Embedded AI

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PhD Computer Science & Engineering

Course Contents

- AI Fundamentals
- Supervised Learning, Unsupervised Learning, Ensemble Techniques, Time Series Forecasting, Neural Networks and Deep Learning
- Embedded AI applications
- Embedded AI frameworks
- Feature Engineering, Model Selection & Tuning
- Development and Deployment of embedded ML models
- Case Study on Embedded AI

Trainer Introduction

- **Name**: Dr. Akshita S. Chanchlani
- **Designation** : Associate Head - Technical
- **Education** :
  - PhD : Computer Science and Engineering
  - Masters of Engineering (ME) in Information Technology
  - B.Tech in Computer Engineering, From VJTI Mumbai
- **Training Experience**
  - PreCAT Batches at Sunbeam
  - PG Courses: Core Java, Python, Data Structure
  - Modular Batches : Core Java , Python , Machine Learning
  - Internship : Python, Machine Learning
- **Professional Experience**
  - **13+ years**
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Pre-requisites

- Python Language Experience
  - Scripting
  - Operations
  - Functions
  - Packages
- Introduction to Statistics (basics about Differential[mean, median, mode] and Inferential[hypothesis])
  - What is data ?
  - Population vs Sample
  - Types of Data

Day1 Agenda

- Introduction to data science
- AI, ML, DL, ML Applications
- ML Program
- Types of ML
  - Supervised
  - Unsupervised
  - Reinforcement
- End to end process
- Covariance and Correlation
- Regression Analysis

Data Science

What is Data Science ?

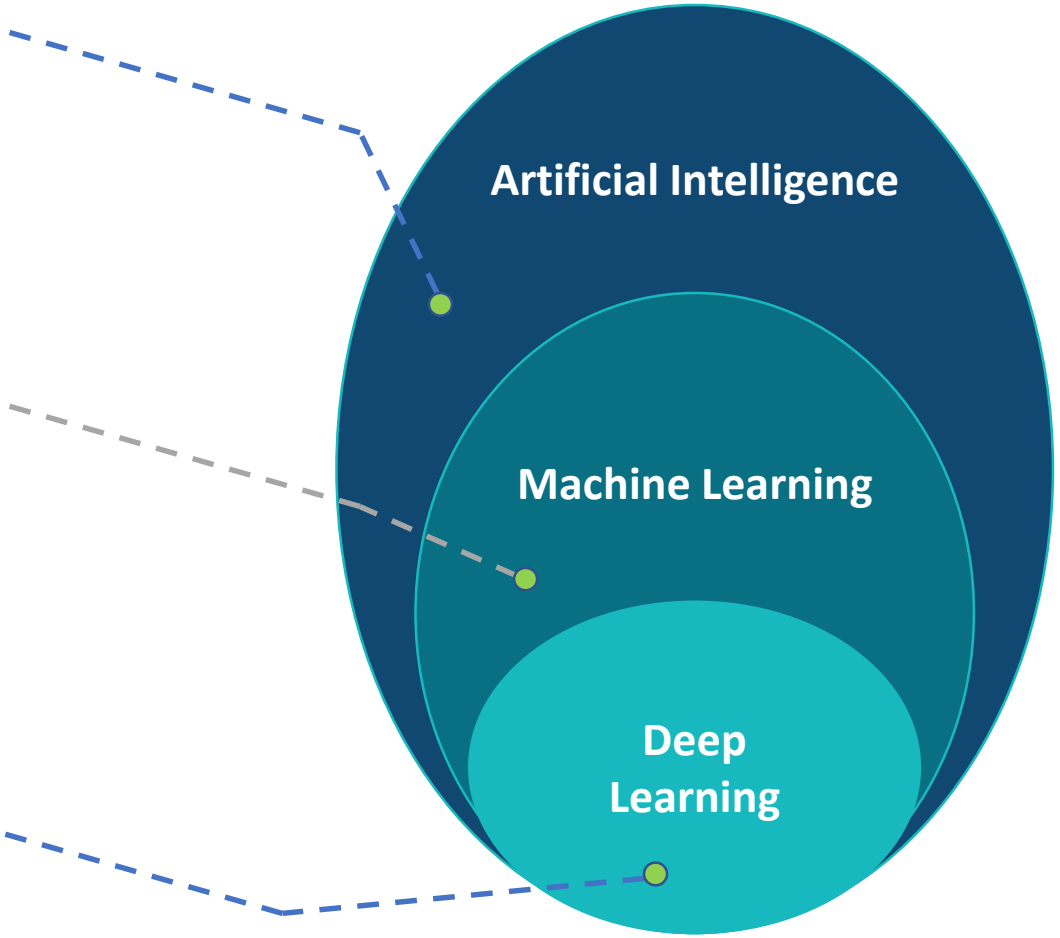
- Data science is an inter-disciplinary field that uses scientific methods, processes, algorithms and systems to extract knowledge and insights from many structural and unstructured data.
- Data science is related to data mining, machine learning and big data
- Data science is a "concept to unify statistics, data analysis and their related methods" in order to "understand and analyze actual phenomena" with data

AI, ML, DL

Artificial Intelligence:
- A technique which enables machine to mimic human behavior

Machine Learning:
- Subset of AI which uses statistical methods to enable machines to improve the experience

Deep Learning:
- Subset of ML which makes the computation of multi-layer neural network feasible



Artificial Intelligence

What is AI?

- Artificial Intelligence (AI), sometimes called machine intelligence, is intelligence demonstrated by machines, in contrast to the natural intelligence displayed by humans
- Any device that perceives its environment and takes actions that maximize its chance of successfully achieving its goals
- The theory and development of computer system able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision making and translation
- Often used to describe machines (or computers) that mimic "cognitive" functions that humans associate with the human mind, such as "learning" and "problem solving”

AI applications

- Google’s search engine
- JPMorgan Chase’s Contract Intelligence (COiN) platform uses AI, machine learning and image recognition software to analyse legal documents
- IBM Watson: Healthcare organizations use IBM AI (Watson) technology for medial diagnosis
- Google’s AI Eye Doctor can examine retina scans and identify a condition called as diabetic retinopathy which can cause blindness
- Facebook uses ML and DL to detect facial features and tag your friends
- Twitter uses AI to identify hate speech and terroristic language in the tweets
- Smart Assistants: Siri, Google Assistant, Alexa, Cortana
- Tesla automated cars
- Netflix uses AI for movie recommendations
- Spam filtering

Machine Learning

What is machine learning ?

- A computer program is said to learn from experience E with respect to some task T and some performance measure P, if its performance on T, as measured by P, improves with experience E
  - Tom Mitchell, 1997

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

- Machine Learning is the science (and art) of programming computers so they can learn from data

Examples of Applications

- Analyzing images of products on a production line to automatically classify them
  - This is image classification, typically performed using convolutional neural networks
- Detecting tumors in brain scans
  - This is semantic segmentation, where each pixel in the image is classified (typically use CNNs)
- Automatically classifying news articles
  - This is natural language processing (NLP), and more specifically text classification
- Automatically flagging offensive comments on discussion forums
  - This is also text classification, using the same NLP tools
- Forecasting your company's revenue next year, based on many performance metrics
  - This is a regression task (i.e., predicting values) that may be tackled using any regression model
- Making your app react to voice commands
  - This is speech recognition, which requires processing audio samples: since they are long and complex sequences, they are typically processed using RNNs, CNNs, or Transformers

Examples of Applications

- Detecting credit card fraud
  - This is anomaly detection example
- Segmenting clients based on their purchases so that you can design a different marketing strategy for each segment
  - This is clustering example
- Representing a complex, high-dimensional dataset in a clear and insightful diagram
  - This is data visualization, often involving dimensionality reduction techniques
- Recommending a product that a client may be interested in, based on past purchases
  - This is a recommender system
- Building an intelligent bot for a game
  - This is often tackled using Reinforcement Learning

Take an Example

x	Y
1	1
2	4
3	9
4	16
5	25
8	??

$y = x^2$

Formula / Model / Function

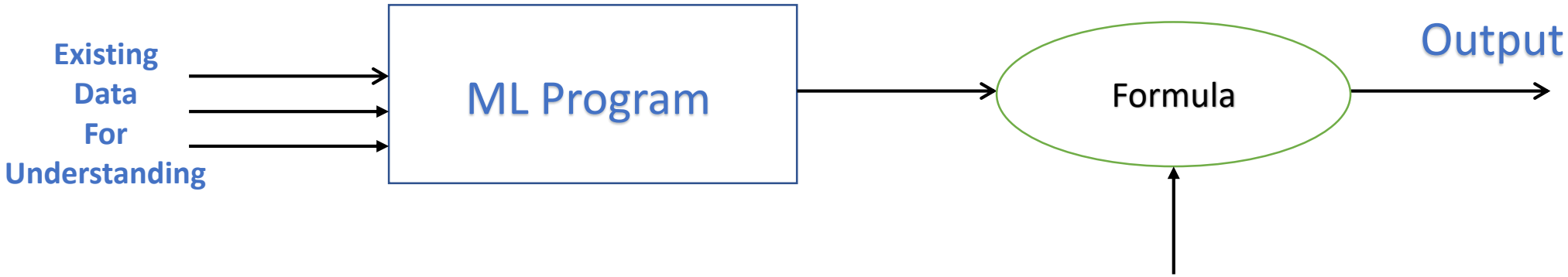
$= 8^2$

$= 64$

ML Program

Non ML Programming

ML Programming



Where to use machine learning ?

- Problems for which existing solutions require a lot of fine-tuning or long lists of rules:
  - one Machine Learning algorithm can often simplify code and perform better than the traditional approach
- Complex problems for which using a traditional approach yields no good solution:
  - the best Machine Learning techniques can perhaps find a solution
- Fluctuating environments:
  - a Machine Learning system can adapt to new data
- Getting insights about complex problems and large amounts of data

Types

Types of machine learning

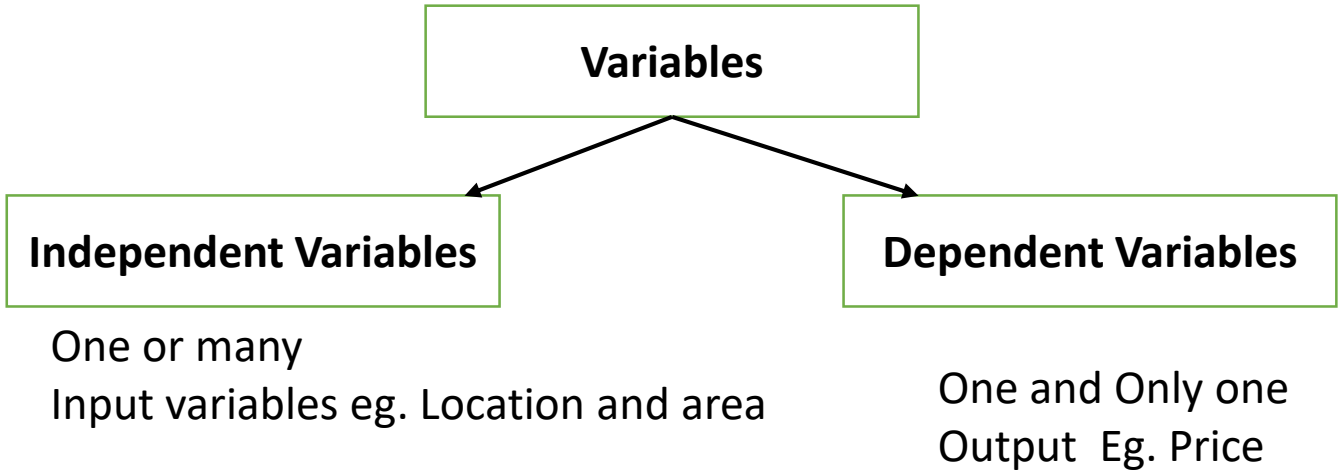
- There are so many different types of Machine Learning systems that it is useful to classify them in broad categories, based on the following criteria
  - Whether or not they are trained with human supervision
    - supervised, unsupervised, and Reinforcement Learning
  - Whether or not they can learn incrementally on the fly
    - online versus batch learning
  - Whether they work by simply comparing new data points to known data points, or instead by detecting patterns in the training data and building a predictive model, much like scientists do
    - instance-based versus model-based learning

Variable / Column / Feature

No.	Location	Area	Price
1	Pune	Abc	70
2	Mumbai	Pqr	90

Known Data
Or
Labelled Data

No. column not required
Location and Area are Independent variables
Price is Dependent Variable



Supervised
Unsupervised
Reinforcement Learning

Supervised Learning

- The majority of practical machine learning uses supervised learning
- 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

$$Y = f(X) \quad \Rightarrow \quad \text{model / formula} \quad ,$$

- 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
- It is called supervised learning because 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 (measured in terms of **accuracy**)

Supervised Learning – Problems

- **Regression**
  - Related to predicting future values
  - E.g.
    - Population growth prediction
    - Expecting life expectancy
    - Market forecasting/prediction
    - Advertising Popularity prediction
    - Stock prediction
  - Algorithms
    - Linear and multi-linear regression
    - Logistic regression
    - Naïve Bayes
    - Support Vector Machine

Supervised Learning – Problems

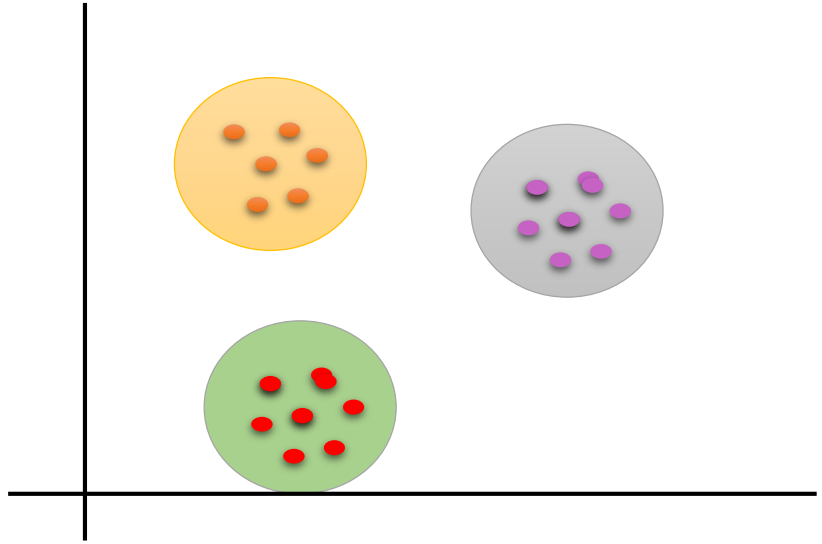
- **Classification**
  - Related to classify the records
  - Based on class / labels (eg. Email : Spam / Ham , Gender : Male / Female , Loan : Yes / No)
  - E.g.
    - Find whether an email received is a spam or ham
    - Identify customer segments
    - Find if a bank loan is granted
    - Identify if a kid will pass or fail in an examination
  - Algorithms
    - Logistic Regression
    - Decision Tree
    - Random Forest
    - Support Vector Machine
    - K-nearest neighbor

Unsupervised Learning

- Unsupervised learning is where you only have input data (X) and no corresponding output variables
- The goal for unsupervised learning is to model the underlying structure or distribution in the data in order to learn more about the data
- These are called unsupervised learning because unlike supervised learning above there is no correct answers and there is no teacher
- Algorithms are left to their own devises to discover and present the interesting **structure** in the data
- Structure in the form of GROUPS / CLUSTERS / ASSOCIATION
- Mostly used for EDA (Exploratory Data Analysis)

Unsupervised Learning - Problems

- **Clustering**
  - discover the inherent groupings in the data, such as grouping customers by purchasing behaviour
  - E.g.
    - Batsman vs bowler
    - Customer spending more money vs less money
  - Algorithms
    - K-means clustering
    - Hierarchical clustering



Unsupervised Learning - Problems

- **Association**
  - An association rule learning problem is where you want to discover rules that describe large portions of your data, such as people that buy X also tend to buy Y
  - E.g.
    - Market basket analysis
  - Algorithms
    - Apriori
    - Eclat

Reinforcement Learning

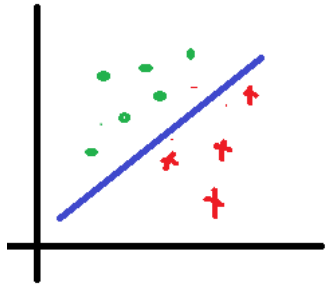
- It is about taking suitable action to maximize reward in a particular situation
- It is employed by various software and machines to find the best possible behaviour or path it should take in a specific situation
- Reinforcement learning differs from the supervised learning in a way that in supervised learning the training data has the answer key with it so the model is trained with the correct answer itself whereas in reinforcement learning, there is no answer but the reinforcement agent decides what to do to perform the given task
- In the absence of training dataset, it is bound to learn from its experience

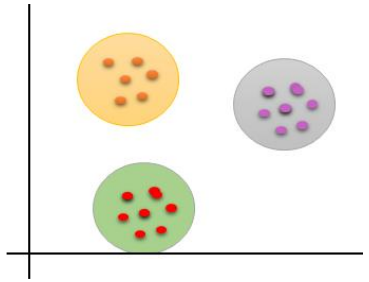
Reinforcement Learning

- Examples
  - Resources management in computer clusters
  - Traffic Light Control
  - Robotics
  - Web system configuration
  - Chemistry
- Algorithms
  - Q-Learning
  - Deep Q-Learning

Machine Learning

- **Supervised**
  - Regression
  - Classification
- **UnSupervised**
  - Clustering
  - Rule Mining
- **Reinforcement**
  - Agent Based / Feedback Based





Association
Product1 -> product 2
Bread -> butter

Binary = 2 classes / labels
Multiclass means >2

End to End Process

Steps

- Look at the big picture
- Get the data
- Discover and visualize the data to gain insights (**Exploratory Data Analysis** (**EDA**))
- Prepare the data for Machine Learning algorithms
- Select a model and train it
- Fine-tune your model
- Present your solution
- Launch, monitor, and maintain your system

Look at the Big Picture

- Frame the Problem
  - The first question to ask your boss is what exactly the business objective is
  - Building a model is probably not the end goal
  - How does the company expect to use and benefit from this model?
  - Knowing the objective is important because it will determine
    - how you frame the problem
    - which algorithms you will select
    - which performance measure you will use to evaluate your model
    - how much effort you will spend tweaking it
- Select a Performance Measure
  - Your next step is to select a performance measure
  - A typical performance measure for **regression** problems is the **Root Mean Square Error (RMSE) and MAE(Mean Absolute Error)**
  - It gives an idea of how much error the system typically makes in its predictions, with a higher weight for large errors

Performance Measures

Regression

- RMSE (Root Mean Squared Error) :square root of Mean Squared error
- MAE (Mean Absolute Error) : the average of the absolute difference between the actual and predicted values in the dataset
- MSE :the average of the squared difference between the original and predicted values in the data set

$$RMSE = \sqrt{MSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(y_i - \hat{y})^2}$$

$$MAE = \frac{1}{N}\sum_{i=1}^{N}|y_i - \hat{y}|$$

$$MSE = \frac{1}{N}\sum_{i=1}^{N}(y_i - \hat{y})^2$$

Where,

$\hat{y}$ – *predicted value of* y

$\bar{y}$ – *mean value of* y

The lower value of MAE, MSE, and RMSE implies higher accuracy of a regression model

Performance Measures

Classification

- Accuracy Score : measures how often the classifier correctly predicts
- F1-Score : the harmonic mean of precision and recall.
- Confusion Matrix :It is a matrix of size 2×2 for binary classification with actual values on one axis and predicted on another

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

$$F1 = 2.\frac{Precision \times Recall}{Precision + Recall}$$

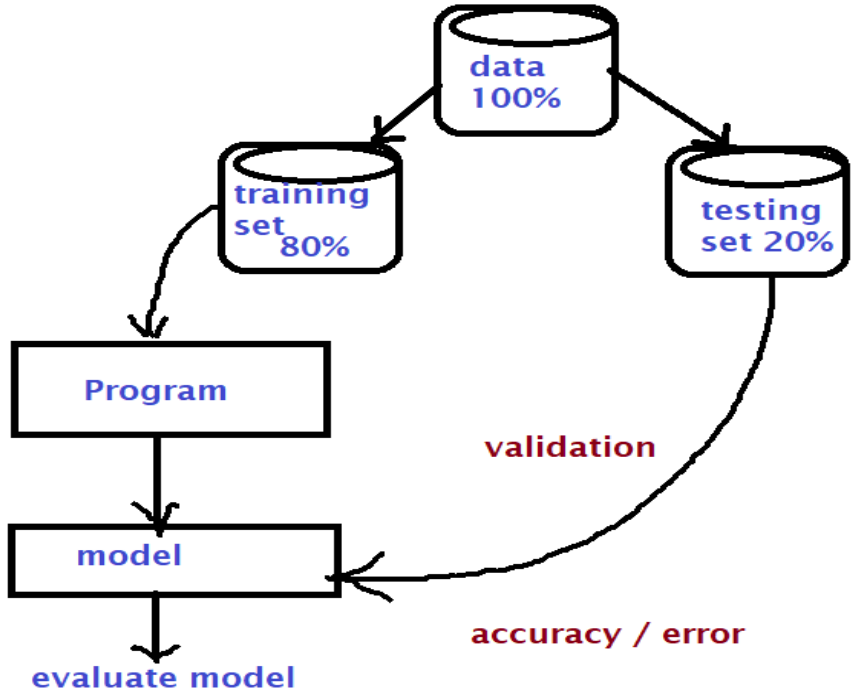
$$Precision = \frac{TruePositive}{TruePositive + FalsePositive}$$

$$Recall = \frac{TruePositive}{TruePositive + FalseNegative}$$

PREDICTION \ ACTUAL	Negative	Positive
Negative	TRUE NEGATIVE	FALSE NEGATIVE
Positive	FALSE POSITIVE	TRUE POSITIVE

Get the data

- Decide the data source (file / database / online /api)
- Download the data and make it available for the further learning
- Take a Quick Look at the Data Structure
  - Understand the data set (numeric / textual / categorical etc) and understand its features / columns /variables
  - Evaluate the features and decide which one(s) are nee
- Create a Test Set
  - Keep some records aside for testing and validation



Discover and Visualize the Data to Gain Insights

- Visualize the data
  - Use libraries like matplotlib or seaborn
  - Understand the pattern and relationship
- Look for correlation
- Experiment with attribute combinations

Prepare the Data for Machine Learning Algorithms

- Data Cleaning
  - Process of cleaning the data set to prepare it for ML algorithm
  - Steps
    - Check for the missing data
    - Check for wrong data types
    - Add features if needed
    - Remove unwanted features
- Feature Scaling
  - ML algorithms don’t perform well when the input numerical attributes have very different scale
  - Scale the features to bring all of them to a single scale
- Handle categorical / text data
  - Use transformers to convert categorical to numerical (eg. Label encoding / ordinal encoding etc)

Select and Train a Model

- Training the model using train data set
  - Create a model using selected algorithm
  - Save the model for future use
- Evaluation the model
  - Evaluate the model to see if there is any chance to improve the accuracy
  - Techniques
    - Cross Validation

Fine-Tune Your Model

- Grid Search
  - One option would be to fiddle with the hyperparameters manually, until you find a great combination of hyperparameter values
  - This would be very tedious work, and you may not have time to explore many combinations
  - You can also automate this process using libraries like sci-kit
- Randomized Search
  - The grid search approach is fine when you are exploring relatively few combinations
  - But when the hyperparameter search space is large, it is often preferable to use randomized search
- Ensemble Methods
  - Another way to fine-tune your system is to try to combine the models that perform best
  - The group (or “ensemble”) will often perform better than the best individual model, especially if the individual models make very different types of errors.
- Analyse the Best Models and Their Errors
- Evaluate Your System on the Test Set

Launch, Monitor, and Maintain Your System

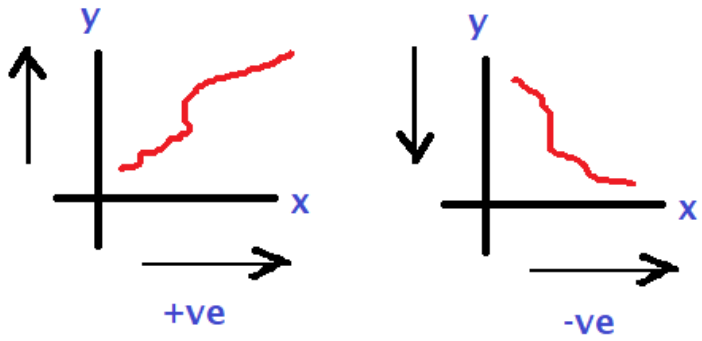
- Deploy the application for the end users
- Monitor the application's performance
- If the data keeps evolving, update your datasets and retrain your model regularly
- You should probably automate the whole process as much as possible
  - Collect fresh data regularly and label it
  - Write a script to train the model and fine-tune the hyperparameters automatically. This script could run automatically, for example every day or every week, depending on your needs
  - Write another script that will evaluate both the new model and the previous model on the updated test set, and deploy the model to production if the performance has not decreased (if it did, make sure you investigate why)

Covariance and Correlation

Terminology

- **Univariate**
  - This type of data consists of only one variable (eg. Temperature value)
  - It does not deal with causes or relationships
  - the main purpose of the analysis is to describe the data and find patterns that exist within it

- **Bivariate**
  - This type of data involves two different variables
  - The analysis of this type of data deals with causes and relationships
  - the analysis is done to find out the relationship among the two variables

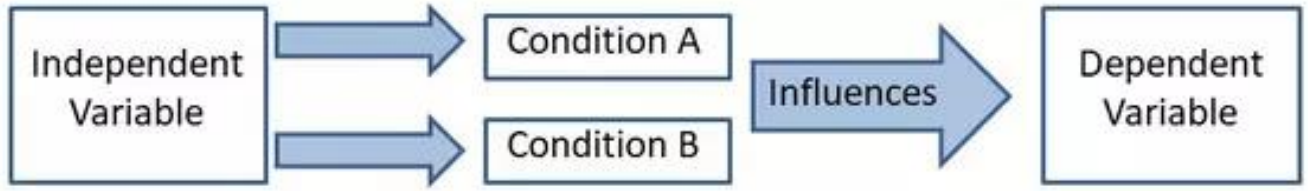


- **Multivariate**
  - When the data involves three or more variables
  - It is similar to bivariate but contains more than one independent variable

Terminology

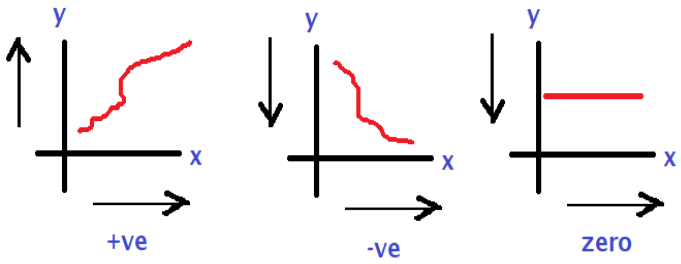
- **Independent variable(s)**
  - A variable that represents a quantity that is being manipulated in an experiment
  - **Represents input**
  - Also known as regressors in a statistical context.
  - x is often the variable used to represent the independent variable in an equation

- **Dependent variable**
  - A quantity whose value *depends* on how the independent variable is manipulated
  - **Represents output**
  - y is often the variable used to represent the independent variable in an equation



Covariance

- A measure of the relationship between two random variables
- The metric evaluates how much – to what extent – the variables change together
- A positive covariance would indicate a positive linear relationship between the variables
- A negative covariance would indicate the opposite



$$cov(x,y) = \frac{\sum(X_i - \mu)(Y_i - \mu)}{N}$$

Population

$$cov(x,y) = \frac{\sum(X_i - \overline{x})(Y_i - \overline{y})}{n}$$

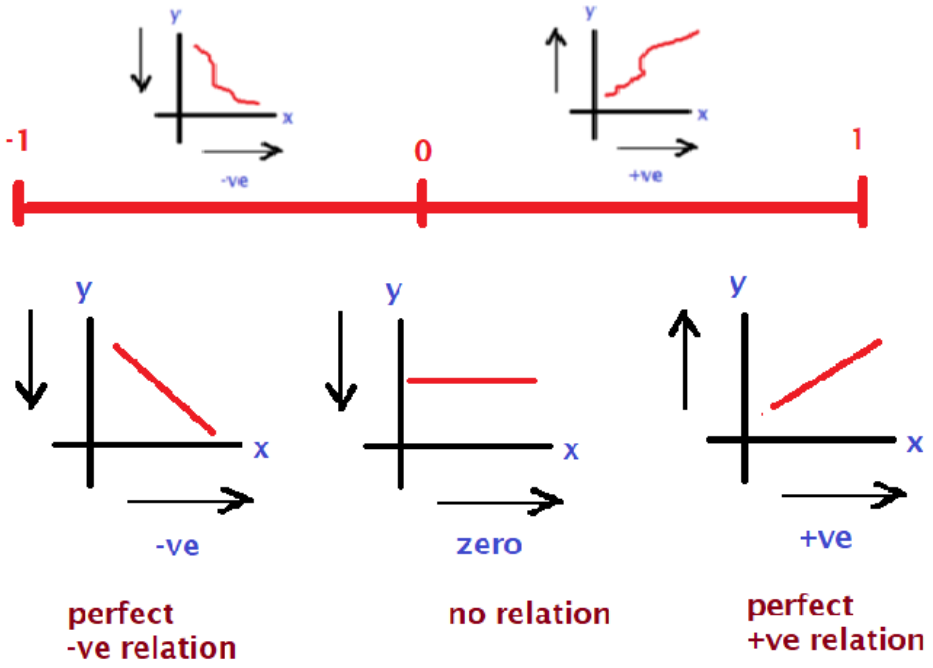
Sample

- Where
  - X_i – the values of the X-variable
  - Y_i – the values of the Y-variable
  - $\overline{x}$ – the mean (average) of the X-variable
  - $\overline{y}$ – the mean (average) of the Y-variable
  - n – the number of the data points in sample
  - N – the number of the data points in Population

Correlation

- Measures the strength of the relationship between variables
- Correlation is the scaled measure of covariance
- It is dimensionless: the correlation coefficient is always a pure value and not measured in any units

$$\rho(X,Y) = \frac{cov(X,Y)}{\sigma_x \sigma_y}$$



- Where
  - ρ(X,Y) – the correlation between the variables X and Y
  - cov(X,Y) – the covariance between the variables X and Y
  - σ_X – the standard deviation of the X-variable
  - σ_Y – the standard deviation of the Y-variable

Correlation coefficient

- Following are the ways to calculate correlation coefficient
  - Karl Pearson's coefficient of correlation
  - Spearman's Rank correlation
  - Scatter diagram
  - Coefficient of concurrent duration

- Correlation (r)
  - -1 <= r <= 1
  - r = 1 (perfect correlation)
  - r = -1 (perfect negative correlation)
  - r > 0 (positive correlation)
  - r < 0 (negative correlation)
  - r = 0 (no correlation)

Regression Analysis

What is regression analysis

- Regression analysis is a statistical method to model the relationship between a dependent (target) and independent (predictor) variables with one or more independent variables.
- Regression analysis helps us to understand how the value of the dependent variable is changing corresponding to an independent variable when other independent variables are held fixed.
- It predicts continuous/real values such as **temperature, age, salary, price,** etc.
- In Regression, we plot a graph between the variables which best fits the given datapoints, using this plot, the machine learning model can make predictions about the data.
- ***Regression shows a line or curve that passes through all the data points on target-predictor graph in such a way that the vertical distance between the data points and the regression line is minimum.***

What is regression analysis

- Linear regression is a basic and commonly used type of predictive analysis
- The dictionary meaning of the word Regression is ‘Stepping back’ or ‘Going back’
- Set of statistical processes for estimating the relationships between a dependent variable and one or more independent variables
- It attempts to establish the functional relationship between the variables and thereby provide a mechanism for prediction or forecasting
- The overall idea of regression is to examine two things
  - does a set of predictor variables do a good job in predicting an outcome (dependent) variable?
  - Which variables in particular are significant predictors of the outcome variable, and in what way do they– indicated by the magnitude and sign of the beta estimates–impact the outcome variable?
- These regression estimates are used to explain the relationship between one dependent variable and one or more independent variables

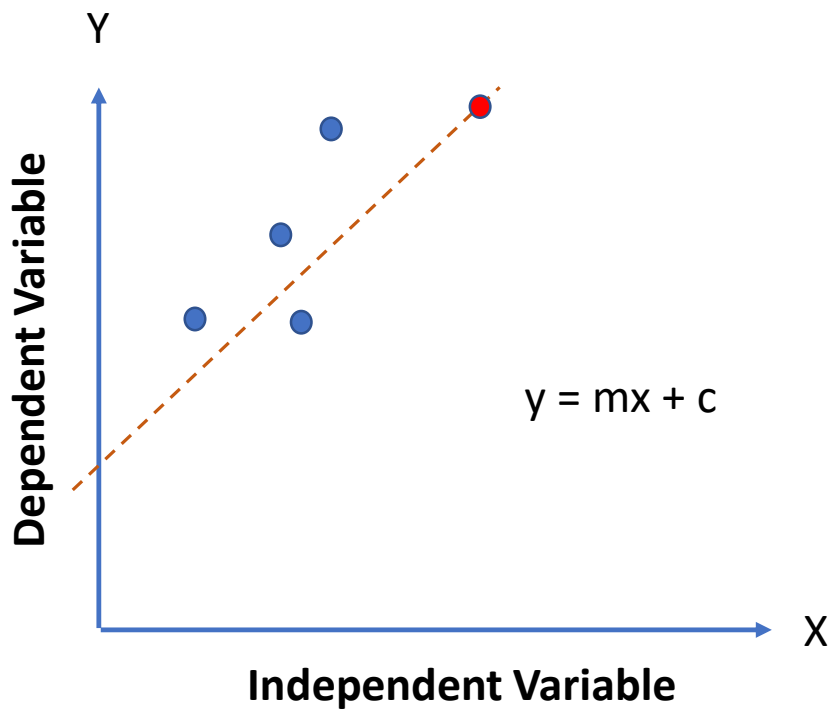
Applications of regression analysis

- It helps in the formulation and determination of functional relationship between two or more variables
- It helps in establishing a cause and effect relationship between two variables in economics and business research
- It helps in predicting and estimating the value of dependent variable as price production sales etc
- It helps to measure the variability or spread of values of a dependent variable with respect to the **regression line**
- In the field of business regression is widely used by businessmen in
  - Predicting future production
  - Investment analysis
  - Forecasting on sales etc.
- In the advertising business, an application delivering targeted advertisements
- In e-commerce, a batch application filtering customers to make more relevant commercial offers or an online app recommending products to buy on the basis of ephemeral data such as navigation records
- In the credit or insurance business, an application selecting whether to proceed with online inquiries from users, basing its judgment on their credit rating and past relationship with the company

Linear Regression

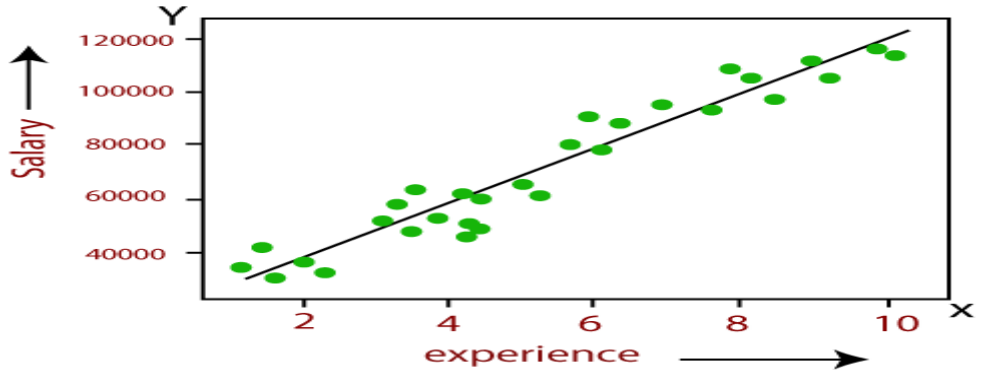
Overview

- The data in Linear Regression is modelled using a straight line
- Linear regression is a statistical regression method which is used for predictive analysis.
- It is one of the very simple and easy algorithms which works on regression and shows the relationship between the continuous variables.
- It is used with continuous variable
- It gives a future value as an output
- To calculate accuracy following methods are used
  - R-squared
  - Adjusted R-squared



Simple and Multiple Linear Regression

- If there is only one input variable (x), then such linear regression is called **simple linear regression**.
- If there is more than one input variable, then such linear regression is called **multiple linear regression**.
- Predicting the salary of an employee on the basis of **the year of experience**.
- Y= aX+b
- Y = dependent variables (target variables),
  X= Independent variables (predictor variables),
  a and b are the linear coefficients
- Eg . Analyzing trends and sales estimates
- Eg. Salary forecasting



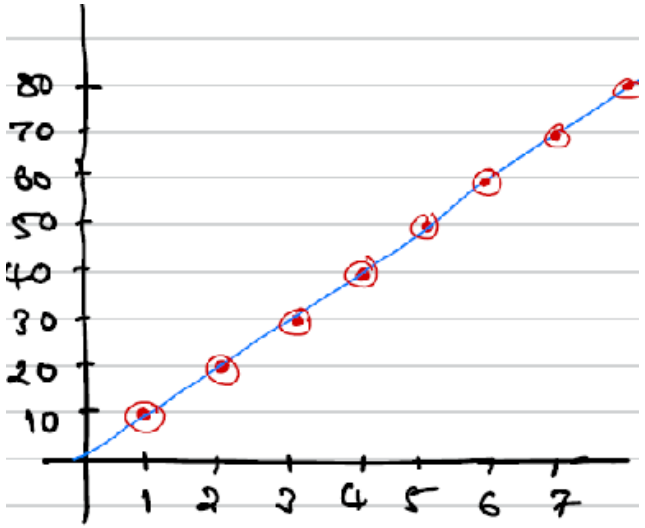
Regression Equation

X	Y
1	10
2	20
3	30
4	40
5	?

$\overline{Y} = 25$

X	Y	$Y - \overline{Y}$	$(Y - \overline{Y})^2$
1	10	-15	225
2	20	-5	25
3	30	5	25
4	40	15	225

What likely to be the value of Y if X = 5



Y = 10 * x
= 10 *5
= 50

Logistic Regression

Overview Logistic Regression

- Logistic regression is another supervised learning algorithm which is used to solve the classification problems. In **classification problems**, we have dependent variables in a binary or **discrete format** such as 0 or 1.
- It was then used in many social science applications
- Logistic Regression is used when the **dependent variable(target) is categorical** such as 0 or 1, Yes or No, True or False, Spam or not spam, etc.
- The dependent variable is a binary variable that contains data coded as 1 (yes, success, etc.) or 0 (no, failure, etc.)
- Unlike linear regression, logistic regression can directly predict probabilities (values that are restricted to the (0,1) interval)
- Furthermore, those probabilities are well-calibrated when compared to the probabilities predicted by some other classifiers
- E.g.
  - To predict whether an email is spam (1) or (0)
  - Whether the tumor is malignant (1) or not (0)

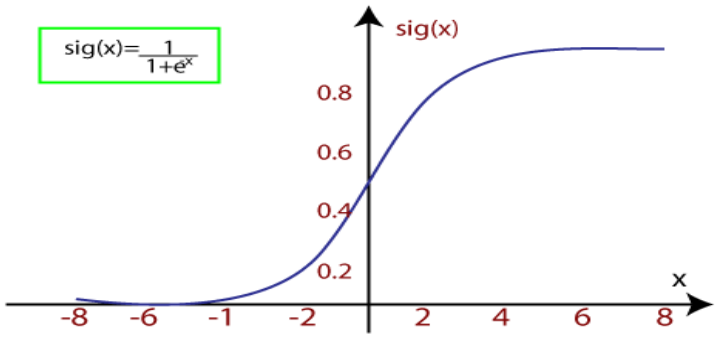
Logistic Regression

- Logistic regression uses **sigmoid function** or logistic function which is a complex cost function. This sigmoid function is used to model the data in logistic regression. The function can be represented as:

$$f(x)= \frac{1}{1+e^{-x}}$$

f(x)= Output between the 0 and 1 value.
x= input to the function
e= base of natural logarithm.

- When we provide the input values (data) to the function, it gives the S-curve as follows:



Logistic Regression

- It uses the concept of threshold levels, values above the threshold level are rounded up to 1, and values below the threshold level are rounded up to 0.
- There are three types of logistic regression:
  - **Binary(0/1, pass/fail)**
  - **Multi(cats, dogs, lions)**
  - **Ordinal(low, medium, high)**

Thank you

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