Hands on Machine Learning Chapter 1 - The Machine Learning Landscape

Python Book Clubs, Cohort 1
Sam Bryce-Smith - 29-03-2021

Chapter 1 - The Machine Learning Landscape

- What is Machine Learning?

- Types of Machine Learning algorithms

- Typical challenges with Machine Learning

What is Machine Learning?

- *“[Machine Learning is the] field of study that gives computers the ability to learn without being explicitly programmed”*
    - *Arthur Samuel, 1959*

- (We) program computers to learn from data and perform complex tasks

What is Machine Learning?

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- E.g. **email spam filter**

✉️ ***Training instance/'sample'***
■ **Label - non-spam email**
■ **Label - spam email**

Training set

Spam emails flagged by users ✉️✉️✉️

Regular non-spam emails ✉️✉️✉️

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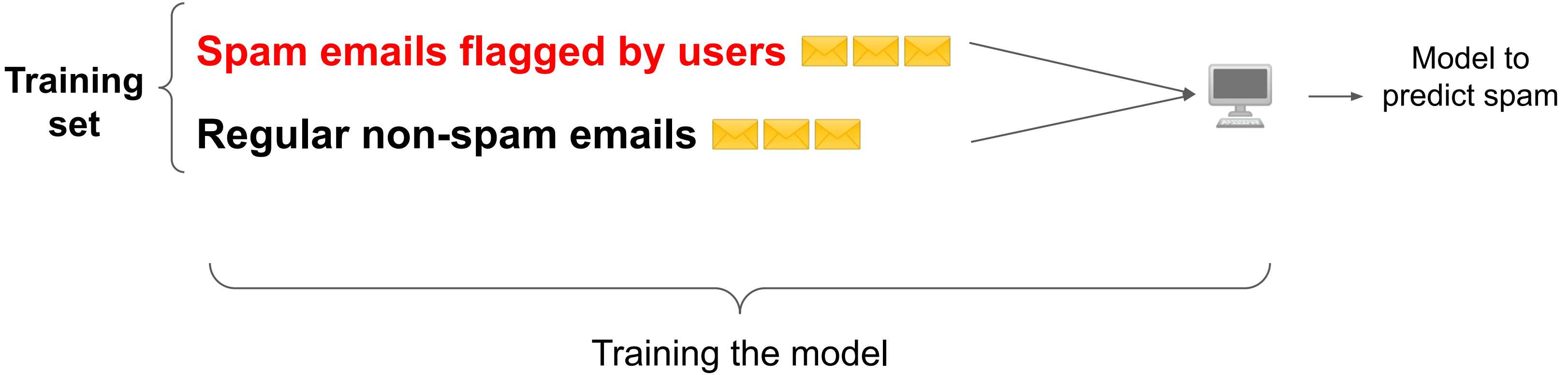

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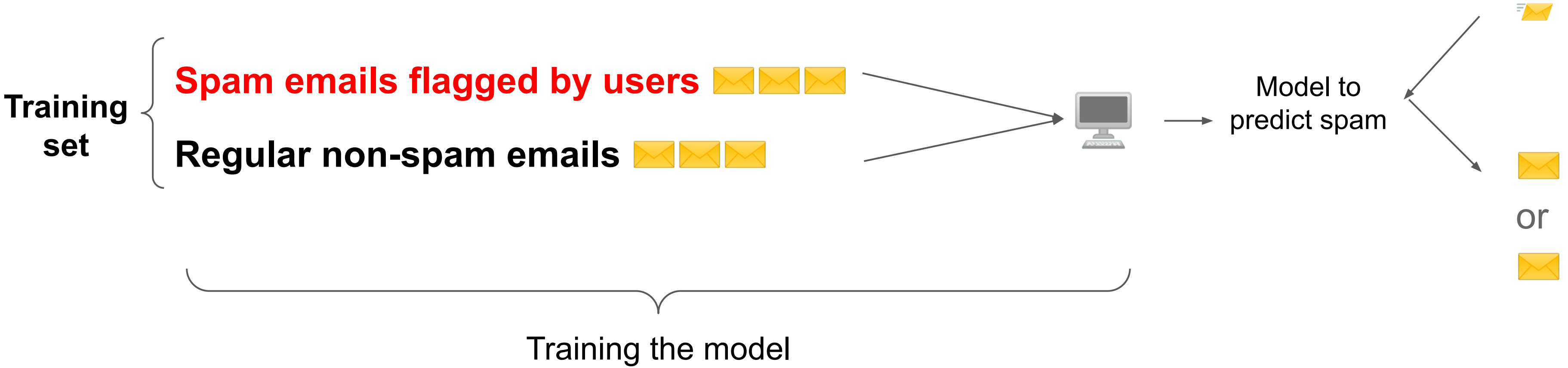


Why use machine learning?

- Can adapt to new data (e.g. spammers trying new tricks)

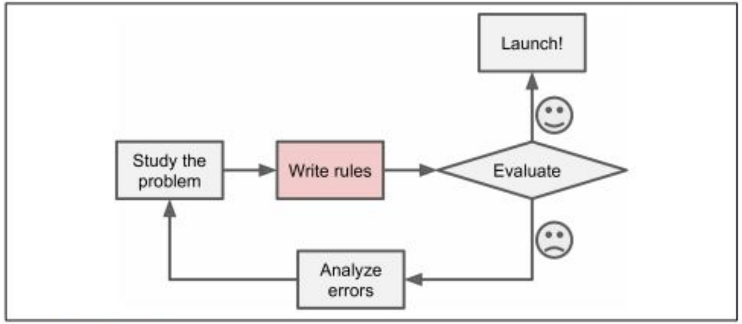


Figure 1-1. The traditional approach

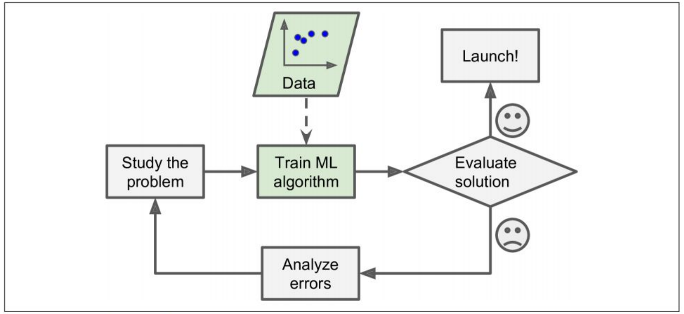
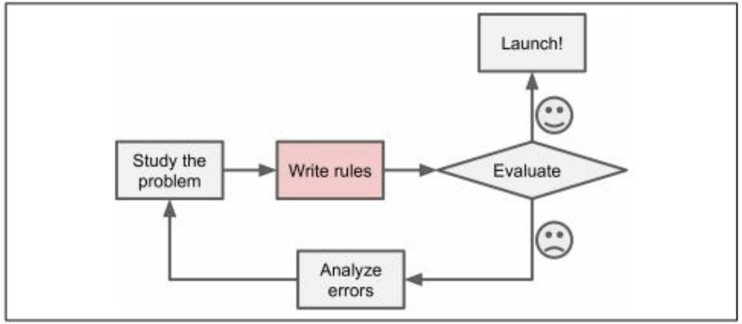


Figure 1-2. Machine Learning approach

Why use machine learning?

- Can adapt to new data (e.g. spammers trying new tricks)

- Find patterns in large datasets to help us learn (e.g. what words/phrases best predict a spam email?)



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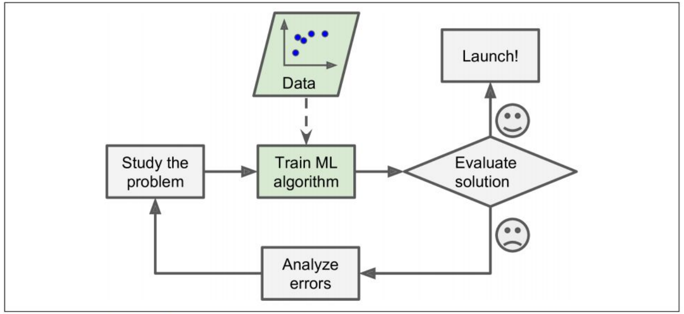

Figure 1-2. Machine Learning approach

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- **What is Machine Learning?**
  - **Make computers perform tasks by learning from data**
  - **Find underlying patterns in large datasets to**
    - **Simplify complex problems & adapt to changing data**
    - **Help us understand complex systems/problems**

- Types of Machine Learning algorithms

- Typical challenges with Machine Learning

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Types of Machine Learning Systems

- How training data is provided
  - Labelled with desired solutions
- How the system trains
  - All data in one go
  - On the fly/as the data becomes available
- How it generalises to new datasets
  - Compare new data points to known data points
  - Detect patterns in training data and build a predictive model

Supervised/Unsupervised - is data labelled or not?

Supervised learning

- Training data contains desired solutions (spam/not spam) - ***labels***
- Classification (is new email spam or not?)
- Regression (predict a *target* numeric value given features)

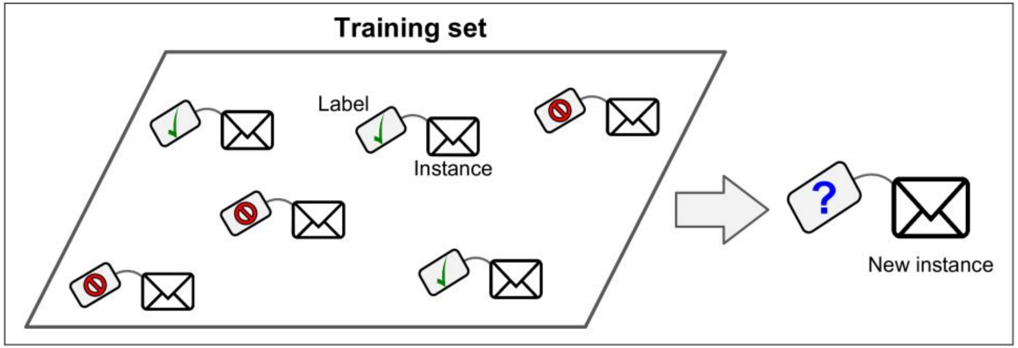

Figure 1-5. A labeled training set for supervised learning (e.g., spam classification)

Supervised/Unsupervised - is data labelled or not?

Unsupervised learning

- Training data does not contain desired solutions - ***unlabelled***
- Clustering (find groups of samples with similar features)
- Anomaly detection (which samples/instances look abnormal)

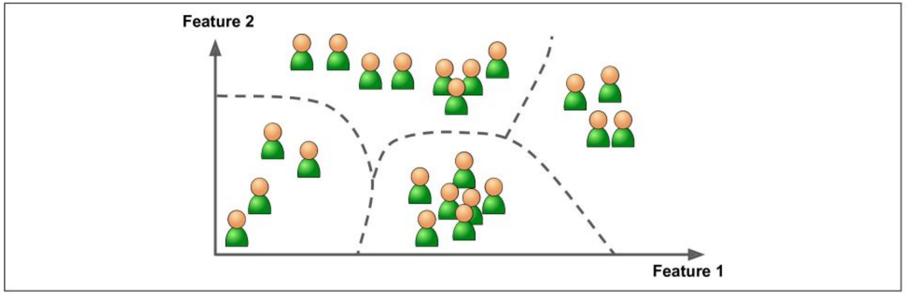

Figure 1-8. Clustering

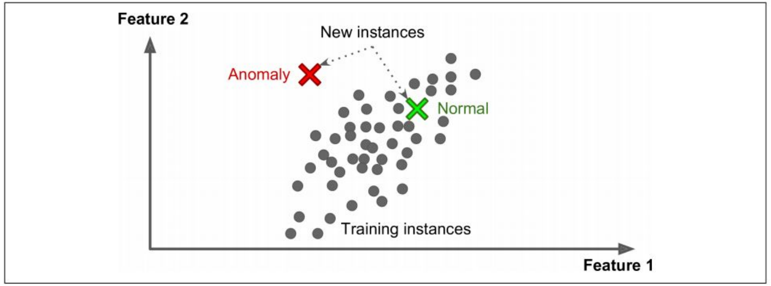

Figure 1-10. Anomaly detection

Supervised/Unsupervised - is data labelled or not?

Semi-supervised Learning

- Some instances in training data are labelled, some are not
- Combinations of supervised & unsupervised algorithms

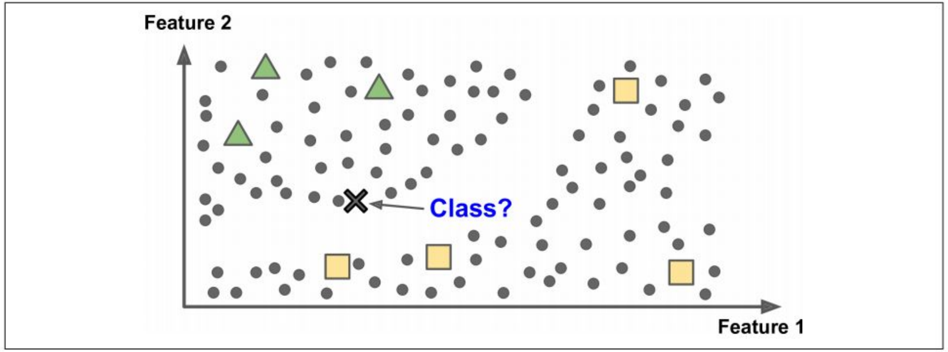

Figure 1-11. Semisupervised learning

Types of Machine Learning Systems

- **How training data is provided**
  - **Supervised - training data labelled with solutions you want**
  - **Unsupervised - training data is not labelled with solutions**

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Batch/Online Learning - learn continuously from flow of data or not?

Batch/offline learning

- Cannot learn instance by instance
- Train on all available data, then doesn’t learn from future incoming data

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Incremental/Online learning

- Can learn from data one/ a few instances at a time
- ***Learning rate*** controls how fast a system incorporates new data into its model

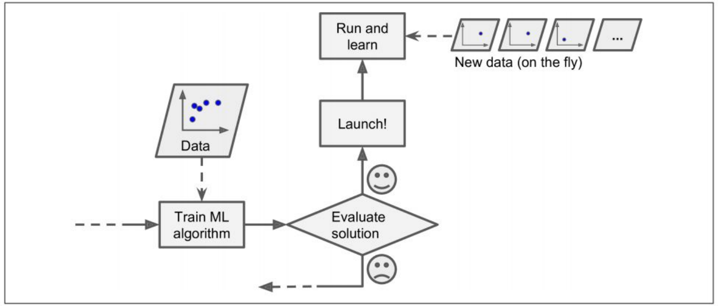

Figure 1-13. Online learning

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- **How the system trains**
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  - **Detect patterns in training data and build a predictive model**

Instance/Model based - compare to known points or build a predictive model?

Instance-based learning

- Learn by heart from training data
- Use a ***similarity measure*** to compare new data to known data points

Model-based learning

- Build a model of instances from training data
- Use model to make predictions on incoming new data

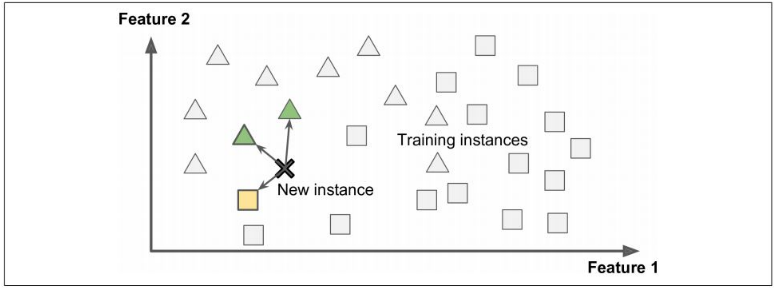

Figure 1-15. Instance-based learning

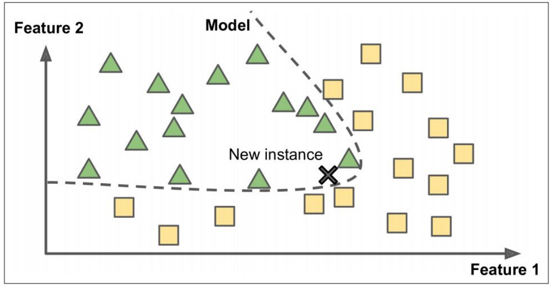

Figure 1-16. Model-based learning

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- **How it generalises to new datasets**
  - **Instance-based - compare new data points to known data points**
  - **Model-based - detect patterns in training data and build a predictive model**

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- Types of Machine Learning algorithms
  - Training data labelled or not labelled
  - Model learns from batch of data or on the fly
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- **Typical challenges with Machine Learning**
  - Bad / insufficient quality data
  - Bad / insufficient performing algorithms

Bad input - Insufficient quantity & quality of training data

Not enough training data

- ML algorithms tend to need at least 1000s of training instances
- Algorithm choice still important for small datasets

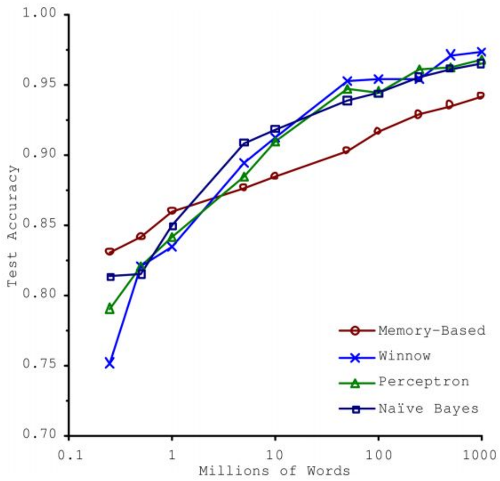

Figure 1-20. The importance of data versus algorithms[9]

Bad input - Insufficient quantity & quality of training data

Non-representative training data

- Can’t make accurate predictions if training data doesn’t reflect data want to generalise
- Sampling bias affects large samples sizes/training sets
  - I.e. flawed sampling methodology
- Sampling noise affects small sample sizes/training sets
  - I.e. Sample is unrepresentative due to random chance

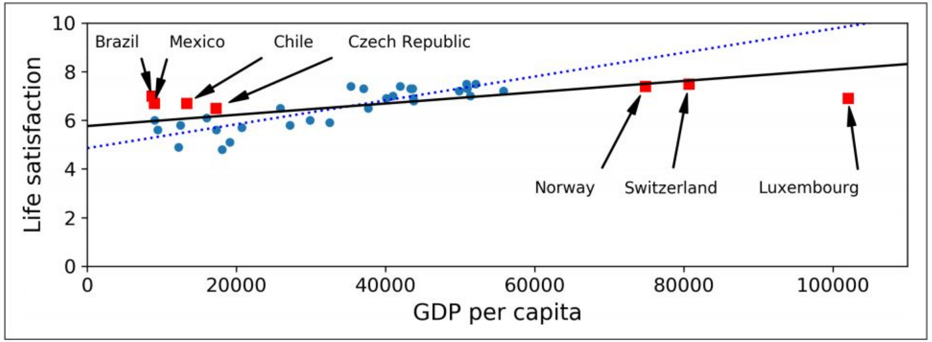

Figure 1-21. A more representative training sample

Bad input - Insufficient quantity & quality of training data

Outliers or noise in measurements

- Introduce unwanted variation - harder to detect underlying patterns in data
- Clear outliers should be removed

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Missing values for some instances in training data

- Remove instances with missing values
- Fill in missing values (e.g. with median of training set)
- Train a model with feature containing missing values & one without

- (Hopefully these decisions will be discussed later in book)

Bad input - Insufficient quantity & quality of training data

Providing irrelevant features for the model to train on

- A model is only as good as the training data/features it is provided

- ***Feature engineering*** - finding good quality features to train your model on
    - *Feature selection* - pick out most useful features among features to train on
    - *Feature extraction* - creating new features from existing features
    - Gather more data & create new features

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    - Not enough training data
    - Outliers, missing features in training data
    - Irrelevant features (don’t help to find underlying patterns in data)
    - **Bad / insufficiently performing algorithms**

Bad ‘model behaviour’ - Overfitting training data

- Model fits the training data (too) well but does not generalise to new data
- ***“Overfitting happens when the model is too complex relative to the amount & robustness of the training data”***

- ***Regularisation*** - constrain/limit values of a parameter in model
    - **Hyperparameter** - how much algorithm applies regularisation when training

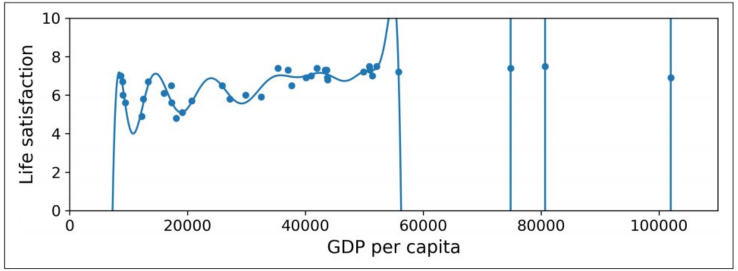

Figure 1-22. Overfitting the training data

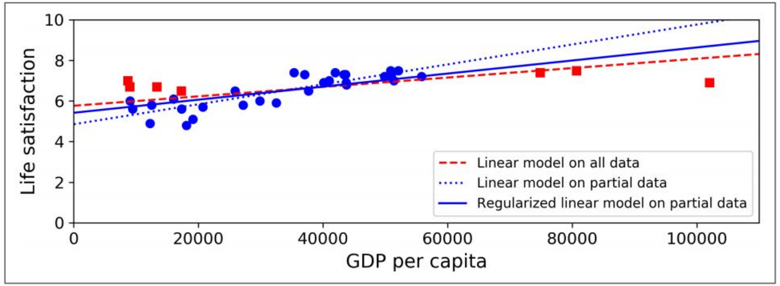

Figure 1-23. Regularization reduces the risk of overfitting

Bad ‘model behaviour’ - Underfitting training data

- Model too simple to identify underlying patterns in the data
  - Pick a more complex model (more parameters)
  - Find better features for the model (feature engineering)
  - Reduce the regularisation hyperparameter (more flexibility in values a parameter can take)

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- How to evaluate performance of a model?

Splitting your input data into training and test sets aids evaluation before using model on new data

Evaluating performance before running new data through model

- Split input data into *training* and *test* sets
  - *Training error* - error rate on cases in training set
  - *Generalisation error* - error rate on ‘new’ cases in test set

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Evaluating performance before running new data through model

- Split input data into *training* and *test* sets
  - *Training error -* error rate on cases in training set
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Choosing between different models (and hyperparameter values)

- ***Holdout validation*** - set aside part of training data for evaluation (*validation set, dev set)*
  - Train all potential models on reduced training data
  - Select model that performs best on validation set

Splitting your input data into training and test sets aids evaluation before using model on new data

Repetition is key

- One split = have adapted model for one particular training & test set

- ***Cross-validation*** *-* repeat training & testing with multiple validation sets
  - Pick model with best average performance

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- **Typical challenges with Machine Learning**
  - Not enough and/or poor quality training data
  - Overfitting training data - (poor predictions on new data)
  - Underfitting training data - (poor predictions of both training & new data)
  - Not enough training data
  - Outliers, missing features in training data
  - Irrelevant features (don’t help to find underlying patterns in data)

The typical workflow of a ML project (Chapter 2 👀)

1. **Gather training data for your task of choice & select an algorithm**

2. **Train & evaluate algorithm on training data**

3. **Apply model to new data (to make inferences)**

- Thoughts on chapter?
- How to split workload for next few sessions?