

# Ensemble methods: stacking

*By Marios Michailidis*



# Examined ensemble methods

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

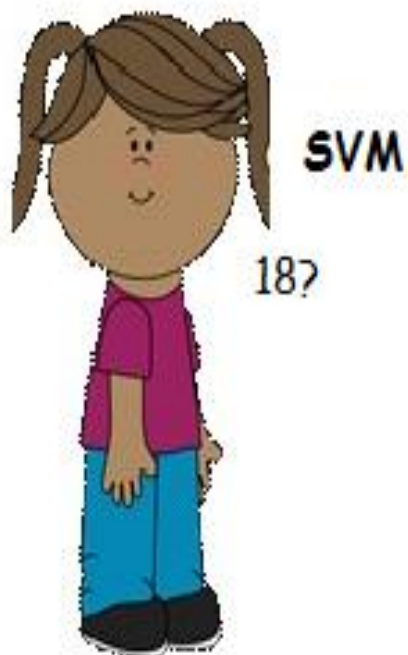
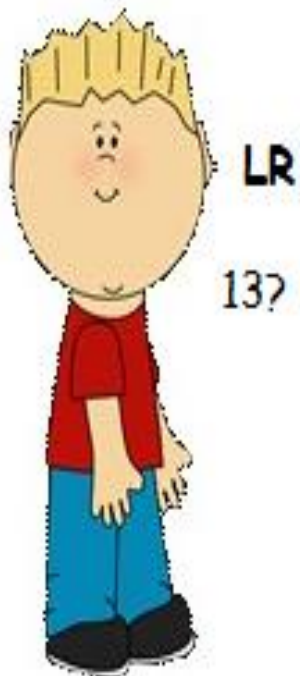


# What is Stacking

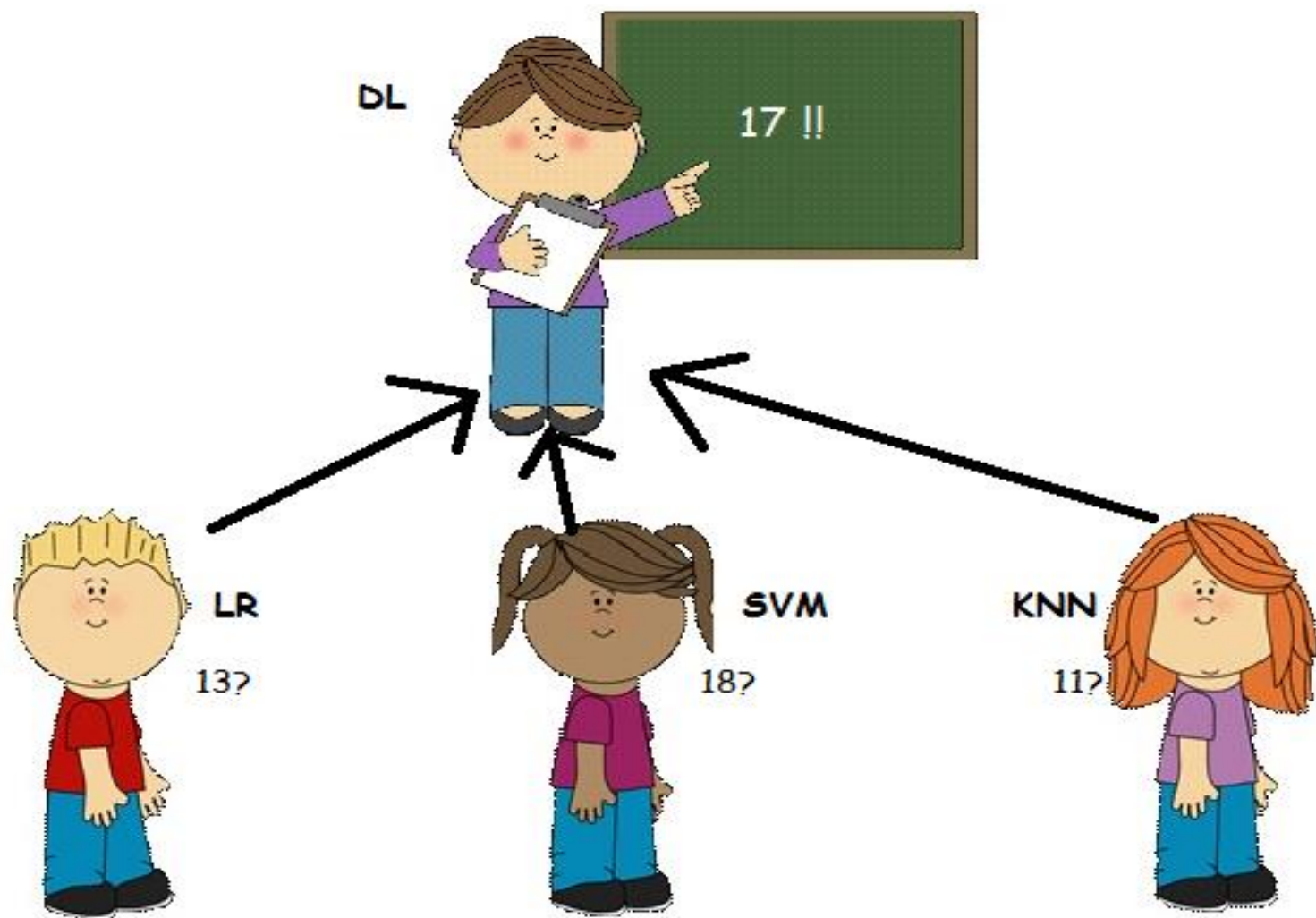
Means making predictions of a number of models in a hold-out set and then using a different (Meta) model to train on these predictions.



# Naïve example



# Naïve example



# 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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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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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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0.38	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	?
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0.90	0.47	0.09	?
0.20	0.09	0.61	?

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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# train is the training data
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# Stacking example

```
#split train data in 2 parts, training and validation.
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)
#make predictions on the stacked predictions of the test data
final_predictions=meta_model.predict(stacked_test_predictions)
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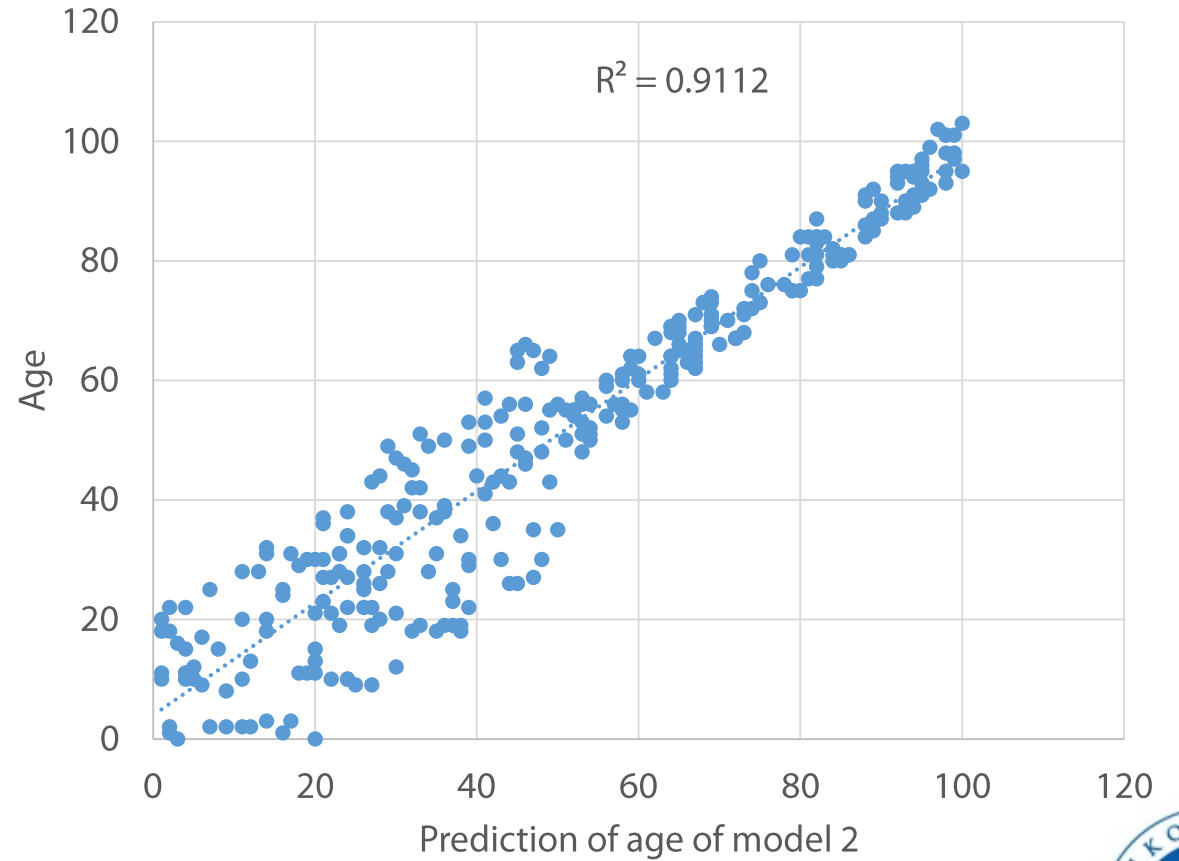
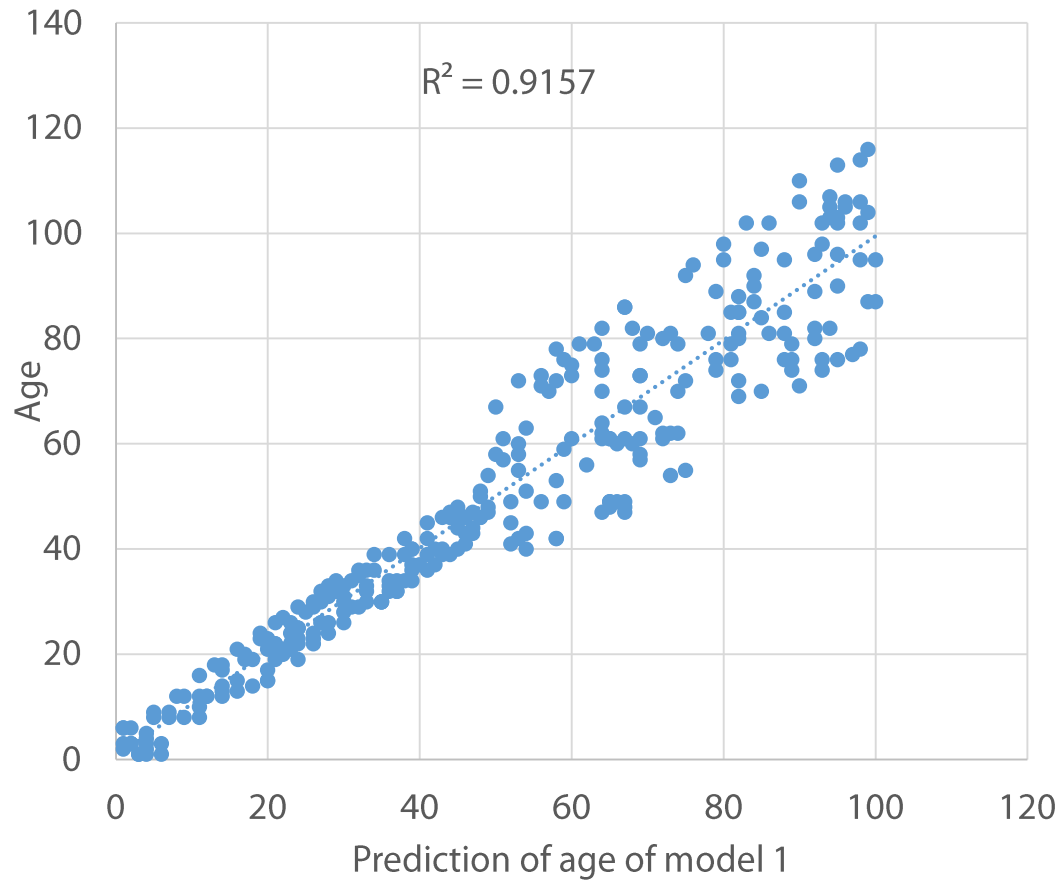


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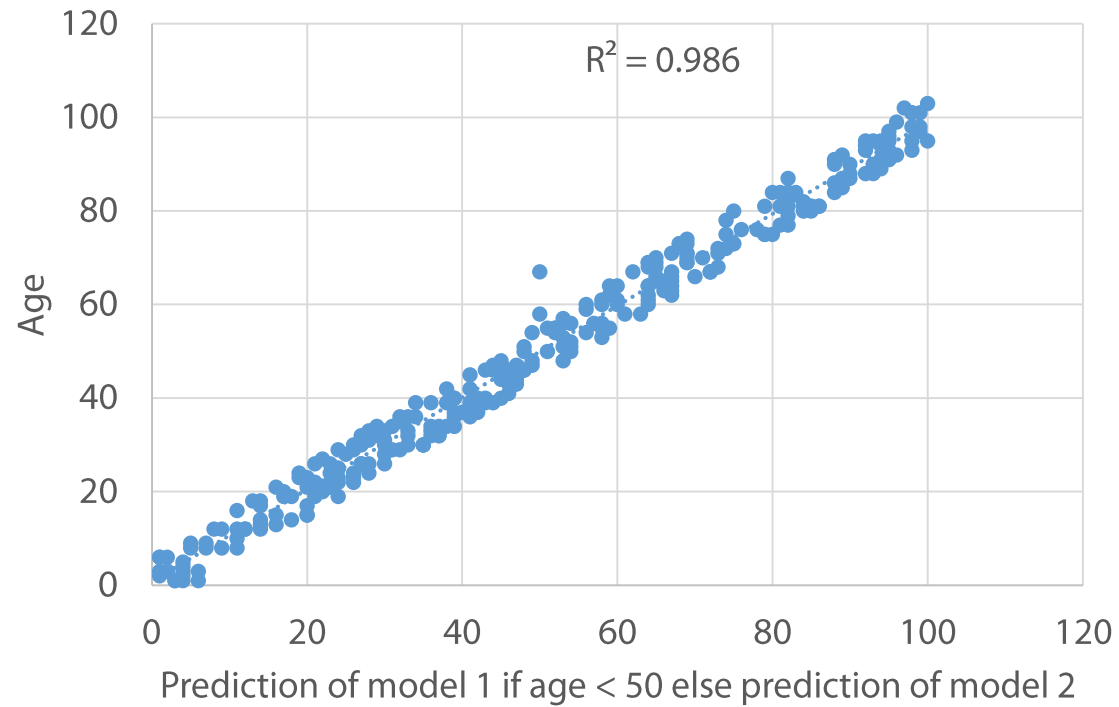


# Stacking (past) example

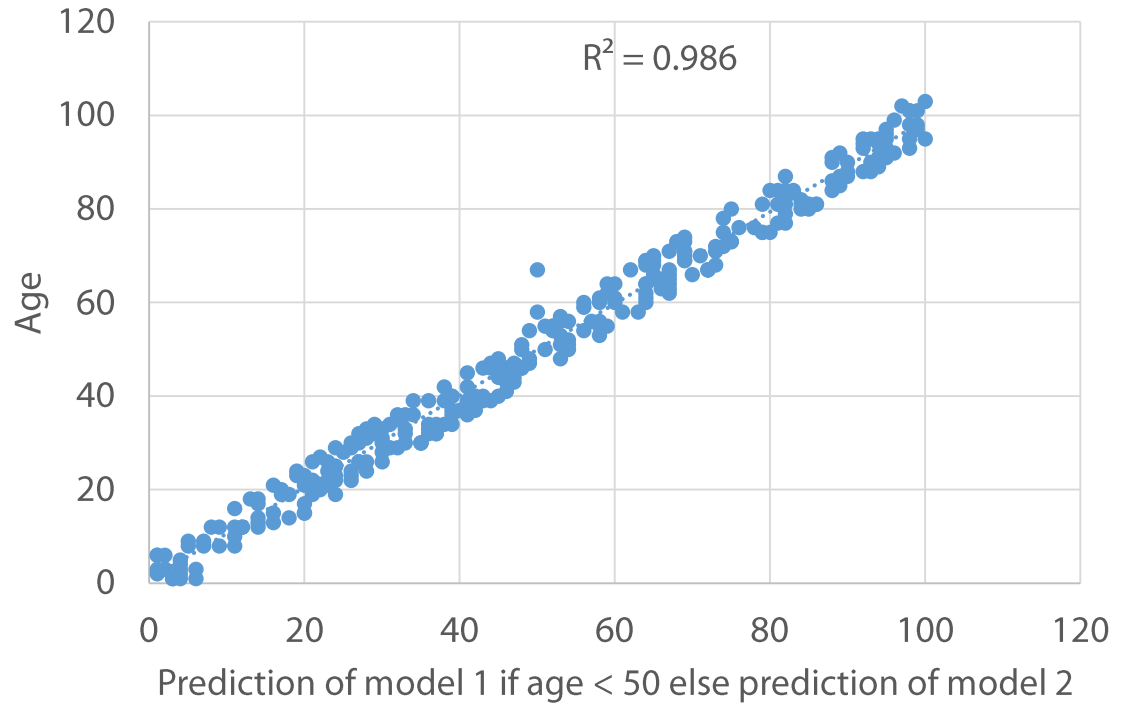
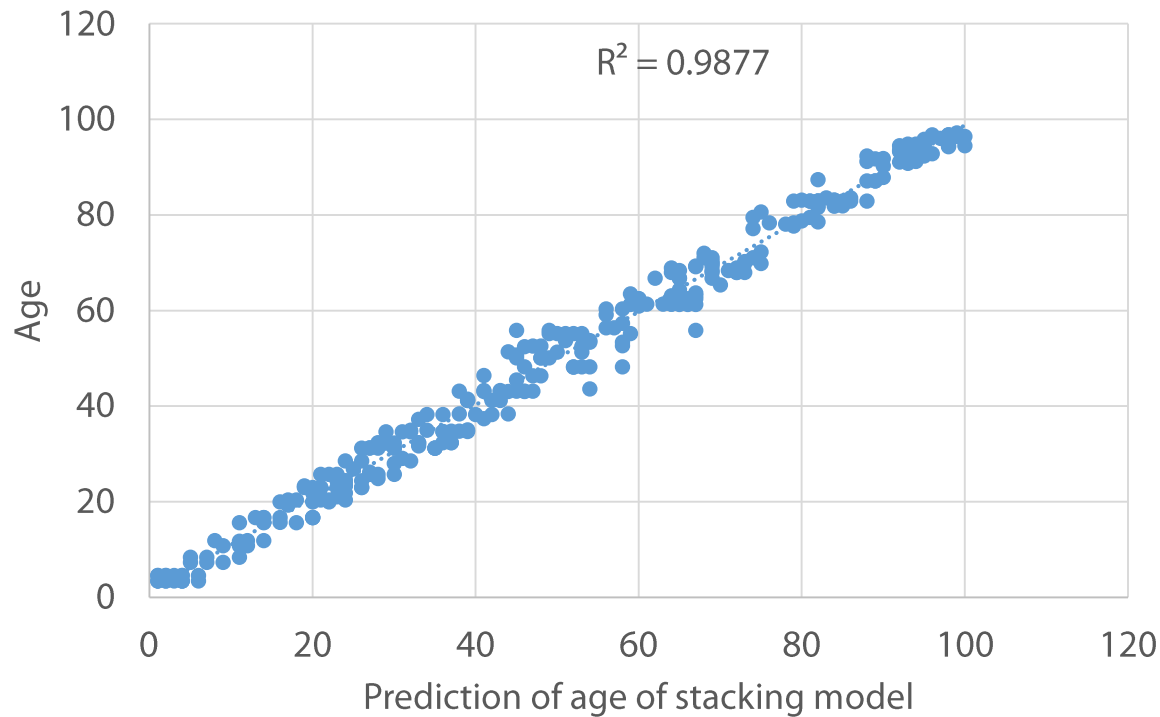




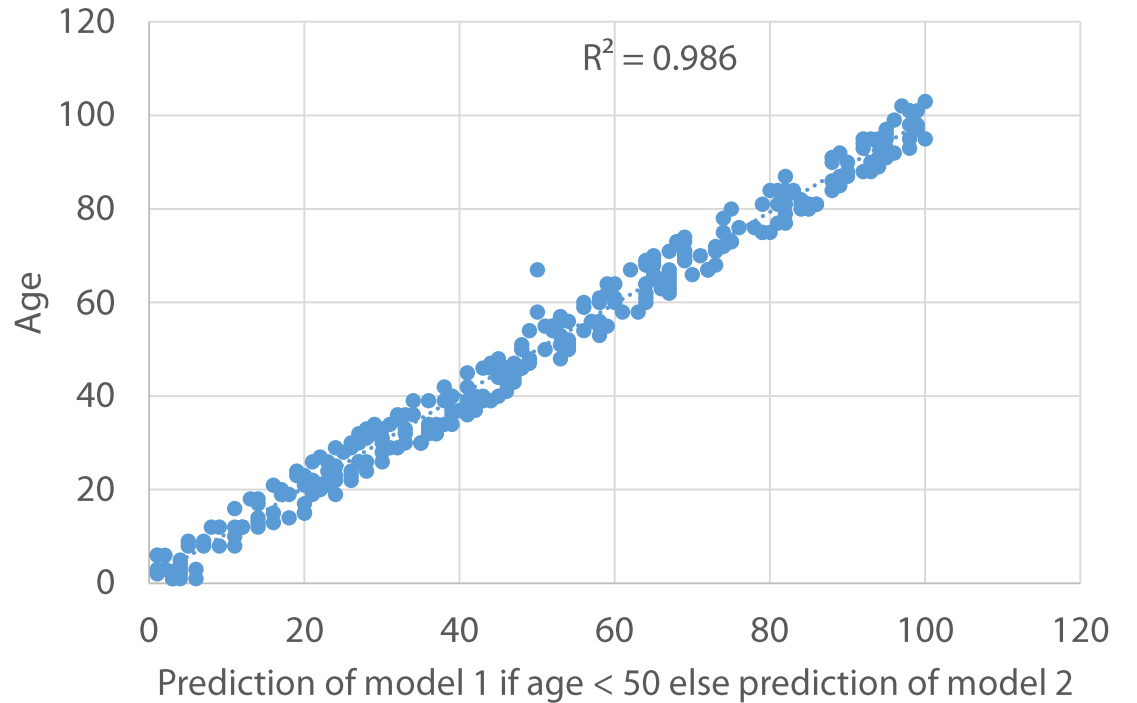
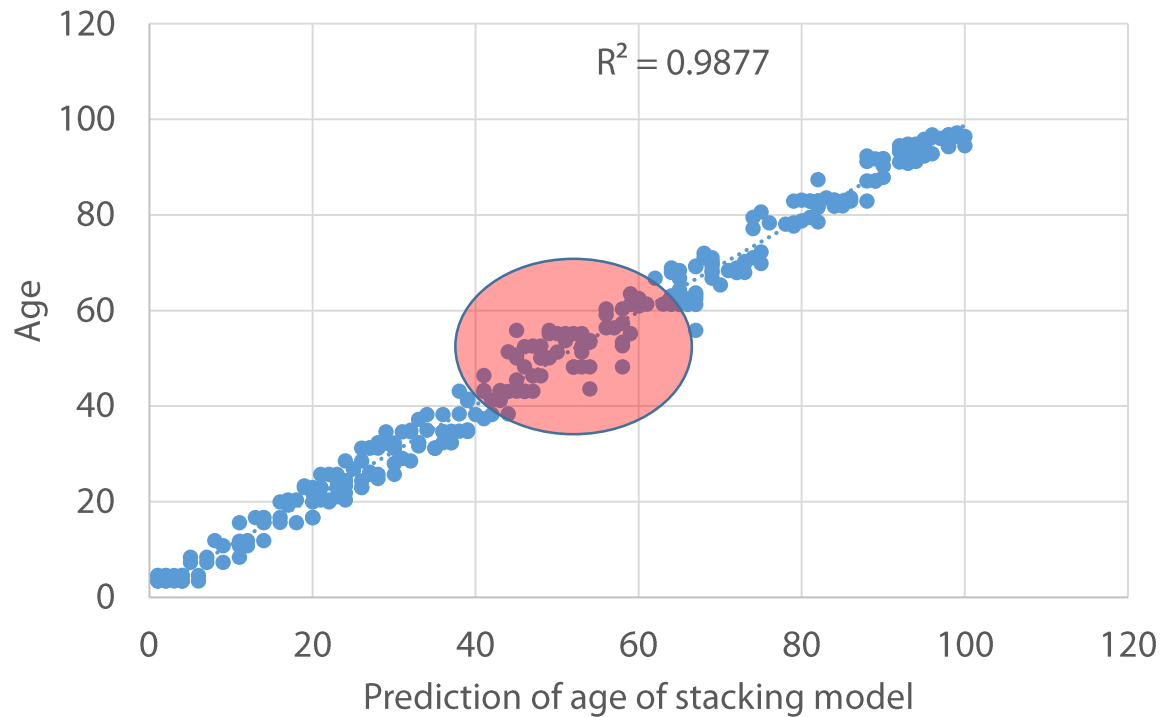
# Stacking (past) example



# Stacking (past) example



# Stacking (past) example



# 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

