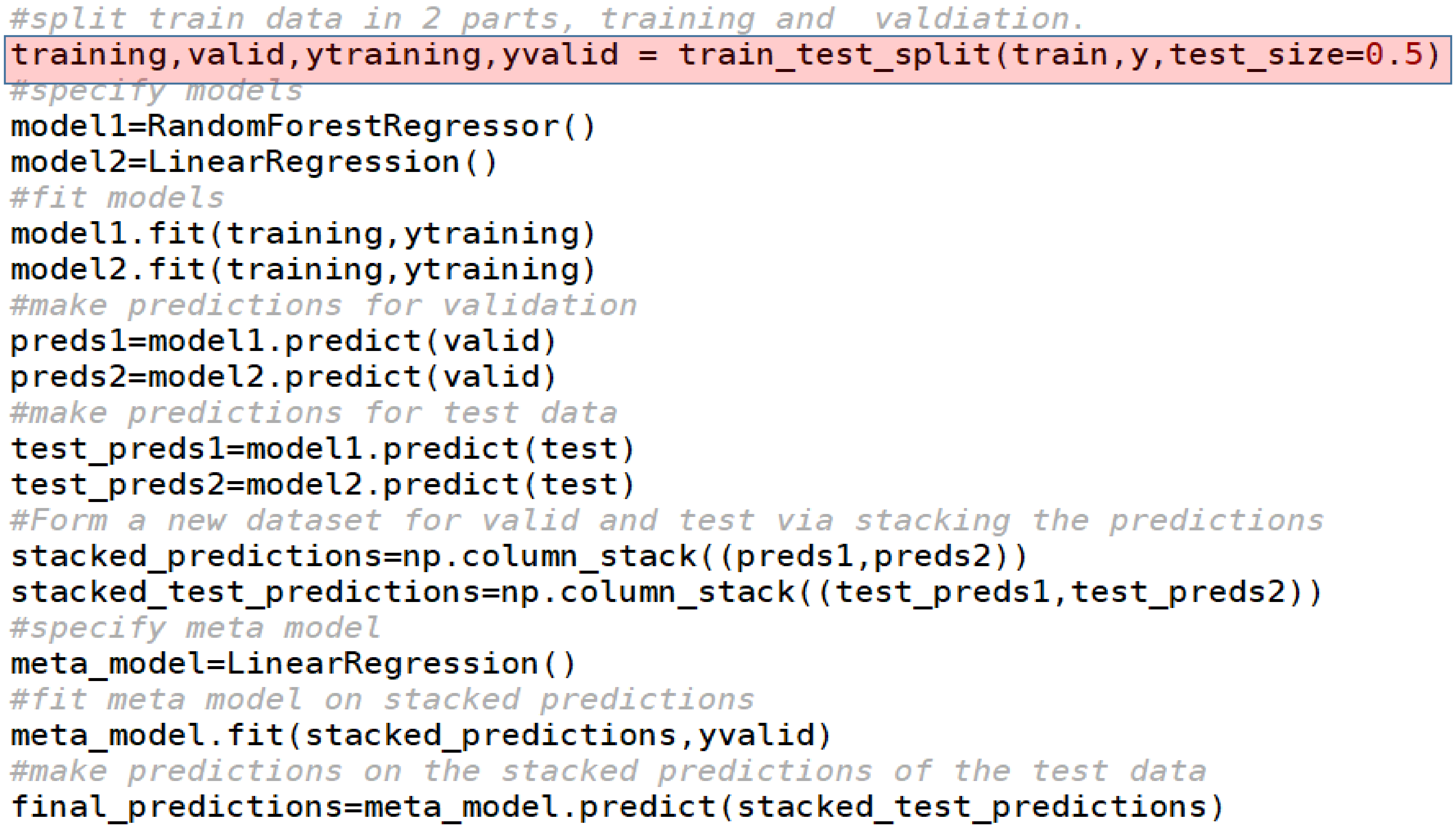

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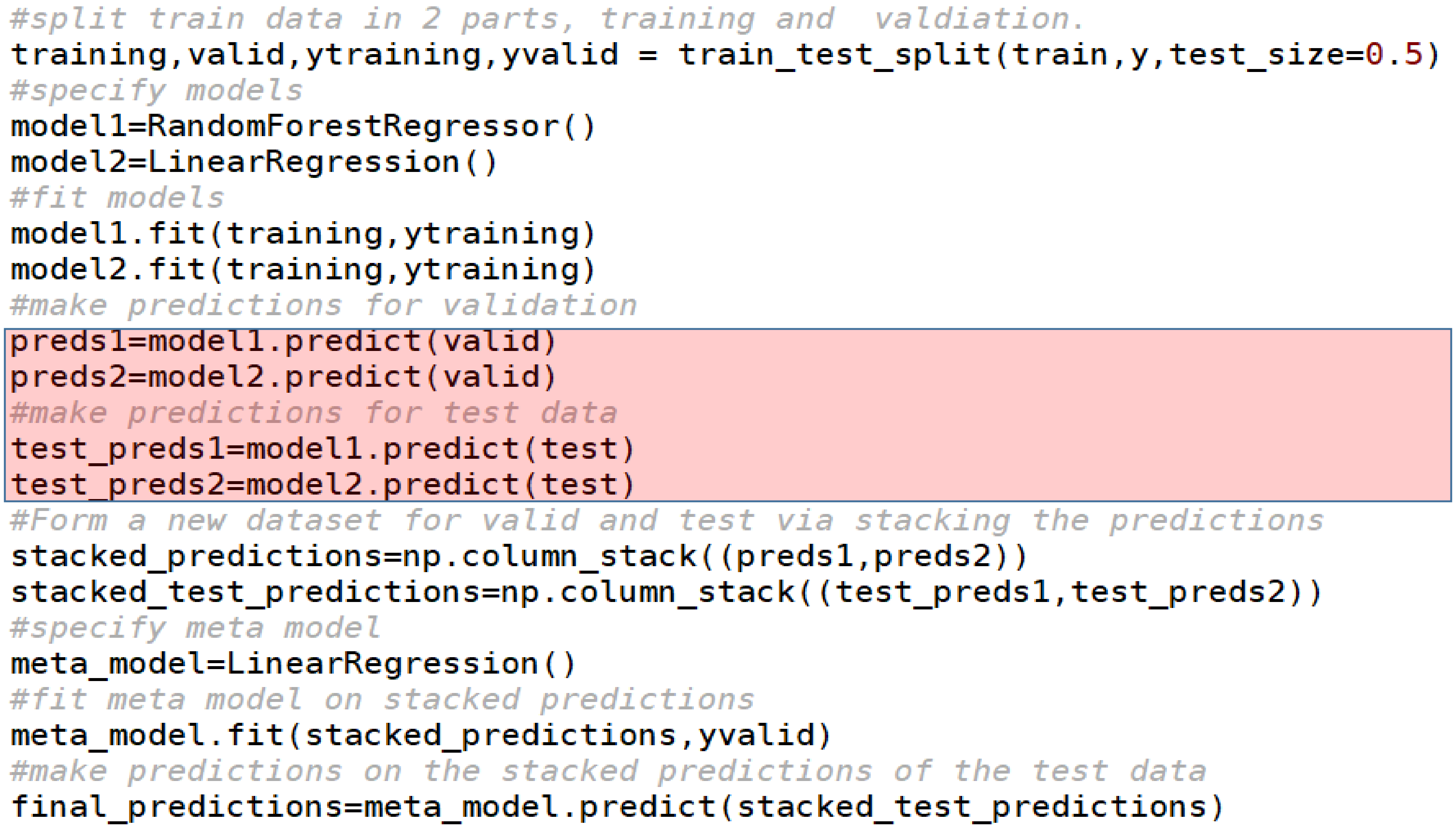

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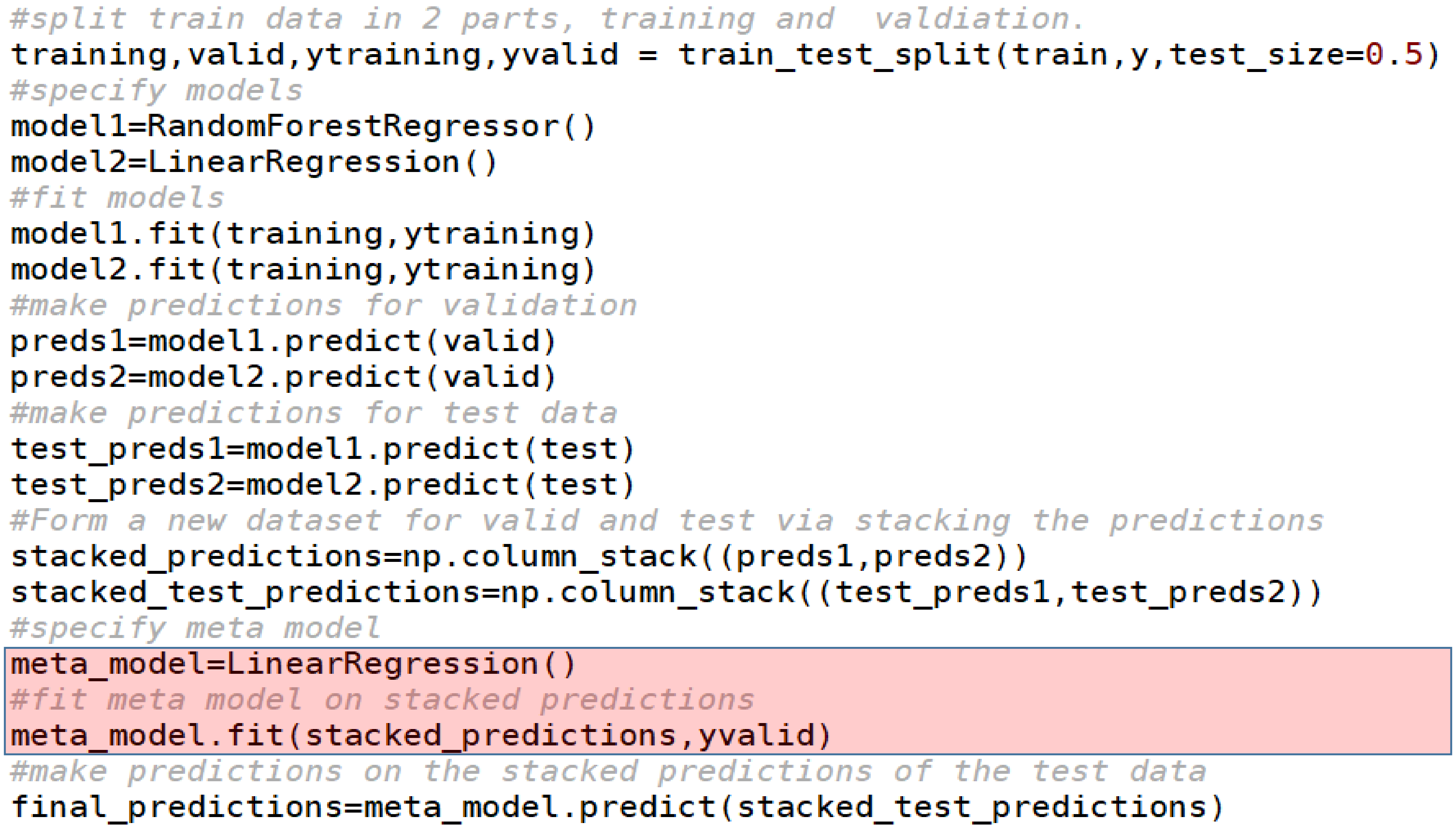

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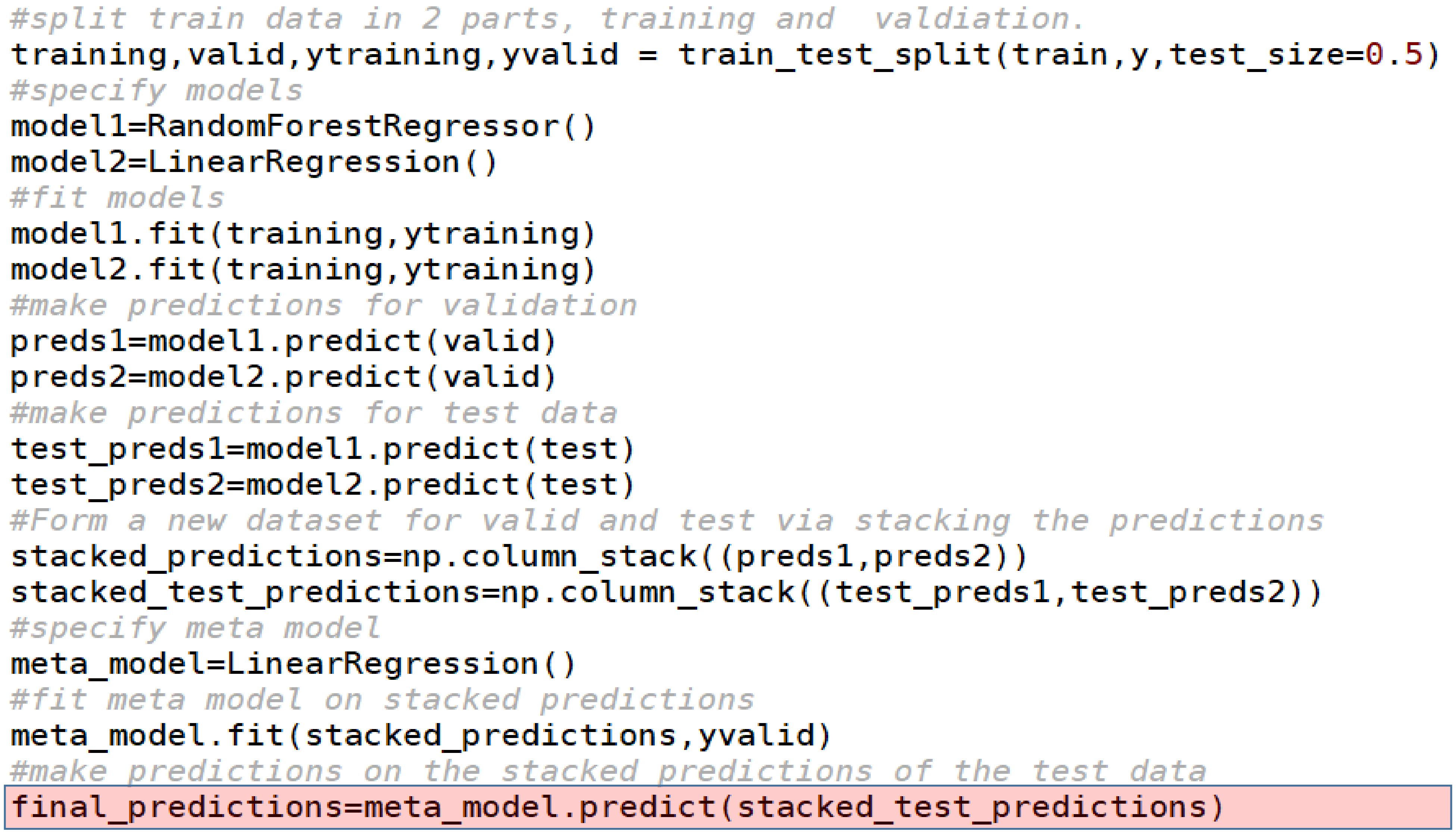

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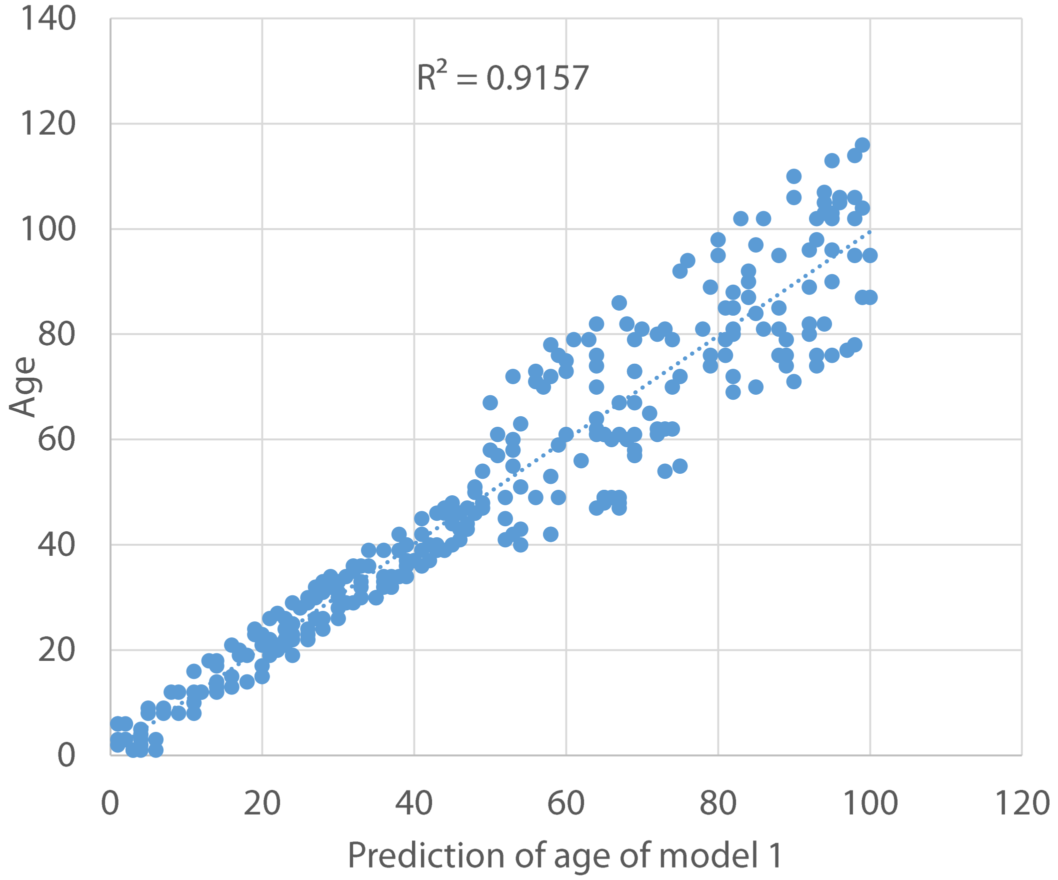
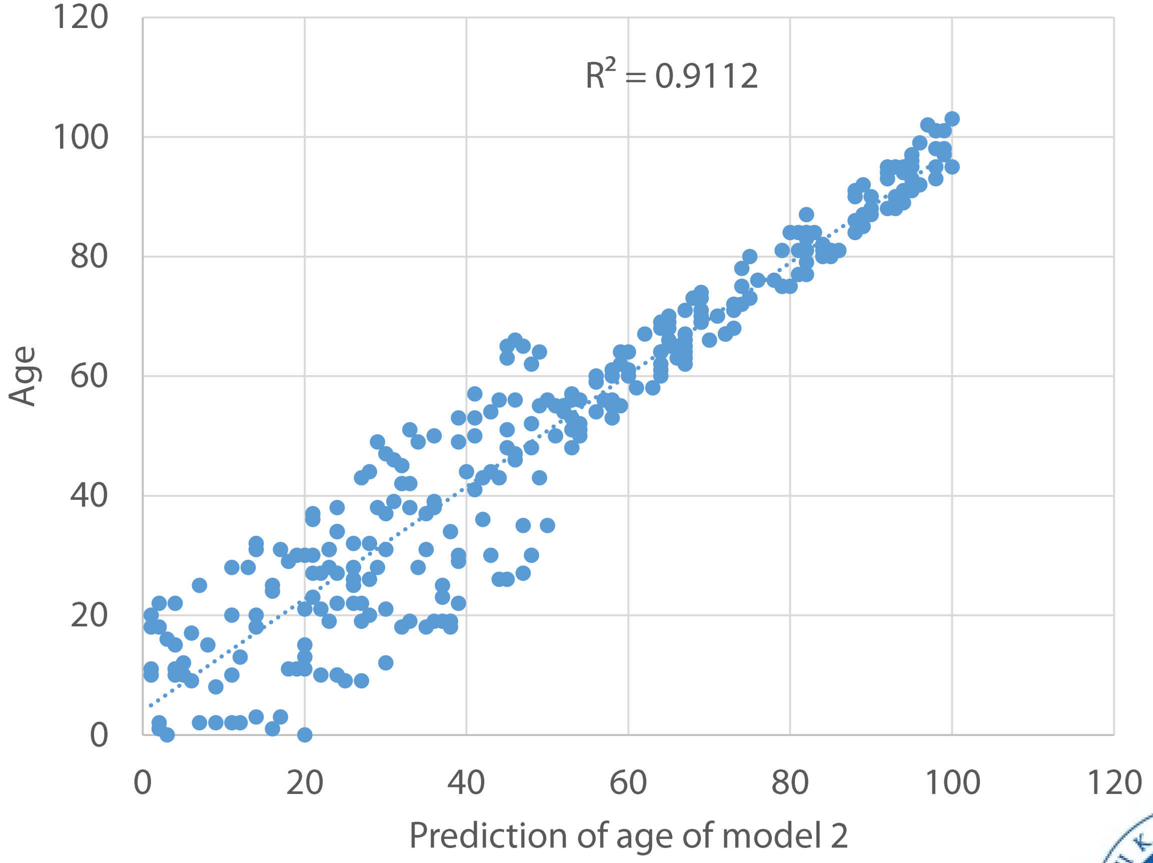
Stacking (past) example





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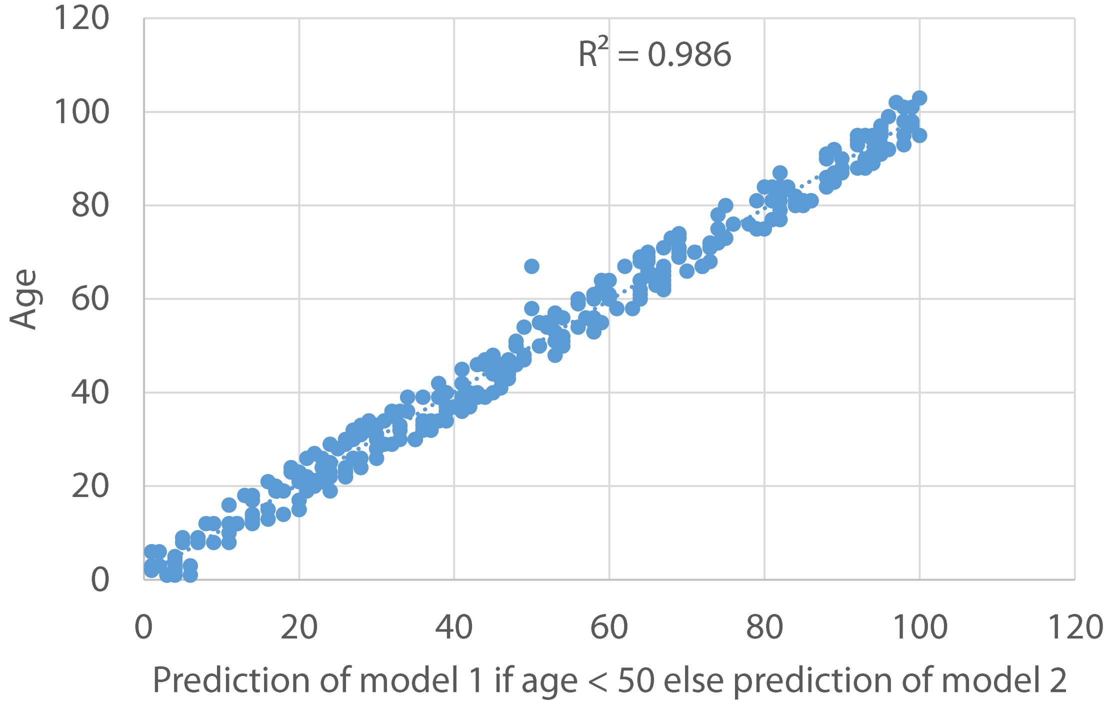

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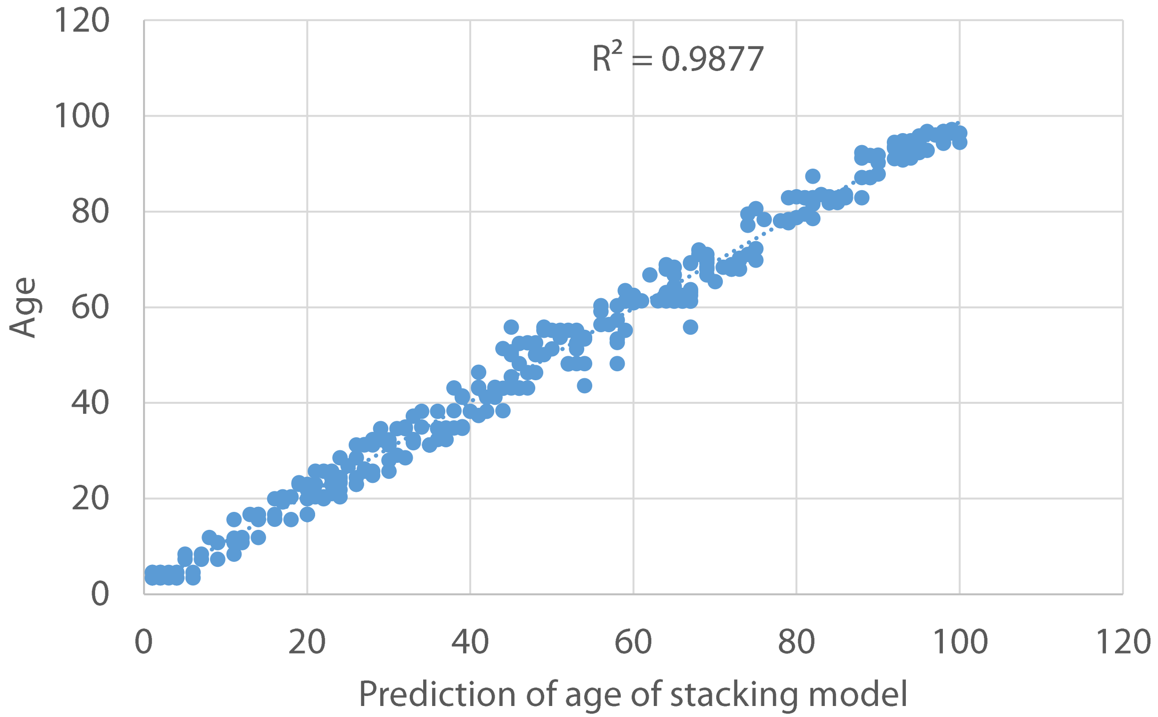

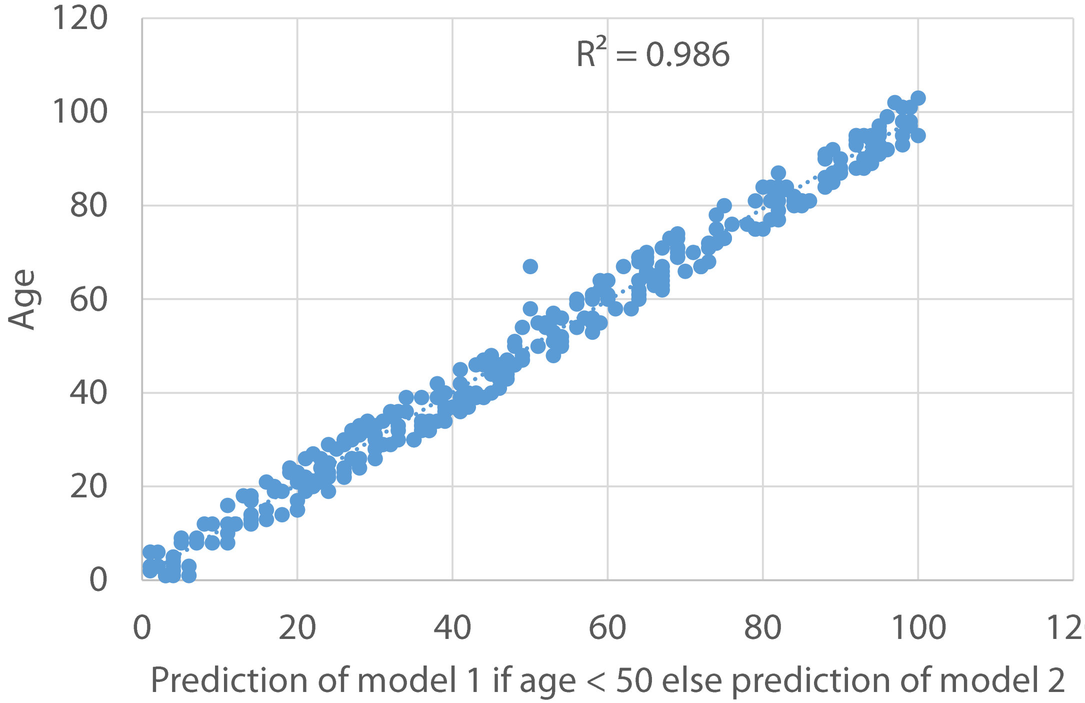

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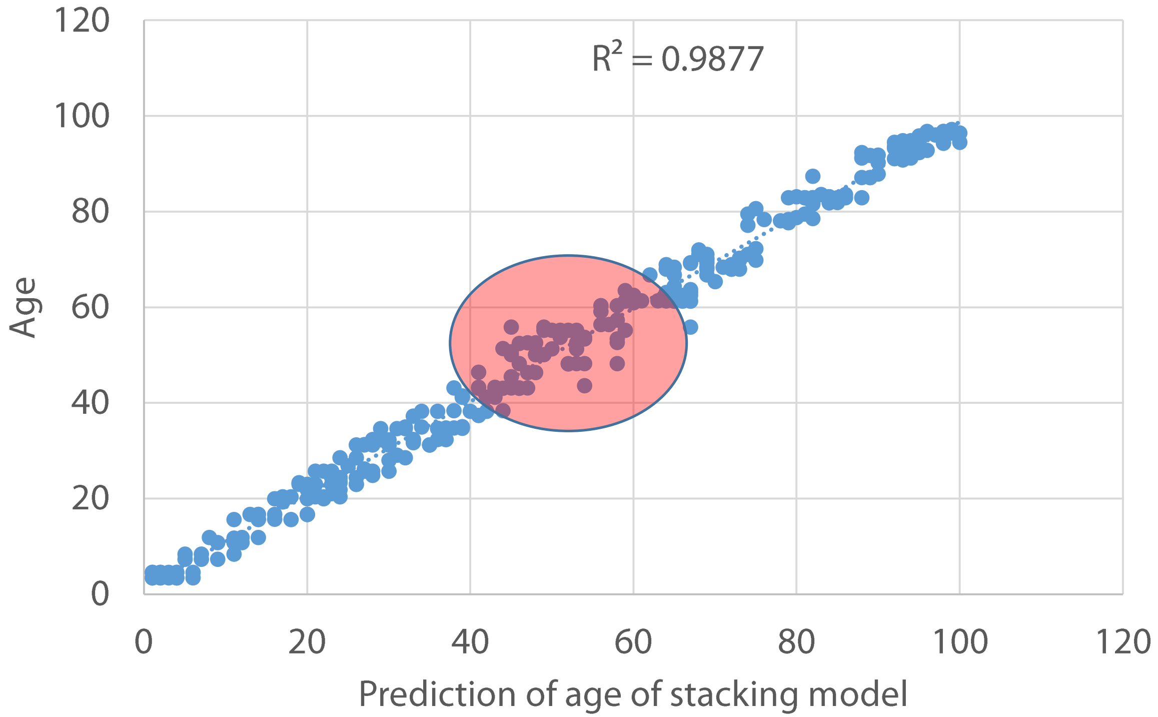

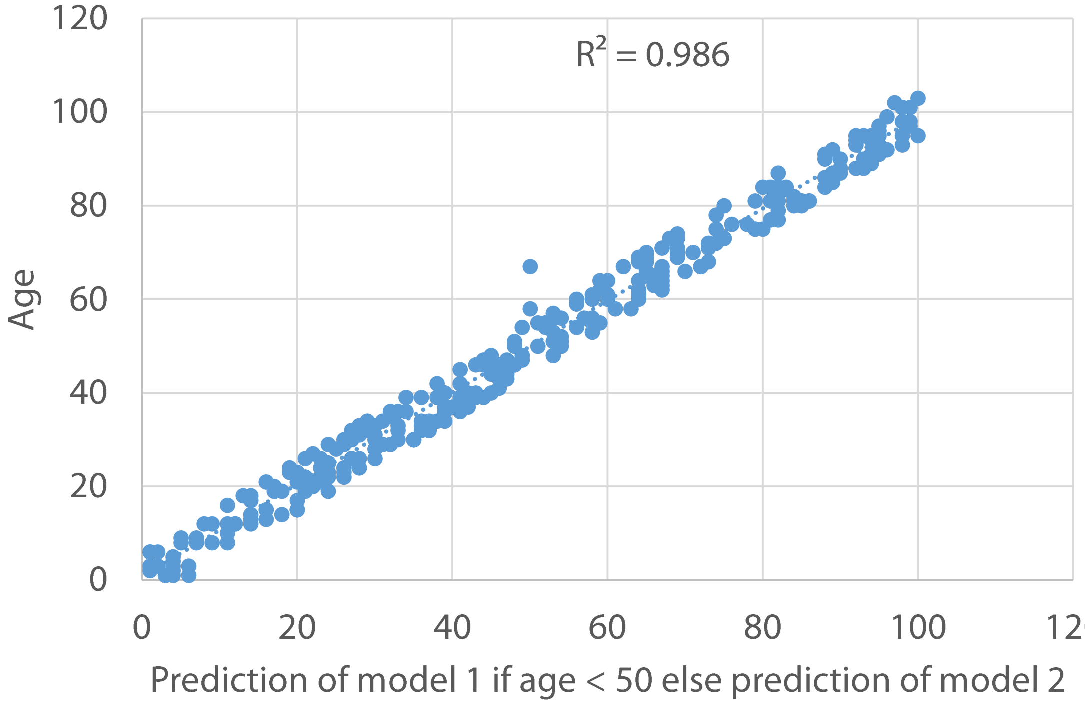

Things to be mindful of

- With time sensitive data – respect time
- Diversity as important as performance
- Diversity may come from:
  - Different algorithms
  - Different input features
- Performance plateauing after N models
- Meta model is normally modest