

# Internet of Things

## Programming

### WEEK 10

## Advanced Topic In IoT: Machine Learning

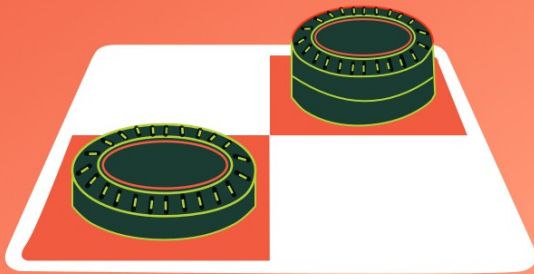
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Swinburne University of Technology  
May 2023

# PART-1 What is Machine Learning

# ARTIFICIAL INTELLIGENCE

Early Artificial Intelligence stirs excitement



# MACHINE LEARNING

Machine Learning begins to flourish



# DEEP LEARNING

Deep Learning breakthroughs drive AI practice



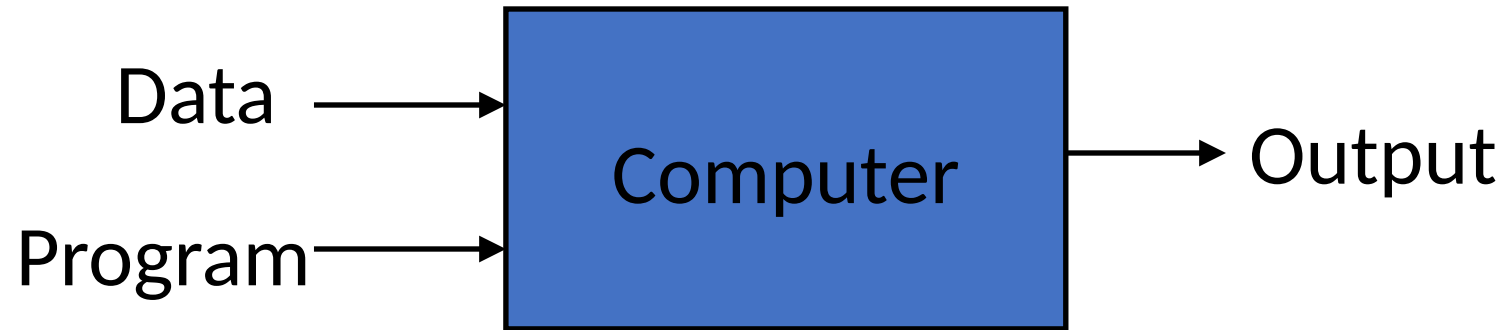
<https://www.wavelabs.ai/wavelabs-conducts-deep-learning-workshop-in-association-with-malai-club/>

## Beginning of Artificial Intelligence:

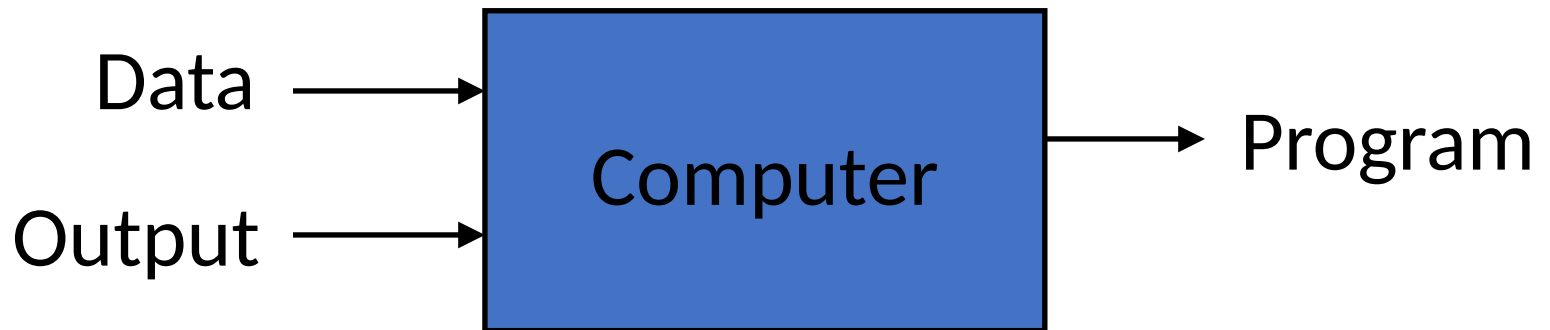
A. M. Turing (1950) Computing Machinery and Intelligence. Mind 49: 433-460.

<https://www.csee.umbc.edu/courses/471/papers/turing.pdf>

## Traditional Programming



## Machine Learning



# Definitions of machine learning

- “Field of study that gives computers the ability to learn without being explicitly programmed”

Arthur Samuel (1959)

- “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 in  $T$ , as measured by  $P$ , improves with experience  $E$ .”

– Tom M. Mitchell

Machine Learning, Tom Mitchell, McGraw Hill, 1997.

<http://www.cs.cmu.edu/~tom/mlbook.html>

# Why Machine Learning

- ▶ Some tasks cannot be defined well, except by example
- ▶ Relationships and correlations can be hidden within large amount of data.
- ▶ Amount of knowledge available about a certain task might be too large for explicit encoding
- ▶ New knowledge about task is constantly being discovered
- ▶ Machine learning is a form of AI that enables a system to learn from data rather than through explicit programming.

## Data everywhere!

1. **Google:** processes 24 peta bytes of data per day.
2. **Facebook:** 10 million photos uploaded every hour.
3. **Youtube:** 1 hour of video uploaded every second.
4. **Twitter:** 400 million tweets per day.
5. **Astronomy:** Satellite data is in hundreds of PB.
6. ...
7. **“By 2020 the digital universe will reach 44 zettabytes...”**

The Digital Universe of Opportunities: Rich Data and the  
Increasing Value of the Internet of Things, April 2014.

That's 44 trillion gigabytes!

# Some applications

- Robotics.
- Web search.
- Speech recognition.
- Translation.
- Space exploration.
- Genomics.

# Machine Learning Systems

- Training is a critical step in the machine learning process
- When you're training a machine learning system, you know the inputs (for example customer income, buying history, location, and so on), and you know your desired goal (predicting a customer's propensity to churn).
- Training a machine learning algorithm to create an accurate model can be broken down into three steps:
  - Representation
  - Evaluation
  - Optimisation



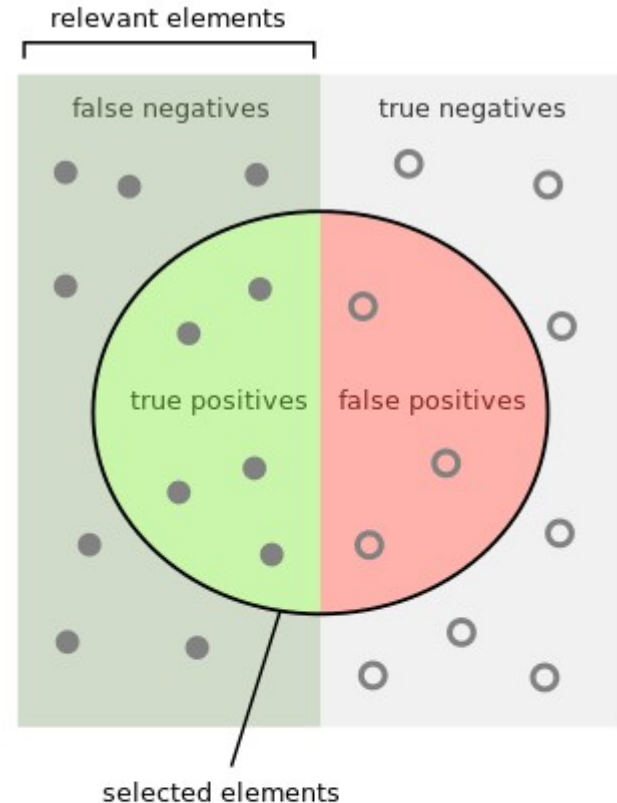
# Representation

A classifier must be represented in some formal language that the computer can handle.

- Decision trees
- Sets of rules / Logic programs
- Instances
- Graphical models (Bayes/Markov nets)
- Support vector machines
- Model ensembles
- The algorithm creates a model to transform the inputted data into the desired results.

# Evaluation

- As the algorithm creates multiple models, either a human or the algorithm will need to evaluate and score the models based on which model produces the most accurate predictions.
- Accuracy
- Precision and recall
- Etc.



How many selected items are relevant?

Precision =



How many relevant items are selected?

Recall =



# Optimization

- After the algorithm creates and scores multiple models, select the best performing algorithm.
- As you expose the algorithm to more diverse sets of input data, select the most generalised model
- The most important part of the training process is to have enough data so you're in a position to test your model

# The machine learning framework

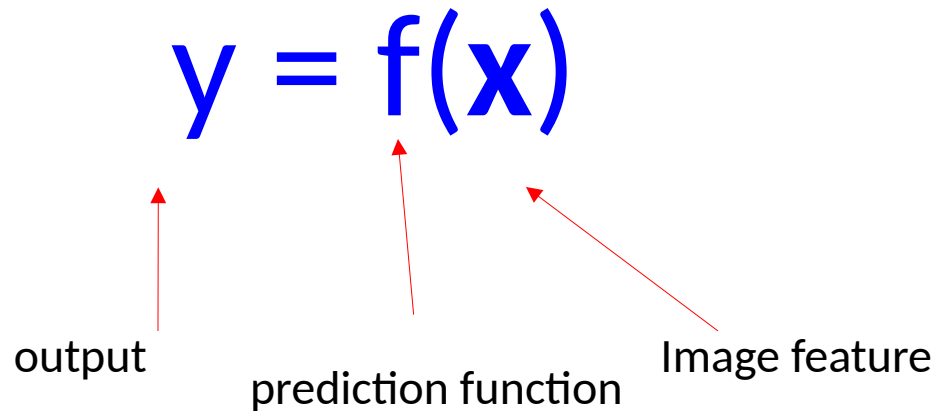
- Apply a prediction function to a feature representation of the image to get the desired output:

$$f(\text{apple image}) = \text{"apple"}$$

$$f(\text{tomato image}) = \text{"tomato"}$$

$$f(\text{cow image}) = \text{"cow"}$$

# The machine learning framework

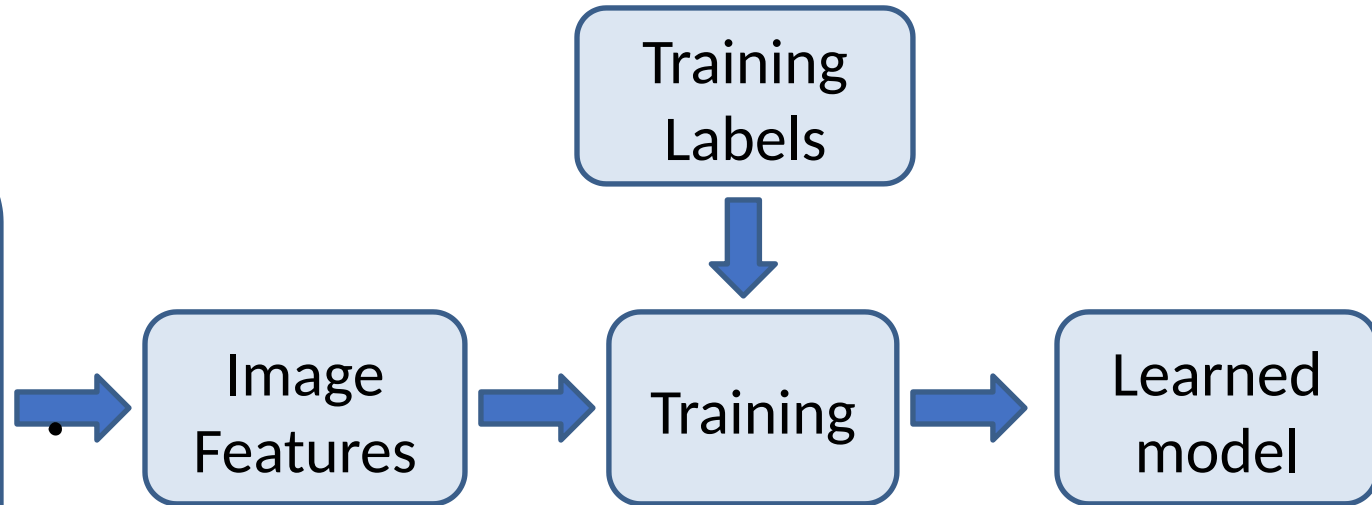


- **Training:** given a *training set* of labeled examples  $\{(\mathbf{x}_1, y_1), \dots, (\mathbf{x}_N, y_N)\}$ , estimate the prediction function  $f$  by minimizing the prediction error on the training set
- **Testing:** apply  $f$  to a never before seen *test example*  $\mathbf{x}$  and output the predicted value  $y = f(\mathbf{x})$

# Steps

## Training

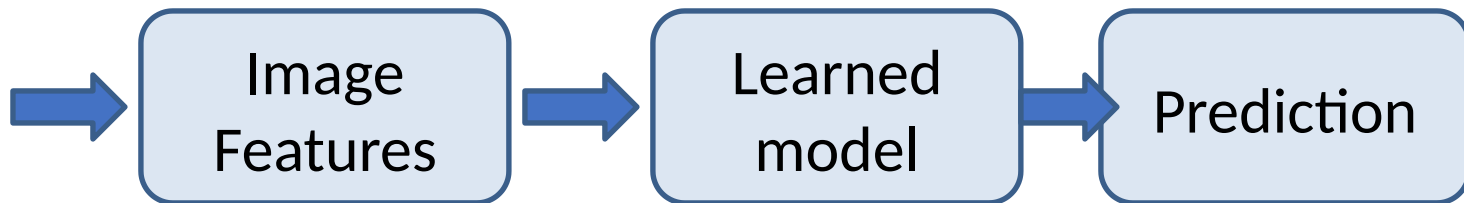
Training  
Images



## Testing



Test Image



# PART-II Types of Machine Learning

# Machine learning $\subseteq$ artificial intelligence

## ARTIFICIAL INTELLIGENCE

Design an intelligent agent that perceives its environment and makes decisions to maximize chances of achieving its goal.

Subfields: vision, robotics, machine learning, natural language processing, planning, ...

## MACHINE LEARNING

Gives "computers the ability to learn without being explicitly programmed" (Arthur Samuel, 1959)

### SUPERVISED LEARNING

Classification, regression

### UNSUPERVISED LEARNING

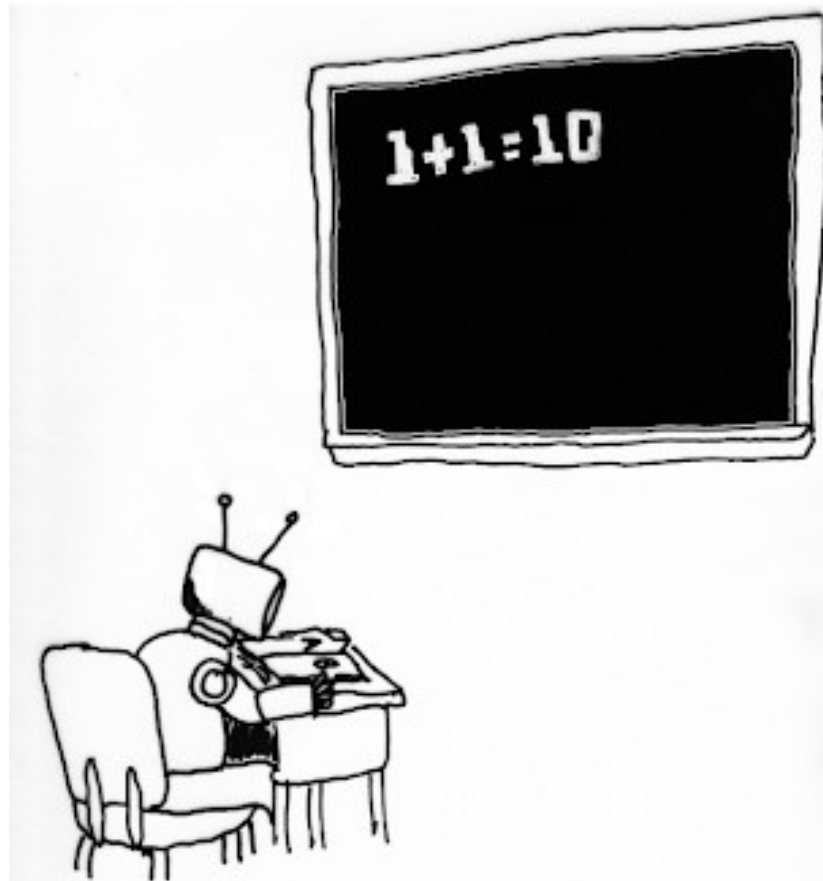
Clustering, dimensionality  
reduction, recommendation

### REINFORCEMENT LEARNING

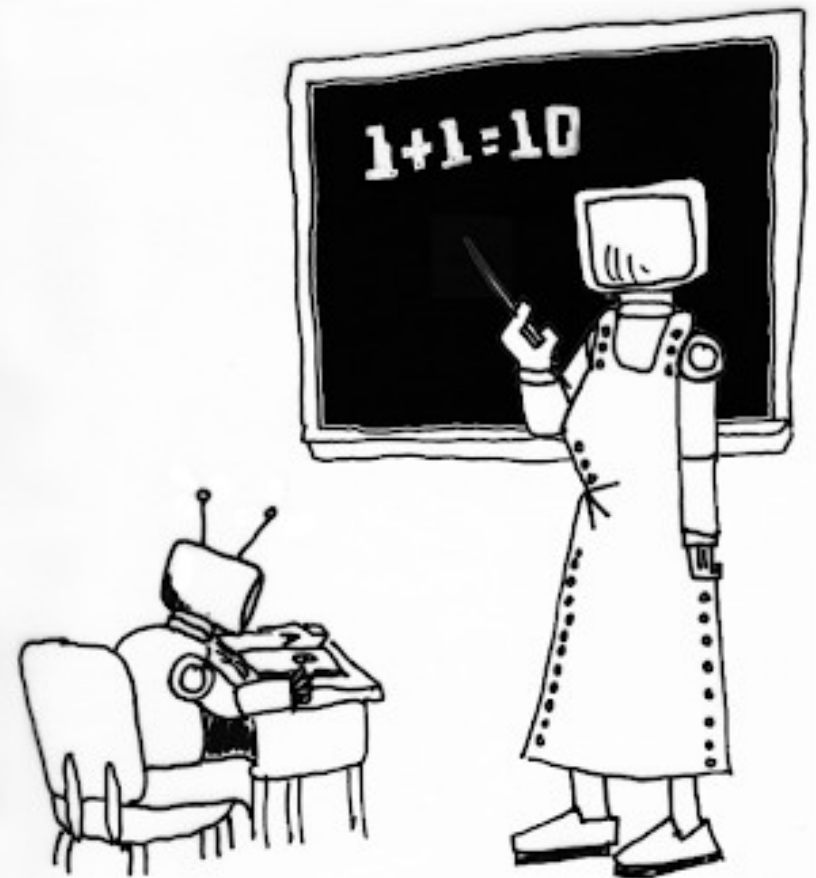
Reward maximization



UNSUPERVISED MACHINE LEARNING



SUPERVISED MACHINE LEARNING



PROOFFREADERSWHIMSY.BLOGSPOT.CA

# Supervised Learning



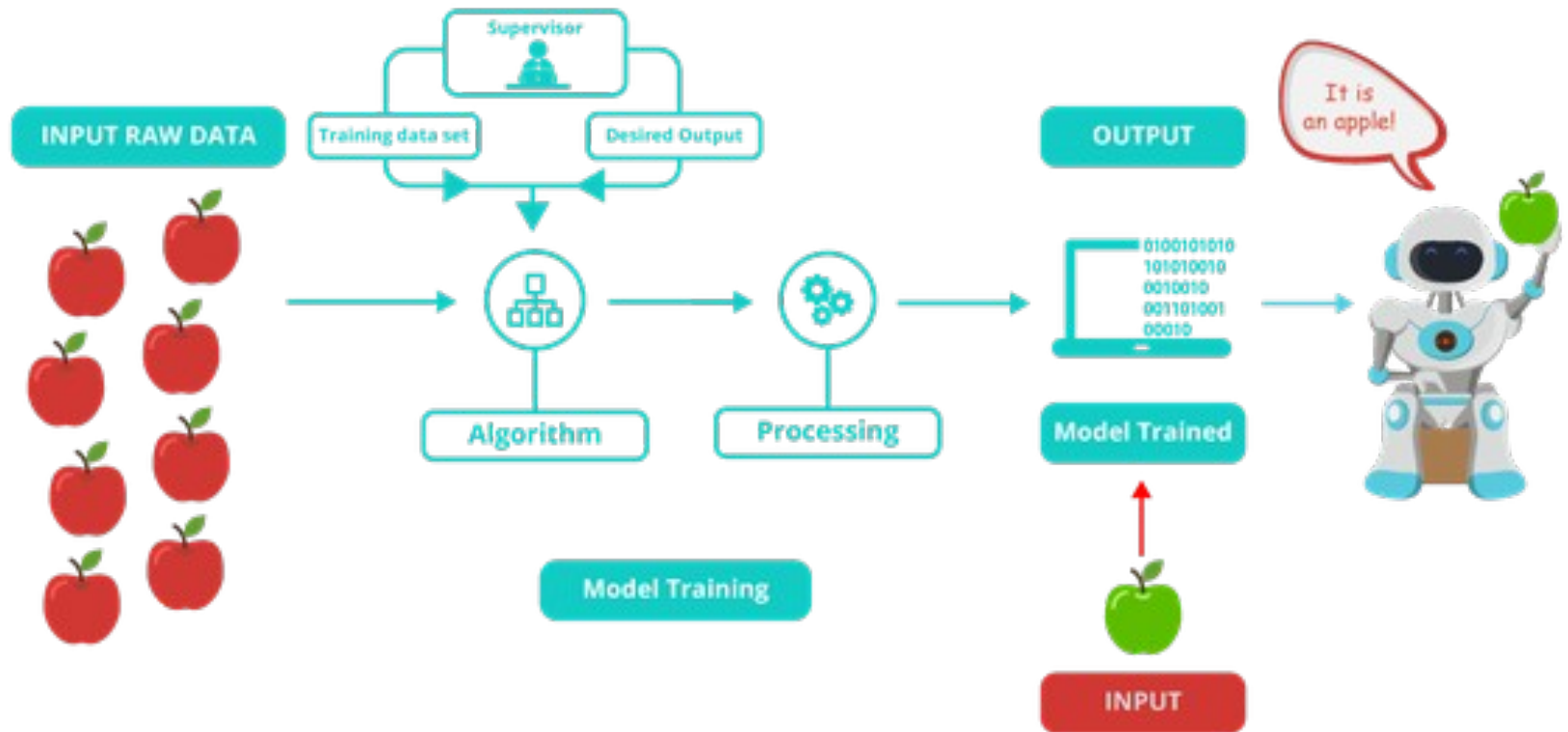
Supervised learning typically begins with an established set of data and a certain understanding of how that data is classified



Supervised learning is intended to find patterns in data that can be applied to an analytics process



Supervised learning helps you understand the correlation between variables



# Classification

$$f = R^n \rightarrow \{1, 2, \dots, k\}$$

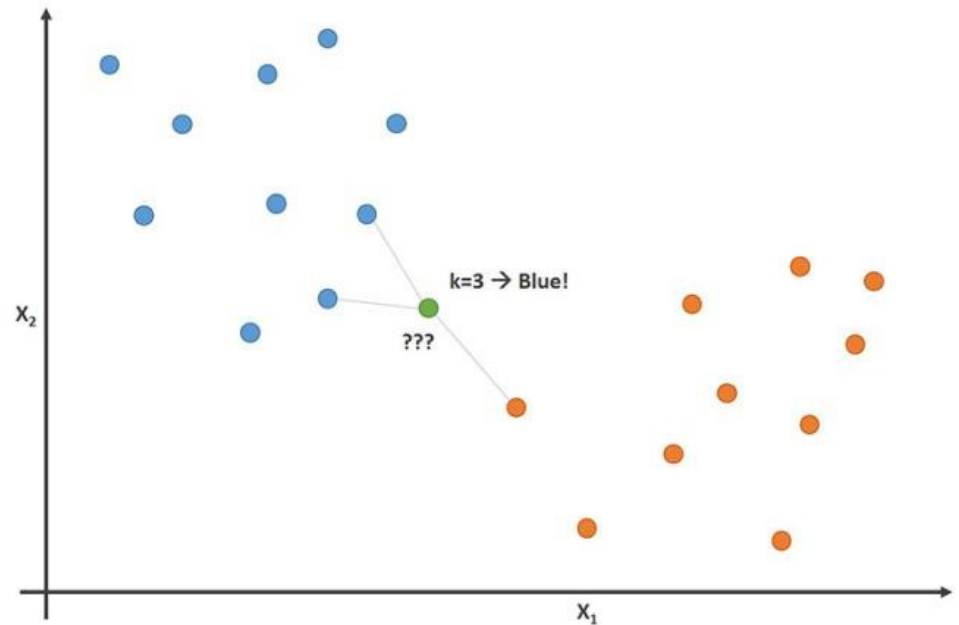
**Example:**

Object recognition: where the input is an image, and the output is a numeric code identifying the object in the image.

- In this type of task, the computer program is asked to specify which of  $k$  categories some input belongs to. To solve this task, the learning algorithm is usually asked to produce a function
- When  $y = f(x)$ , the model assigns an input described by vector  $x$  to a category identified by numeric code  $y$ . There are other variants of classification task, for example where  $f$  outputs a probability distribution over classes.

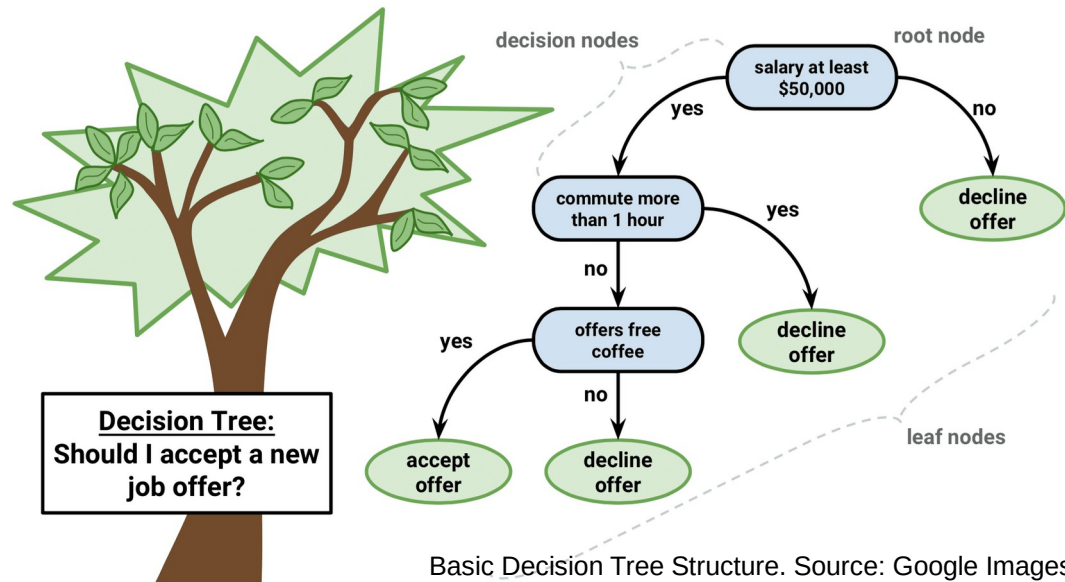
# K-nearest Neighbours

- K-Nearest Neighbours (K-NN) is one of the simplest machine learning algorithms
- When a new situation occurs, it scans through all past experiences and looks up the  $k$  closest experiences
- Those experiences (or: data points) are what we call the  $k$  nearest neighbours.



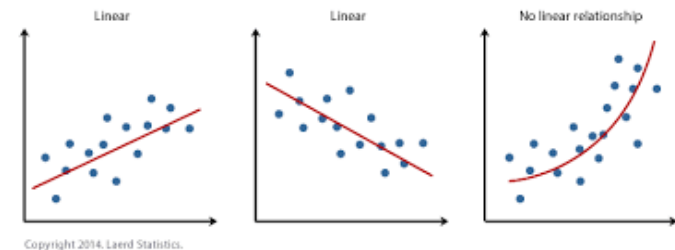
# Decision Tree

- Decision tree algorithms use a branching structure to illustrate the results of a decision.
- Decision trees can be used to map the possible outcomes of a decision.
- Each node of a decision tree represents a possible outcome.
- Percentages are assigned to nodes based on the likelihood of the outcome occurring



# Regression

- In this type of task, the computer program is asked to predict a numeric value given some input. To solve this task, the learning algorithm is asked to output a function
- This type of task is similar to classification, except that the format of output is different.
- **Example:** an example of regression task is the prediction of the expected claim amount that an insured person will make (used to set insurance premiums), or the predictions of future prices of securities.





Regression algorithms are commonly used for statistical analysis and are key algorithms for use in machine learning



Regression algorithms help analysts model relationships between data points



Regression algorithms can quantify the strength of correlation between variables in a data set

# Linear Regression



# Unsupervised Learning



Unsupervised learning is best suited when the problem requires a massive amount of data that is unlabelled



For example, social media applications, such as Twitter have large amounts of unlabelled data



Unsupervised learning is used with email spam-detecting technology

There are far too many variables in spam emails for an analyst to flag

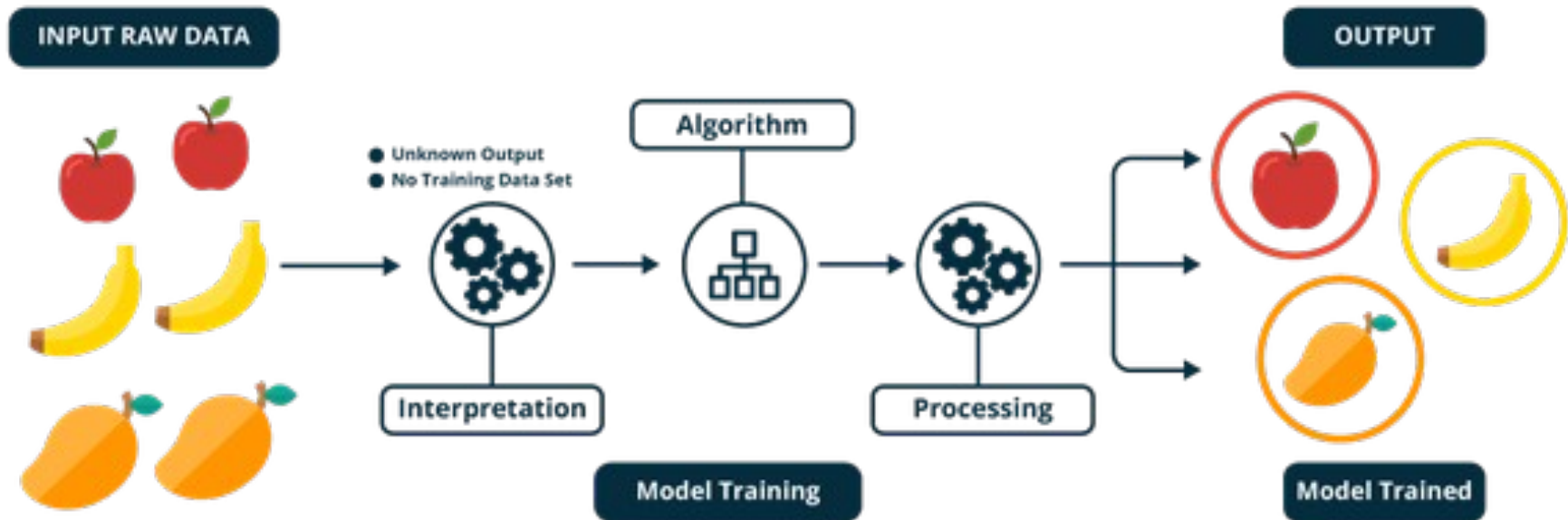


Unsupervised learning algorithms segment data into groups of examples (clusters) or groups of features



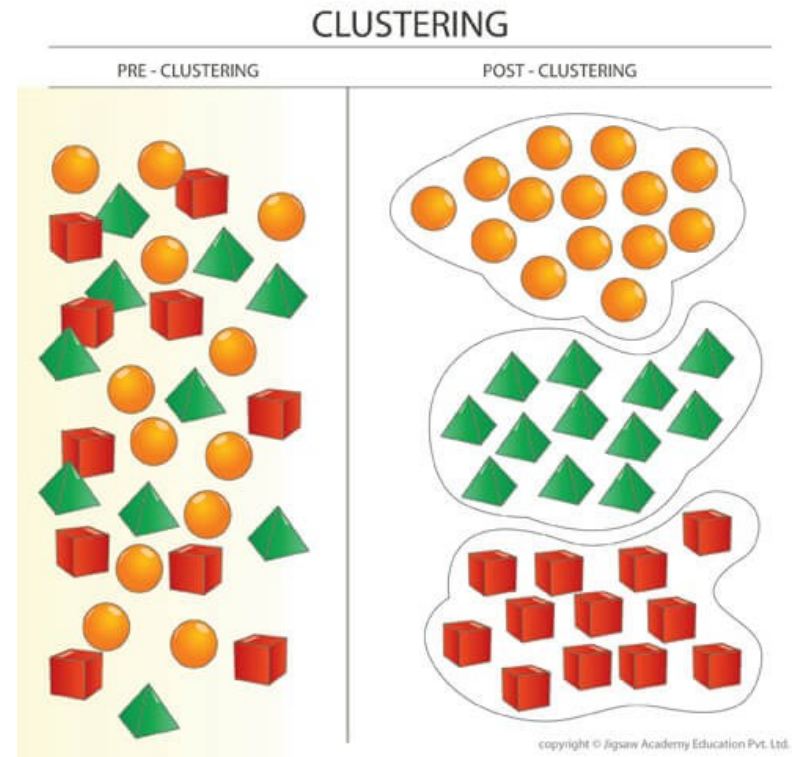
For example, in healthcare, collecting huge amounts of data about a specific disease can help practitioners gain insights into the patterns of symptoms and relate those to outcomes from patients

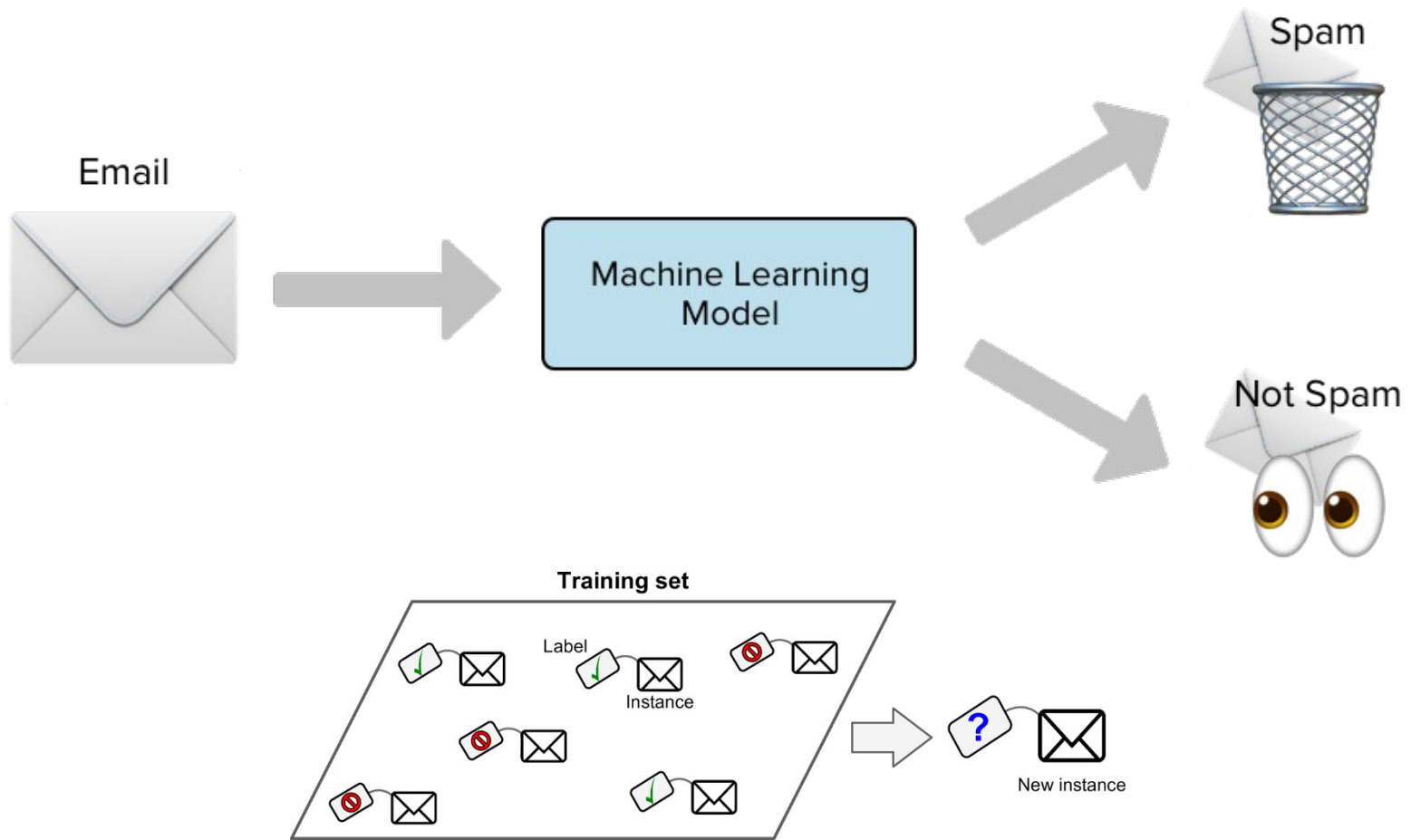
# Unsupervised learning



# Clustering

- Clustering is a fairly straightforward technique to understand — objects with similar parameters are grouped together (in a cluster).
- All objects in a cluster are more similar to each other than objects in other clusters.
- Clustering is a type of unsupervised learning because the data is not labelled.
- The algorithm interprets the parameters that make up each item and then groups them accordingly.





A Case for Unsupervised-Learning-based Spam Filtering:  
<https://www.eecs.umich.edu/techreports/cse/2010/CSE-TR-561-10.pdf>

# Anomaly detection

- In this type of the task, the computer program sifts through a set of events or objects and flags some of them as being unusual or anomaly.
- **Example**
  - **Credit-card fraud detection:** An example of an anomaly detection task is credit card fraud detection. By modeling your purchasing habits, a credit card company can detect misuse of your credit cards. If a thief steals your credit card or credit card information, the thief's purchases will often come from a different probability distribution over purchase types than your own. The credit card company can prevent the fraud by placing a hold on an account as soon as that card has been used for an uncharacteristic purchase.
  - **Intrusion detection system for the network traffic.**



Dimensionality reduction helps systems remove data that's not useful for analysis.



This group of algorithms is used to remove redundant data, outliers, and other non-useful data.



Dimensionality reduction can be helpful when analysing data from sensors and other Internet of Things (IoT) use cases



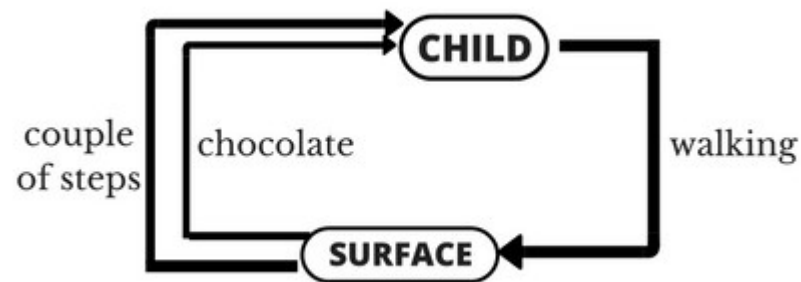
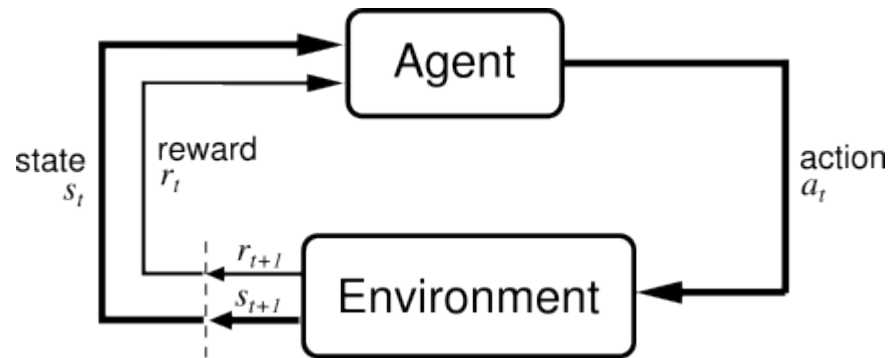
In IoT systems, there might be thousands of data points simply telling you that a sensor is turned on. Storing and analyzing that “on” data is not helpful and will occupy important storage space.

## Dimensionality reduction

- Reinforcement learning is a behavioural learning model
- The algorithm receives feedback from the analysis of the data so the user is guided to the best outcome
- Reinforcement learning differs from other types of supervised learning because the system isn't trained with the sample data set. Rather, the system learns through trial and error
- A sequence of successful decisions will result in the process being "reinforced" because it best solves the problem at hand
- One of the most common applications of reinforcement learning is in robotics or game playing

## Reinforcement learning

# Reinforcement learning





# Supervised vs. Reinforcement Learning



In supervised learning, there's an external “supervisor”, which has knowledge of the environment and who shares it with the agent to complete the task.

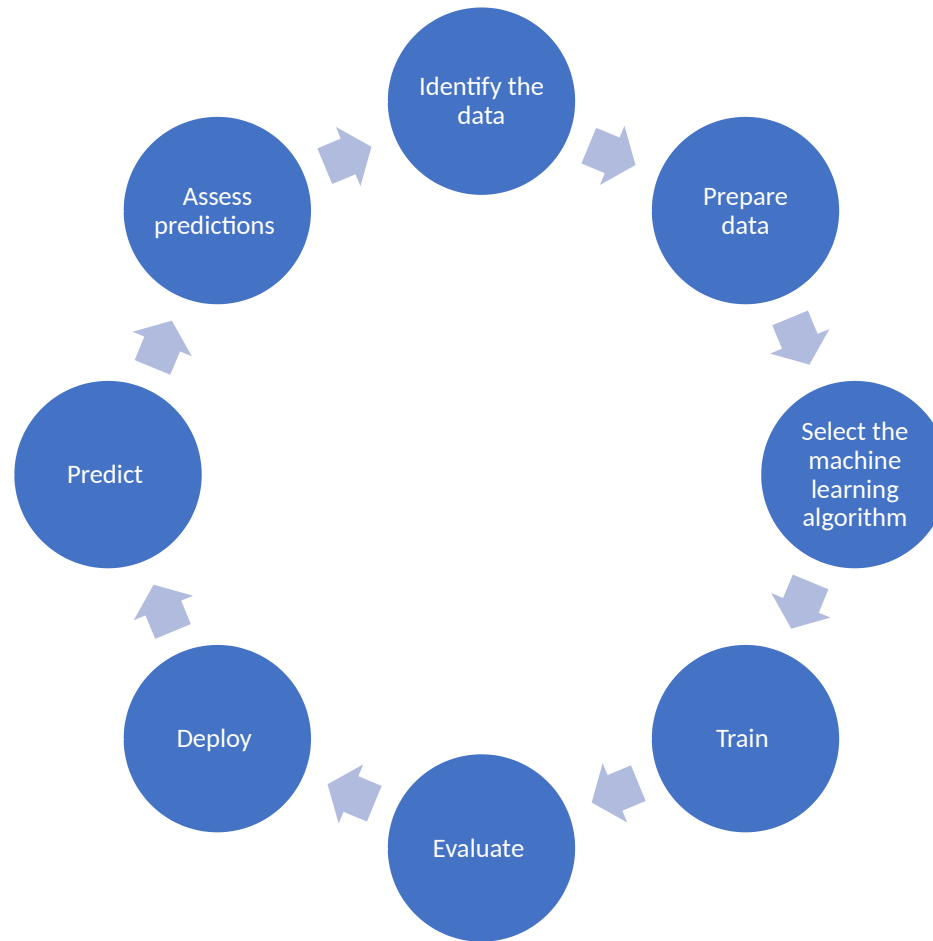


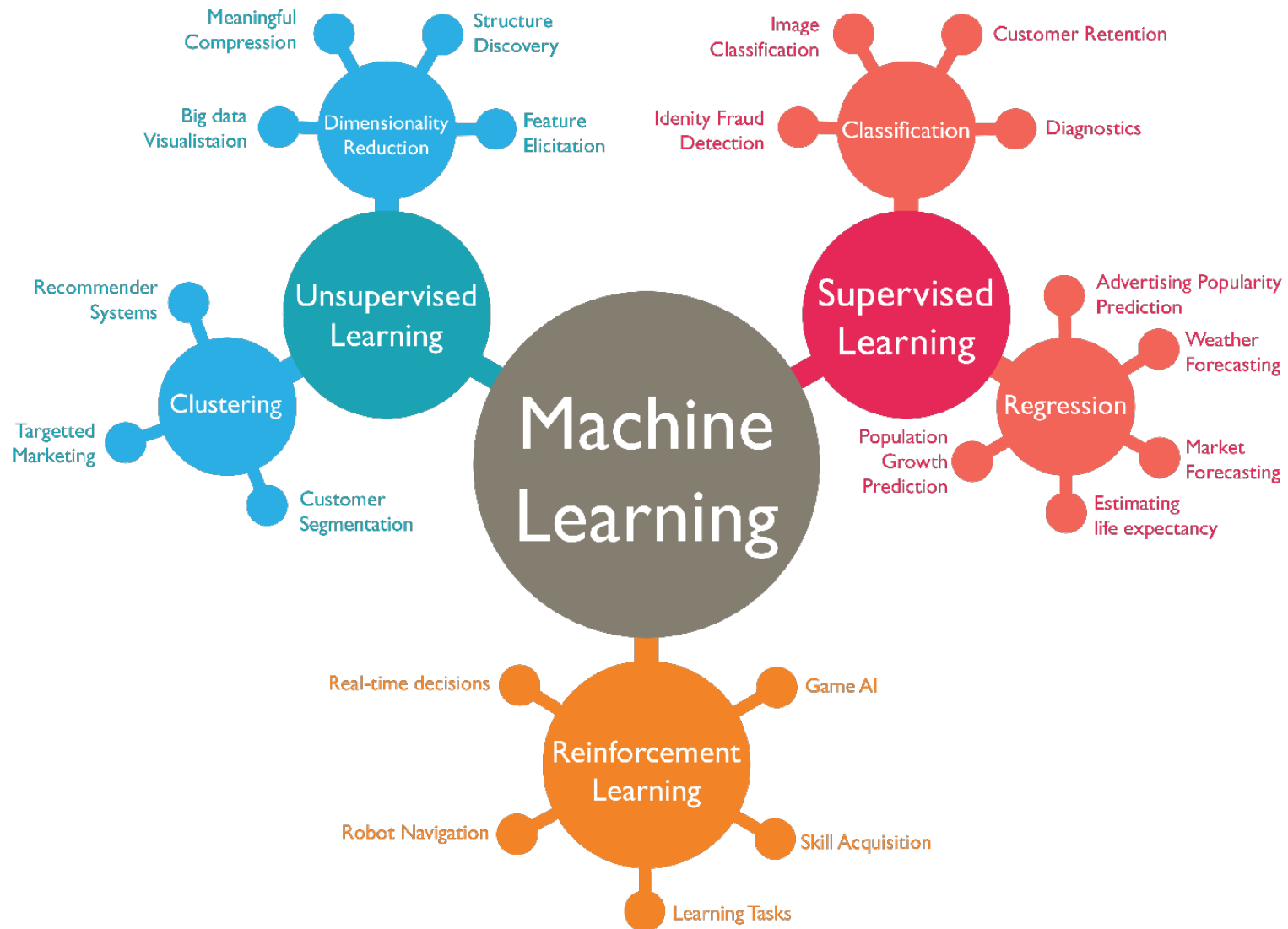
But there are some problems in which there are so many combinations of subtasks that the agent can perform to achieve the objective.

- In reinforcement learning, there's a mapping from input to output which is not present in unsupervised learning. In unsupervised learning, the main task is to find the underlying patterns rather than the mapping.

## **Unsupervised vs. Reinforcement Learning**

# The Machine Learning Cycle





# PART-III IoT and Machine Learning

# IoT and Machine Learning

- 31 Billion connected device to the Internet 2018
- Filtering, sorting, querying?
- Can we use machine learning models and algorithms to generate intelligence?

# IoT and ML

- Automation
  - Optimizing existing process
  - Main or improve quality
  - Reduce cost
- Enrichment
  - Add new feature or products
  - Customised manufacturing
  - New customers
- Invention
  - Create new products and categories

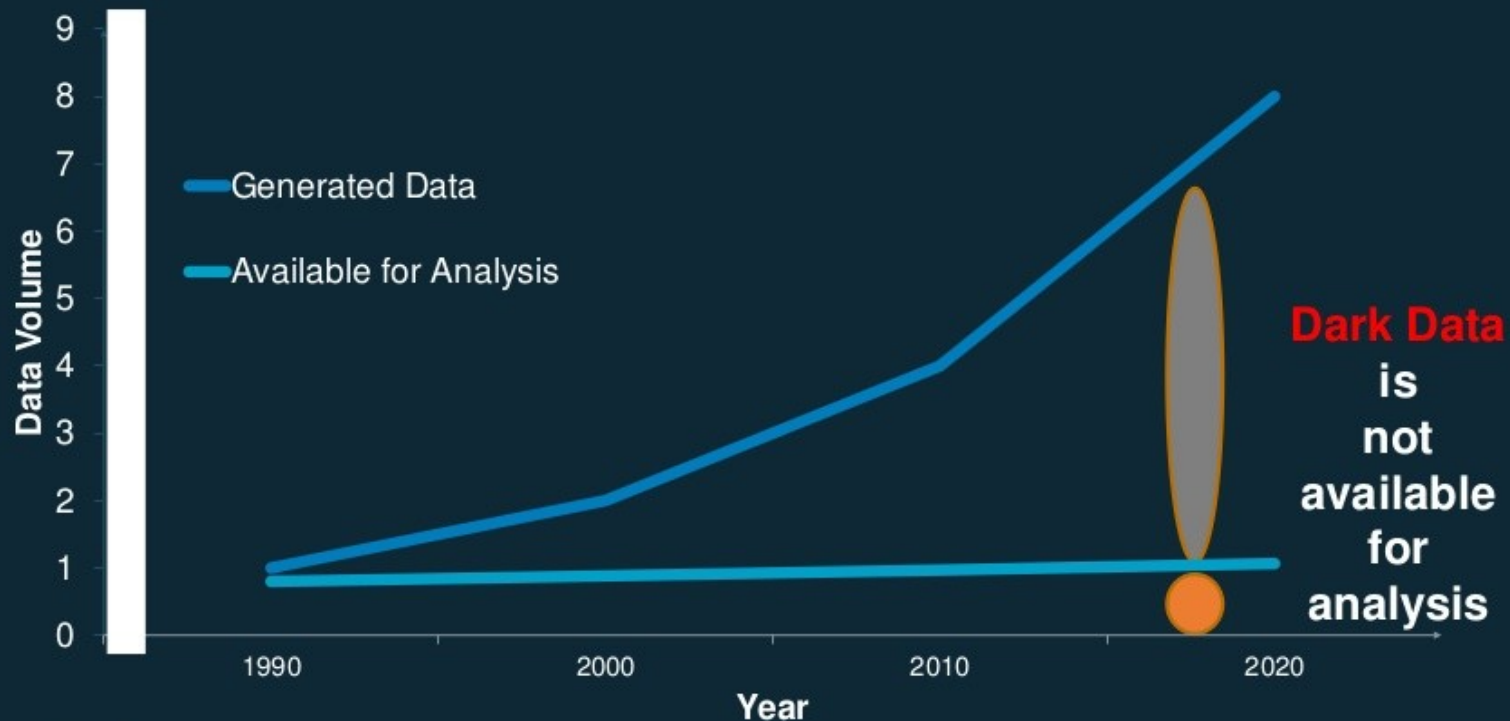
Machine Learning  
+  
IoT Data  
=  
Smart World



# A Flywheel for Data



# Most generated data is unavailable for analysis



Sources:  
Gartner: User Survey Analysis: Key Trends Shaping the Future of Data Center Infrastructure Through 2011  
© 2018, Amazon Web Services, Inc. or its Affiliates. All rights reserved.  
IDC: Worldwide Business Analytics Software 2012-2016 Forecast and 2011 Vendor Shares



**Dark data** is **data** which is acquired through various computer network operations but not used in any manner to derive insights or for decision making.

# AI/ML Adoption Challenges

1

While the power of ML is unrivaled, “data scientists spend around 80% of their time on preparing and managing data for analysis” ... hence only 20% of their time is used to derive insights

2

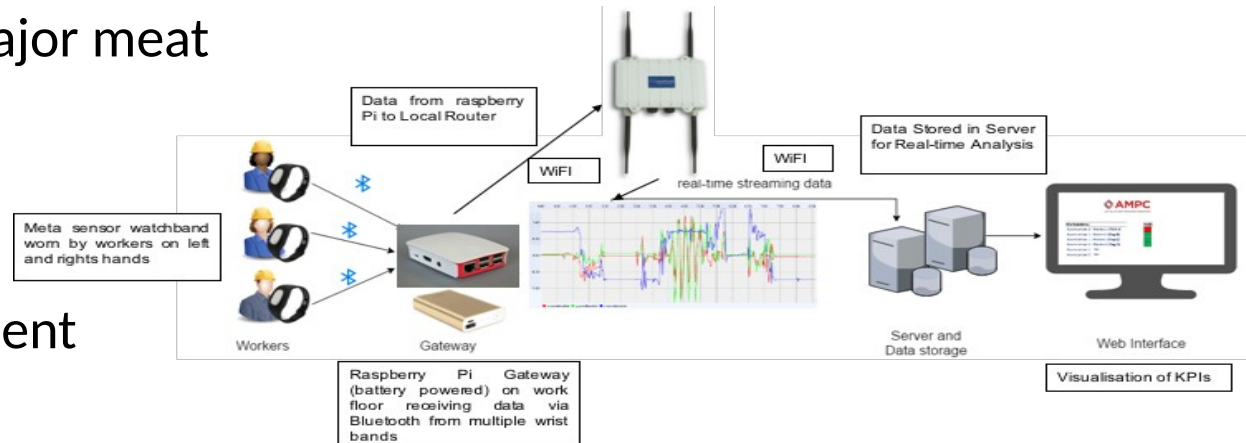
While “60% of companies agree that big data will help improve their decision making and competitiveness ... only 28% indicate that they are currently generating strategic value from their data”

3

The value of data science relies upon operationalizing models within business applications and processes, yet “50% of the predictive models [built] don’t get implemented”

# Measuring and Improving Worker Productivity

- Conducted trials in a major meat processing plant
- IoT solution payback in 0.4 years
- IoT solution will lead to significant improvement in plant productivity



	Worker 1 (Experienced)	Worker 2 (Inexperienced)
Idle Time	36%	8%
Productive Time	63%	91%
Alignment Time	1%	1%
Active States	49	30

# Kaggle: Machine learning and data science community

- Over 19,000 public datasets.
- 200,000 public notebooks.

<https://www.kaggle.com/datasets>

You may learn from COVID-19 dataset uploaded quite recently.

# WEKA

- Weka is a collection of machine learning algorithms for data mining tasks
- It contains tools for data preparation, classification, regression, clustering, association rules mining, and visualization
- Found only on the islands of New Zealand, the Weka is a flightless bird with an inquisitive nature.

Weka requires Java.

<http://www.cs.waikato.ac.nz/ml/weka/downloading.html>

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# Questions?

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