Introduction to Data Science

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Outline

- Basics of Machine Learning

Machine Learning

- Machine learning is a method of data analysis that automates analytical model building. It is a branch of artificial intelligence based on the idea that systems can learn from data, identify patterns and make decisions with minimal human intervention.

- Machine learning is an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed. Machine learning focuses on the development of computer programs that can access data and use it to learn for themselves.

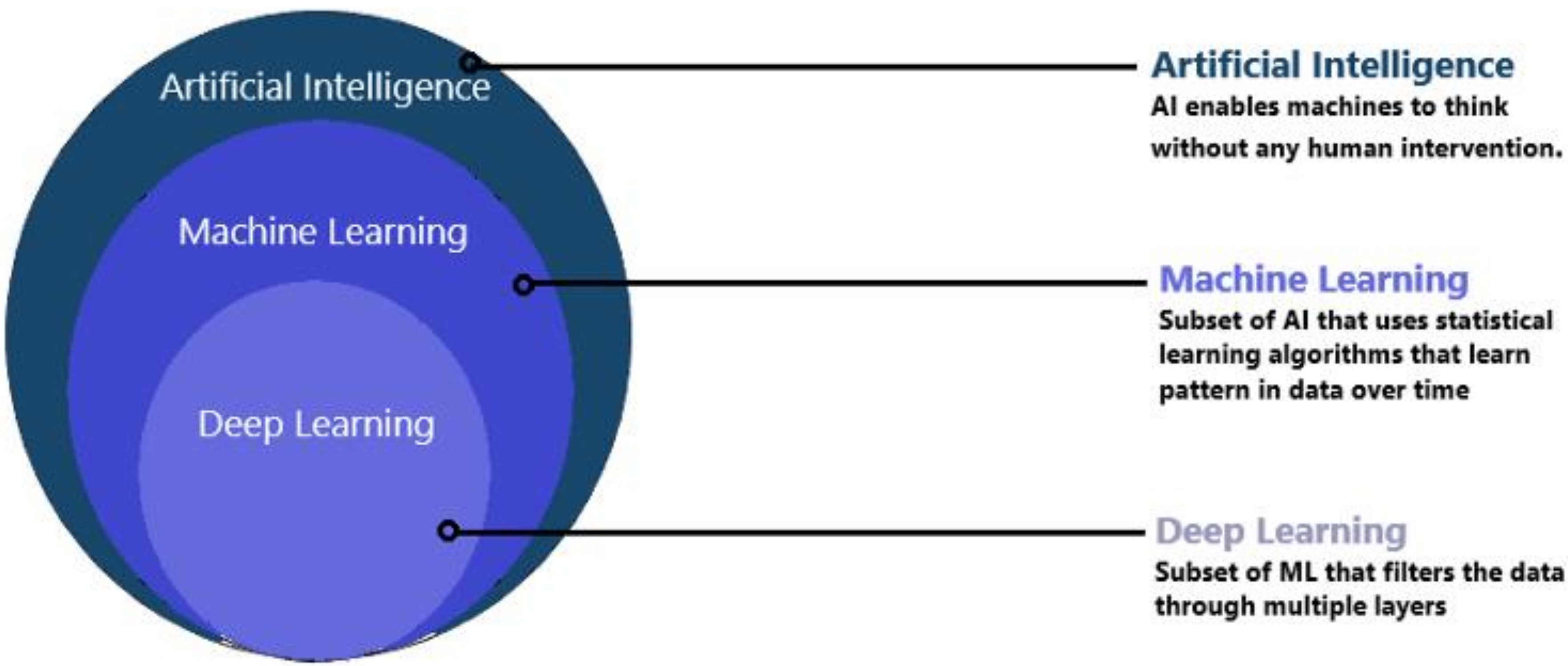
Machine Learning

- Machine learning (ML) is a type of artificial intelligence (AI) that allows software applications <u>to become more accurate at predicting outcomes</u> without being explicitly programmed to do so. Machine learning algorithms use historical data as input to predict new output values.

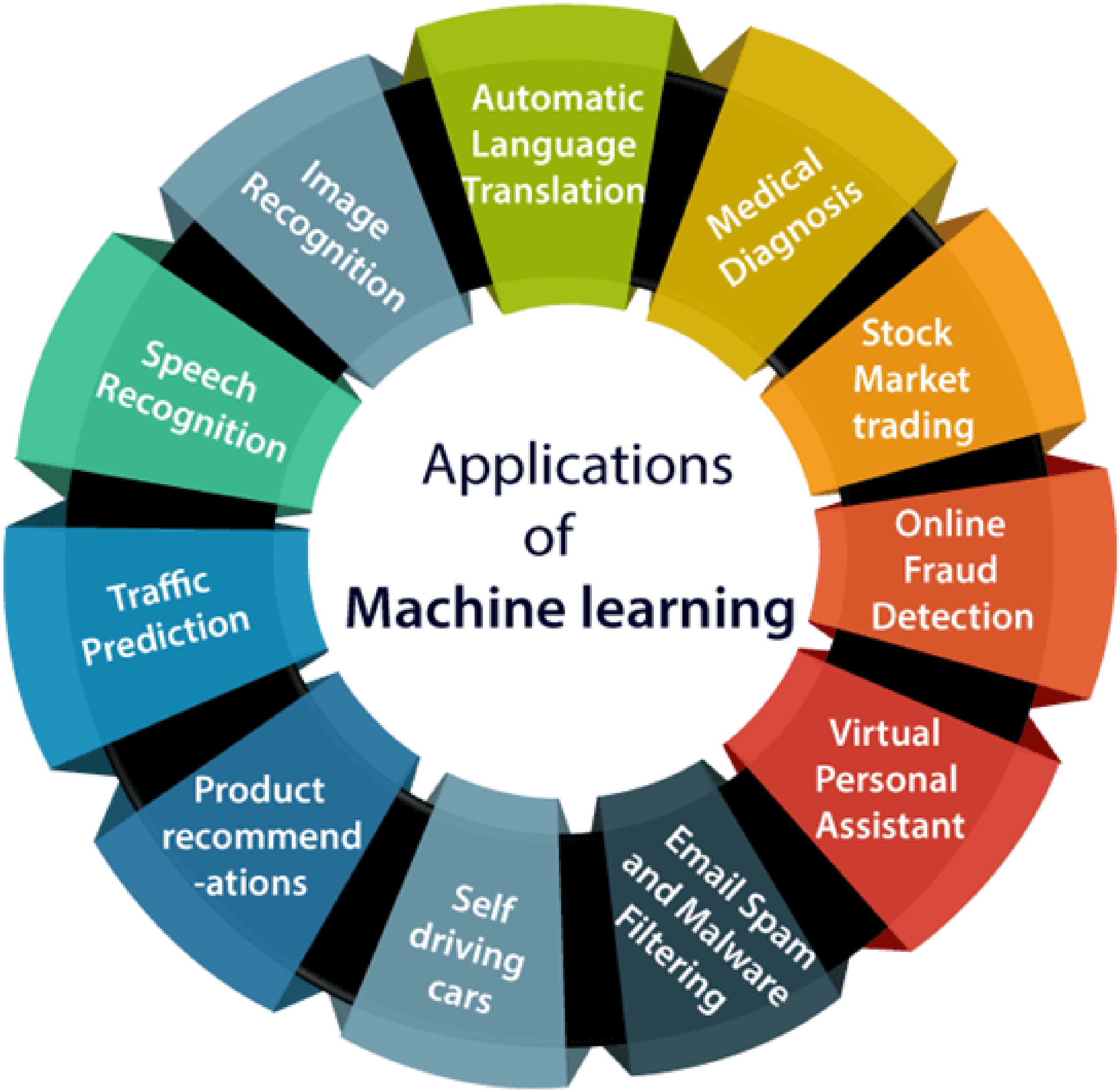
- Machine learning (ML) is the <u>study of computer algorithms that improve automatically</u> through experience and by the use of data. It is seen as a part of artificial intelligence.

- In Machine Learning, we train a machine <u>**how**</u> to learn.

Machine Learning



Applications of Machine Learning



Types of Machine Learning Algorithms

- Supervised Machine Learning
- Un-supervised Machine Learning
- Semi-supervised Machine Learning
- Reinforcement Learning

Supervised Learning

- Algorithms are trained using labeled examples, such as an input where the desired output is known.

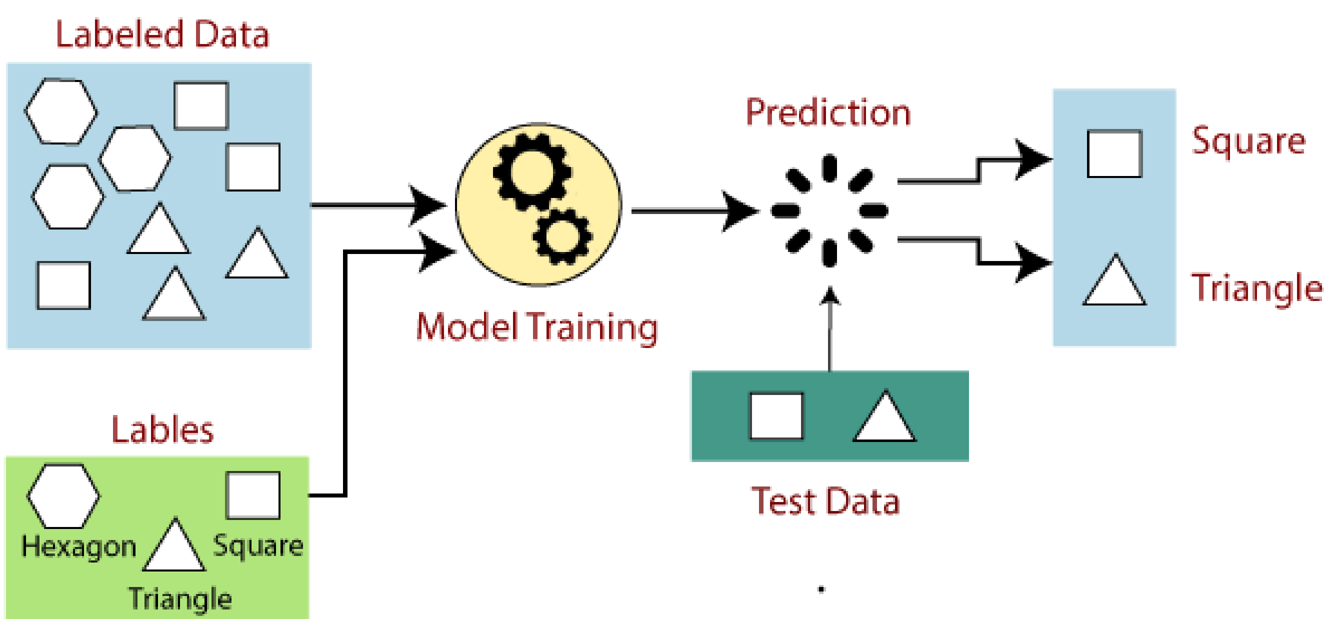
- Can apply what has been learned in the past to new data using labeled examples to predict future events.

- Supply algorithms with labeled training data and define the variables they want the algorithm to assess for correlations.

- **In machine learning, a target is called a label.**
- **In statistics, a target is called a dependent variable.**

Supervised Learning

- Through methods like classification, regression, prediction and gradient boosting, supervised learning uses patterns to predict the values of the label on additional unlabeled data.
- Supervised learning is commonly used in applications where historical data predicts likely future events

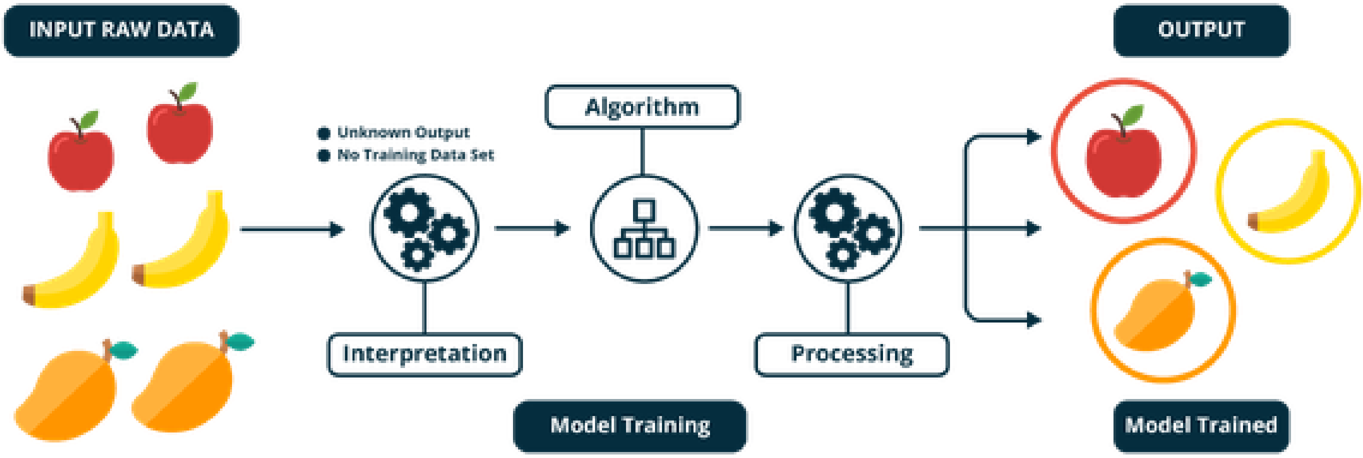


Un-supervised Learning

- Unsupervised learning is used against data that has no historical labels. The system is not told the "right answer." The algorithm must figure out what is being shown. The goal is to explore the data and find some structure within.
- Unsupervised learning studies how systems can infer a function to **describe a hidden structure from unlabeled data**. The system doesn’t figure out the right output, but it explores the data and can draw inferences from datasets to describe hidden structures from unlabeled data.
- The algorithm scans through data sets looking for any meaningful connection.

Un-supervised Learning

- Unsupervised learning works well on transactional data. For example, it can identify segments of customers with similar attributes who can then be treated similarly in marketing campaigns.
- **A variable in statistics is called a feature in machine learning.**



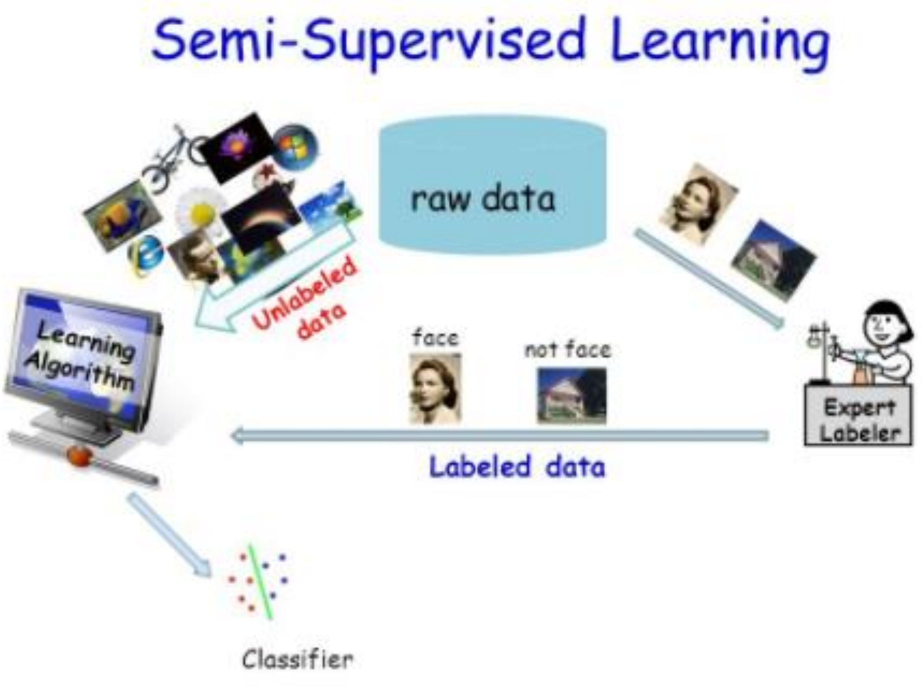
Semi-supervised Learning

- It is used for the same applications as supervised learning. But it uses both labeled and unlabeled data for training – typically a small amount of labeled data with a large amount of unlabeled data (because unlabeled data is less expensive and takes less effort to acquire).

- This type of learning can be used with methods such as classification, regression and prediction. Semi-supervised learning is useful when the cost associated with labeling is too high to allow for a fully labeled training process.

Semi-supervised Learning

- Usually, semi-supervised learning is chosen when the acquired labeled data requires skilled and relevant resources in order to train it / learn from it.
- Early examples of this include identifying a person's face on a web cam.



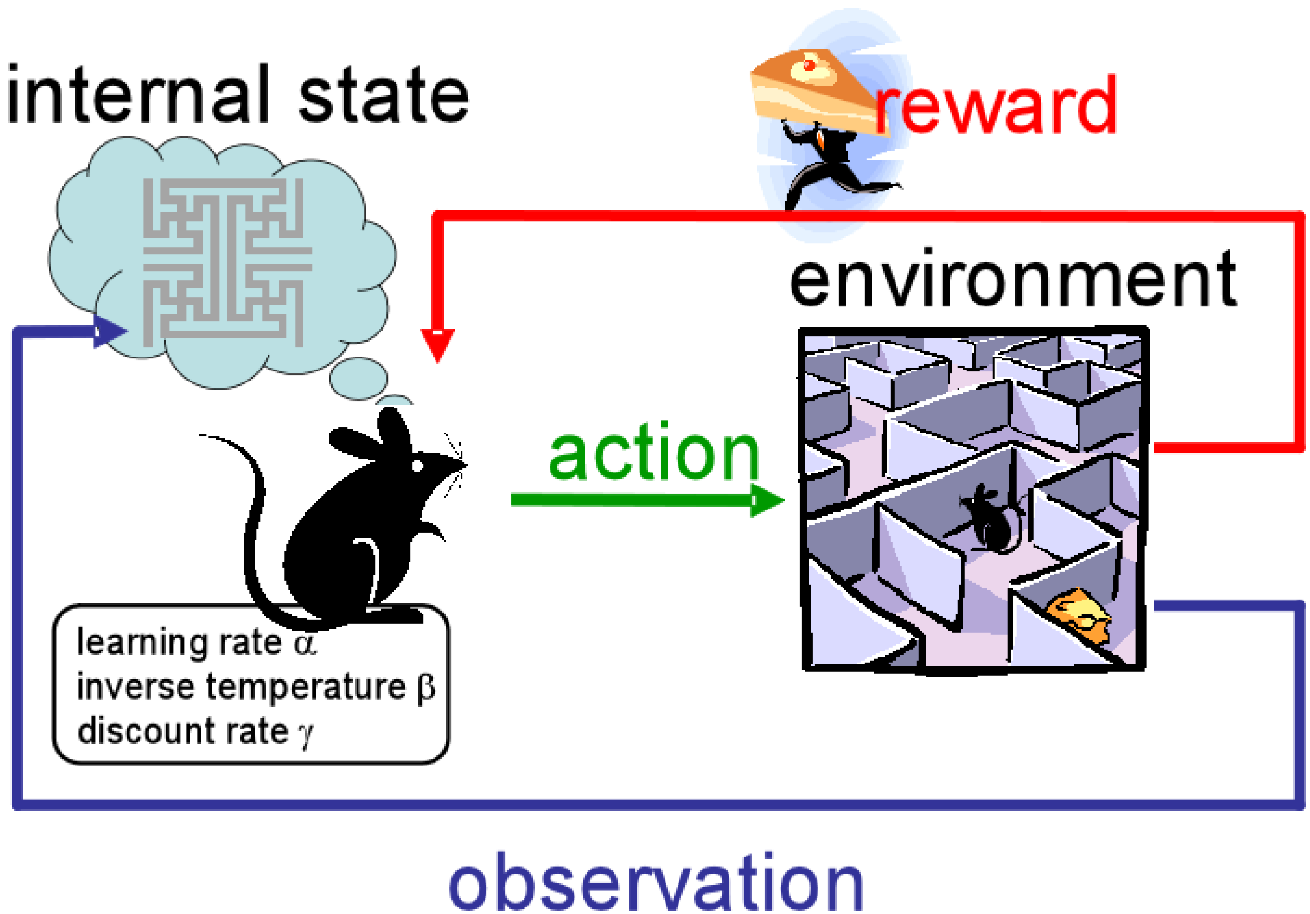
Reinforcement Learning

- With reinforcement learning, the algorithm discovers through trial and error which actions yield the greatest rewards. This type of learning has three primary components: the agent (the learner or decision maker), the environment (everything the agent interacts with) and actions (what the agent can do).

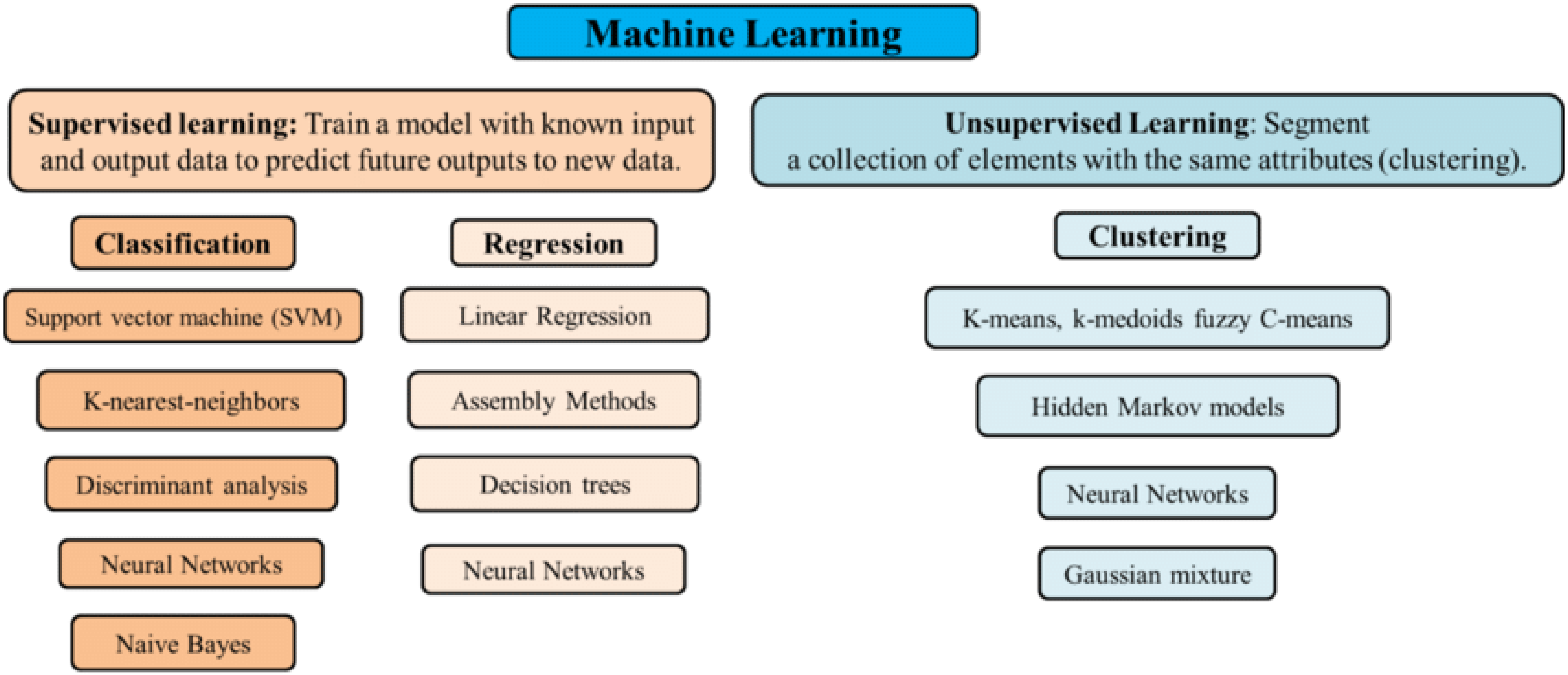
- Data scientists program an algorithm to complete a task and give it positive or negative cues as it works out how to complete a task. But for the most part, the algorithm decides on its own what steps to take along the way.

Reinforcement Learning

- The objective is for the agent to choose actions that maximize the expected reward over a given amount of time.



Machine Learning Algorithms



Supervised Machine Learning Algorithms

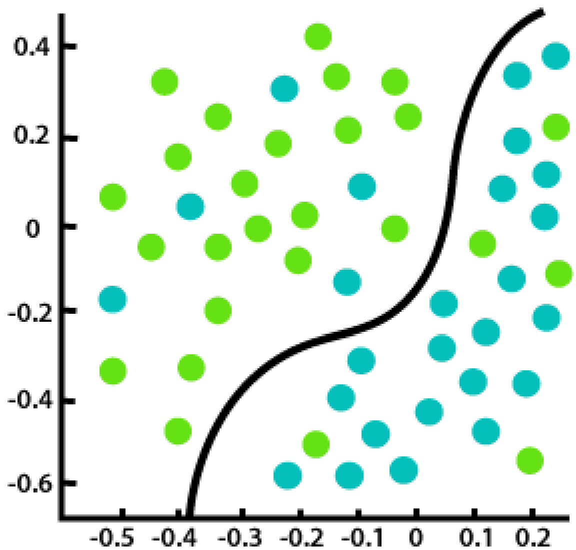
- Supervised learning is where you have input variables (x) and an output variable (Y) and you use an algorithm to learn the mapping function from the input to the output.

$$Y = f(X)$$

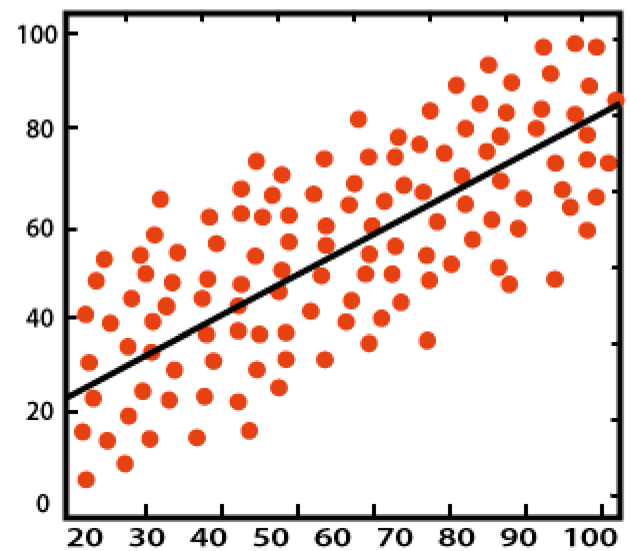
- The goal is to approximate the mapping function so well that when you have new input data (x) that you can predict the output variables (Y) for that data.
- The process of an algorithm learning from the training dataset can be thought of as a teacher supervising the learning process. We know the correct answers, the algorithm iteratively makes predictions on the training data and is corrected by the teacher. Learning stops when the algorithm achieves an acceptable level of performance.

Supervised Machine Learning Algorithms

- **Classification:** A classification problem is when the output variable is a category, such as “red” or “blue” or “disease” and “no disease”.
- **Regression:** A regression problem is when the output variable is a real value, such as “age” or “weight”.



Classification



Regression

Unsupervised Machine Learning Algorithms

- Unsupervised learning refers to the use of artificial intelligence (AI) algorithms to identify patterns in data sets containing data points that are not labeled.

- The algorithms are thus allowed to classify, label and/or group the data points contained within the data sets without having any external guidance in performing that task.

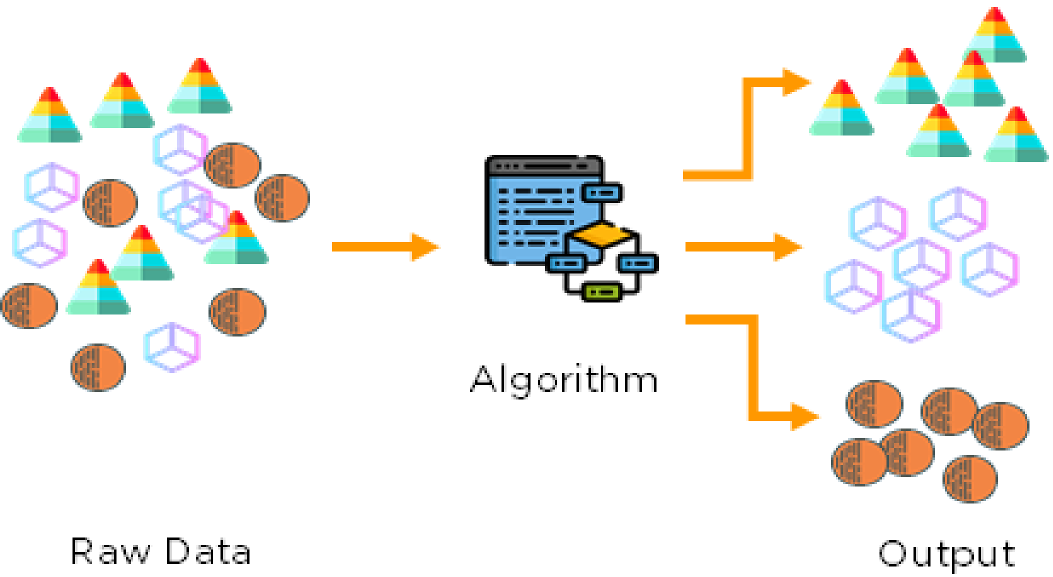
- In unsupervised learning, an AI system will group unsorted information according to similarities and differences even though there are no categories provided.

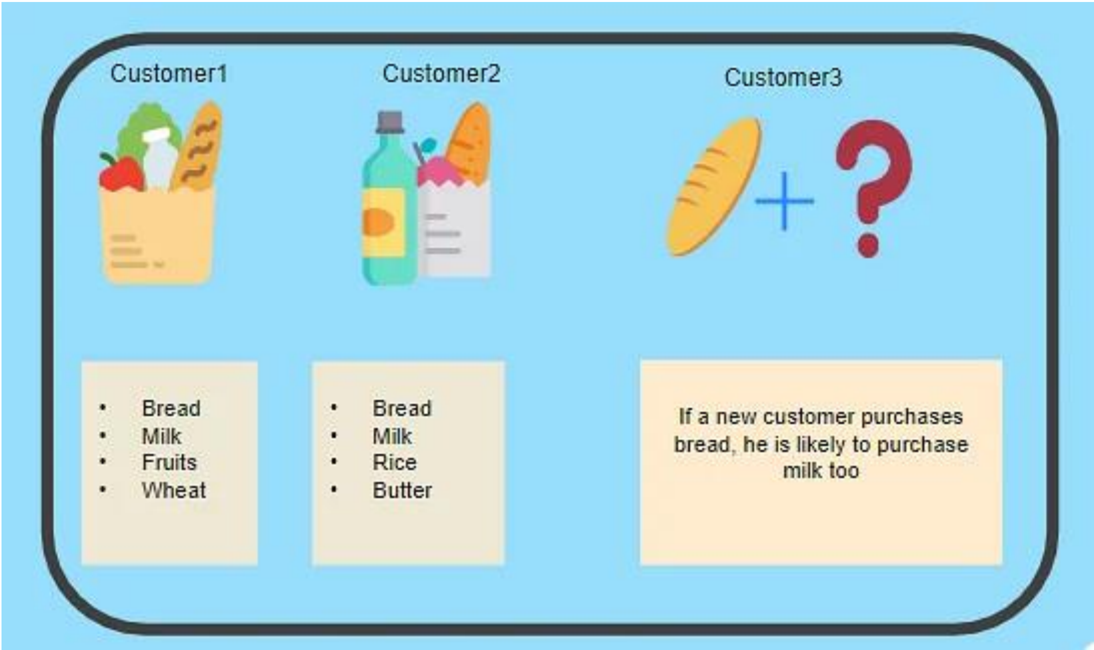
Unsupervised Machine Learning Algorithms

- **Clustering:** Clustering is a method of grouping the objects into clusters such that objects with most similarities remains into a group and has less or no similarities with the objects of another group.

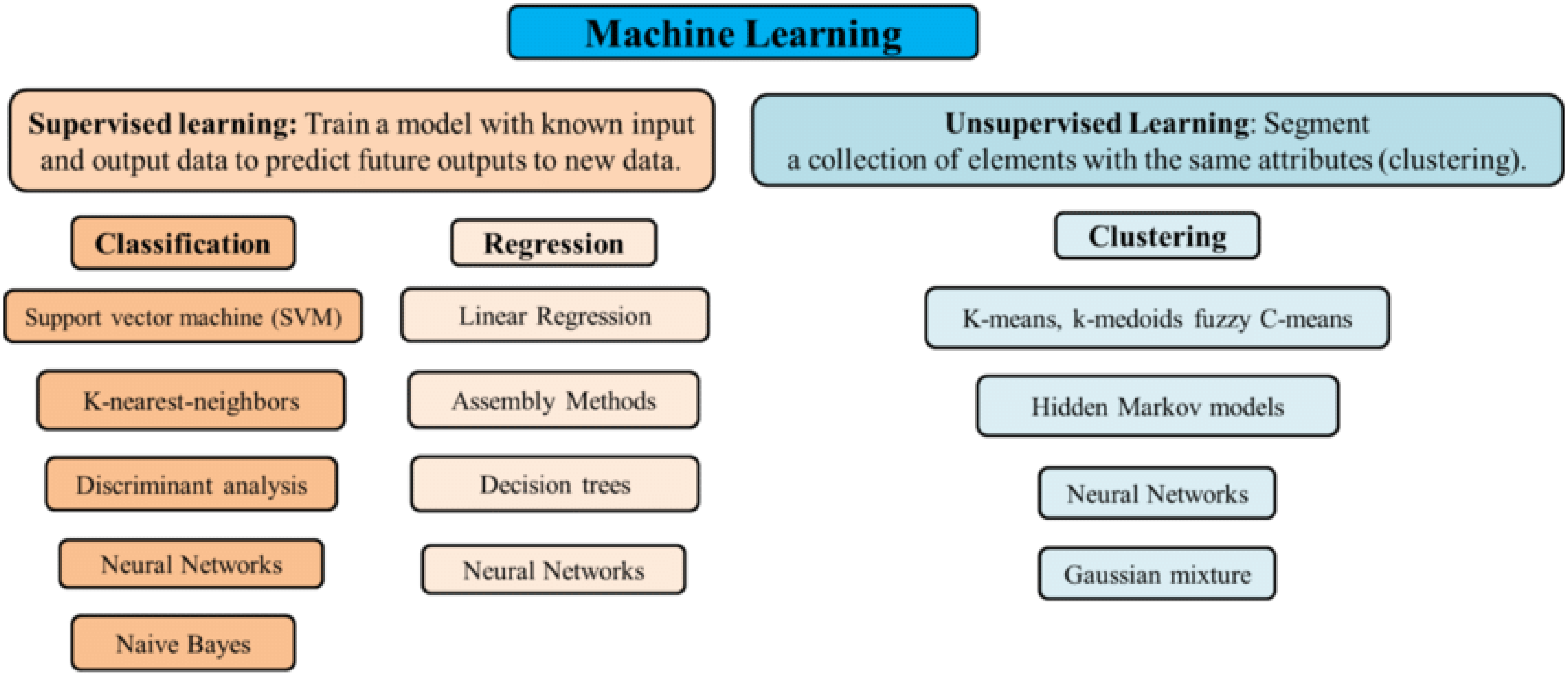
- **Association:** An association rule is an unsupervised learning method which is used for finding the relationships between variables in the large database. It determines the set of items that occurs together in the dataset. Association rule makes marketing strategy more effective. Such as people who buy X item (suppose a bread) are also tend to purchase Y (Butter/Jam) item.

Unsupervised Machine Learning Algorithms



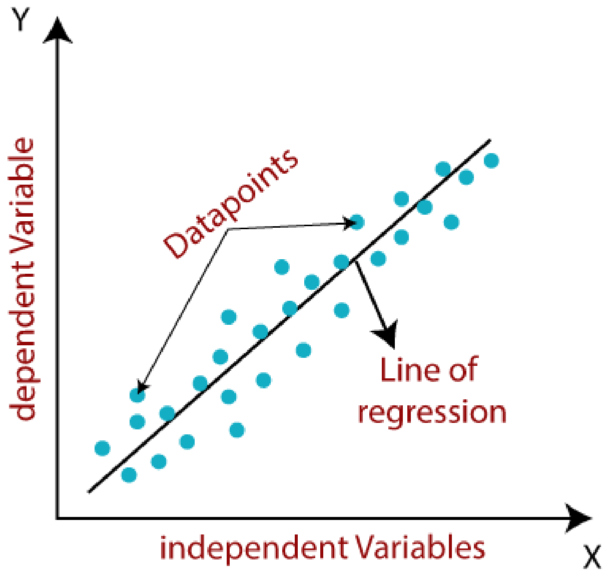


Machine Learning Algorithms



Linear Regression

- It is a statistical method that is used for predictive analysis. Linear regression makes predictions for continuous/real or numeric variables such as sales, salary, age, price, etc.
- Linear regression algorithm shows a linear relationship between a dependent (y) and one or more independent (y) variables, hence called as linear regression.



Linear Regression

The formula for a simple linear regression is:

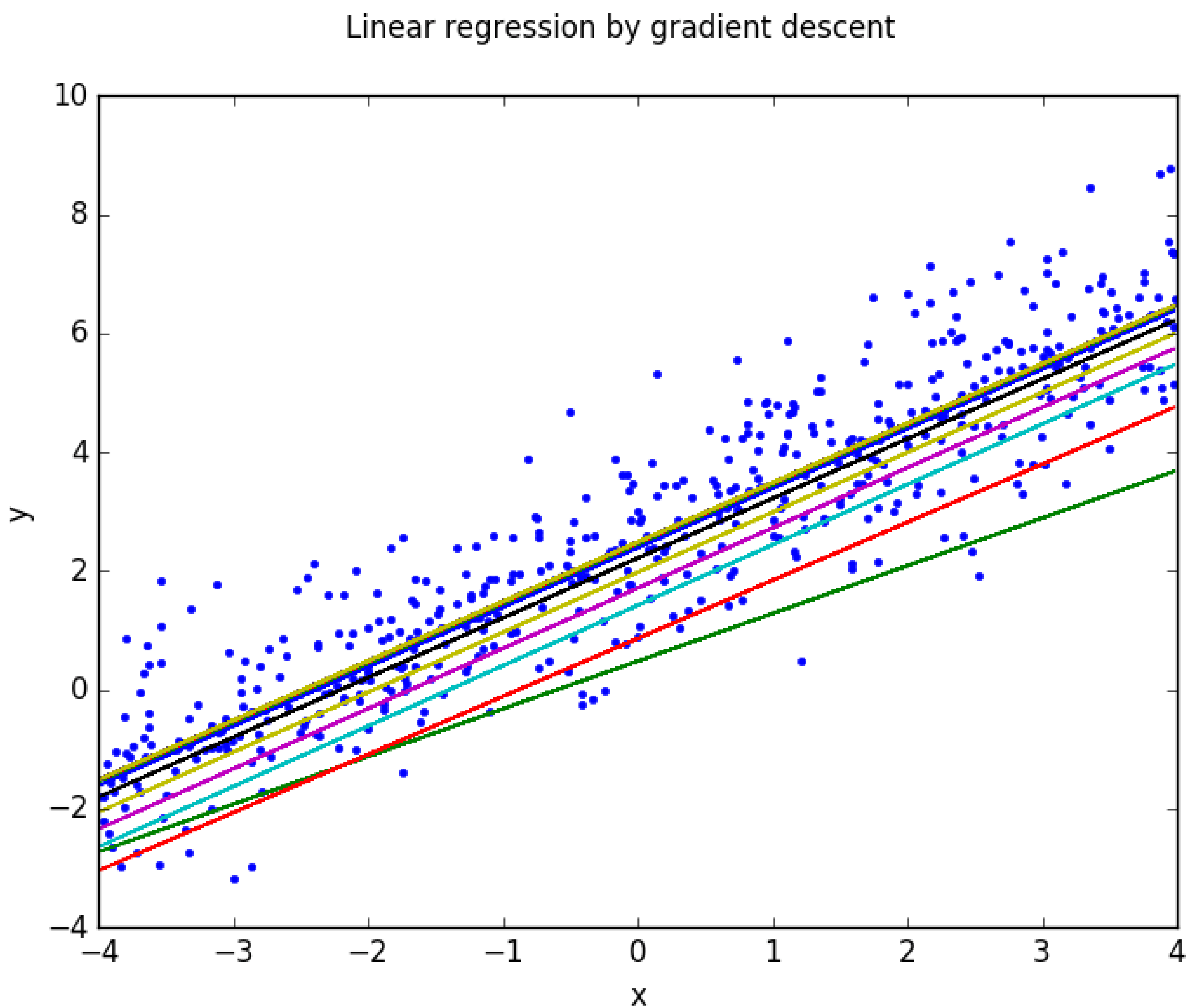
$$y = \beta_0 + \beta_1 X + \varepsilon$$

- **y** is the predicted value of the dependent variable (**y**) for any given value of the independent variable (**x**).
- $\mathbf{B_0}$ is the **intercept**, the predicted value of **y** when the **x** is 0.
- $\mathbf{B_1}$ is the regression coefficient – how much we expect **y** to change as **x** increases.
- **x** is the independent variable (the variable we expect is influencing **y**).
- **e** is the **error** of the estimate, or how much variation there is in our estimate of the regression coefficient.

Linear Regression

- When working with linear regression, our main goal is to find the best fit line that means the error between predicted values and actual values should be minimized. The best fit line will have the least error.

- The different values for weights or the coefficient of lines (β_0, β_1) gives a different line of regression, so we need to calculate the best values for β_0 and β_1 to find the best fit line, so to calculate this we use **cost function**.


Linear regression by gradient descent
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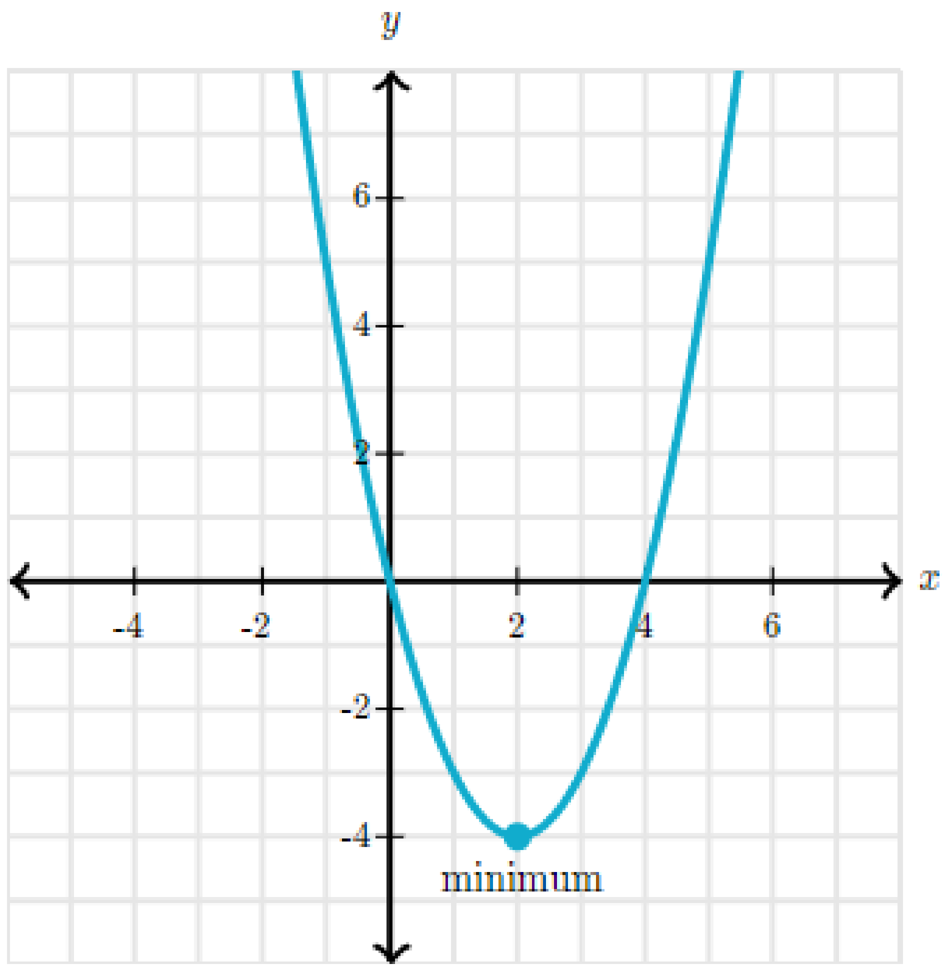
Gradient Descent

- Gradient descent is an algorithm that **numerically estimates** where a function outputs its lowest values.

- That means it finds local minima, but not by setting f=0. Instead of finding minima by manipulating symbols, gradient descent approximates the solution with numbers.

Gradient Descent

- $f(x) = x^2 - 4x$



Gradient Descent

$$x_{n+1} = x_n - \alpha \nabla F(x_n)$$

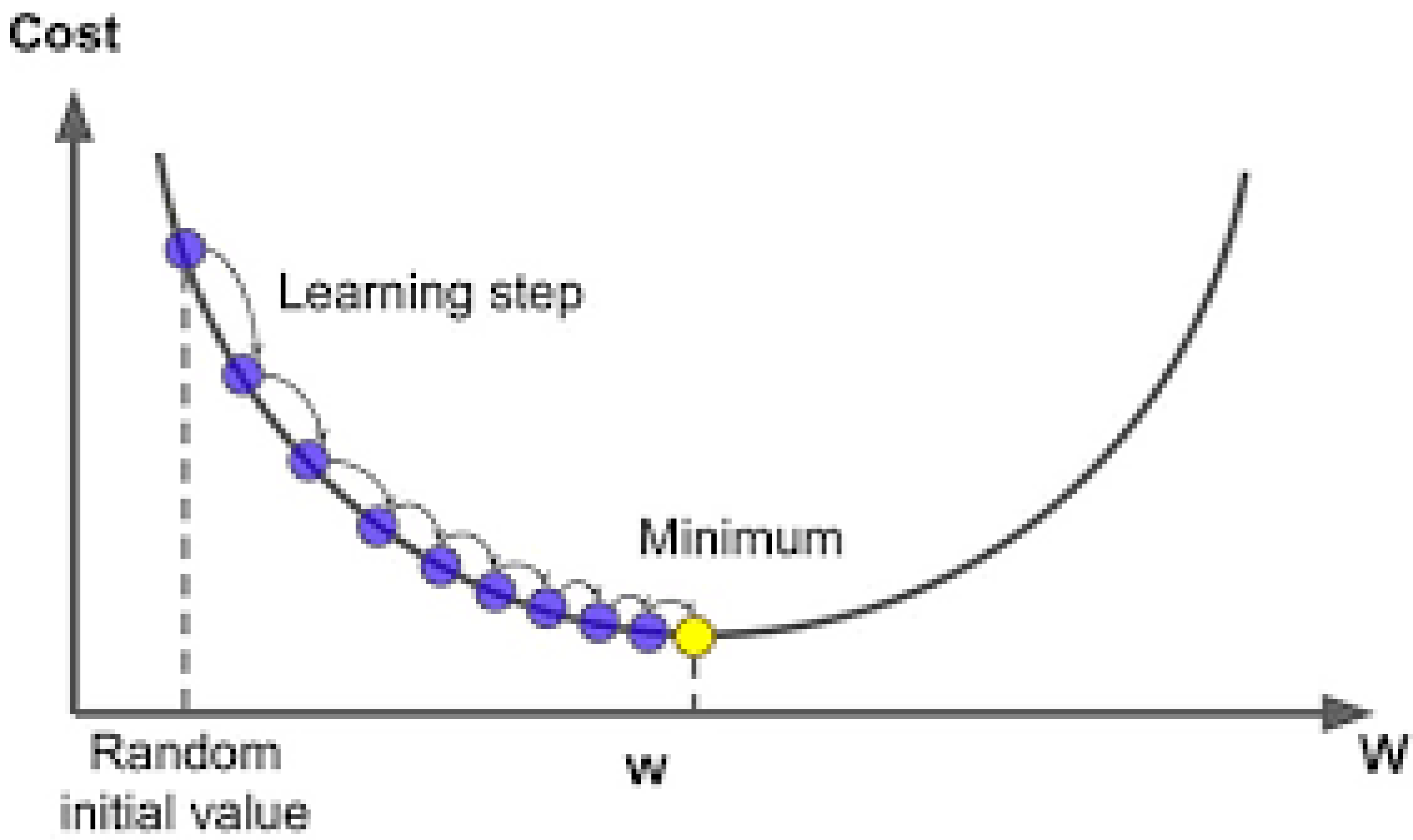
$$F(x_n) = x^2$$

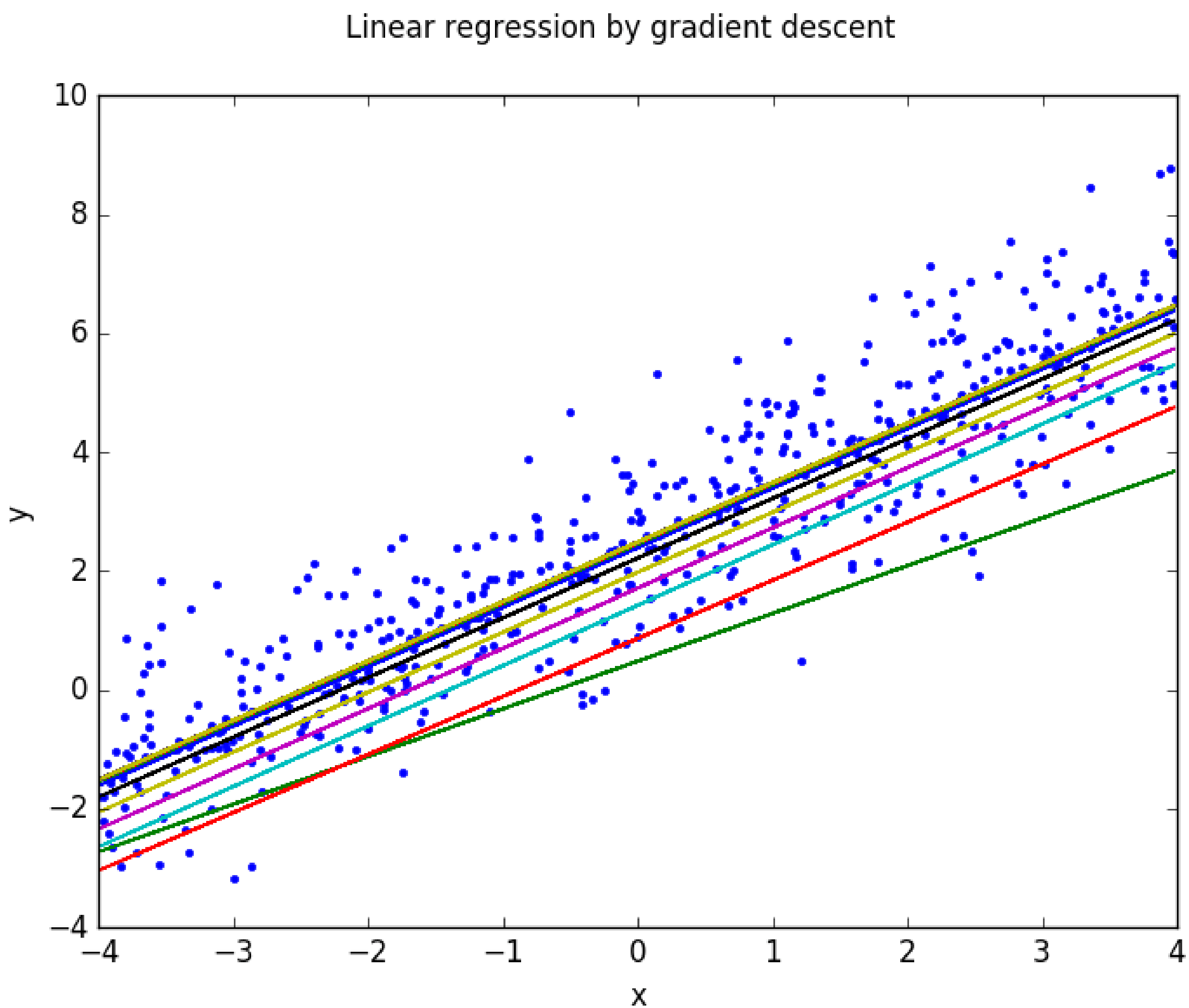
We calculate $\nabla F(x_n)$:

$$\nabla F(x_n) = \frac{\partial F(x_n)}{\partial x_n} = 2x_n$$

$$\Rightarrow x_{n+1} = x_n - \alpha \cdot 2x_n$$

Gradient Descent





Linear regression by gradient descent
10
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Linear Regression: Cost Function

- The different values for weights or coefficient of lines (β_0, β_1) gives the different line of regression, and the cost function is used to estimate the values of the coefficient for the best fit line.

- Cost function optimizes the regression coefficients or weights. It measures how a linear regression model is performing.

- We can use the cost function to find the accuracy of the mapping function, which maps the input variable to the output variable.

Linear Regression: Cost Function

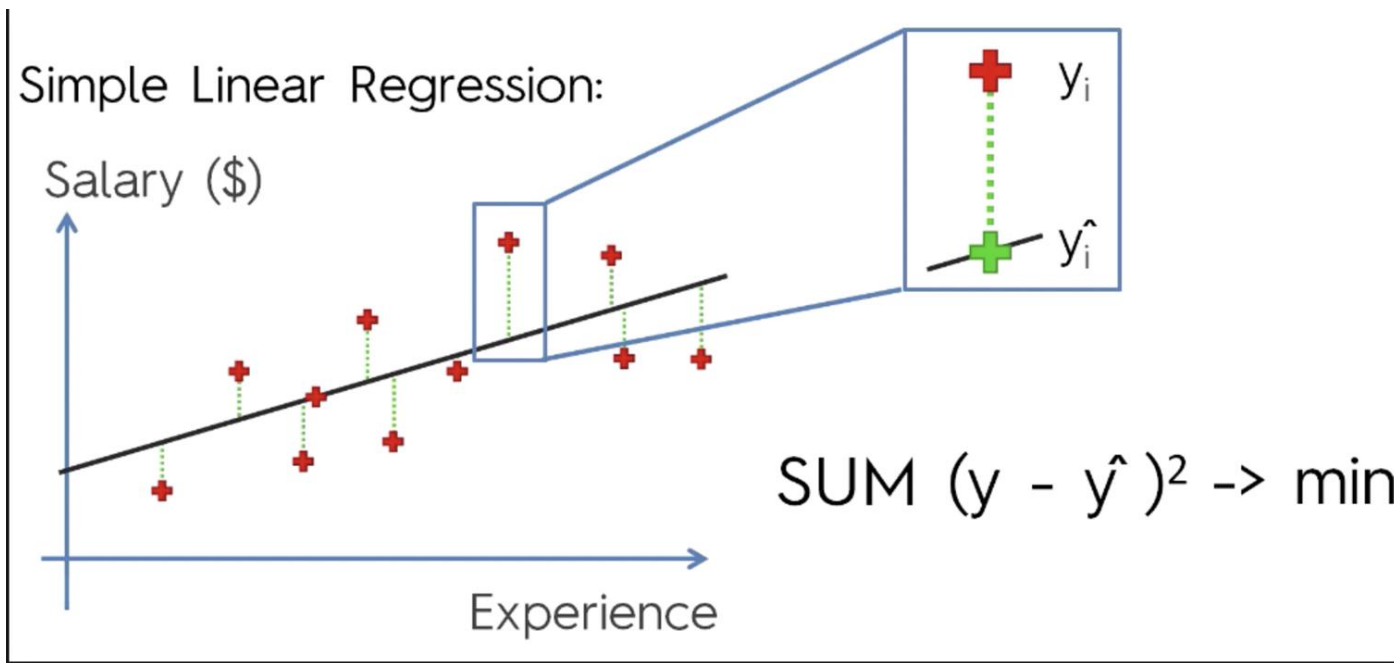
- For Linear Regression, we use the Mean Squared Error (MSE) cost function, which is the average of squared error occurred between the predicted values and actual values.

$$error = (guess - actual)$$

$$MSE = \frac{1}{n} \Sigma \underbrace{\left(y - \widehat{y} \right)^2}_{\text{The square of the difference between actual and predicted}}$$

Linear Regression: Cost Function

$$MSE = \frac{1}{n}\Sigma\left(\underbrace{y - \widehat{y}}_{\text{The square of the difference between actual and predicted}}\right)^2$$



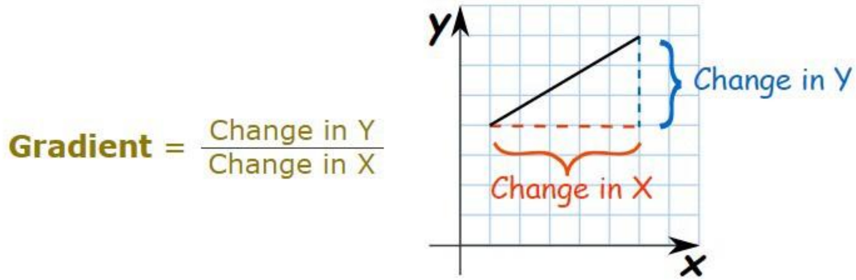
Linear Regression: Gradient Descent:

- Gradient descent is used to minimize the MSE by calculating the gradient of the cost function.
- A regression model uses gradient descent to update the coefficients of the line by reducing the cost function.
- It is done by a random selection of values of coefficient and then iteratively update the values to reach the minimum cost function.

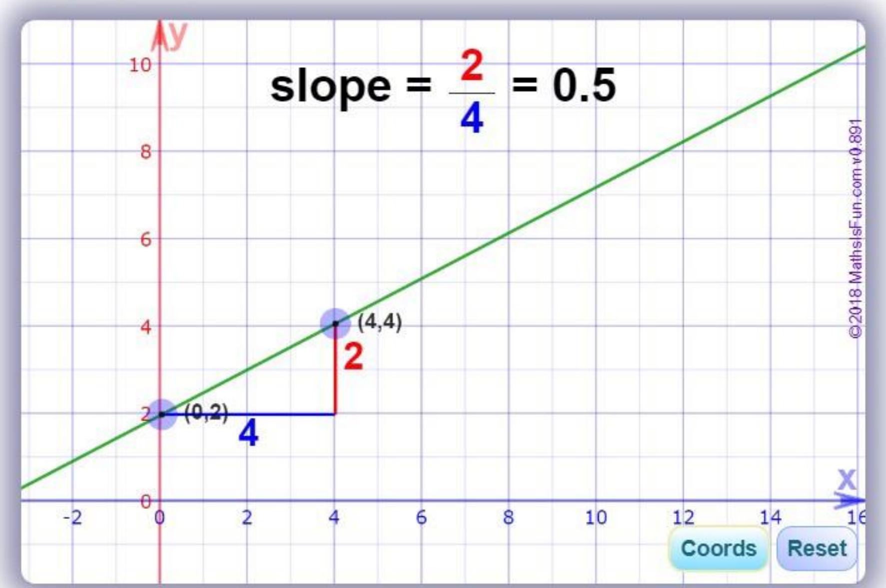
- Gradient:
  - An inclined part of a road or railway; a slope.
  - An increase or decrease in the magnitude of a property (e.g. temperature, pressure, or concentration) observed in passing from one point or moment to another.

Linear Regression: Gradient Descent:

- Optimization algorithm that tweaks its parameters iteratively.

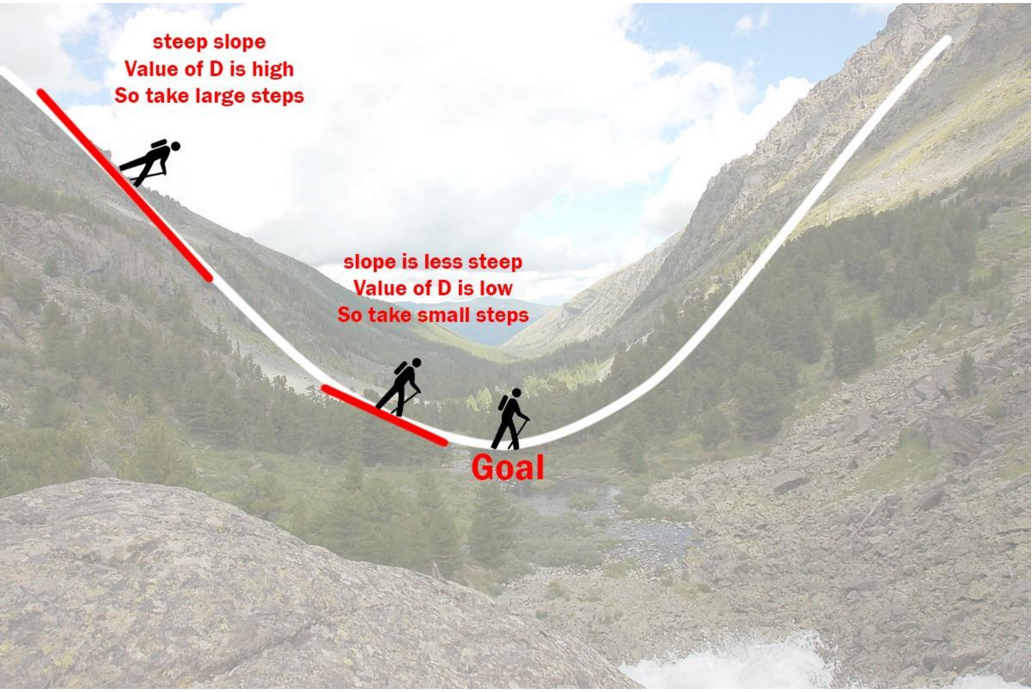


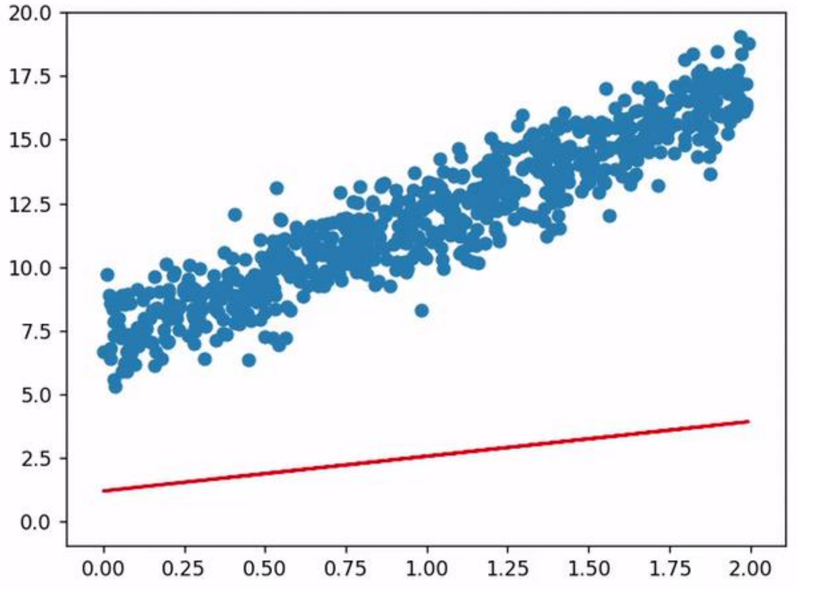
Have a play (drag the points):



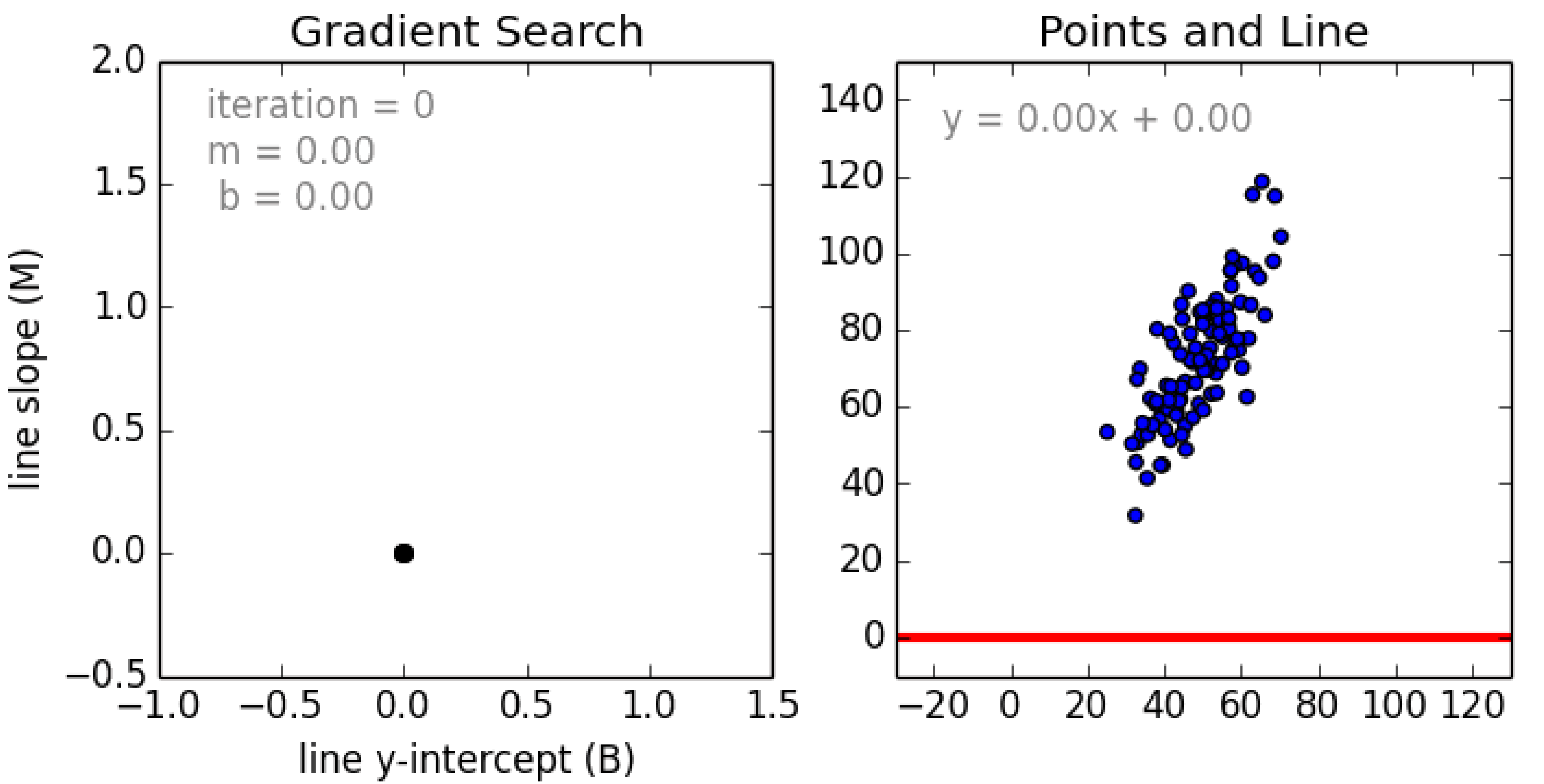
Linear Regression: Gradient Descent:

- Optimization algorithm that tweaks its parameters iteratively.





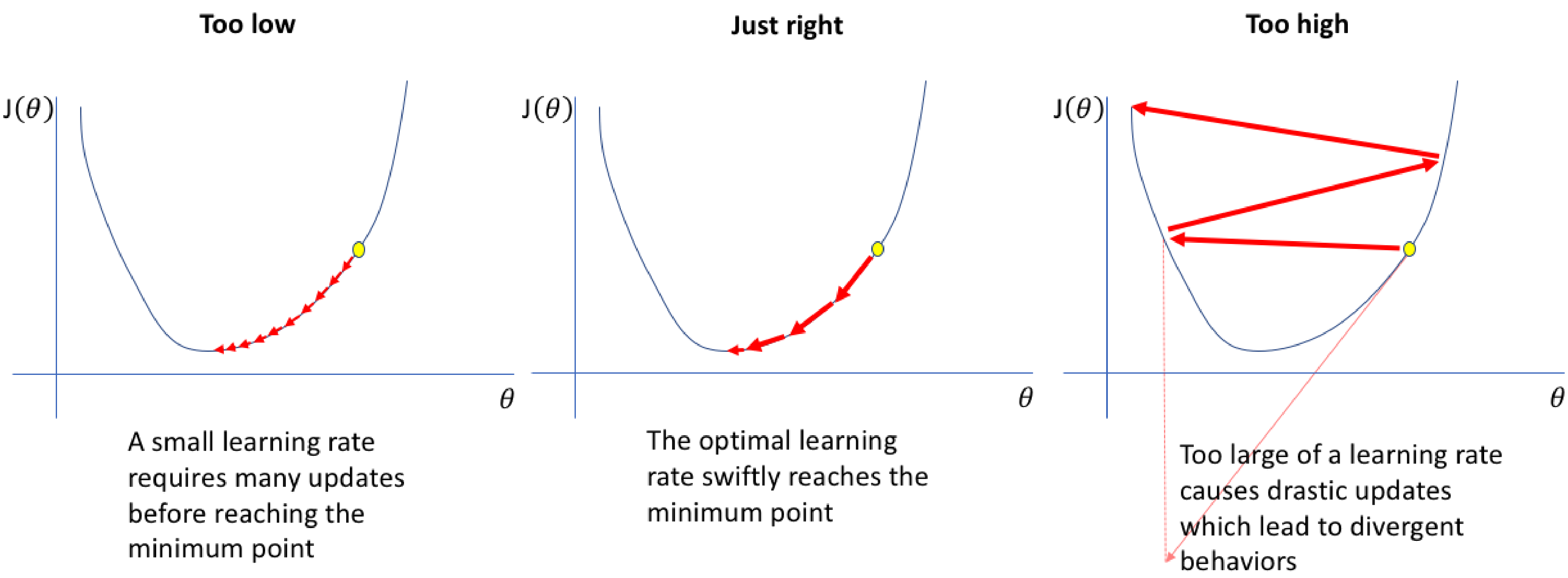
Linear Regression: Finding Gradient Descent:



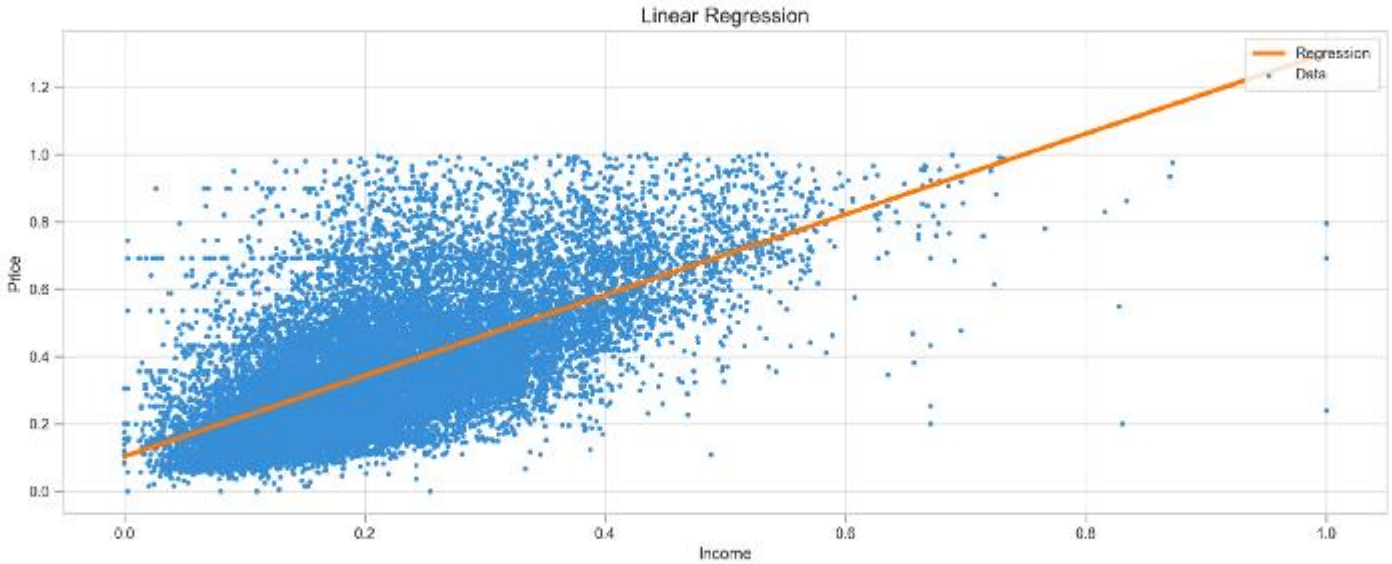
Source: https://raw.githubusercontent.com/mattnedrich/GradientDescentExample/master/gradient_descent_example.gif?source=post_page---------------------------

Linear Regression: Gradient Descent: Learning Rate

- Optimization algorithm that tweaks its parameters iteratively.



Linear Regression: Finding Gradient Descent:



$$\hat{y} = mx + b$$

$$MSE = \frac{1}{n} \sum_{i=1}^{n} (y_i - \hat{y}_i)^2 \quad \text{where} \quad \hat{y}_i = mx_i + b$$

Linear Regression: Finding Gradient Descent:

We use partial derivatives to find how each individual parameter affects MSE, so that's where word partial comes from. We take these derivatives with respect to m and b separately.

$$f(m, b) = \frac{1}{n} \sum_{i=1}^{n} (y_i - (mx_i + b))^2$$

$$\frac{\partial f}{\partial m} = \frac{1}{n} \sum_{i=1}^{n} -2x_i(y_i - (mx_i + b))$$

$$\frac{\partial f}{\partial b} = \frac{1}{n} \sum_{i=1}^{n} -2(y_i - (mx_i + b))$$

Linear Regression: Finding Gradient Descent:

$$D_m = \frac{\partial(Cost\ Function)}{\partial m} = \frac{\partial}{\partial m}\left(\frac{1}{n}\sum_{i=0}^{n}\left(y_i - y_{i\,pred}\right)^2\right)$$

$$= \frac{1}{n}\frac{\partial}{\partial m}\left(\sum_{i=0}^{n}\left(y_i - (mx_i + c)\right)^2\right)$$

$$= \frac{1}{n}\frac{\partial}{\partial m}\left(\sum_{i=0}^{n}\left(y_i^2 + m^2x_i^2 + c^2 + 2mx_ic - 2y_imx_i - 2y_ic\right)\right)$$

$$= \frac{-2}{n}\sum_{i=0}^{n}x_i\left(y_i - (mx_i + c)\right)$$

$$= \frac{-2}{n}\sum_{i=0}^{n}x_i\left(y_i - y_{i\,pred}\right)$$

Linear Regression: Finding Gradient Descent:

$$D_c = \frac{\partial(Cost\ Function)}{\partial c} = \frac{\partial}{\partial c}\left(\frac{1}{n}\sum_{i=0}^{n}\left(y_i - y_{i\,pred}\right)^2\right)$$

$$= \frac{1}{n}\frac{\partial}{\partial c}\left(\sum_{i=0}^{n}\left(y_i - (mx_i + c)\right)^2\right)$$

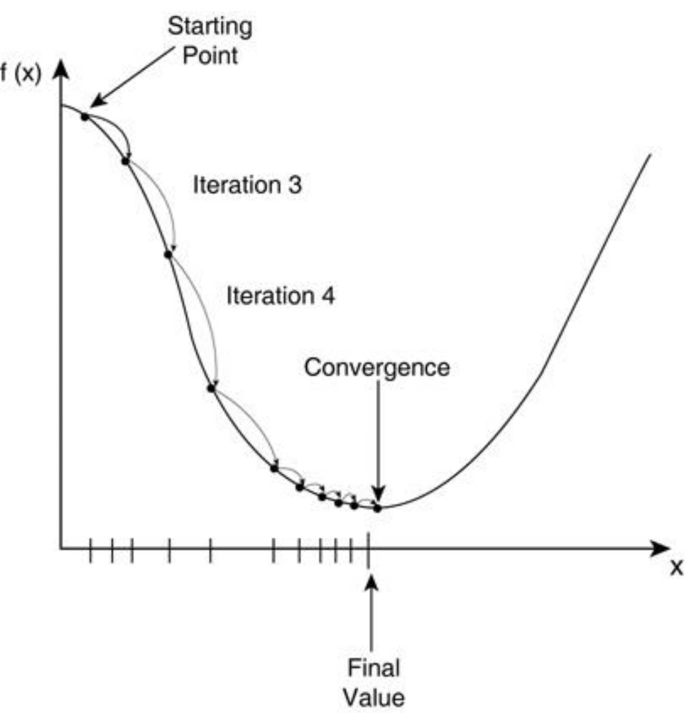
$$= \frac{1}{n}\frac{\partial}{\partial c}\left(\sum_{i=0}^{n}\left(y_i^2 + m^2x_i^2 + c^2 + 2mx_ic - 2y_imx_i - 2y_ic\right)\right)$$

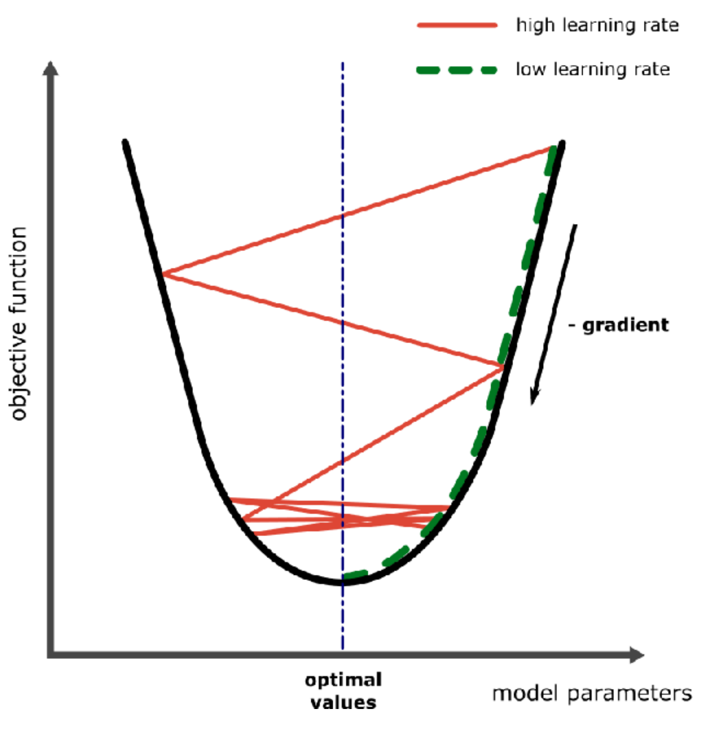
$$= \frac{-2}{n}\sum_{i=0}^{n}\left(y_i - (mx_i + c)\right)$$

$$\frac{-2}{n}\sum_{i=0}^{n}\left(y_i - y_{i\,pred}\right)$$

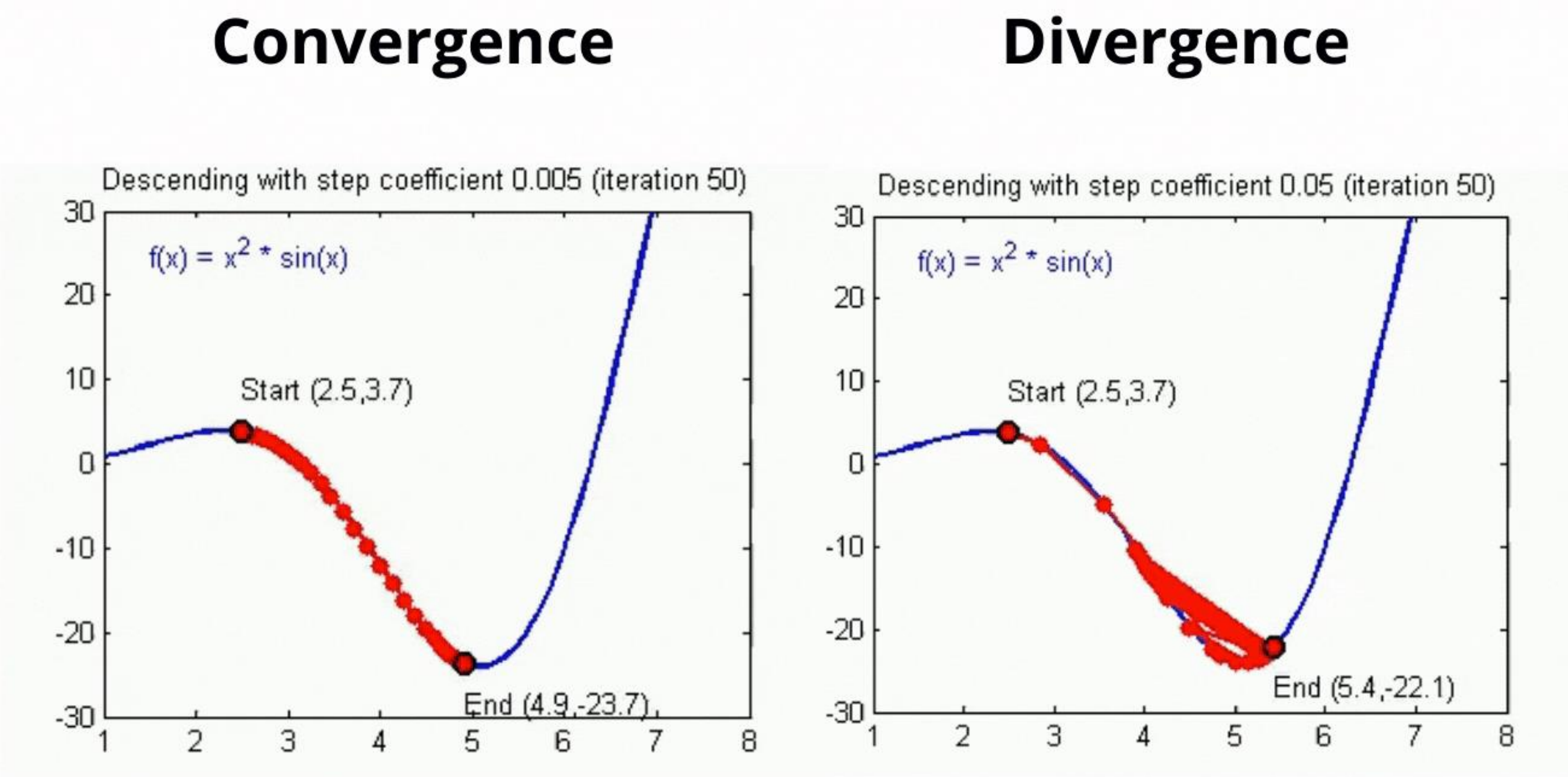
Linear Regression: Finding Gradient Descent:

Convergence: Property of approaching a limit more and more closely as an argument (variable) of the function increases or decreases. For example, the function y = 1/x converges to zero as x increases.





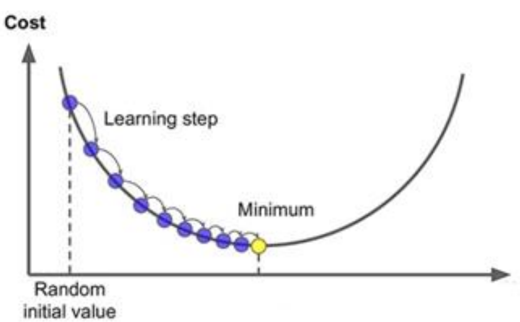
Linear Regression: Finding Gradient Descent:

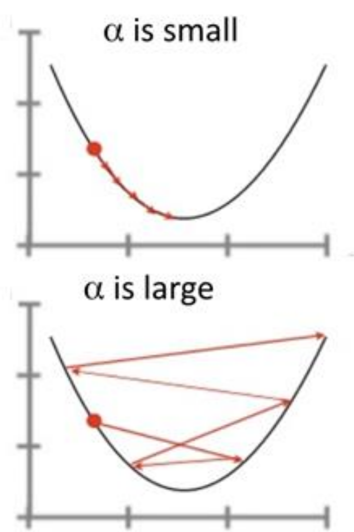


Linear Regression: Finding Gradient Descent:

$$\text{Repeat until converge}\{x := x - \alpha \nabla F(x)\}$$

- The notation := stands for overwriting the value on the left of := with values on the right of := .
- ∇ stands for the gradient of a function, which is the collection of all its partial derivatives into a vector (taking the first derivative of the function with respect to all possible x).
- α stands for the learning rate which is set manually.





$$X = X - lr * \frac{d}{dX} f(X)$$

Where,

$X \quad = \; input$

$F(X) \; = \; output \;\; based \; on \; X$

$lr \quad = \; learning \; rate$

Gradient Descent Algorithm

STEP 1: Take some random values for the coefficients m and b and calculate the MSE (cost function).

STEP 2: Calculate the partial derivatives of MSE with respect to m and b.

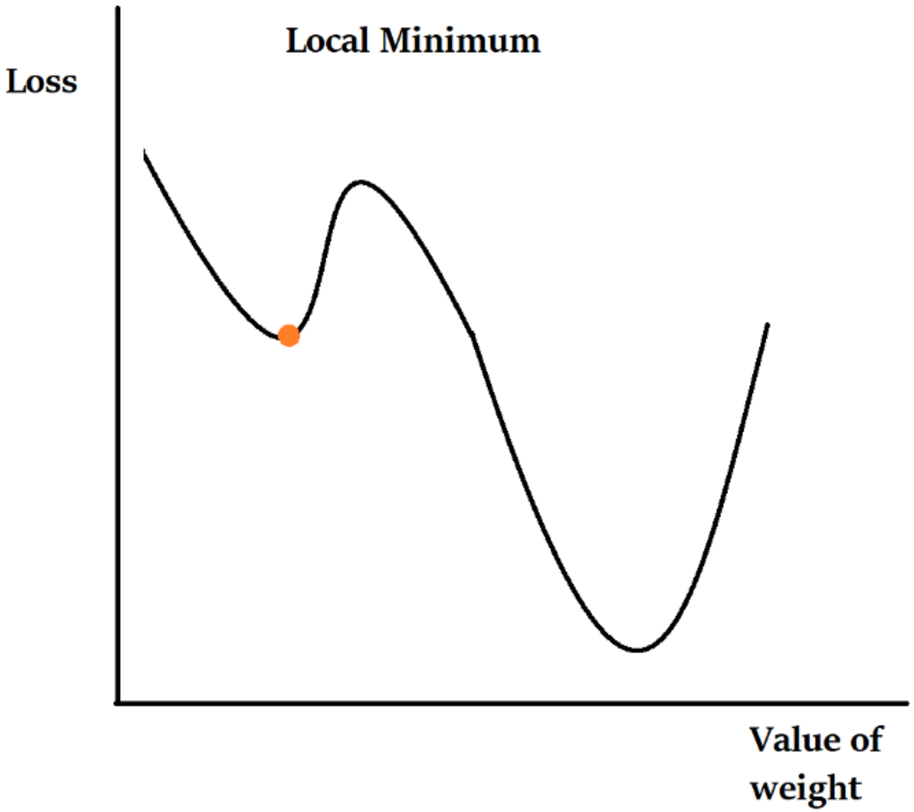
STEP 3: Set a value for the learning rate. And calculate the change in m and b using the following formula.

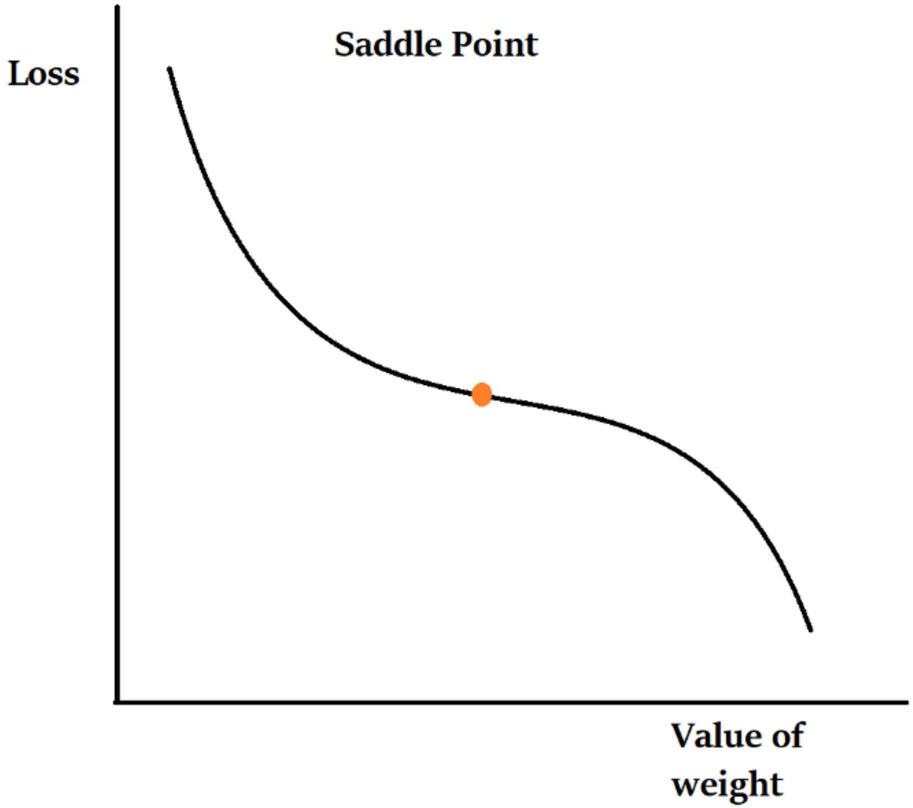
- m = m — learning rate * ∂/∂m = m — α * ∂/∂m
- b = b — learning rate * ∂/∂b = b — α * ∂/∂b

STEP 4: Use these values of m and b to calculate the new MSE.

STEP 5: Repeat steps 2, 3 and 4 until the changes in m and b do not significantly reduce the MSE (cost).

Linear Regression: Finding Gradient Descent:





Linear Regression: Gradient Descent:

Implementation in Python

Summary

- Basics of Machine Learning