Lecture 14
Artificial Intelligence

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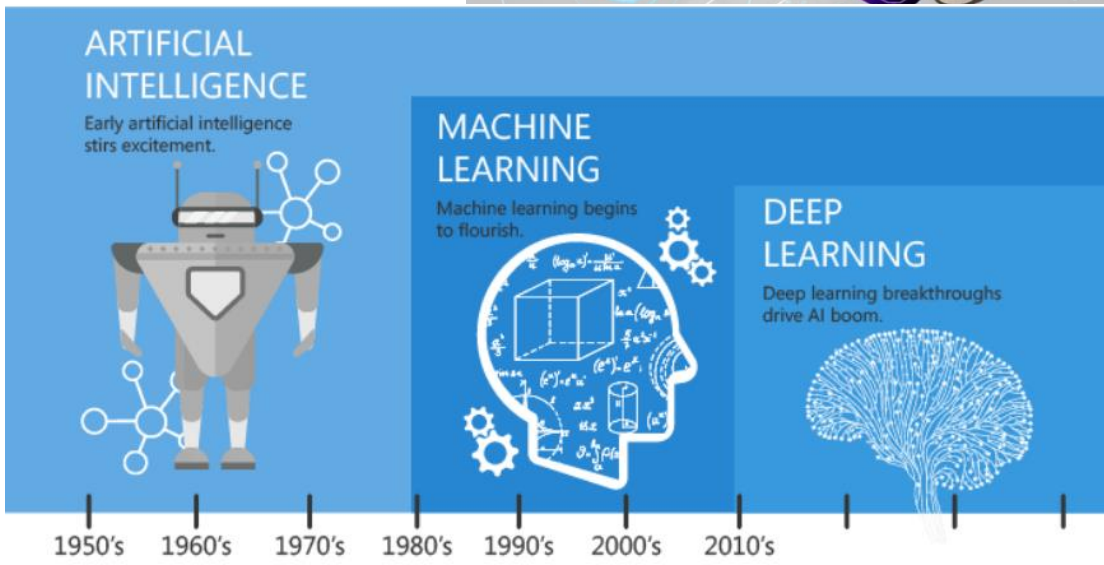
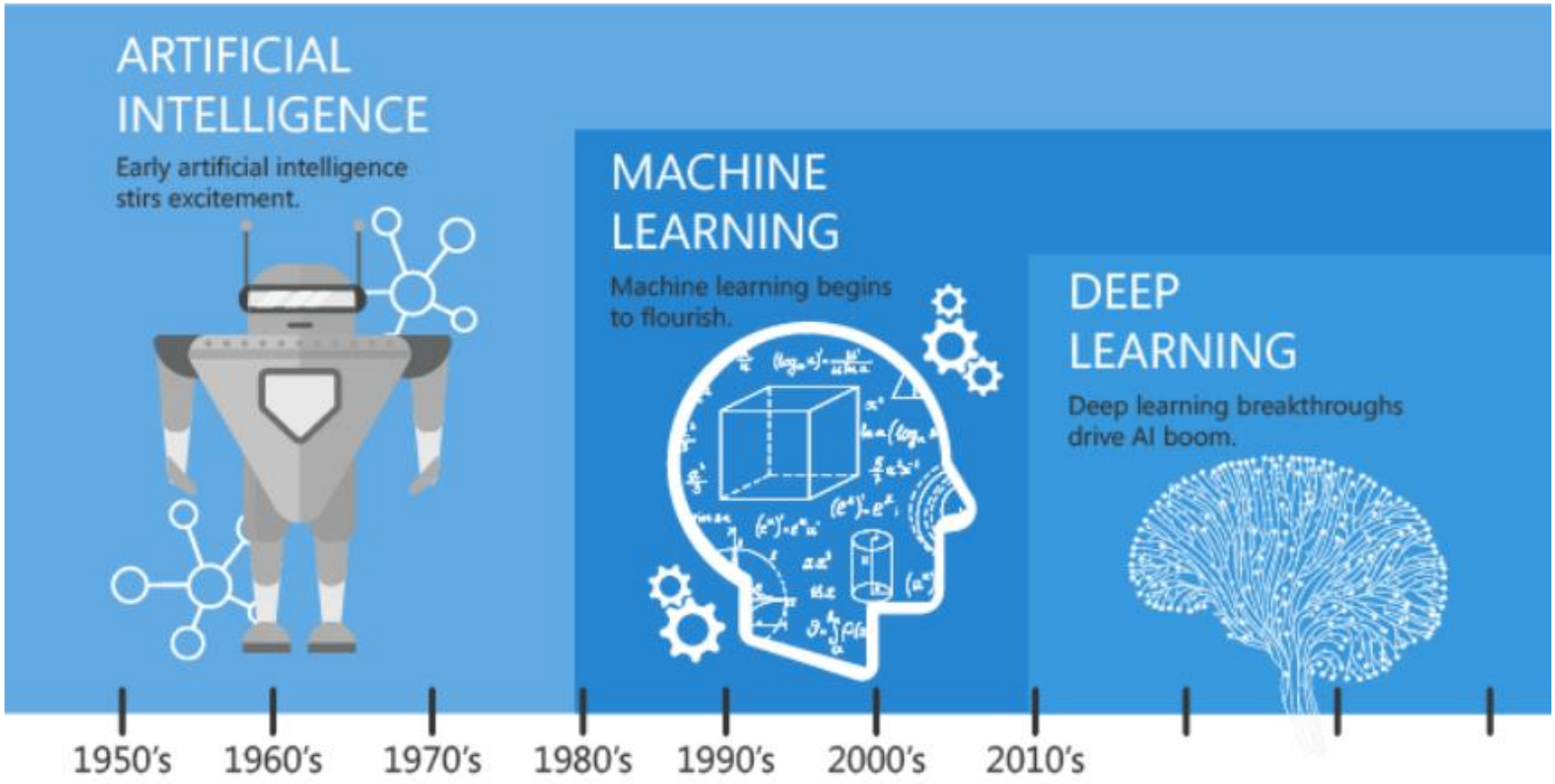


Introduction of machine learning

- Machine learning



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Introduction of machine learning

- Machine learning is a subfield of artificial intelligence (AI).
- Arthur Samuel, coined the term “Machine Learning ”
- He defined machine learning as
  - “the field of study that gives computers the ability to learn without being explicitly programmed “.
- However, there is no universally accepted definition for machine learning.
- given below another definition.
  - The field of study known as machine learning is concerned with the question of how to construct computer programs that automatically improve with experience.

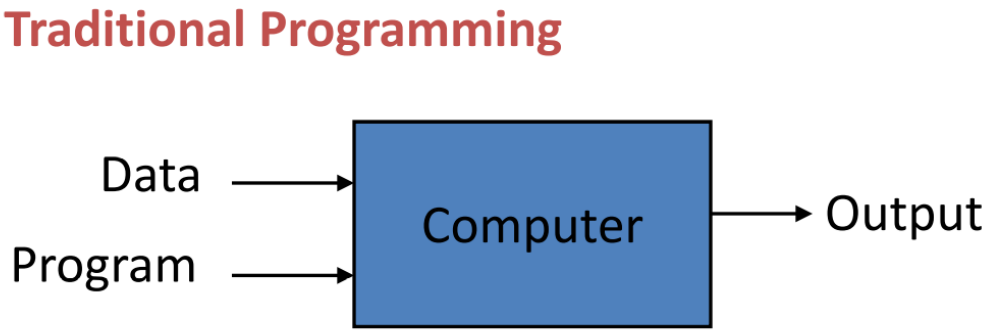
Introduction of machine learning

- A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P , if its performance at tasks T, as measured by P , improves with experience E.
- A well-defined learning task is given by .

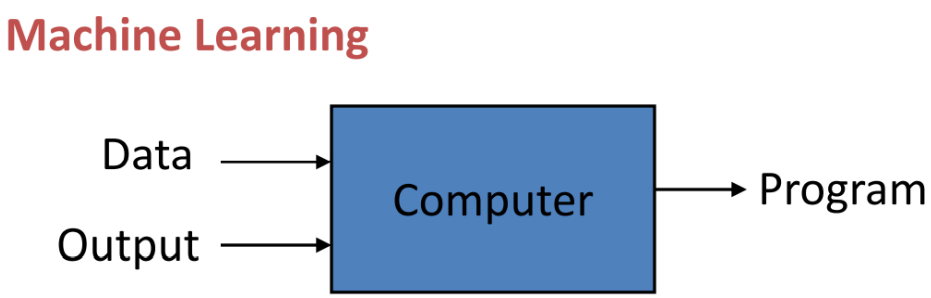
$$<P, T, E>.$$

Introduction of machine learning

- Traditional learning



- Machine learning



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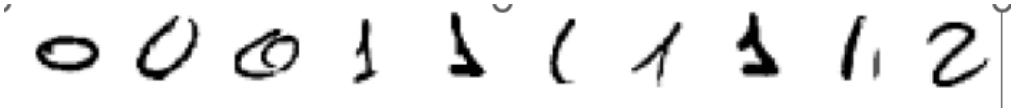
Introduction of machine learning

- Definition of learning:
  - A computer program is said to learn from experience **E** with respect to some class of tasks **T** and performance measure **P** , if its performance at tasks T, as measured by P , improves with experience E.
- **Example:**



- Handwriting recognition learning problem
  - Task T : Recognizing and classifying handwritten words within images
  - Performance P : Percent of words correctly classified
  - Training experience E : A dataset of handwritten words with given classifications

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Introduction of machine learning

- A robot driving learning problem
  - Task T : Driving on highways using vision sensors
  - Performance P : Average distance traveled before an error
  - Training experience E : A sequence of images and steering commands recorded while observing a human driver
- Email Spam Filter:
  - T: Categorize email messages as spam or legitimate
  - P: Percentage of email messages correctly classified
  - E: Database of emails, some with human-given labels

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When Do We Use Machine Learning?

- ML is used when:
  - Human expertise does not exist (navigating on Mars)
  - (speech recognition)
  - Models must be customized (personalized medicine)



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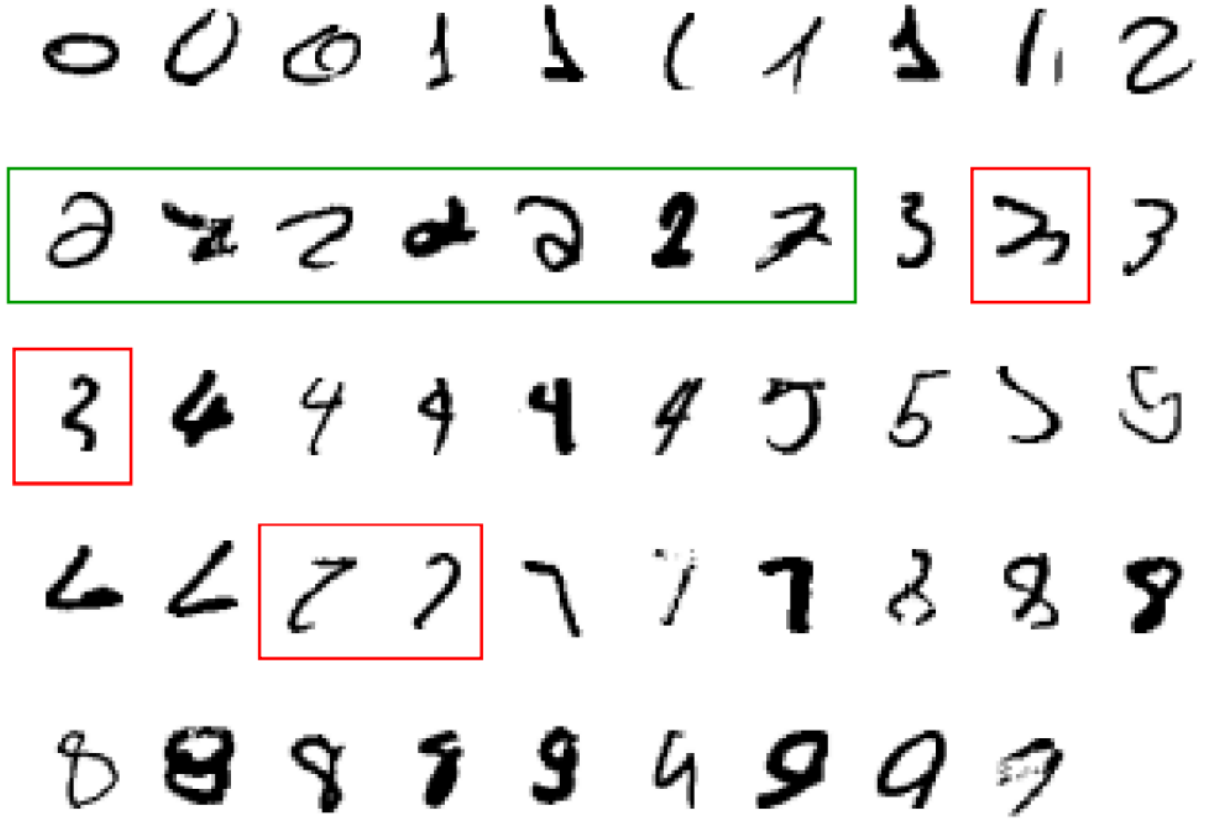
When Do We Use Machine Learning?

- A classic example of a task that requires machine learning: It is very hard to say what makes a 2



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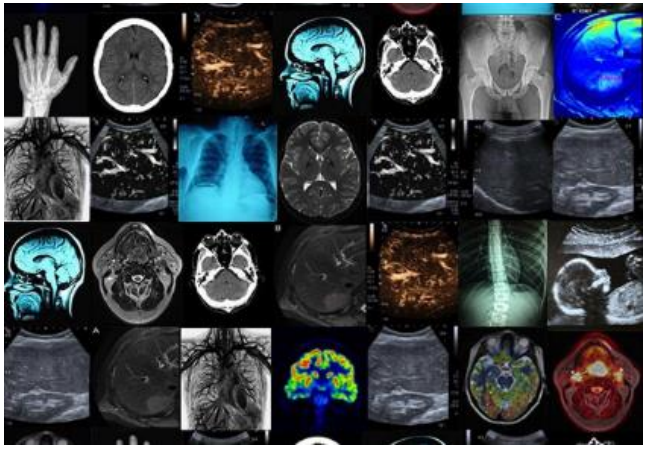
When Do We Use Machine Learning?

- Recognizing patterns:
  - Facial identities or facial expressions
  - Handwritten or spoken words
  - Medical images



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When Do We Use Machine Learning?

- Generating patterns:
  - Generating images
- Recognizing anomalies:
  - Unusual credit card transactions
  - Unusual patterns of sensor readings in a nuclear power plant
  - Detecting anomalies (frauds)
- Prediction:
  - Future stock prices or currency exchange rates
  - Decision Making (AI, Robotics)

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When Do We Use Machine Learning?

- **Sample Application:**
  - Web search
  - Computational biology
  - Finance
  - E-commerce
  - Space exploration
  - Robotics
  - Information extraction
  - Social networks
  - Ranking (Google search, author ranking)
  - Summarization (Social media sentiment)

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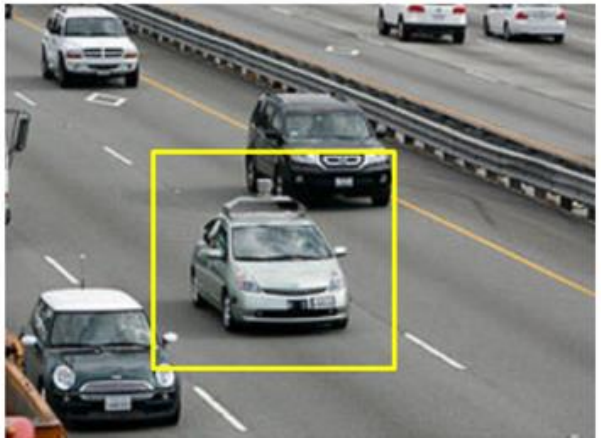
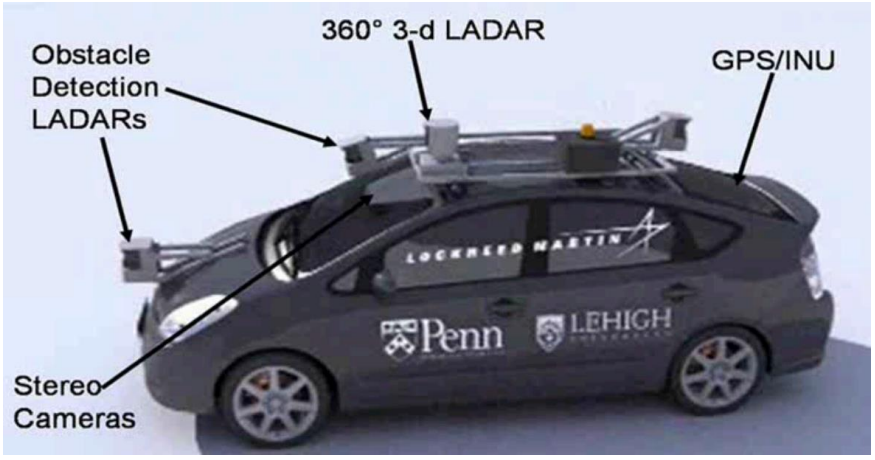
When Do We Use Machine Learning?

- Autonomous Cars





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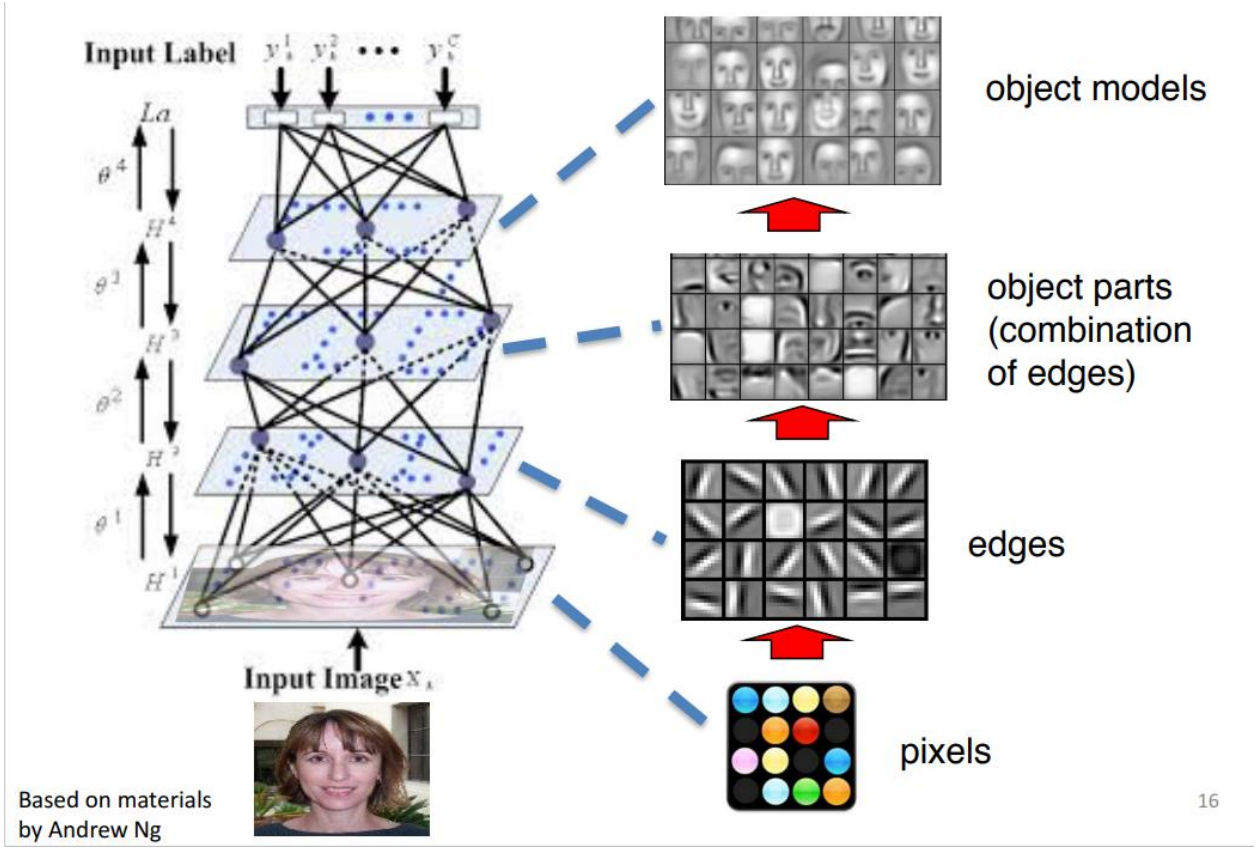
State of the art

- Deep Learning
- Deep Belief Net on Face Images



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Machine learning

Types of learning

- Machine learning implementations are classified into four major categories, depending on the nature of the learning

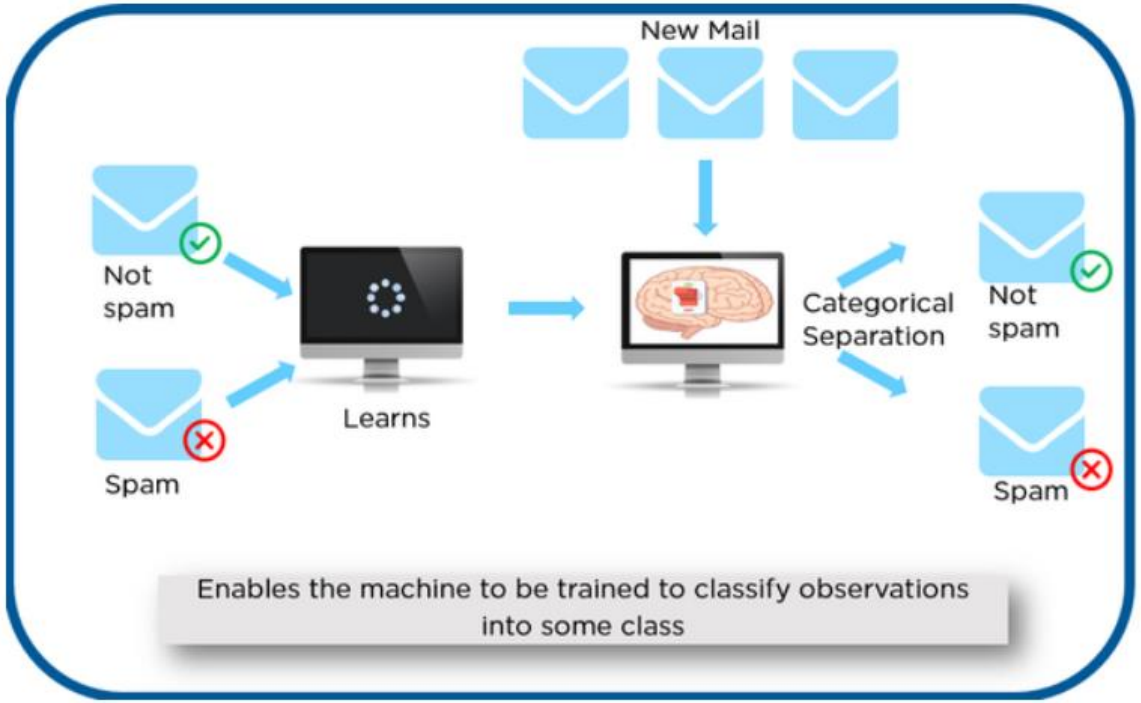
1. Supervised learning
2. Unsupervised learning
3. Reinforcement learning
4. Semi-supervised learning

Machine learning

- Supervised learning:
- Supervised learning is the machine learning task of learning a function that maps an input to an output based on example input-output pairs.
- The given data is labeled
- Both *classification* and *regression* problems are supervised learning problems
  - Example — Consider the following data regarding patients entering a clinic . The data consists of the gender and age of the patients and each patient is labeled as “healthy” or “sick”.

Machine learning

- Supervised learning:
- Example
- Spam Filter



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Machine learning

- Supervised learning:
- Example
- Consider the following data regarding patients entering a clinic The data consists of the gender and age of the patients and each patient is labeled as “healthy” or “sick”.

gender	age	label
M	48	sick
M	67	sick
F	53	healthy
M	49	sick
F	32	healthy
M	34	healthy
M	21	healthy

Credit: Khola Naseem

Machine learning

- Unsupervised learning:
  - Unsupervised learning is a type of machine learning algorithm used to draw inferences from datasets consisting of input data without labeled responses.
  - In unsupervised learning algorithms, classification or categorization is not included in the observations.
  - Consider the following data regarding patients entering a clinic. The data consists of the gender and age of the patients.

gender	age
M	48
M	67
F	53
M	49
F	34
M	21

Credit: Khola Naseem

Machine learning

- Unsupervised learning:
  - As a kind of learning, it resembles the methods humans use to figure out that certain objects or events are from the same class, such as by observing the degree of similarity between objects.
  - Some recommendation systems that you find on the web in the form of marketing automation are based on this type of learning.

Machine learning

- Reinforcement Learning:
- Reinforcement learning is the problem of getting an agent to act in the world so as to maximize its rewards.
- A learner is not told what actions to take as in most forms of machine learning but instead must discover which actions yield the most reward by trying them.
- For example:
  - Consider teaching a dog a new trick: we cannot tell it what tell it to do what to do, but we can reward/punish it if it does the right/wrong thing.

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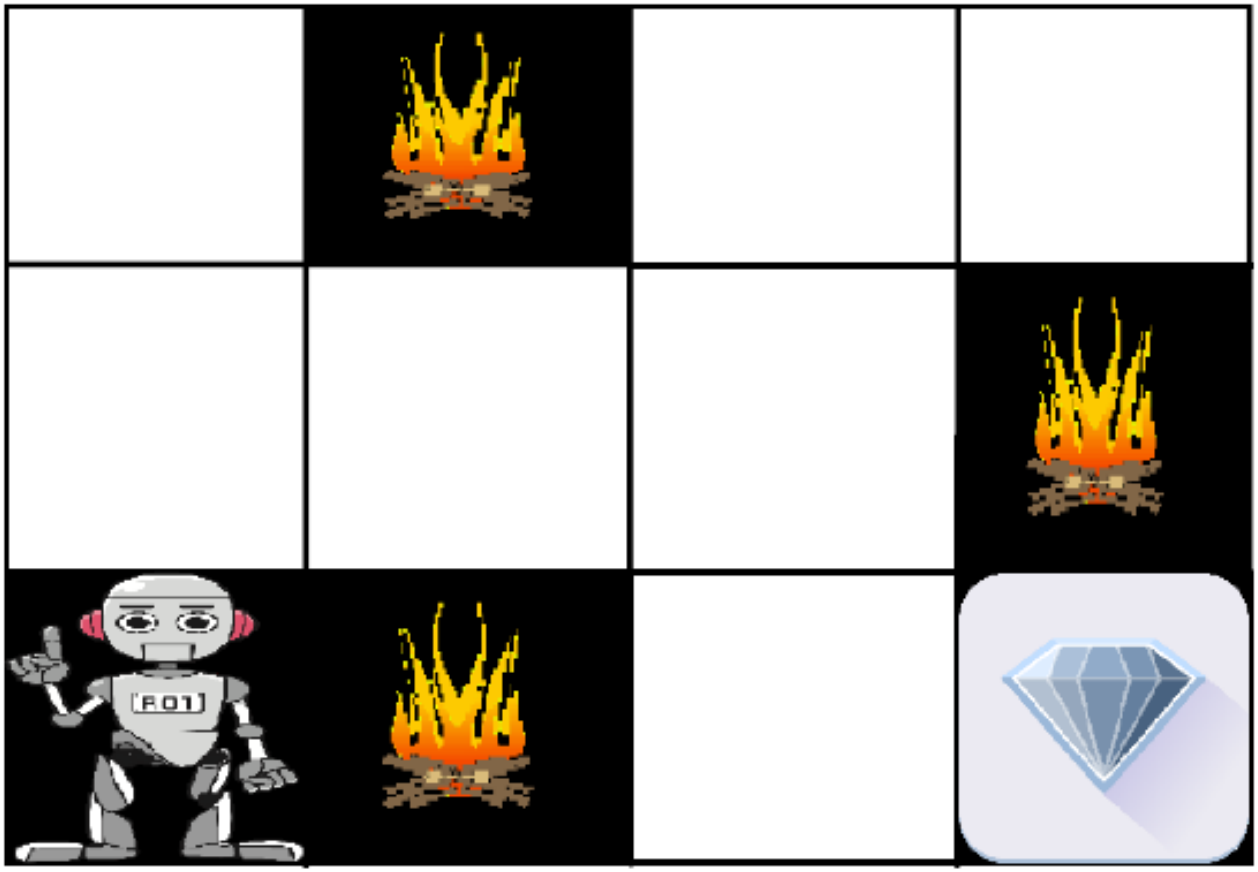
Machine learning

- Reinforcement Learning:



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Machine learning

- Sami-Supervised Learning:
  - Training set with some (often many) of the target outputs missing.
  - Semi-supervised learning is an approach to machine learning that combines small labeled data with a large amount of unlabeled data during training.
  - Semi-supervised learning falls between unsupervised learning and supervised learning.

Credit: Khola Naseem

Supervised Machine learning

Credit: Khola Naseem

Supervised Machine learning

- An example application
  - An emergency room in a hospital measures 17 variables (e.g., blood pressure, age, etc) of newly admitted patients.
  - A decision is needed: whether to put a new patient in an intensive-care unit.
  - Due to the high cost of ICU, those patients who may survive less than a month are given higher priority.
  - Problem: to predict high-risk patients and discriminate them from low-risk patients.

Credit: Khola Naseem

Supervised Machine learning

- An example application
  - A credit card company receives thousands of applications for new cards. Each application contains information about an applicant,
    - age
    - Marital status
    - annual salary
    - outstanding debts
    - credit rating , etc.
  - Problem: to decide whether an application should approved, or to classify applications into two categories, approved and not approved.

Credit: Khola Naseem

Supervised Machine learning

- Like human learning from past experiences.
- A computer does not have “experiences”.
- A computer system learns from data, which represent some “past experiences” of an application domain.
- Our focus: learn a target function that can be used to predict the values of a discrete class attribute, e.g., approve or not-approved, and high-risk or low risk.
- The task is commonly called: Supervised learning, classification, or inductive learning.

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The data and the goal

- Data: A set of data records (also called examples, instances or cases) described by
  - k attributes: A1, A2, … Ak.
  - a class: Each example is labelled with a pre-defined class.
- Goal: To learn a classification model from the data that can be used to predict the classes of new (future, or test) cases/instances.

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The data and the goal

- Data:

Approved or not

ID	Age	Has_Job	Own_House	Credit_Rating	Class
1	young	false	false	fair	**No**
2	young	false	false	good	**No**
3	young	true	false	good	**Yes**
4	young	true	true	fair	**Yes**
5	young	false	false	fair	**No**
6	middle	false	false	fair	**No**
7	middle	false	false	good	**No**
8	middle	true	true	good	**Yes**
9	middle	false	true	excellent	**Yes**
10	middle	false	true	excellent	**Yes**
11	old	false	true	excellent	**Yes**
12	old	false	true	good	**Yes**
13	old	true	false	good	**Yes**
14	old	true	false	excellent	**Yes**
15	old	false	false	fair	**No**

Credit: Khola Naseem

The data and the goal

- Learn a classification model from the data
- Use the model to classify future loan applications into
  - Yes (approved) and
  - No (not approved)
- What is the class for following case/instance?

Age	Has_Job	Own_house	Credit-Rating	Class
young	false	false	good	?

Credit: Khola Naseem

The data and the goal

- Learn a classification model from the data
- What is the class for following case/instance?

Age	Has_Job	Own_house	Credit-Rating	Class
young	false	false	good	?

- No learning: classify all future applications (test data) to the majority class (i.e., Yes):

  Accuracy = 9/15 = 60%.

- We can do better than 60% with learning.

Credit: Khola Naseem

Supervised machine learning:

- Data:
- Data: labeled instances <xi, y>, e.g. emails marked spam/not spam
  - Training Set
  - Held-out Set/validation set
  - Test Set
- Features: attribute-value pairs which characterize each x
- Learn parameters (e.g. model probabilities) on training set (Tune hyper-parameters on held-out set)
- Compute accuracy of test set
- Very important: never "peek" at the test set!

Credit: Khola Naseem

Fundamental assumption of learning:

- Data:
- Assumption: The distribution of training examples is identical to the distribution of test examples (including future unseen examples).
- In practice, this assumption is often violated to certain degree.
- Strong violations will clearly result in poor classification accuracy.
- To achieve good accuracy on the test data, training examples must be sufficiently representative of the test data.

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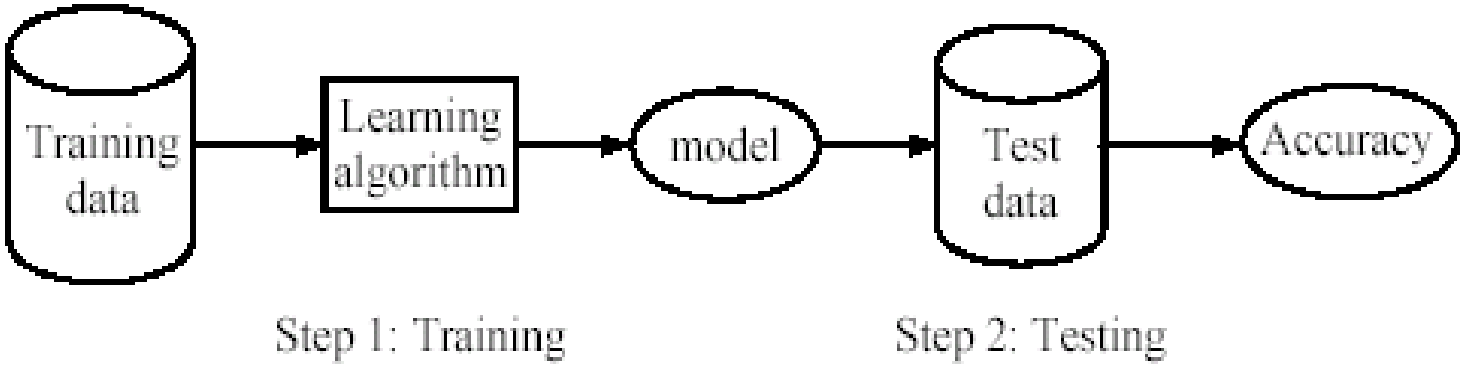
Supervised machine learning:

- Two steps:
  - Learning (training): Learn a model using the training data
  - Testing: Test the model using unseen test data to assess the model accuracy

$$Accuracy = \frac{\text{Number of correct classifications}}{\text{Total number of test cases}},$$



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Supervised machine learning:

- Like all machine learning algorithms, supervised learning is based on training.
- During its training phase, the system is fed with labeled data sets, which instruct the system what output is related to each specific input value.
- The trained model is then presented with test data: This is data that has been labeled, but the labels have not been revealed to the algorithm.
- The aim of the testing data is to measure how accurately the algorithm will perform on unlabeled data.

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Supervised machine learning:

- Supervised learning:

Given a **training set** of N example input–output pairs

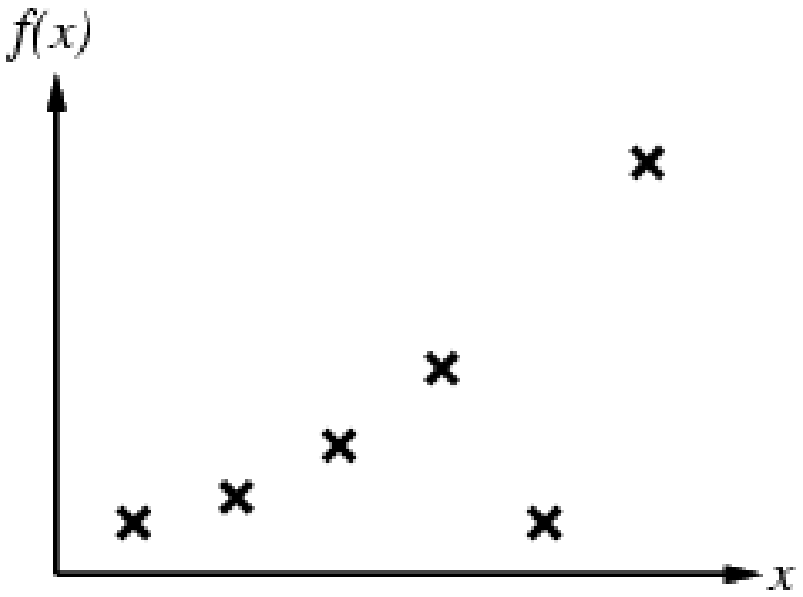
$$(x_1, y_1), (x_2, y_2), \ldots (x_N, y_N) \ ,$$

where each y_j was generated by an unknown function $y = f(x)$,

- Here x and y can be any value; they need not be numbers.
- The function is a hypothesis.
- Learning is a search through the space of possible function for one that will perform well, even on new examples beyond the training set

Supervised machine learning:

- Inductive learning method:
- Construct/adjust h to agree with f on training set
- (h is consistent if it agrees with f on all examples)
- E.g., curve fitting:



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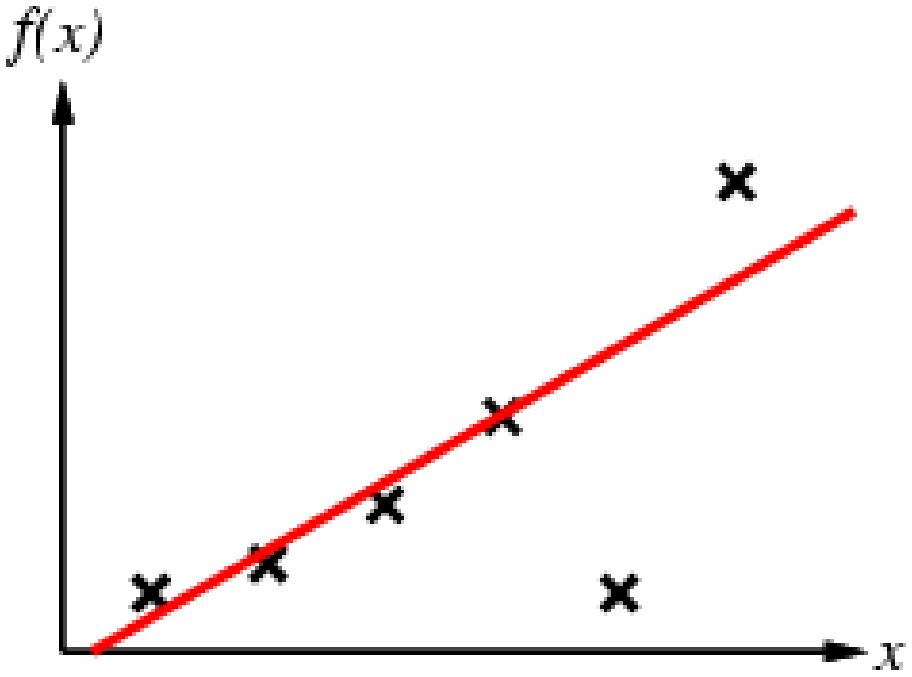

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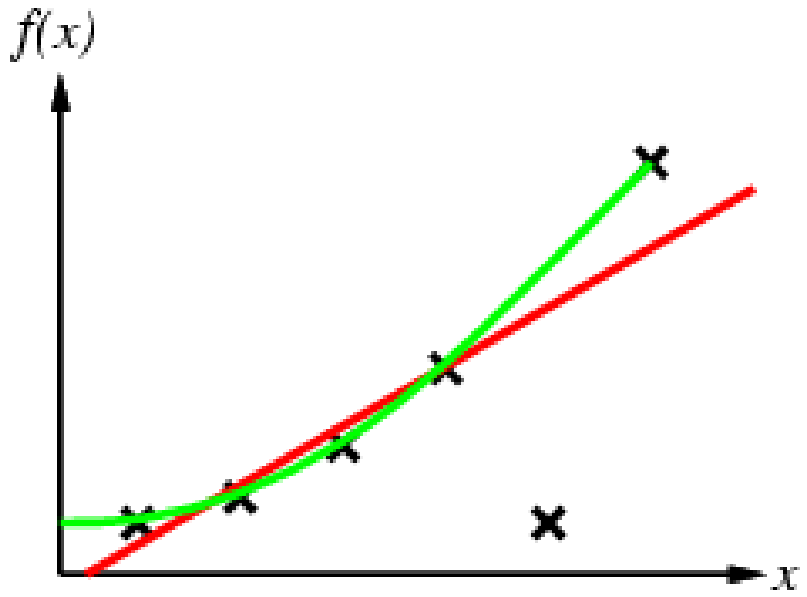

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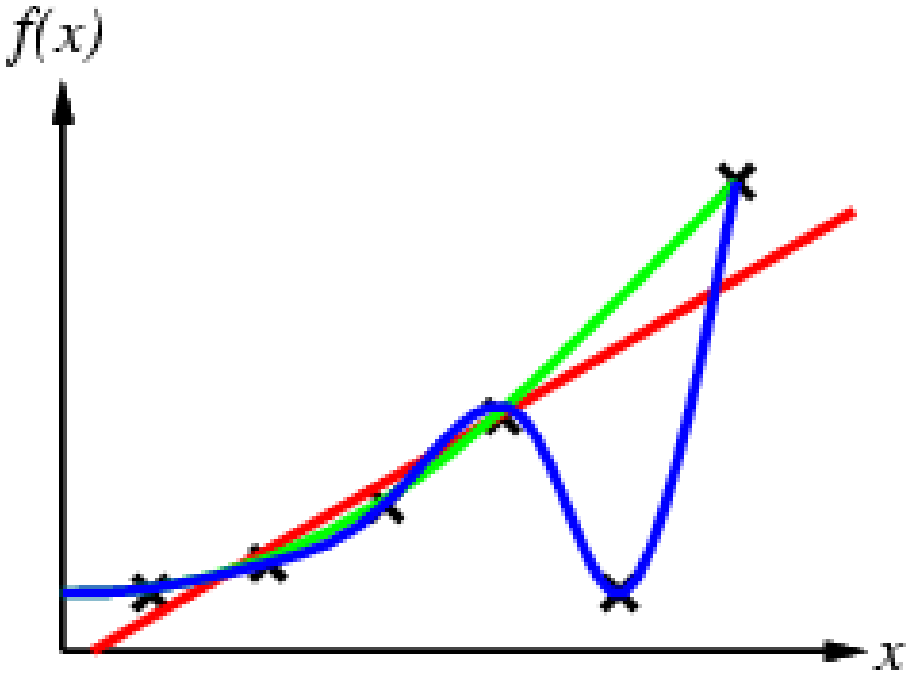

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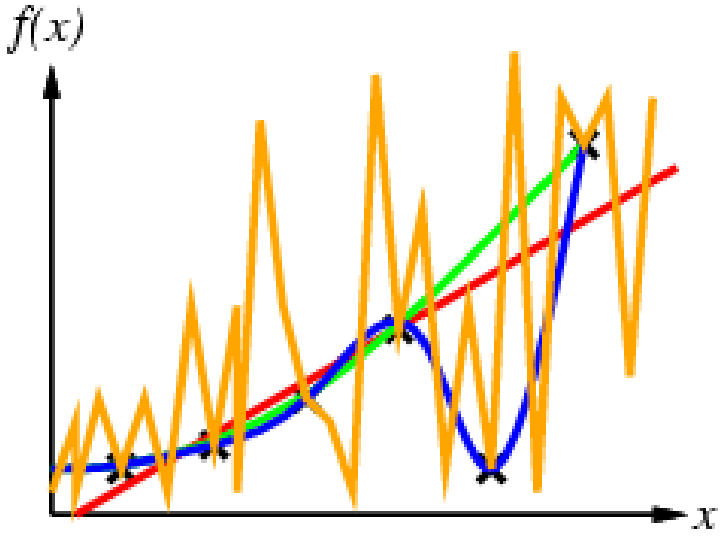

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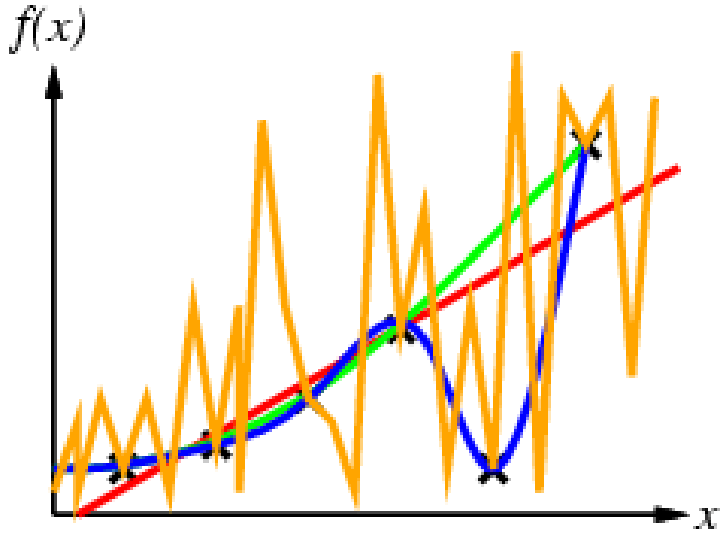


- Ockham's razor: prefer the simplest hypothesis consistent with data

Credit: Khola Naseem

Generalization:

- Hypotheses must generalize to correctly classify instances not in the training data.
- Simply memorizing training examples is a consistent hypothesis that does not generalize.
- Occam's razor:
  - Finding a simple hypothesis helps ensure generalization.

Credit: Khola Naseem

Supervised learning:

- the algorithm measures its accuracy through the loss function, adjusting until the error has been sufficiently minimized.
- Supervised learning can be separated into two types of problems:
  - Classification
  - Regression

Supervised learning:

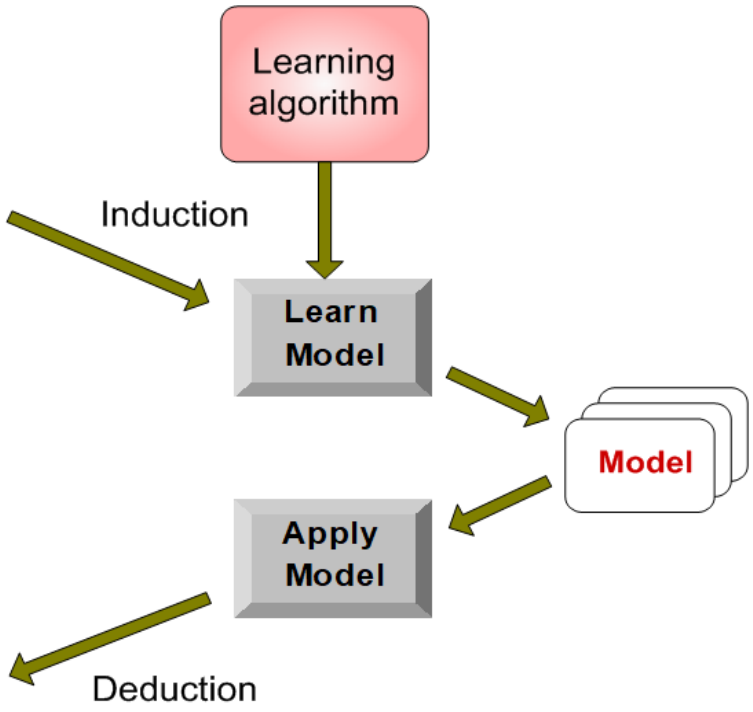
- Supervised learning can be separated into two types of problems:
  - Classification

Tid	Attrib1	Attrib2	Attrib3	Class
1	Yes	Large	125K	No
2	No	Medium	100K	No
3	No	Small	70K	No
4	Yes	Medium	120K	No
5	No	Large	95K	Yes
6	No	Medium	60K	No
7	Yes	Large	220K	No
8	No	Small	85K	Yes
9	No	Medium	75K	No
10	No	Small	90K	Yes

Training Set

Tid	Attrib1	Attrib2	Attrib3	Class
11	No	Small	55K	?
12	Yes	Medium	80K	?
13	Yes	Large	110K	?
14	No	Small	95K	?
15	No	Large	67K	?

Test Set



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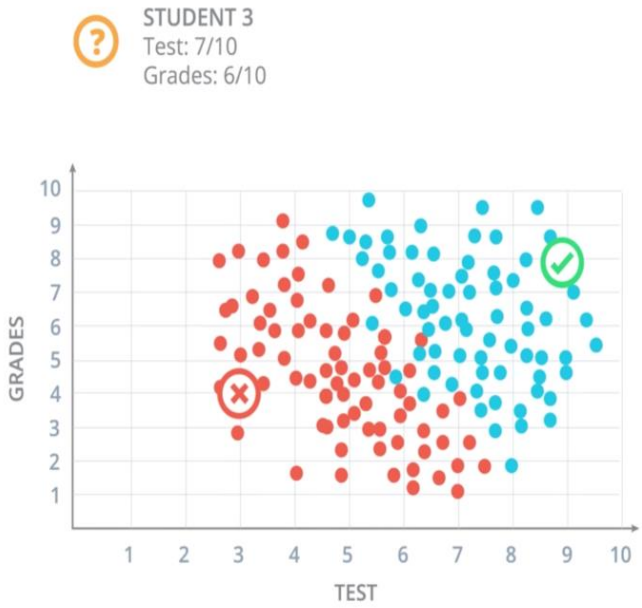
Supervised learning:

- Supervised learning can be separated into two types of problems:
  - Classification



QUIZ

Does the student get Accepted?

- Yes
- No

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Supervised learning:

Regression:

- Regression tasks are different, as they expect the model to produce a numerical relationship between the input and output data.
- Examples of regression models include
  - predicting real estate prices based on zip code, or
  - predicting click rates in online ads in relation to time of day,
  - determining how much customers would be willing to pay for a certain product based on their age.

Supervised learning:

In classification, we predict labels y (classes) for inputs x

Examples:

- OCR (input: images, classes: characters)
- Medical diagnosis (input: symptoms, classes: diseases)
- Automatic essay grader (input: document, classes: grades)
- Fraud detection (input: account activity, classes: fraud / no fraud)
- Recommended articles in a newspaper, recommended books
- DNA and protein sequence identification
- Categorization and identification of astronomical images
- Financial investments
- … many more

Credit: Khola Naseem

Supervised learning:

Pros:

- With the help of supervised learning, the model can predict the output on the basis of prior experiences.
- In supervised learning, we can have an exact idea about the classes of objects.
- Supervised learning model helps us to solve various real-world problems such as fraud detection, spam filtering, etc

Supervised learning:

Cons:

- Supervised learning cannot predict the correct output if the test data is different from the training dataset.
- Training required lots of computation times.
- In supervised learning, we need enough knowledge about the classes of object.