

# DATA 301: Cross Validation and Hyperparameter tuning

# Topics

Model training overview

Bias variance

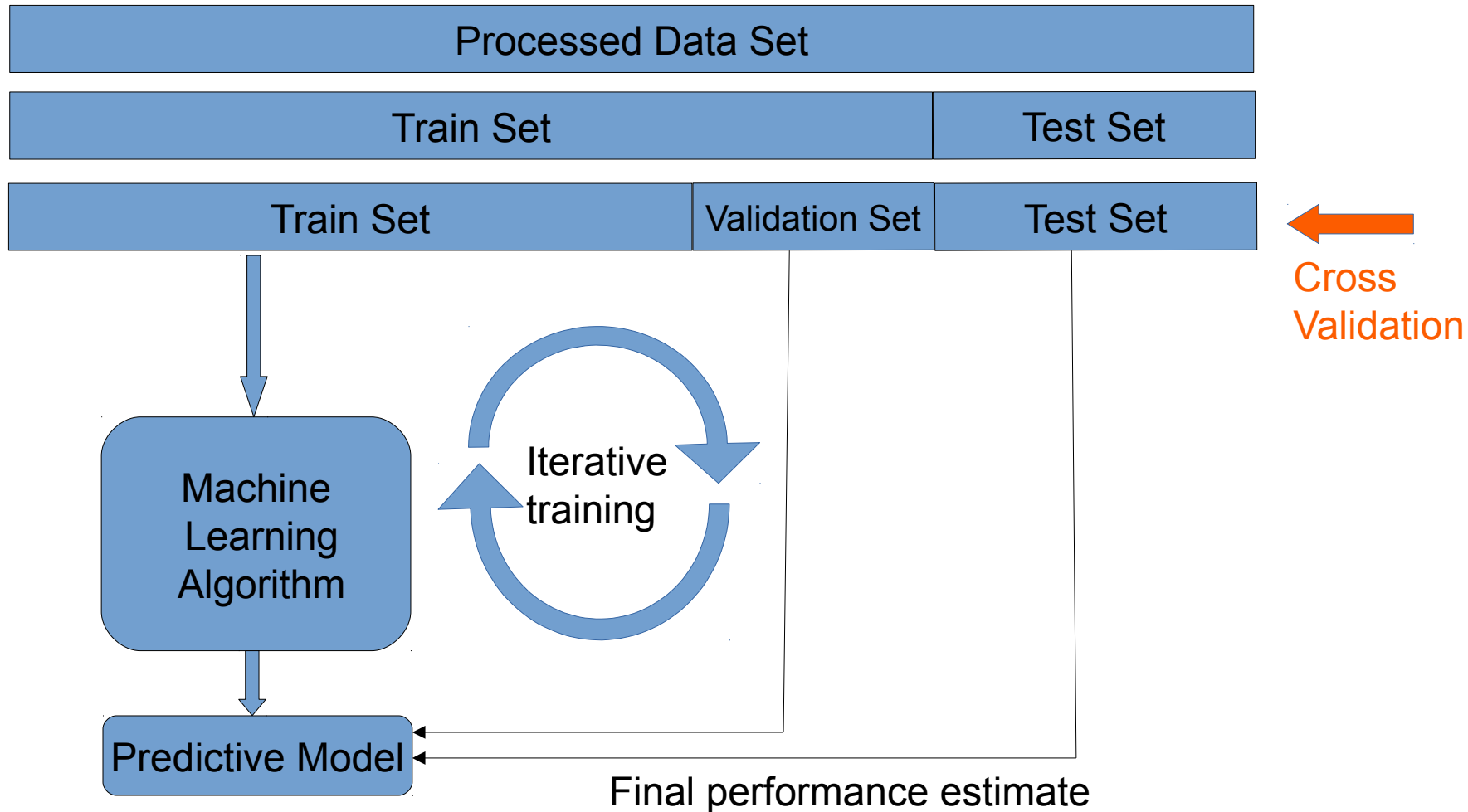
Under and overfitting

Getting a good fit for Trees

Cross Validation

Hyperparameter tuning using Optuna

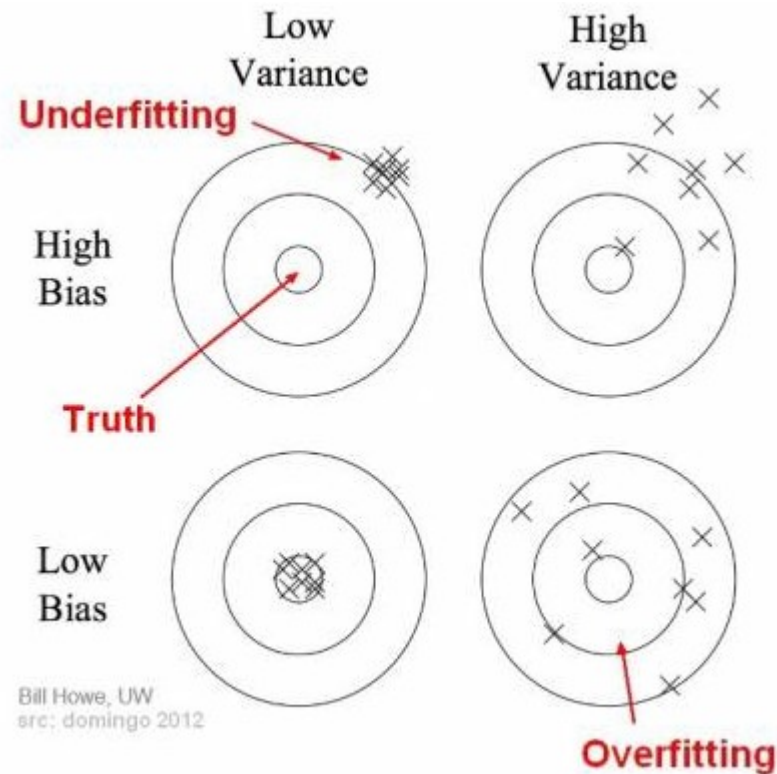
# Model training overview



# Bias/Variance – Supervised Learning

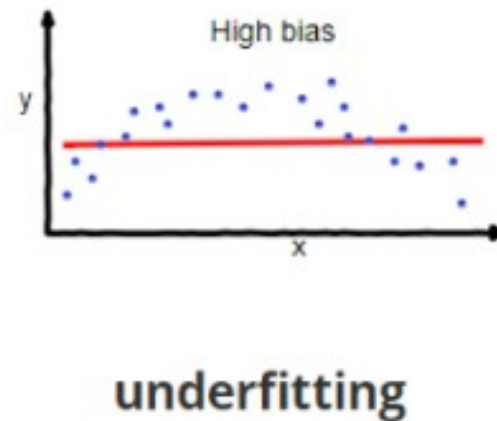
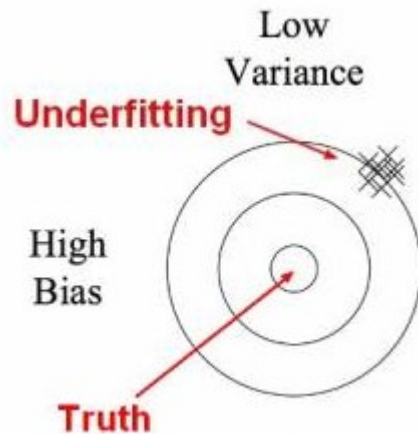
Bias - how close we are to being correct

Variance – how spread out our predictions are



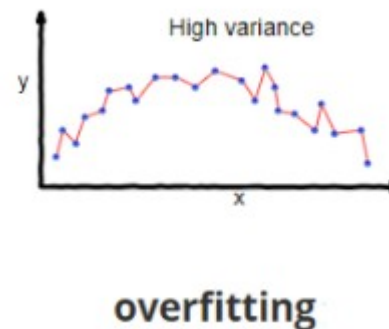
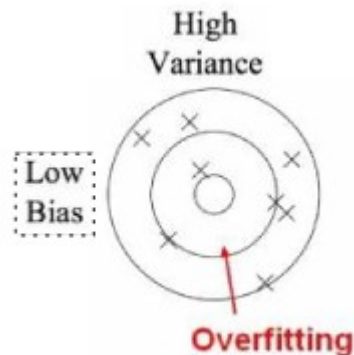
# Bias/Variance – Supervised Learning

**Underfitting:** a model is unable to capture the underlying pattern of the data. Usually have high bias and low variance. This happens if you don't have enough data to build an accurate model or you try to build a linear model with a nonlinear data.



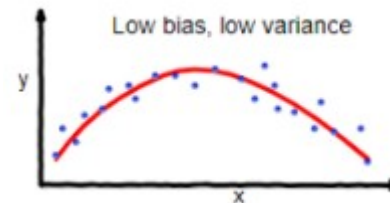
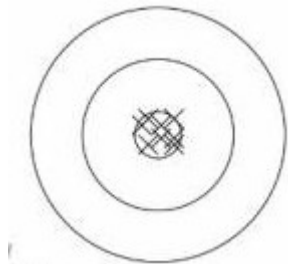
# Bias/Variance – Supervised Learning

**Overfitting:** a model captures the noise along with the underlying pattern in the data. Have low bias and high variance and tend to be overly complex. Neural networks and decision trees are prone to this. **This happens when you train a model too much or misconfigure hyperparameters (more coming on this). The end result is the model starts to memorize training data.**



# Bias/Variance – Supervised Learning

**Well fitted:** the model captures a function that describes the overall distribution of data. Or the model learns how a system behaves, and how it responds to given inputs. You can do more than predict with these systems BTW. You can also harness model knowledge to determine effects of varying an input.



# A tangent

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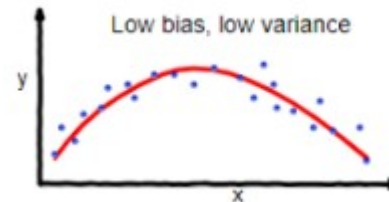
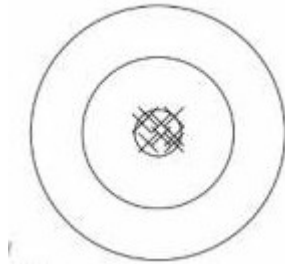
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We will return to this

# Bias/Variance – Supervised Learning

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How do you find this goldilocks model?

# Bias/Variance – Supervised Learning

**Bias Variance Tradeoff:** If model is too simple it may have high bias and low variance. On the other hand if model is too complex then it's going to have high variance and low bias.

We need to find the right/good balance without overfitting or underfitting the data.

How? By reducing the total error

$$\text{Total Error} = \text{Bias}^2 + \text{Variance} + \text{Irreducible Error}$$

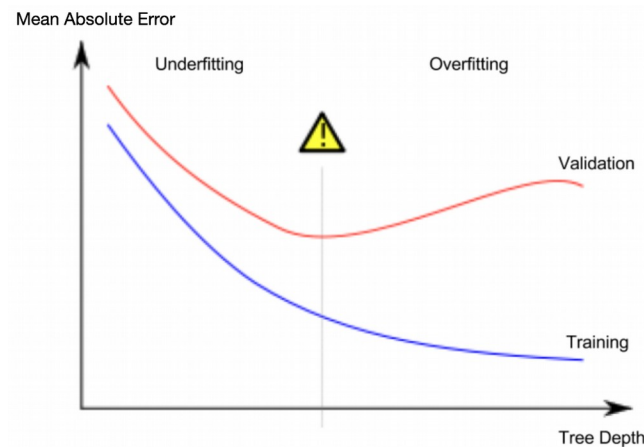
See wikipedia for derivation

Or, go to the next slide for a practical way

# Getting a good fit for Trees

To find a good model for trees, just find the tree hyperparameters that give **the lowest MAE on the Validation set**

(BTW this procedure is a bit more complex for neural networks)



What tree hyperparameters do you adjust?



# Which tree parameters to adjust

Decision trees over fit when they fit the training data too well and do not generalize to the validation data. They are too complex.

Tree complexity **is not** controlled by:

- `numb_trees` – you can have as many as you want

Tree complexity **is** controlled by:

- `max_depth`
- `min_sample_split`

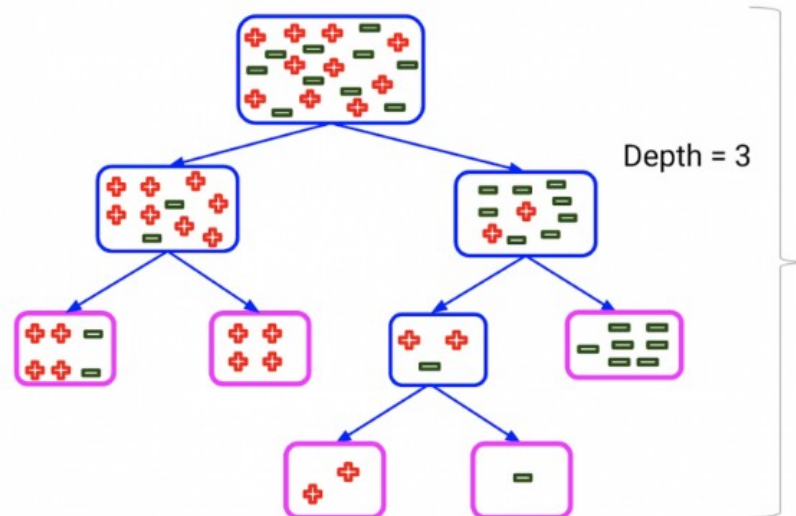
And several others (see scikitlearn's Tree documentation)

Also `model.get_params()`

# Hyperparameter explanation

**max\_depth** – how many levels in tree.

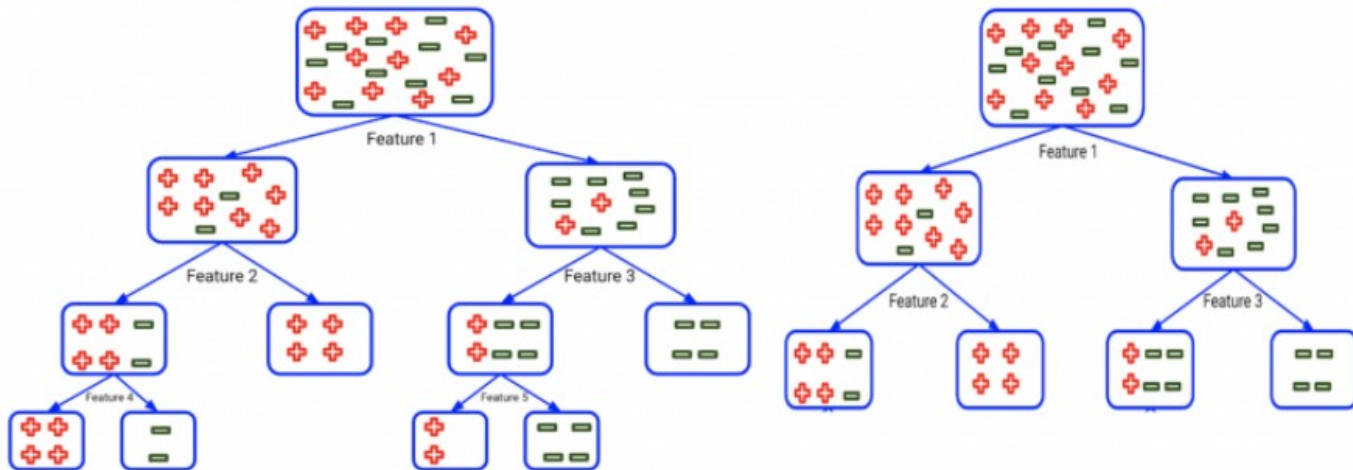
The more levels the more complex the tree. Eventually the tree will fit the training set perfectly, but will not generalize to the test set



# Hyperparameter explanation

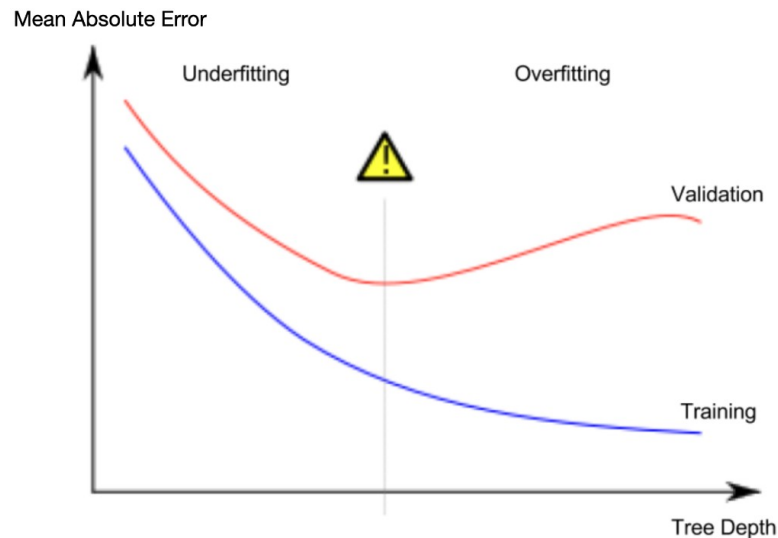
**min\_sample\_split** – the minimum required number of observations in any given node in order to split it. default=2.

This means that if any terminal node has more than two observations and is not pure, it can be split into subnodes. This has the effect that a tree keeps splitting until it gets mostly pure nodes, or impure nodes with just 2 members. Increasing this value reduces the number of splits and the tendency to overfit.



# Hyperparameter tuning

Sklearn has fine default hyperparameters for it's models  
You can **ALWAYS** adjust them to make your model fit your dataset better



Using something called cross validation and hyperparameter tuning

# Cross Validation

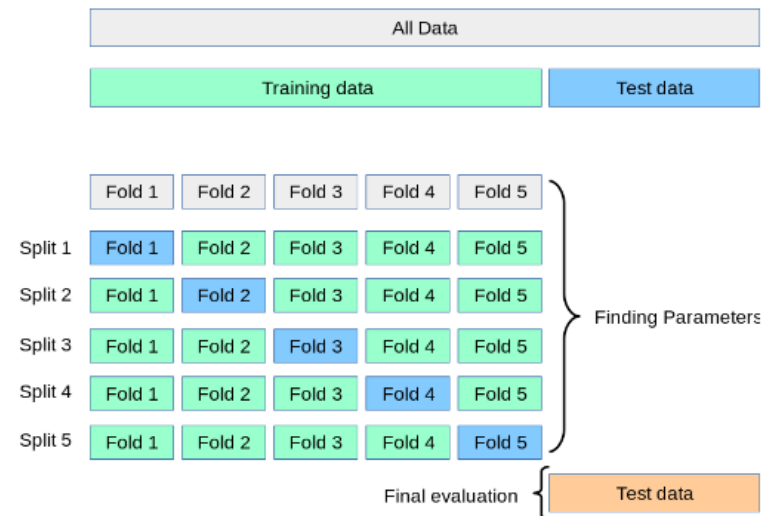
Divide data, into train and test sets, Use kfold cross validation on the train set

```
# Define the model
clf = sklearn.ensemble.RandomForestRegressor()

# get the cross validation score
numb_folds=5
mae=sklearn.model_selection.cross_val_score(clf, train_X, train_y, cv=numb_folds, scoring='neg_mean_absolute_error').mean()
print(f'The mean absolute error={mae}')
```

What does this do?

1. Divides train\_X into 5 equal chunks
2. trains 5 models, 1 for each split  
each model uses the blue fold  
for validation and all other  
green folds for training
3. When done, takes average of all  
5 models to give average mae.



Note: It just generates an estimate not a usable trained model

# Cross Validation

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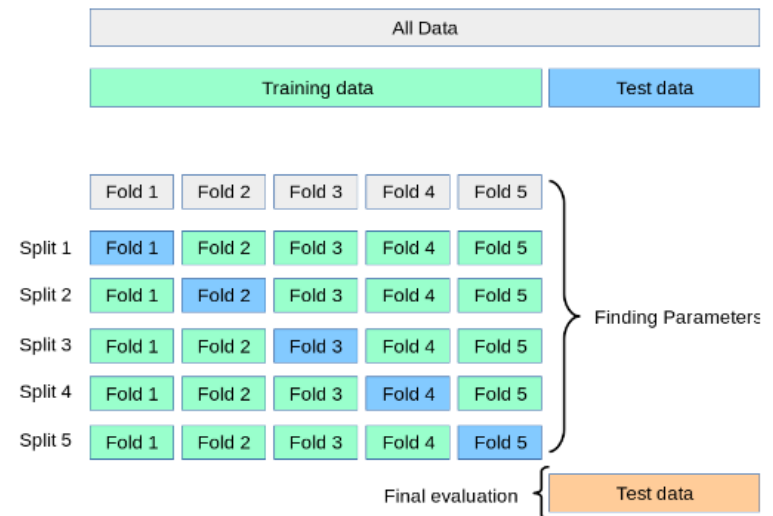
## Advantage:

Generates an estimate for models best performance

## Disadvantages:

Takes k times as long

Does not produce a model just an estimate



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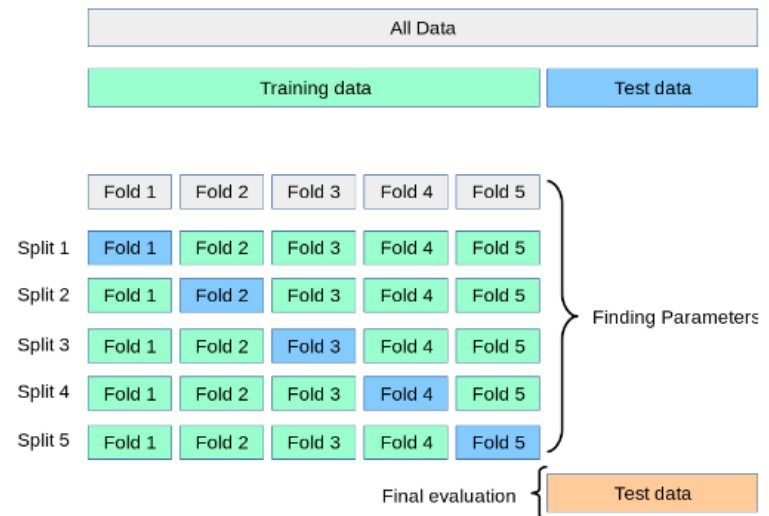
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## Why use it?

Because you can run cross validation in a loop with different hyperparameters, keeping track of scores.

When done, choose hyperparameter combination that returns the best score



# Finally, hyperparameter optimization

We will use Optuna.

It's fast, flexible and very efficient.

(Plus it's well respected and widely used by the cut throat data science competitors at Kaggle)

See notebook for code walk through.



# Summary

Bias variance, Under and overfitting

How to get a good fit: Train or adjust until validation score starts getting worse

Cross Validation : A way to use all your data for training to get a best case estimate for model performance given a set of hyperparameters

Hyperparameter tuning using Optuna: An efficient way to explore a hyperparameter space for the best combination of hyperparameters

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