Ensemble methods: stacking

By Marios Michailidis

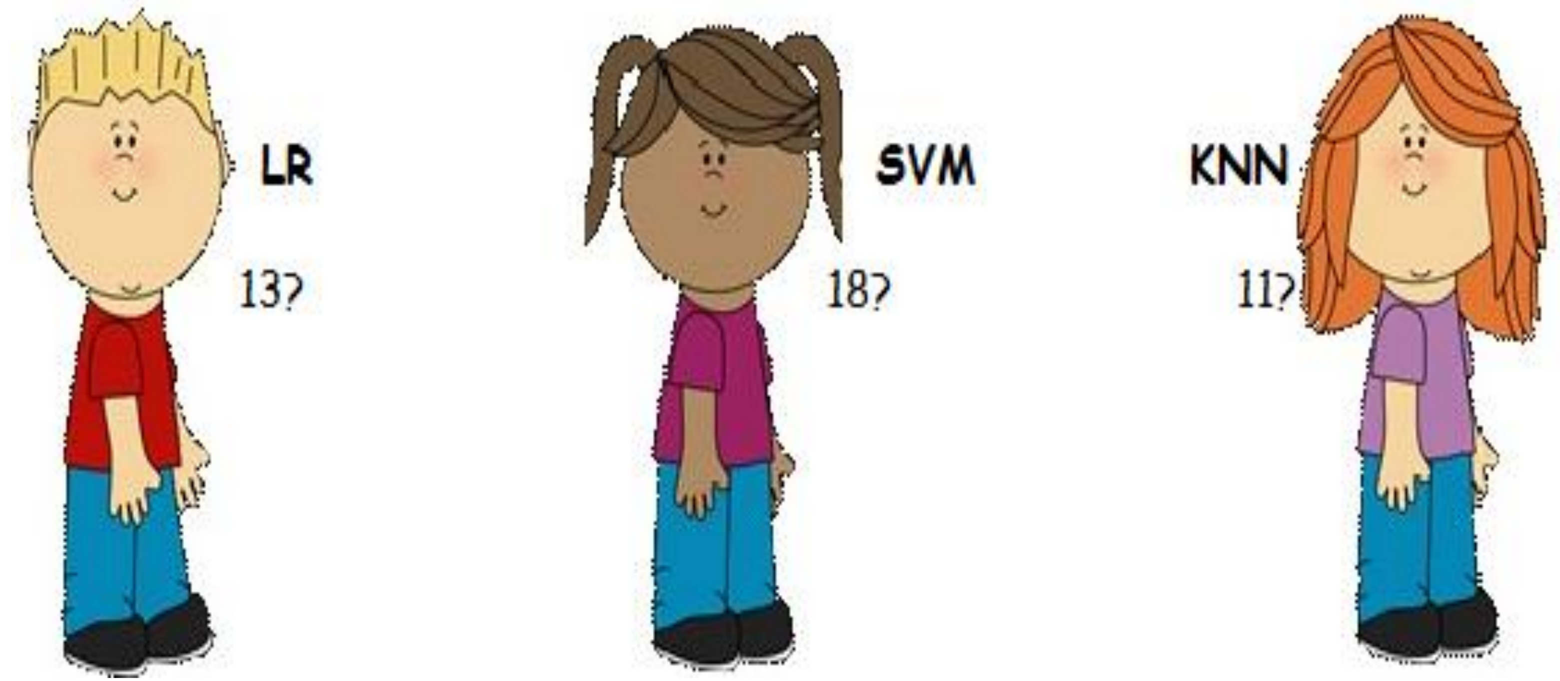
Examined ensemble methods

- 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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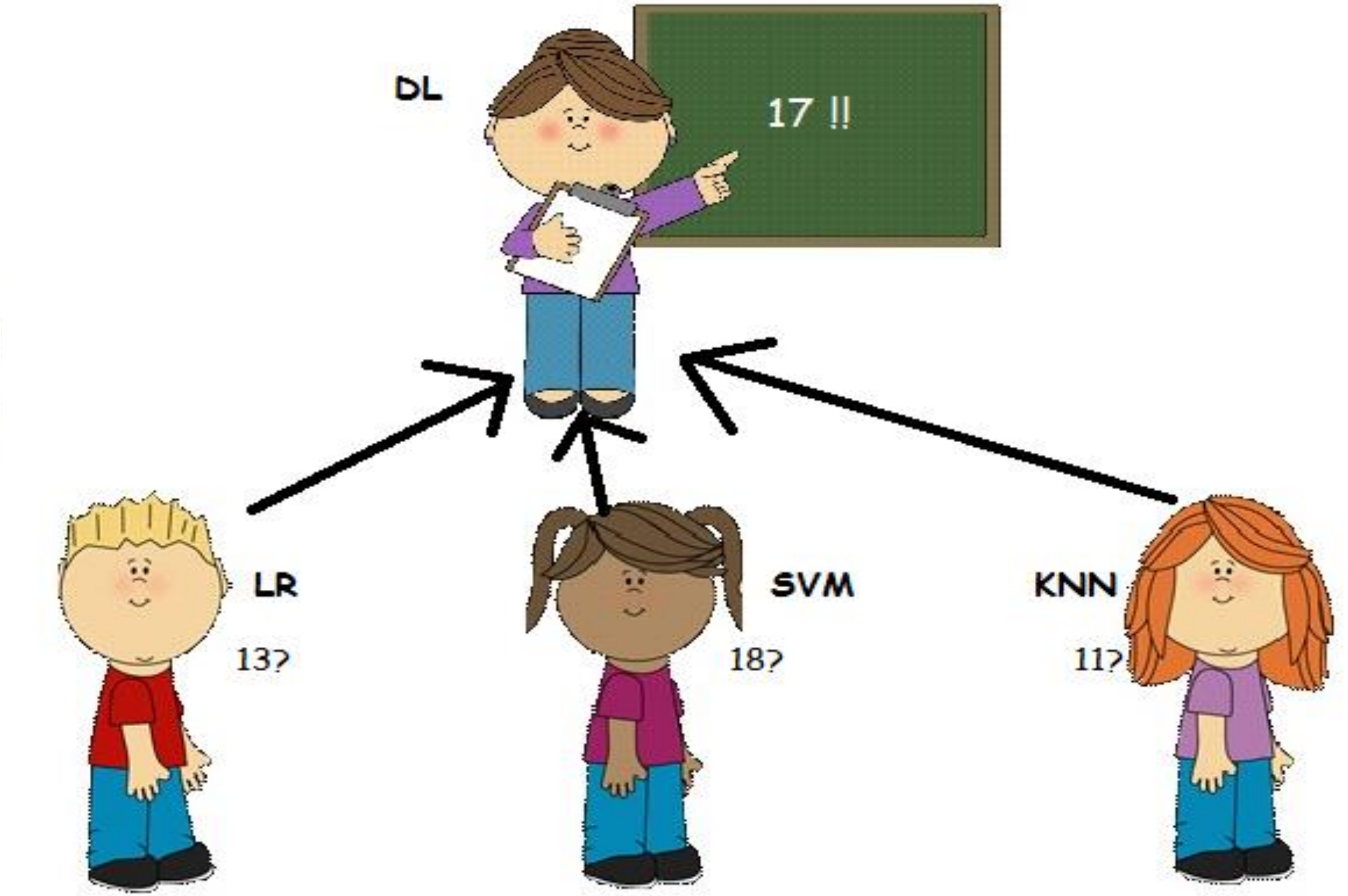

Methodology

- 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

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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	?

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	?
0.20	0.09	0.61	?

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0.11	0.20	0.93	1

C1				
pred0	pred1	pred2	y	Preds3
0.50	0.50	0.39	?	0.45
0.62	0.59	0.46	?	0.23
0.22	0.31	0.54	?	0.99
0.90	0.47	0.09	?	0.34
0.20	0.09	0.61	?	0.05

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

Stacking example

```
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
```

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The main logic is that we will use two base learners on some input data, a random forest and a linear regression. And then, we will try to combine the results, starting with a meta learner, again, it will be linear regression.

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Stacking example

```
#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)
test_preds2=model2.predict(test)
#Form a new dataset for valid and test via stacking the predictions
stacked_predictions=np.column_stack((preds1,preds2))
stacked_test_predictions=np.column_stack((test_preds1,test_preds2))
#specify meta model
meta_model=LinearRegression()
#fit meta model on stacked predictions
meta_model.fit(stacked_predictions,yvalid)
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final_predictions=meta_model.predict(stacked_test_predictions)
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Then we are going to collect the predictions, we are going to stack the predictions and create two new data sets. One for validation, where we call it stacked_predictions, which consists of preds1 and preds2. And then for the data set for for the test predictions, called stacked_test_predictions, where we stack test_preds1 and test_preds2.

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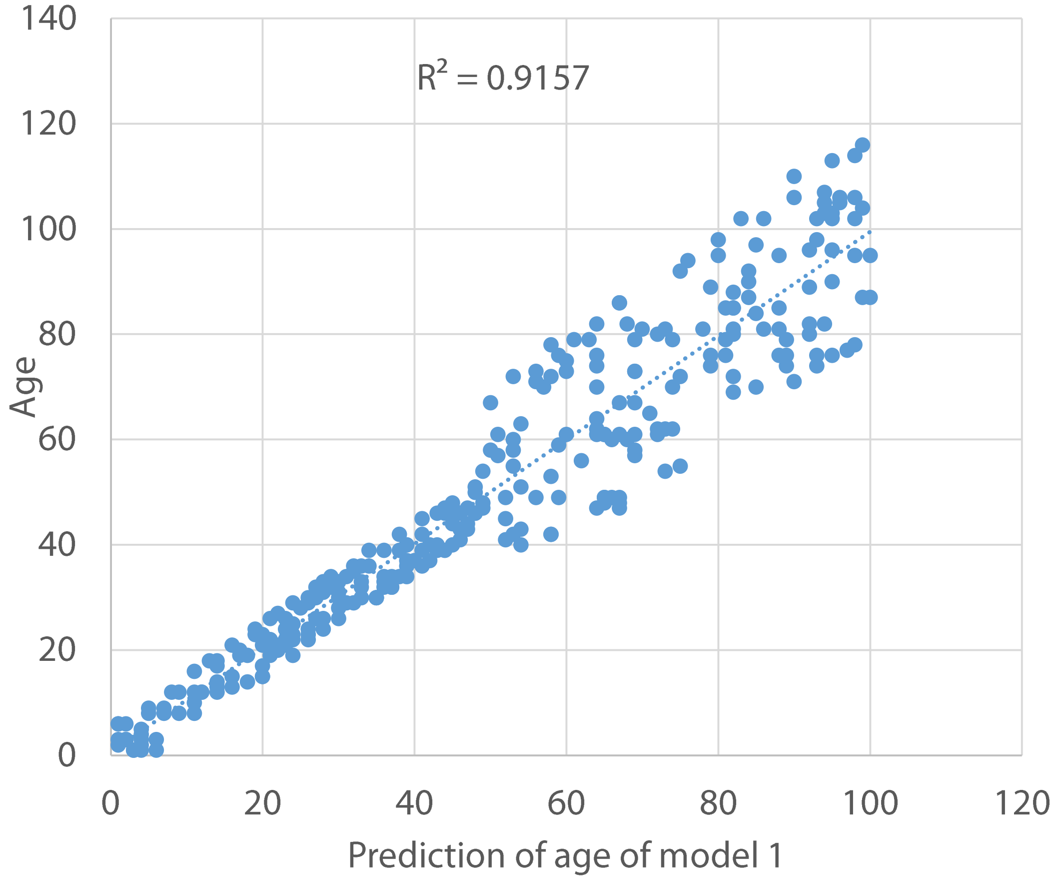
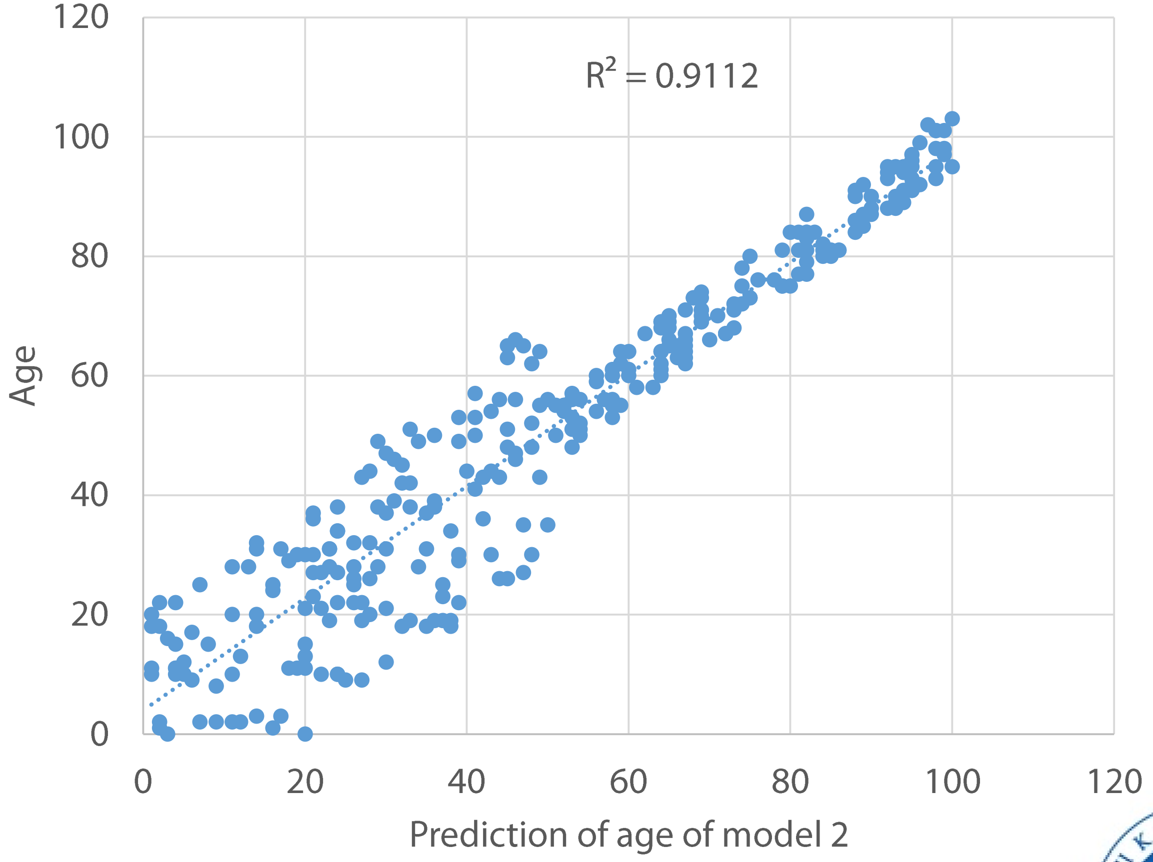
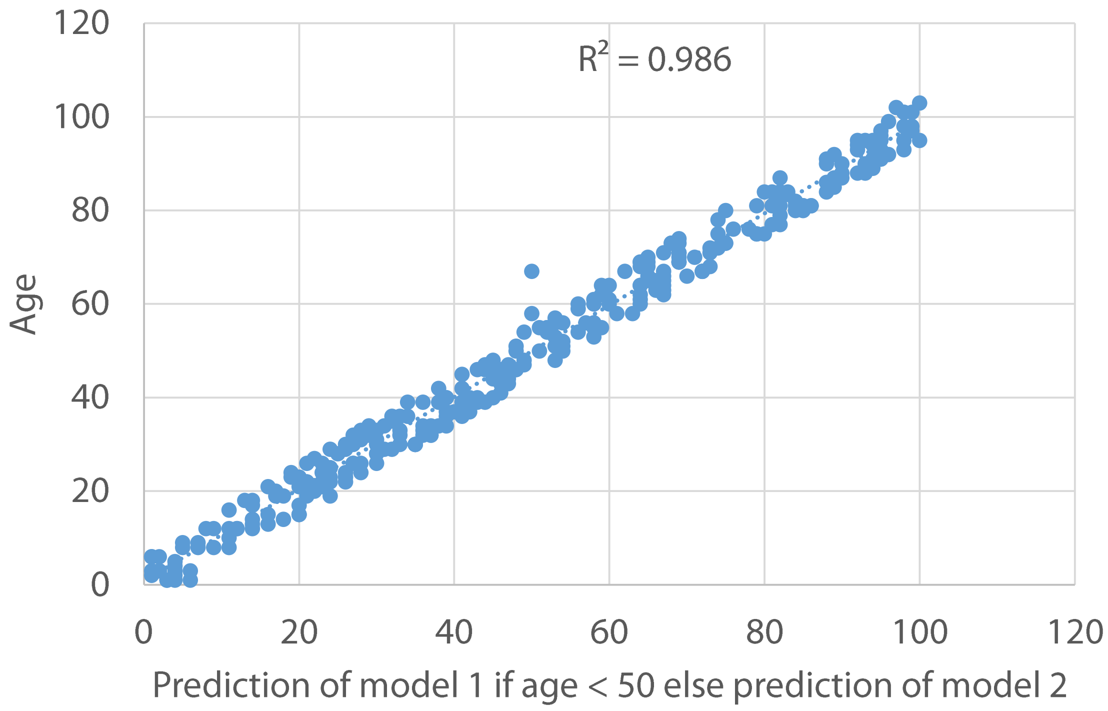




Stacking (past) example



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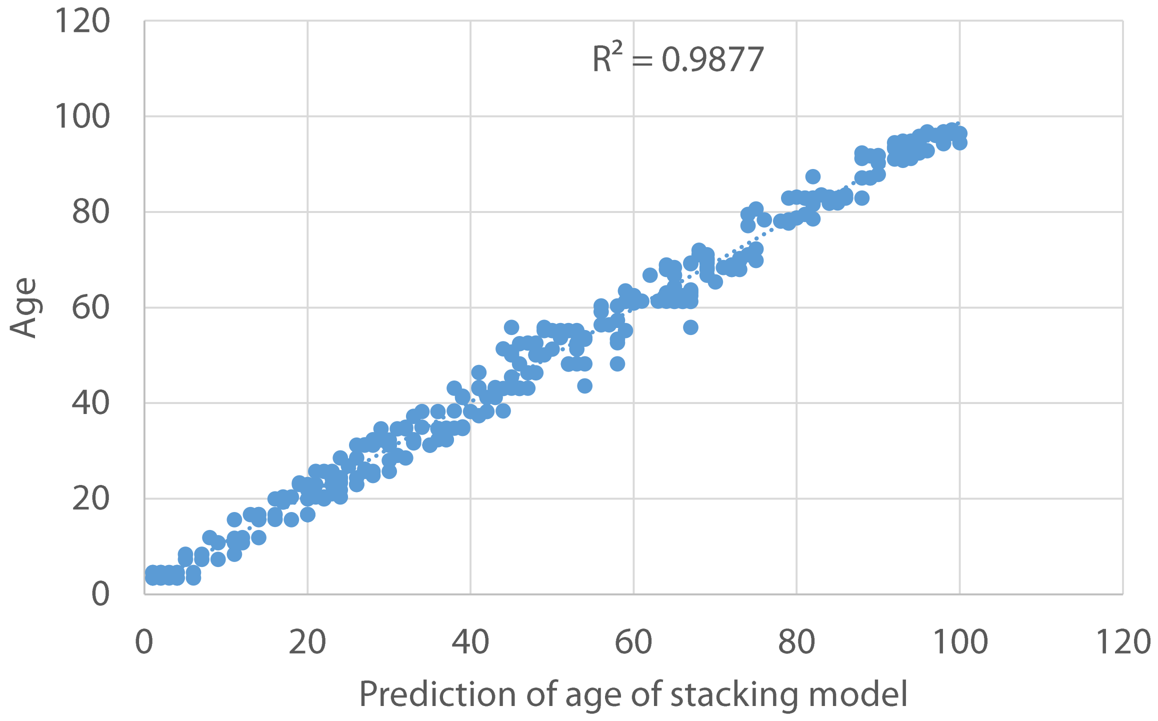

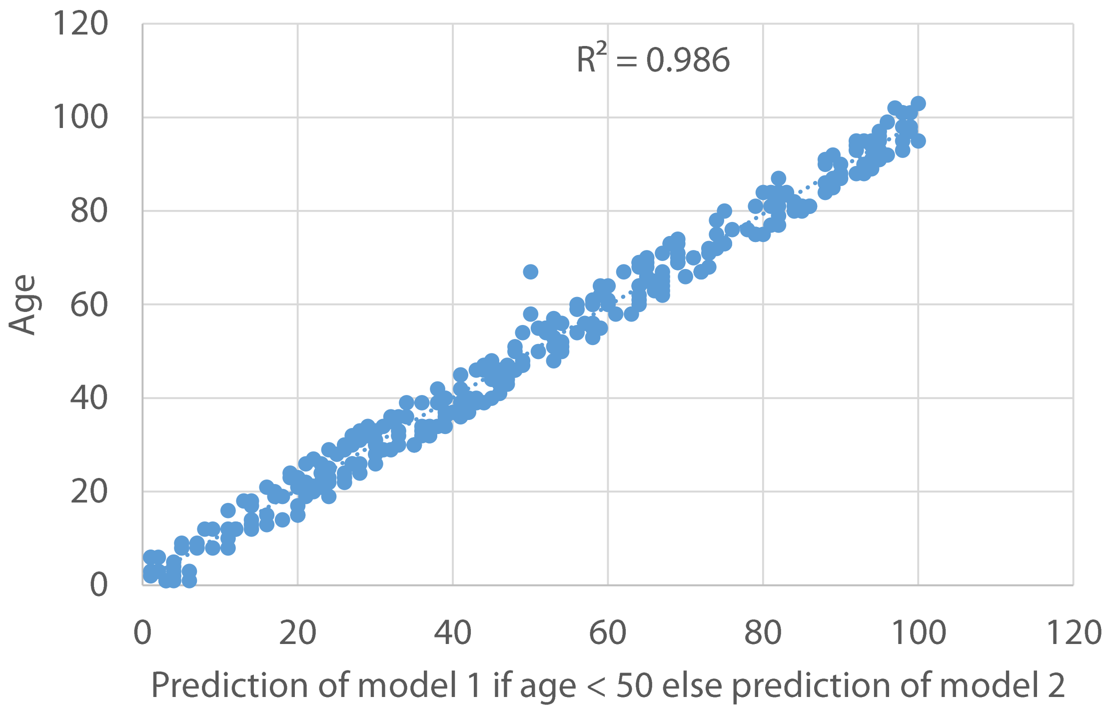

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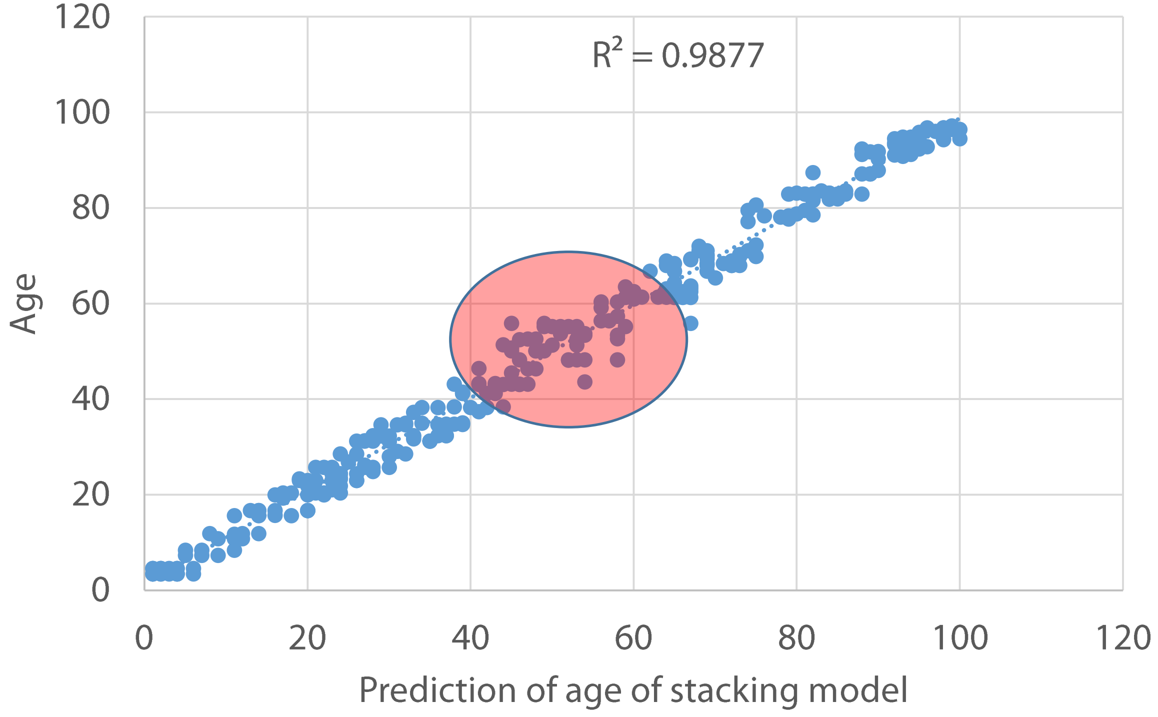

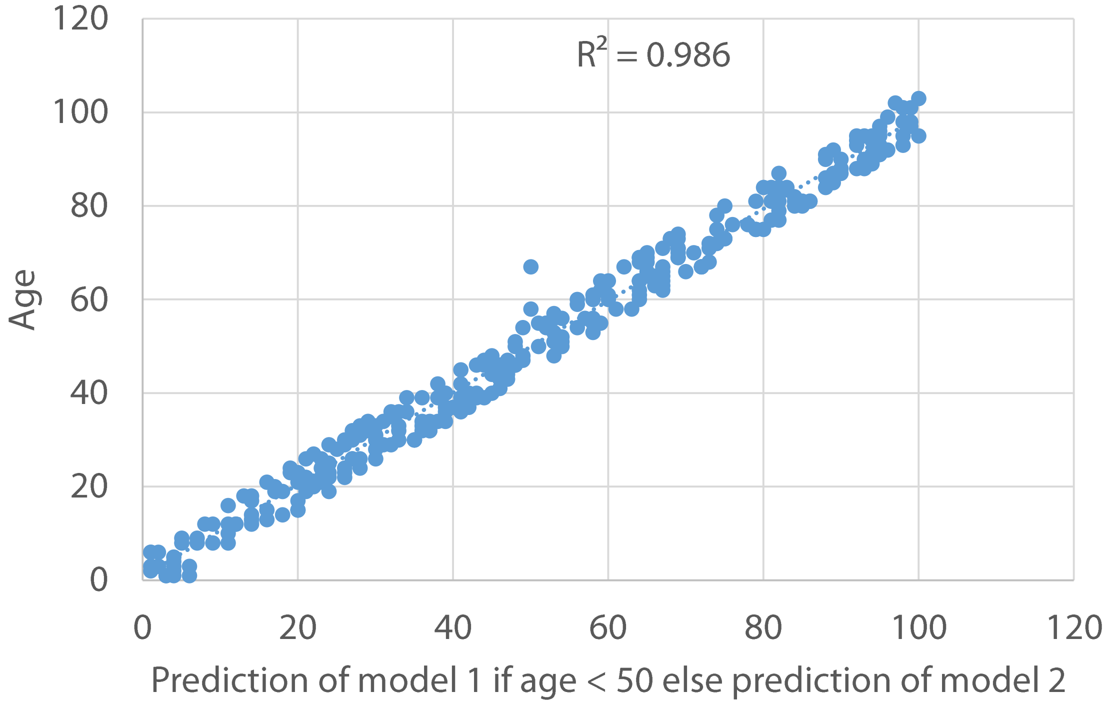

Things to be mindful of

- With time sensitive data – respect time
- Diversity as important as performance
- Diversity may come from:
  - Different algorithms
  - Different input features

For example, in one data set you may treat categorical features as one hot encoding. In another, you may just use label encoding, and the result will probably produce a model that is very different.

- Performance plateauing after N models
- Meta model is normally modest