AKTU B.Tech 3rd Year

CS & CS Allied

Data Analytics & Visualization

Unit-2 in ONE SHOT

Part-I

AKTU PYQs Covered



By Shubhangi Ma'am

Gateway Classes

GATEWAY CLASSES

UNIT—2

Syllabus

GATEWAY CLASSES

Gateway Classes

Data Analysis:

Regression modeling, multivariate analysis, Bayesian modeling, inference and Bayesian networks, support vector and kernel methods, analysis of time series: linear systems analysis & nonlinear dynamics, rule induction, neural networks: learning and generalisation, principal component analysis and neural networks, fuzzy logic: extracting fuzzy models from data, fuzzy decision trees, stochastic search methods.

Regression Modeling AKTU(2025-26)

- **Regression Modeling** is a statistical and machine learning technique used to **predict a continuous (numeric) value** based on one or more independent variables (features).
- **Regression finds the relationship between input variables (X) and an output variable (Y) to make predictions.**
- It is a technique that finds the relationship between an independent variable (X) and dependent variable(Y) to predict a numeric value.

Example :

- Predicting house price based on area and number of rooms.
- Predicting employee salary based on experience.

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Components of Regression

Components	Description
Dependent Variable	The variable that needs to be predicted. **Example:** House Price
Independent Variable	The variable used to predict the output. **Example:** Area of house
Coefficients	Numbers that show how much the output changes when the input changes.
Error(Residuals)	Difference between actual value and predicted value. **Residual = Actual Value − Predicted Value**

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Need of Regression	Applications of Regression
• To predict future values based on past data. • To find the relationship between variables. • To understand how one variable affects another variable. • Helps in decision-making and planning.	• **Business:** Predicting sales and customer demand. • **Finance:** Predicting stock prices and risk analysis. • **Education:** Predicting student performance based on study hours. • **Healthcare:** Predicting disease risk using patient data. • **Real Estate:** Predicting house prices using size, location, and other factors.

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DIFFERENCE BETWEEN REGRESSION AND CLASSIFICATION

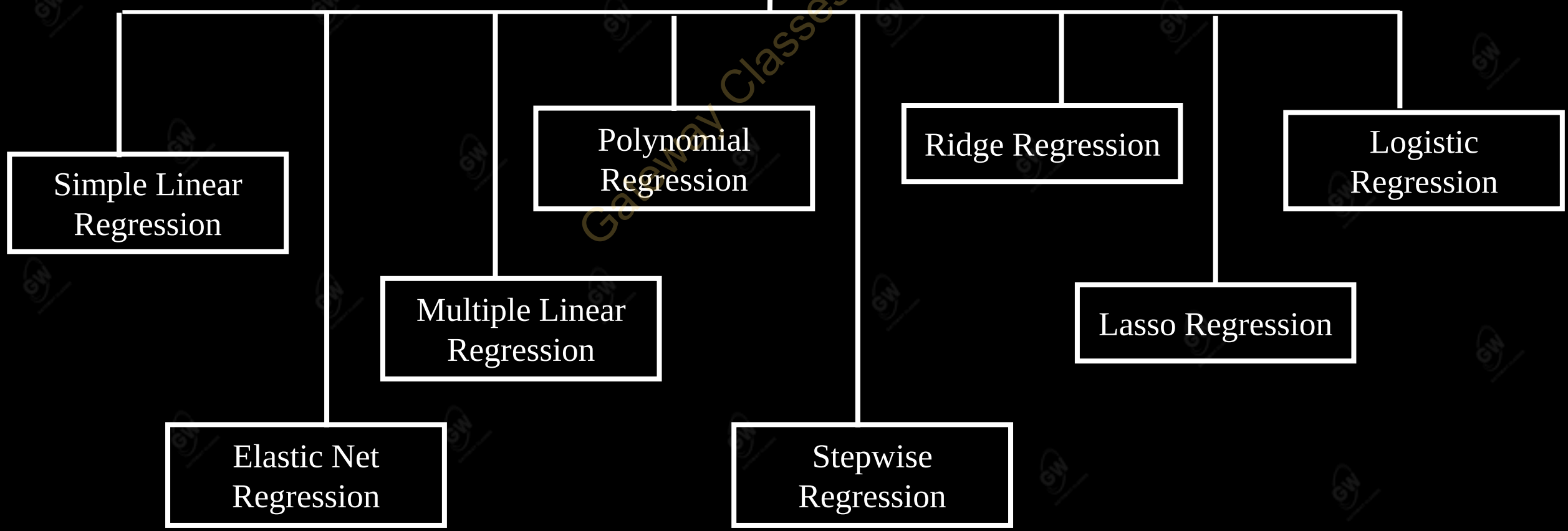
Point	Regression	Classification
1. Purpose	Predicts a continuous numeric value.	Predicts a discrete category or class.
2. Output Type	Continuous output (e.g., 23.5, 98.6).	Categorical output (e.g., Yes/No, Spam/Not Spam).
3. Target Variable	Continuous variable (e.g., price, temperature).	Categorical variable (e.g., email is spam or not).
4. Algorithms Used	Linear Regression, Ridge, Lasso, Polynomial Regression, SVR, etc.	Logistic Regression, Decision Tree, Random Forest, SVM, Naive Bayes, KNN, etc.
5. Evaluation Metrics	MAE, MSE, RMSE, R^2 Score, Adjusted R^2.	Accuracy, Precision, Recall, F1-Score, ROC-AUC, Log Loss, Confusion Matrix.
6. Example Use Cases	Predicting house price, stock price, sales amount, rainfall level, etc.	Email spam detection, disease prediction (yes/no), customer churn (yes/no), image classification, etc.

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Types of Regression

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1. Linear Regression

- Linear Regression is a Statistical method used to determine the linear relationship between an independent variable and a dependent variable.
- It is also is used to predict the value of the dependent variable based on the independent variable.

Types of Linear Regression :

(A) Simple Linear Regression

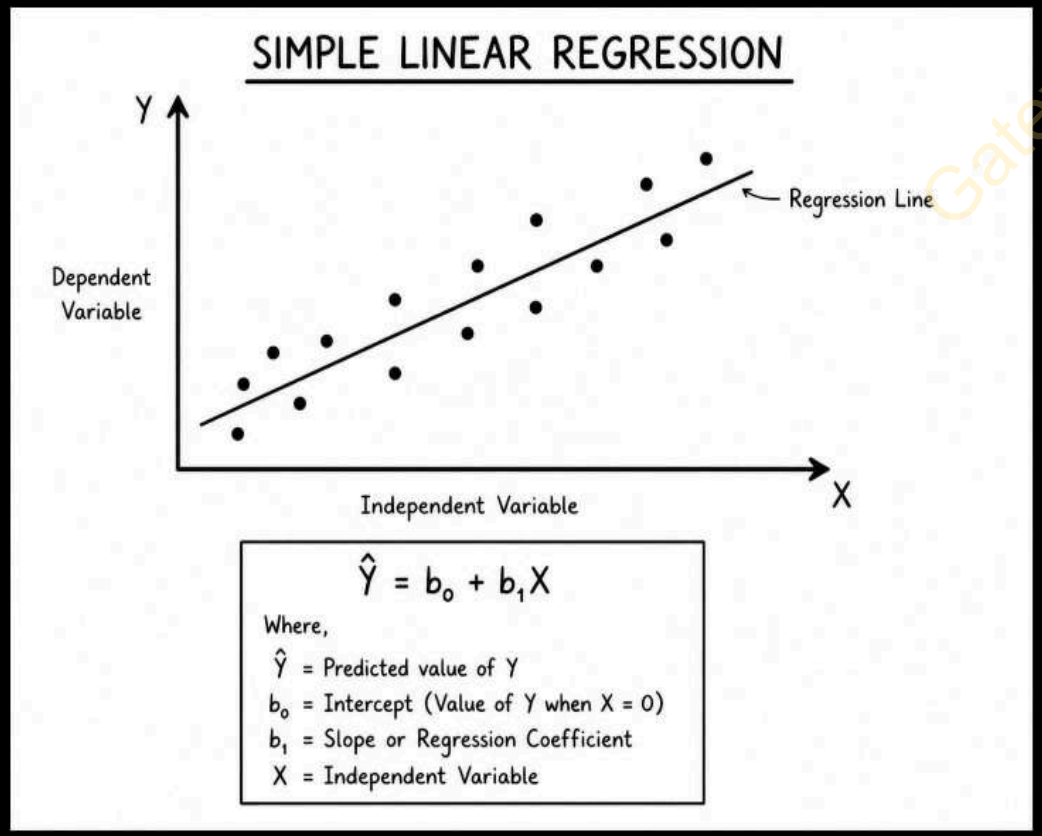
(B) Multiple Linear Regression

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(A) Simple Linear Regression :

- Simple Linear Regression involves **one independent variable (x)** and **one dependent variable (Y).**
- It predicts the value of dependent variable based on the independent variable.

Example : Study hours ⟶ Marks



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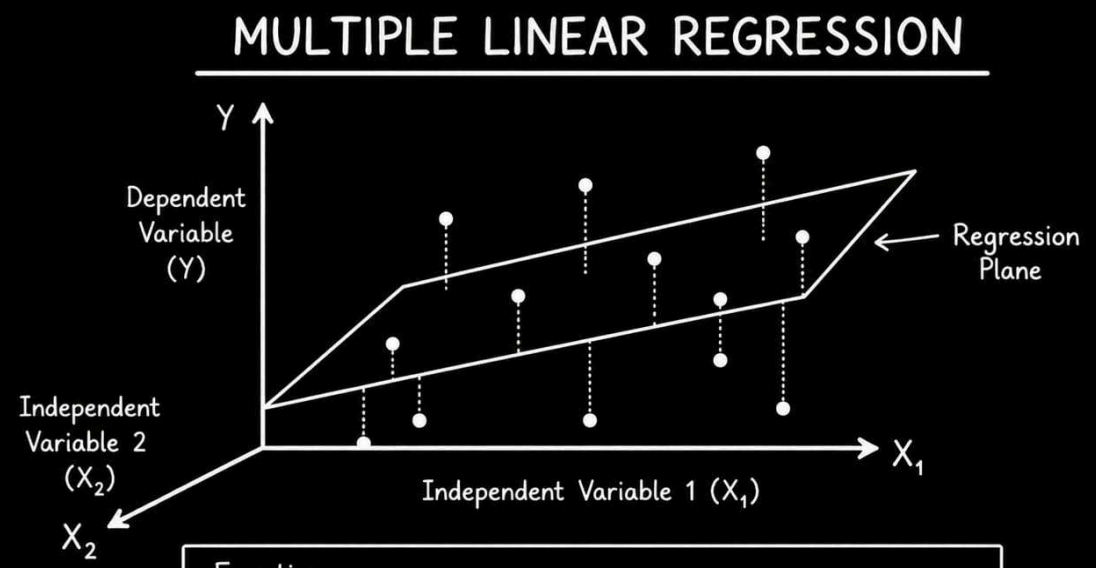
(B) Multiple Linear Regression :

It is regression technique used to study the relationship between **two or more independent variable** and **one dependent variable.**

Example : Study Hours + Attendance + Assignments ⟶ Marks

Applications :

- Predictions house prices using area , location, & number of rooms .
- Predicting employee salary using experience , education , & skills.



Equation:

$$\hat{Y} = b_0 + b_1X_1 + b_2X_2 + \cdots + b_nX_n$$

Where,

- $\hat{Y}$ = Predicted value of Y
- b_0 = Intercept (value of Y when all X's are 0)
- $b_1, b_2, \ldots, b_n$ = Regression coefficients
- $X_1, X_2, \ldots, X_n$ = Independent variables

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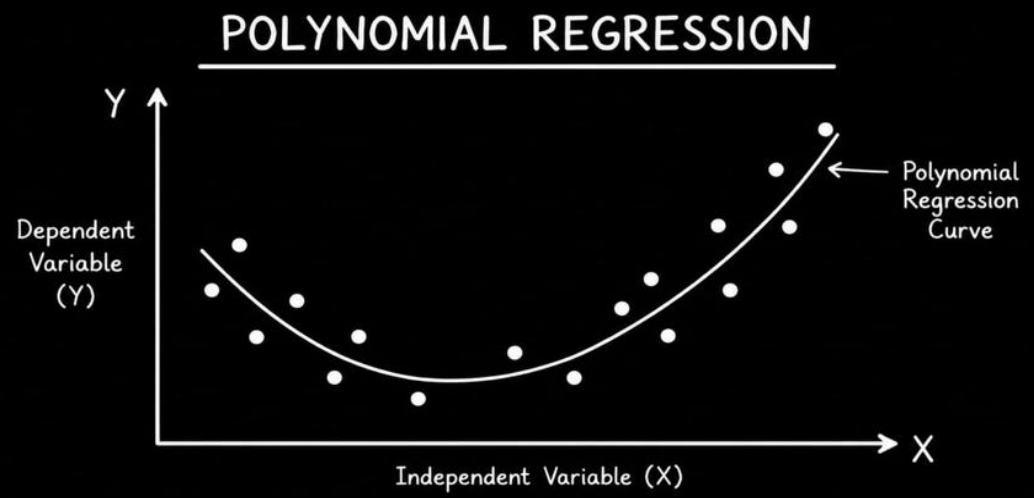
2. Polynomial Regression

- It is used when the relationship between the independent variable and dependent variables is curved rather than a straight line.
- It Captures non – linear relationships .

Applications :

- Population Growth prediction
- Stock market trend analysis
- Weather forecasting

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Equation:

$$\hat{Y} = b_0 + b_1X + b_2X^2 + b_3X^3 + \cdots + b_nX^n$$

Where,

- $\hat{Y}$ = Predicted value of Y
- b_0 = Intercept
- $b_1, b_2, b_3, \ldots, b_n$ = Regression coefficients
- X = Independent variable
- $X^2, X^3, \ldots, X^n$ = Higher order terms of X

3. Logistic Regression

- Logistic Regression is used to classify data into different categories rather than predicting continuous values .
- It is used for classification problems, predicts the probability of an event.
- Output is usually Yes/No , True/False, Pass/fail.

Applications :

- Disease Prediction.
- Email spam detection
- Customer churn prediction
- Loan Approval prediction

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4. Ridge Regression

- It is used when linear regression overfits the data. It reduces overfitting by adding a penalty term, making the model reliable for new data.
- Rideg Regression is a types of linear regression that reduces the effect of less important features or unusual data , helping the model make better and more accurate predictions

Example :

Suppose we want to predict student marks based on study hours. Most students who study 8 hours score 90–95 marks, but one student's marks are entered as 20 by mistake. Linear Regression is affected by the wrong data. Ridge Regression reduces the effect of that wrong value and gives a better prediction.

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5. Lasso Regression AKTU(2024-25)

Lasso Regression is a type of linear regression that reduces overfitting by removing less important features from the model.

Example : Suppose we want to predict house prices.

Features : House size, no. of rooms, parkin, Ignore features line Wall color, House number.

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6. Elastics Net Regression

It is a regularization technique that combines Ridge and lasso Regression.

It reduces the impact of less important features & And can remove unnecessary features to prevent overfitting.

Example : To predict house price, Elastic Net keeps important features like house size, reduces the effect of less important features, and removes useless features like wall color.

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7. Stepwise Regression

It is a feature selection technique that automatically adds or remove features step by step to find the best set of variables for a regression model.

Example : To predict student marks , stepwise regression selects study hours and attendance but removes height & age as they are not useful .

Multivariate Analysis (AKTU 2024-25)

Multivariate Analysis is a statistical method used to analyze multiple variables together to find relationships between them.

Example : To predict house price we analyze multiple factors like house size, location , no of rooms , age of house together.

Need of Multivariate Analysis :

- It helps to analyze multiple variables at the same time.
- It helps to find relationships between different variables.
- It improves prediction and decision-making by using multiple factors together.

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Features of Multivariate Analysis

- **Multiple Variables:** Analyzes two or more variables together.
- **Finds Relationships:** Identifies relationships between variables.
- **Better Prediction:** Helps in making accurate predictions using multiple factors.
- **Data Comparison:** Compares the effect of different variables.
- **Complex Data Analysis:** Helps analyze large and complex datasets.

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Applications

- Used to compare multiple groups based on multiple outcomes.
- Used in education research to compare teaching methods.
- Used in medical research to compare treatments and their effects.
- Used in business research to analyze customer behavior.

Techniques & Types of Multivariate Analysis

1. Factor Analysis : It is a multivariate analysis technique used to reduce many variables into smaller number of importance factor .

Example : A company collects customer data using variables like age, income, spending habits, and buying frequency.

Factor Analysis combines these related variables into fewer factors like customer lifestyle and purchasing behavior to simplify the data.

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2. Principal Component Analysis :

PCA is a multivariate analysis technique used to reduce the number of variables by converting them into a smaller number of new variables called principal components, while keeping important information.

Example : A company collects customer data using age, income, spending habits, and buying frequency.

PCA combines these variables into fewer components like customer behavior to reduce data complexity while keeping important information.

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Cluster Analysis

Cluster Analysis is a technique used to group similar data points into different groups (clusters).

Example:

A company groups customers based on buying habits, income, and age into different clusters like high spenders, medium spenders, and low spenders.

Discriminant Analysis

Discriminant Analysis is a technique used to classify data into already known groups based on their features.

Example:

A bank classifies customers as loan approved or loan rejected based on income, credit score, and age.

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MANOVA

MANOVA (Multivariate Analysis of Variance) is a statistical technique used to compare multiple groups based on two or more dependent variables at the same time.

Example:

A teacher compares three teaching methods (Method A, B, C).

Students' Math marks and Science marks are analyzed together to check which teaching method gives better results.

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Advantages

- Analyzes Multiple Variables Together
- Reduces Errors
- Provides Better Accuracy

Limitations

- Requires a large amount of data.
- Analysis is more complex than ANOVA.
- Results can be affected if assumptions are not satisfied.

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Bayesian Modelling

- Bayesian Modeling is a statistical method that updates the probability of an event whenever new evidence becomes available.
- It is technique that combines prior knowledge with new data to make better predictions and decisions.
- It is based on Baye's Theorem , which was introduced by the mathematician **Thomas Bayes.**

Example : Medical Diagnosis

A Doctor believes that a patient has a 10% of chance of having a disease . This is called the Prior Belief .

After the patient takes a medical test, the result is Positive. This is new evidence.

The doctor updates the probability of the disease using this new evidence. The updated probability is called the Posterior probability.

This process of updating the probability using new evidence is called Bayesian Modeling.

Old Belief + New Evidence = Updated Belief

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Basic Terminology

Terminology	Description
Prior Probability	Probability before getting new evidence.
Likelihood	Probability of getting the evidence if the event is true.
Evidence	New information or observed data
Posterior Probability	Updated probability after considering the new evidence

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Working of Bayesian Probability



Bayes' Theorem

- Bayesian modeling is based on Bayes' theorem . This theorem is used to calculate the updated probability of an event after new evidence is obtained.
- It combines prior knowledge with new evidence to make better predictions and decisions.

$$P(A|B) = \frac{P(B|A) \times P(A)}{P(B)}$$

P(A|B) : Posterior Probability

P(B|A) : Likelihood

P(A) : Prior Probability

P(B) : Evidence

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BAYES' THEOREM
(Rain Example)

$$P(A \mid B) = \frac{P(B \mid A) \times P(A)}{P(B)}$$

- **P(A | B) : Posterior Probability**
  P(Rain | Clouds)
  = Probability of Rain given Clouds
  (Updated probability after seeing evidence)
- **P(B | A) : Likelihood**
  P(Clouds | Rain)
  = Probability of Clouds given Rain
  (If Rain happens, how likely are Clouds)
- **P(A) : Prior Probability**
  P(Rain)
  = Initial probability of Rain
  (Before seeing any evidence)
- **P(B) : Evidence**
  P(Clouds)
  = Overall probability of Clouds
  (Probability of evidence)

Rain Example

1. Prior	2. Evidence	3. Likelihood	4. Posterior
Before seeing clouds	We see dark clouds	If Rain happens, clouds are very likely	After seeing clouds
P(Rain)	P(Clouds)	P(Clouds | Rain)	P(Rain | Clouds)
= 20%	= 30%	= 90%	= ?

(Updated probability using Bayes' Theorem)

In Simple Words:
Start with Prior (P(A)). When we get Evidence (P(B)) i.e., clouds, and we know how likely clouds are if rain happens (Likelihood P(B|A)), we use Bayes' Theorem to find updated probability of rain (Posterior P(A|B)).

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Types of Bayesian Models

Types	Description	Example
Naive Bayes	It is a Bayesian classification technique that assumes all features are independent of each other.	Naïve Bayes predicts whether the email is spam or not spam based on these words
Bayesian Network	It is a graphical model that represents variables and their probabilistic relationships using nodes and directed edges.	The network helps predict traffic based on the probability of rain
Dynamic Bayesian Network	It is an extension of a Bayesian network that is used for data that changes over time.	Suppose a weather system records the weather every day. Today's weather helps predict tomorrow's weather . The model updates its prediction whenever new weather data is available

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Applications

- **Medical diagnosis** – Predicting diseases based on symptoms and patient data.
- **Spam filtering** – Classifying emails as spam or not spam.
- **Weather prediction** – Predicting future weather conditions using past data.
- **Risk analysis** – Used in finance and decision-making.

Advantages	Limitations
• Handles uncertainty in data effectively. • Can work with small amounts of data. • Updates predictions when new information is available. • Provides probability-based results.	• Requires knowledge of prior probabilities. • Calculations can become complex for large datasets. • Results depend on the accuracy of the given assumptions. • Choosing correct probability distributions can be difficult.

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Bayesian Network

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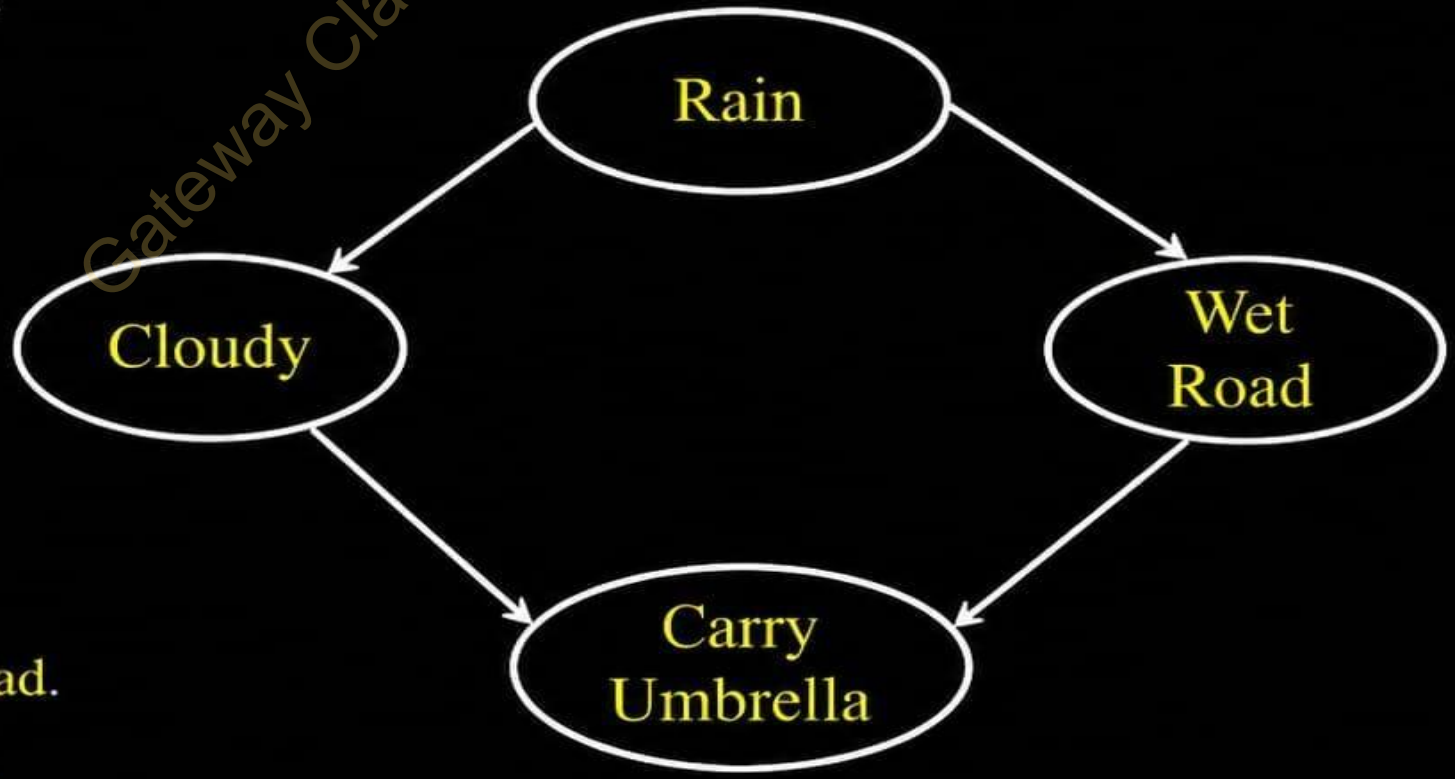
- A Bayesian Network is a graphical model that represents variables and their probabilistic relationships using nodes and directed edges.
- It is directed graph that shows how different variables are related to each other and helps make predictions under uncertainty.

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Example :

Nodes (Variables):
Rain, Cloudy, Wet Road, Carry Umbrella

Directed Edges (Arrows):
Arrow shows the direction of influence (cause → effect).



Explanation:

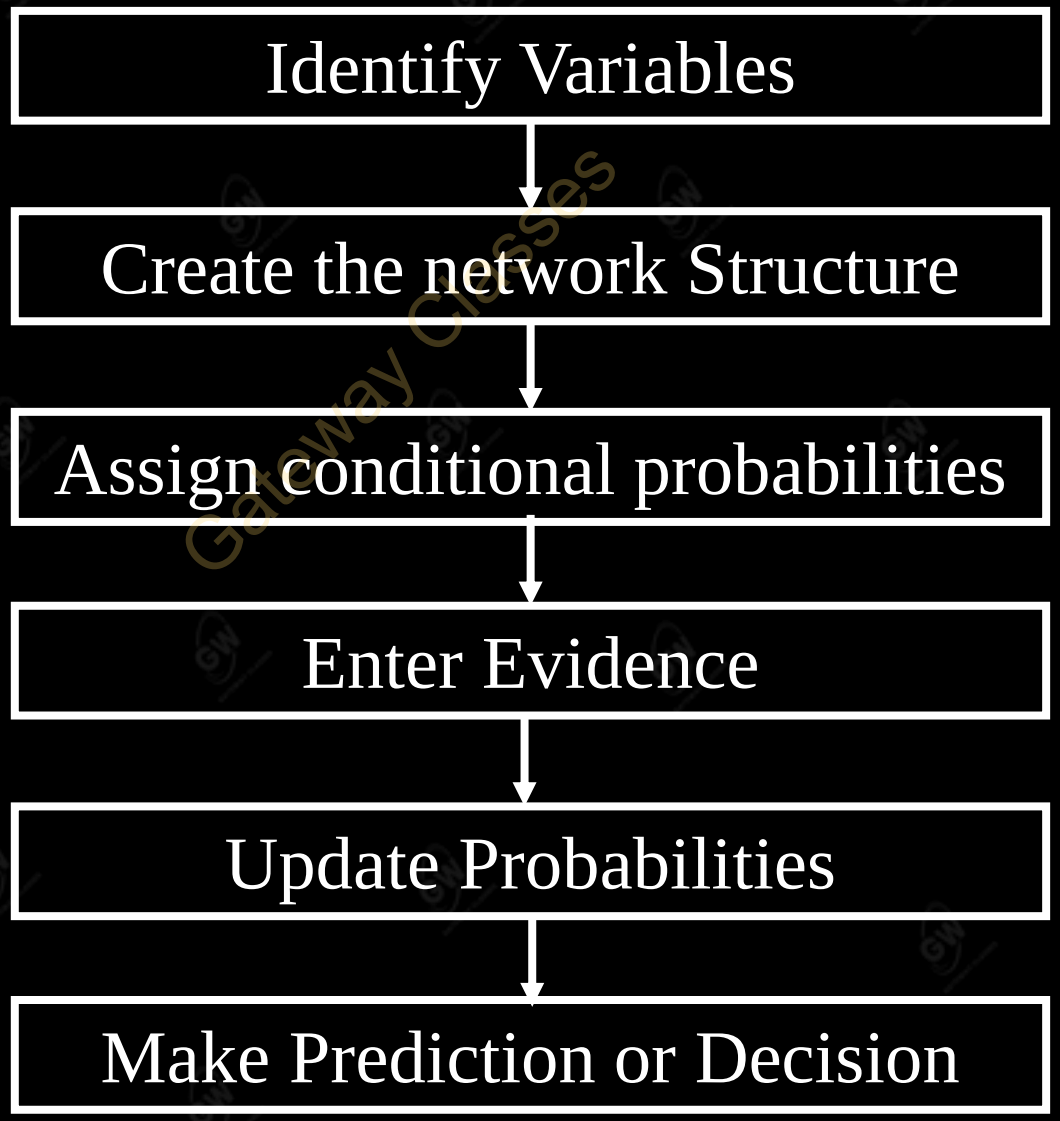
- Rain affects Cloudy and Wet Road.
- Cloudy affects Carry Umbrella.
- Wet Road affects Carry Umbrella.
- Cloudy and Wet Road together affect the decision Carry Umbrella.

Components of Bayesian Network

Components	Description
Nodes	Nodes represent variables or events in a Bayesian Network.
Directed Edges	Directed edges show the dependency relationship between variables
Conditional Probability Table	A Conditional Probability Table (CPT) stores the probability of a node based on its parent node(s)
Directed acyclic Graph	A Bayesian Network is represented by a Directed Acyclic Graph(ACG) , where arrows show the direction of influence and no cycle is allowed.

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Working of Bayesian Networks



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Steps	Description
Identify Variables	Identify all variables or events related to the problem.
Create the Network structure	Connect the variables using directed arrows to show their relationships.
Assign conditional probabilities	Assign probabilities to each variable using a Conditional Probability Table . (CPT)
Enter Evidence	Provide new information or observed data to the network.
Update probabilities	The network updates the probabilities of related variables using Baye's Theorem
Make Prediction & Decision	Use the updated probabilities to predict the most likely outcome or make a decision.

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Applications of Bayesian Network :

Medical diagnosis	Used to predict diseases based on symptoms and test results.
Weather Forecasting	Used to predict weather conditions such as rain or storms
Fraud Detection	Used to identify suspicious or fraudulent financial transactions
Spam Email Detections	Used to classify emails as spam or non spams
Risk Analysis	Used to analyze and manage risks in business and finance
Machine Learning	Used to make predictions and support intelligent decision-making

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Advantages

Handles Uncertainty : It works effectively even when the data is uncertain or incomplete.

Updates with new Evidence : It updates probabilities whenever new information becomes available.

Represents Relationships clearly : It shows the dependency between variables using a graphical model.

Supports Better Decision making : It helps in making accurate predictions and informed decisions.

Limitations

Difficult to Build : Creating a Bayesian Network can be complex & time – consuming.

Requires Expert Knowledge : It Needs domain experts to define the correct relationships between variables .

High Computational Cost : Large Bayesian networks requires more memory and processing power.

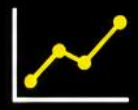
Difficult to handle large networks : As the number of variables increases, the inaccurate results.

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DIFFERENCE BETWEEN BAYESIAN MODELING AND REGRESSION

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POINT	BAYESIAN MODELING	REGRESSION
1. APPROACH 	Bayesian modeling is based on Bayes' theorem and uses prior information along with data.	Regression is a frequentist approach that relies only on observed data and does not use prior information.
2. OUTPUT 	Provides a full probability distribution of parameters and predictions (uncertainty is quantified).	Provides point estimates for parameters and predictions (uncertainty is not fully quantified).
3. UNCERTAINTY 	Explicitly quantifies uncertainty through probability distributions (credible intervals).	Uncertainty is described using confidence intervals and p-values.
4. INTERPRETATION 	Results are probabilistic; parameters have a probability of being in a certain range.	Results are based on long-run frequency properties; parameters are fixed but unknown.
5. FLEXIBILITY 	More flexible; can model complex hierarchical structures and incorporate prior knowledge easily.	Less flexible; mainly focuses on estimating relationships between variables.
6. USE CASE 	Useful when prior information is available, sample size is small, or uncertainty estimation is important.	Useful for large datasets and when prior information is not available or required.

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Inference

- Inference is the process of drawing conclusions or making predictions from available data or evidence .
- It helps in making decisions when complete information is not available.

Example :

Suppose a doctor knows that a patient has fever and cough.

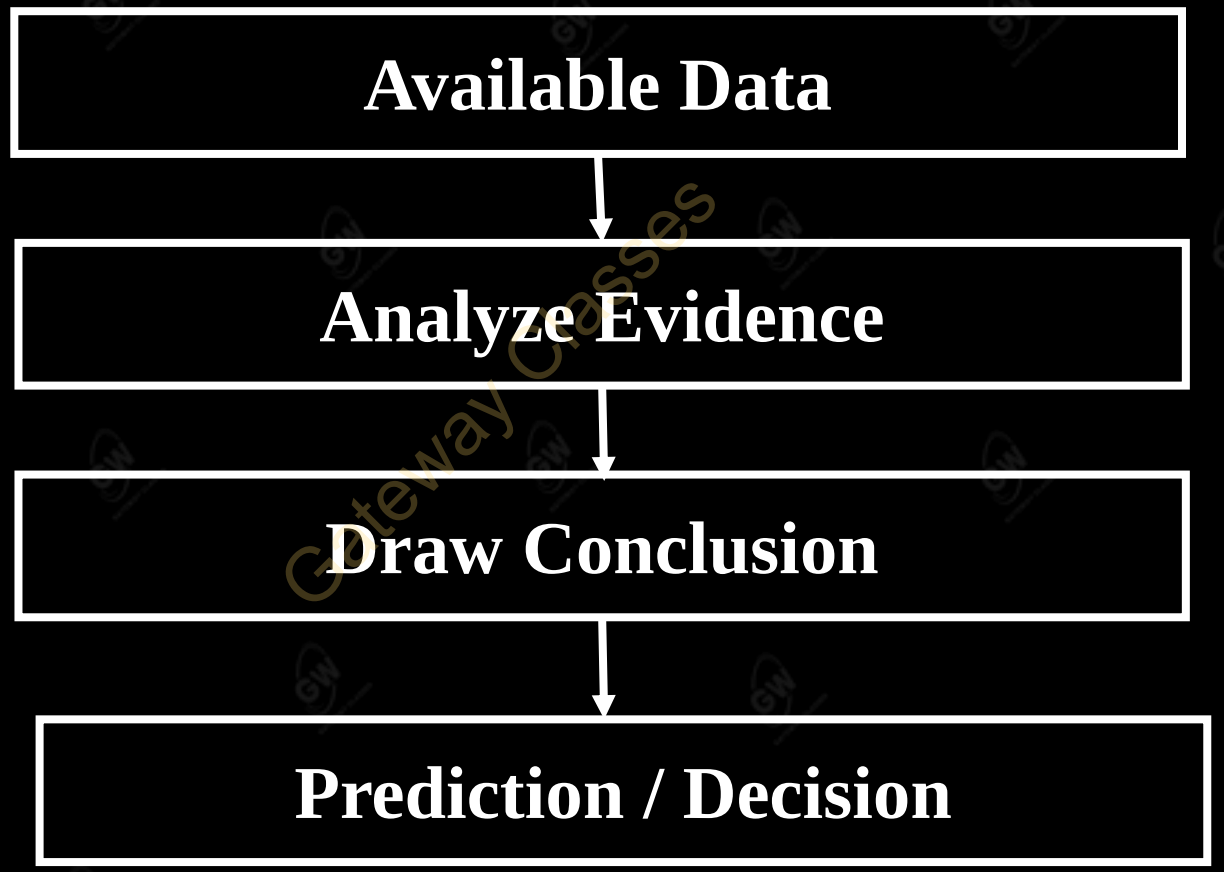
Based on these symptoms, the doctor predicts that the patient may have flu.

This process of making a conclusion from available information is called inference.

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Real life Analogy	
Bayesian Network	Road maps (Shows Roads or connections)
Bayesian Theorem	Calculate distance & traffic formula
Inference	Reached at 15 minutes

Flow of Inference



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Need of Inference

- To make Better decisions.
- To predict unknown events.
- To analyze available data.
- To handle uncertain situations.
- To improve the accuracy of predictions.

Features of Inference

- Uses available data or evidence.
- Helps in prediction and decision – making
- Works even with incomplete information
- Supports data analysis
- Reduces uncertainty.

Applications of Inference

- Medical diagnosis
- Weather forecasting
- Fraud detection
- Machine learning
- Business decision – making
- Risk analysis

Advantages of Inference

- Helps in making better decisions.
- Improves prediction accuracy.
- Works with incomplete information
- Supports data – driven analysis
- Reduces uncertainty

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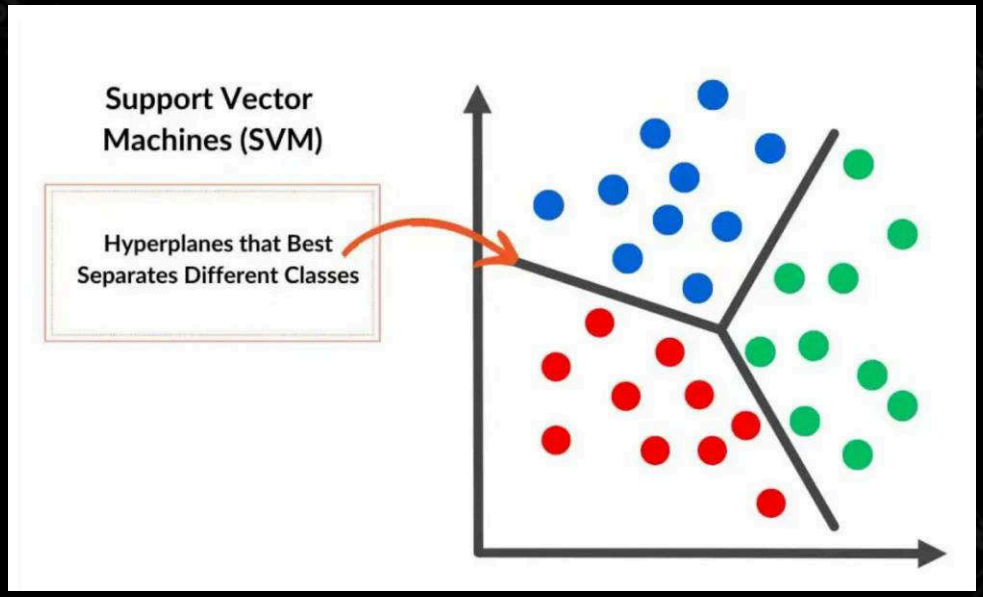
Support Vector & kernel Methods

Support Vector Machine(SVM) & Kernel methods are powerful machine learning technique used for classification and predictions.

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Support Vector machines

- Support Vector machines (SVM) is a supervised machine learning algorithm used for classification and regression .
- It separates data into different classes by finding the best decision boundary, called a hyperlane.

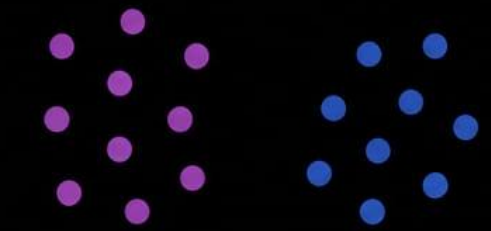


SUPPORT VECTOR MACHINE (SVM)

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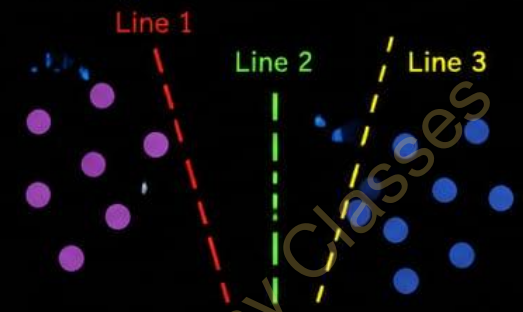
Real Life Example - Boys & Girls

1. Two Groups



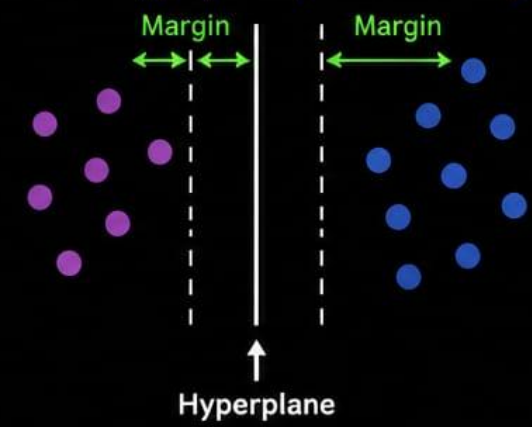
Girls (Class 1) Boys (Class 2)

2. Many Possible Lines

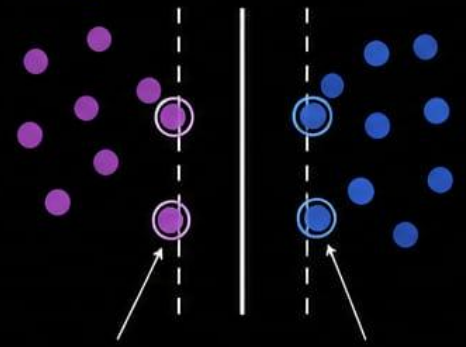


Many lines can separate the two classes,
but SVM chooses the best one.

3. Best Hyperplane (Maximum Margin)

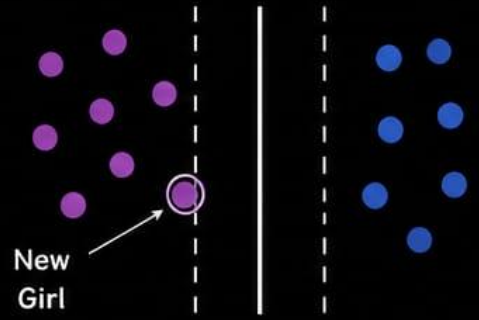


4. Support Vectors



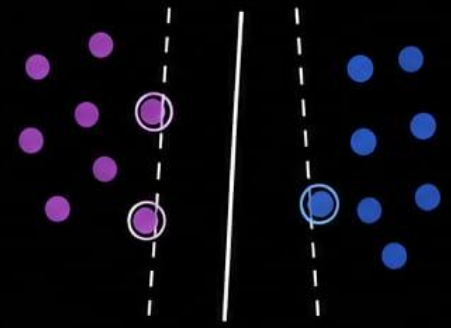
These nearest points are called
Support Vectors.
They decide the position of the hyperplane.

5. New Student Arrives



A new girl comes closer,
so the hyperplane will shift.

6. Hyperplane Shifts



Now new nearest points become
Support Vectors
and hyperplane shifts.

Key Terms

- **Hyperplane** – The decision boundary
- **Margin** – Distance between hyperplane and nearest points
- **Support Vectors** – Nearest points that decide the hyperplane

Summary

SVM finds the hyperplane that separates classes with MAXIMUM MARGIN.
The nearest points are SUPPORT VECTORS, and they help in making the best decision boundary.

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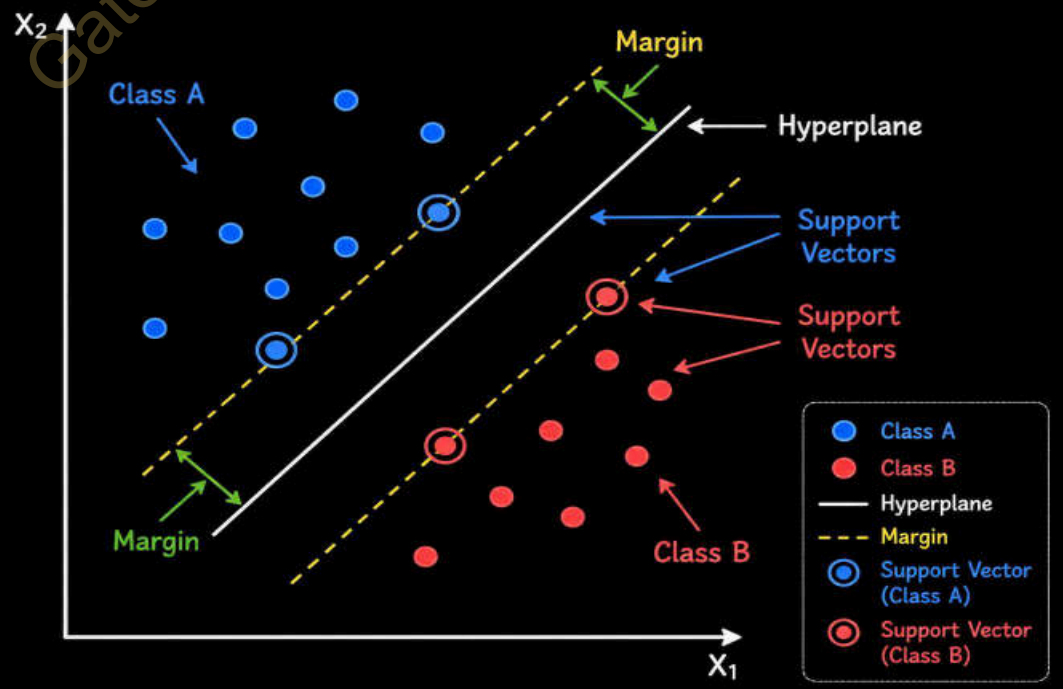
Key Concepts of SVM

Hyperlane : It is a decision boundary that separates data into different classes.

Support Vectors : They are the data points closest to the hyperlane. They help determine the position of the hyperlane.

Margin : It is the distance between the hyperlane & the nearest support Vectors.

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Working of SVM

Steps	Description
Collect data	The Training Dataset is collected
Identify different classes	The data is divided into different categories or classes.
Find the best hyperlane	SVM finds the hyperlane
Maximize the margin	The algorithm choses the hyperlane with the maximum margin between the classes
Classify New Data	New data points are classified based on which side of the hyperlane they fall

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Applications of SVM

- Image classification
- Face recognition
- Spam email detection
- Medical diagonsis

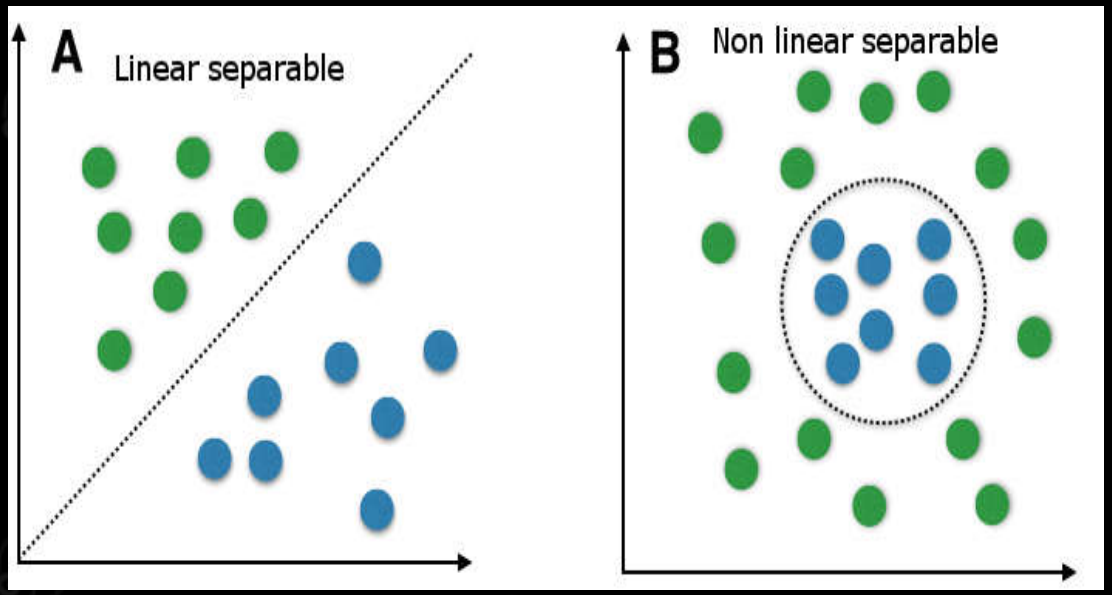
Types of SVM

1. **Linear SVM :** It is used when the data can be separated by a straight line(Hyperlane).

Example : Two groups of data can be divided using a single straight line.

2. **Non – Linear SVM :** It is used When the data cannot be separated by a straight line. It used kernel methods to transform the data into a higher – dimensional space.

Example : Circular data patterns that cannot be separated using straight line.



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Kernel Methods

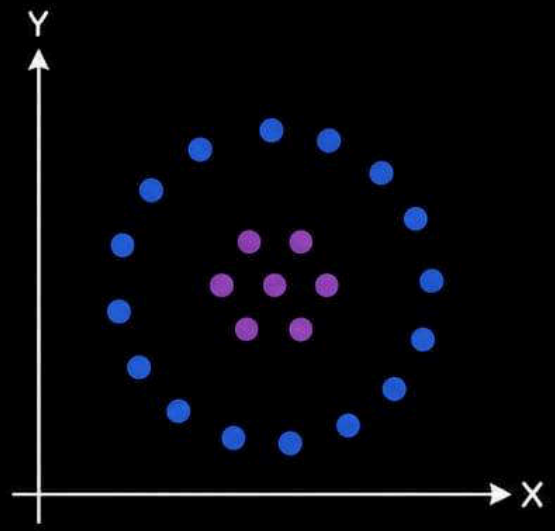
- Kernel Methods are machine learning Techniques that help Support Vector Machine (SVM) classify non – linear data by transforming it into a higher dimensional feature space without explicitly calculating the transformation.
- **Kernel Trick** is a technique that allows SVM to work in a higher – dimensional space without actually transforming all the data points. This makes computation faster & more efficient.
- When the data cannot be separated using a linear hyperlane in the original feature space , the kernel method maps the data into a higher – dimensional space.
- In that higher dimensional space , SVM can find the best linear hyperlane to separate the classes.

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KERNEL METHOD - SIMPLE EXPLANATION

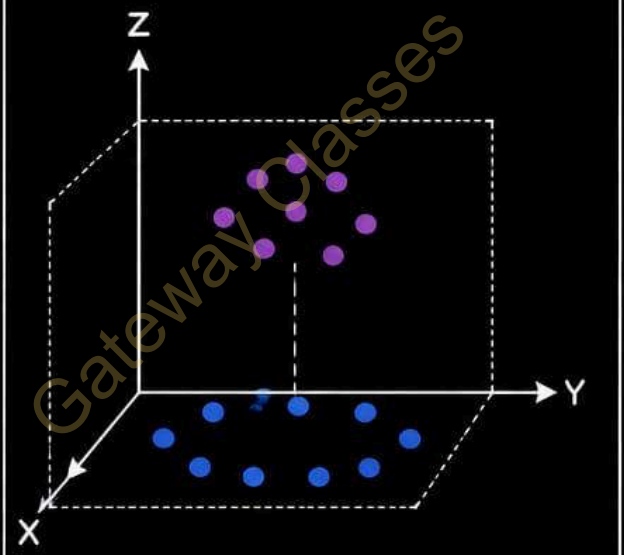
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1 Original Data (Not Separable)



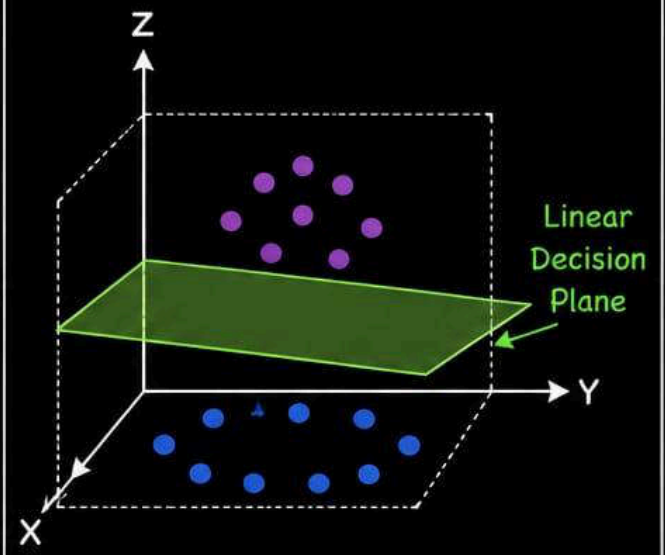
In this 2D space, classes cannot be separated with a straight line.

2 Kernel Transformation (Into Higher Dimension)



Kernel maps data to a higher dimension (3D). Now classes are separable by a plane.

3 Linear Separation (In Higher Dimension)



In this space, a straight plane (hyperplane) separates the two classes perfectly.

Class 1

Class 2

Kernel Method allows SVM to solve problems that are not possible in original 2D/3D space by converting them into a higher-dimensional space.

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Working of Kernel Methods

Step 1 : Collect Data - Collect the training Dataset

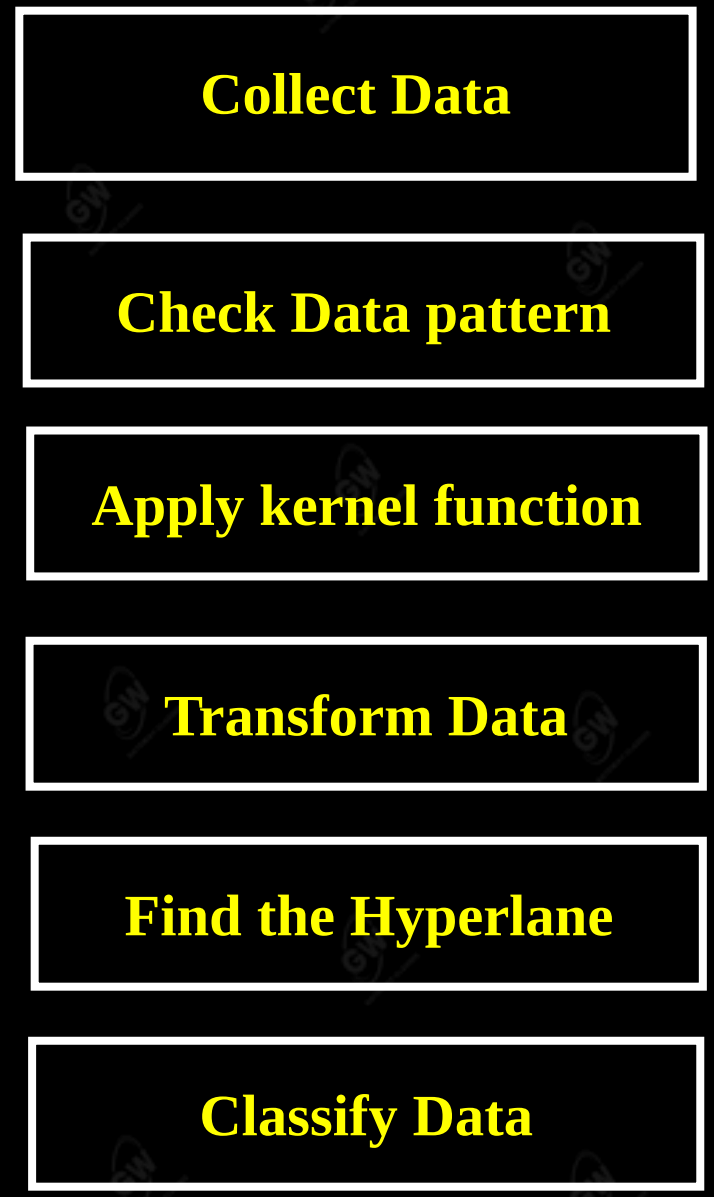
Step 2 : Check Data pattern – Determine whether the data is linearly separable or non separable .

Step 3 : Apply kernel Function – If the data is non non – linear , apply a suitable kernel function.

Step 4 : Transform Data – The kernel maps the data into higher dimensional feature space.

Step 5 : find the hyperlane – SVM finds the best hyperlane in the transformed space.

Step 6 : Classify data – The data is classified into different classes



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Types of kernel Methods

Types	Description
Linear Kernel	The Linear kernel is used to when the data is linearly separable. Example : Students are classified as pass or fail using a straight line.
Polynomial Kernel	It is used when the relationship between data points is curved or polynomial. Example : Classify students based on marks and study hours
Radial Bias function(RBF) or Gaussian kernel	Used for complex non – linear data. It creates flexible boundaries. Example : Face recognition , Handwriting recognition, Cancer detection
Sigmoid kernel	Behaves like a neural network activation function and is used in some classification problems. Example : Pattern recognition & txt classification

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Advantages of kernel methods

- Handles non linear data effectively
- Improves the accuracy of SVM
- Works well with high dimensional data

Need of Kernel Methods :

- They help classify non – linear data.
- They improve the performance of SVM.
- They make complex data easier to separate.
- They avoid direct computation in higher dimensions using the kernel trick.

Limitations of kernel methods

- Choosing the correct kernel is difficult
- Training can be slow for large datasets
- Can be difficult to interpret.

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Previous Year Important Questions

Q.1 What is regression modeling? Mention one application. (2025-26)

Q.2 Explain regression modeling and discuss its limitations. (2025-26)

Q.3 Explain Bayesian modeling and in data analytics. (2025-26)

Q.4 Compare regression modeling and Bayesian modeling. (2025-26)

Q.7 Critical analyze the challenges of multivariate analysis in high-dimensional datasets. How can these challenges be addressed ? (2024-25)

Q.8 What is regression modeling? Mention one application. (2025-26)

Q.9 Explain regression modeling and discuss its limitations. (2025-26)

Q.10 Explain Bayesian modeling and in data analytics. (2025-26)

Q.11 Compare regression modeling and Bayesian modeling. (2025-26)

Q.12 Critical analyze the challenges of multivariate analysis in high-dimensional datasets. How can these challenges be addressed ? (2024-25)

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Q. 13 Illustrate with example Regression and Bayesian modelling. (2023-24)

Q.14 List various types of regression analysis technique. (2022-23)

Q.15 Illustrate Bayesian network with an example. (2022-23)

Q.16 What is regression analysis? (2025-26)

Q.17 Explain Bayesian modeling and the role of prior and posterior probabilities. (2025-26)

Q.18 Describe the concept of Lasso Regression. (2024-25)

Q.19 Discuss the advantages of using Bayesian methods in real-world applications. (2023-24)

Q.20 Explain the concept of Bayesian networks and their applications in modeling probabilities relationships among variable. Discuss how Bayesian networks can be constructed from data and used for reasoning under uncertainty ? (2023-24)

Q.21 Explain multivariate analysis and Bayesian network. (2022-23)

Q.22 What are the different kernel methods of Data Analytics ? (2022-23)

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Unit-2

in ONE SHOT

Part-II

AKTU PYQs Covered



By Shubhangi Ma'am

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GATEWAY CLASSES

UNIT—2
Syllabus

GATEWAY CLASSES

Data Analysis:

Regression modeling, multivariate analysis, Bayesian modeling, inference and Bayesian networks, support vector and kernel methods, analysis of time series: linear systems analysis & nonlinear dynamics, rule induction, neural networks: learning and generalisation, principal component analysis and neural networks, fuzzy logic: extracting fuzzy models from data, fuzzy decision trees, stochastic search methods.

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Time Series Analysis AKTU (2022-23)

Time Series Analysis is the process of studying data collected over a period of time to understand its pattern and changes & predict future values .

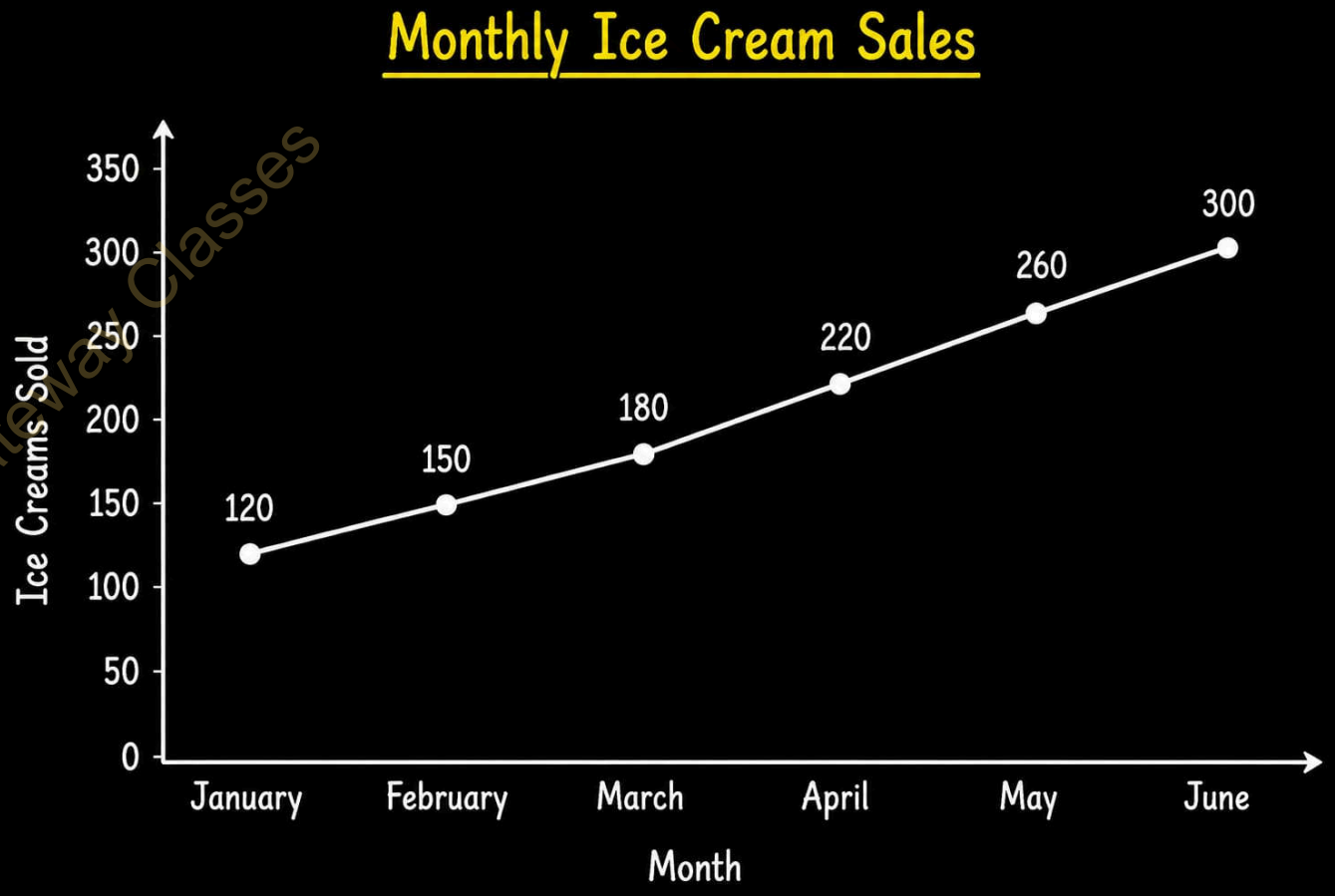
Example:

A company records its monthly ice cream sales.

Month	Ice Creams Sold
January	120
February	150
March	180
April	220
May	260
June	300

- Data is collected every month.
- We study how sales change over time.
- We can find the pattern and predict future sales.

This is called Time Series Analysis.



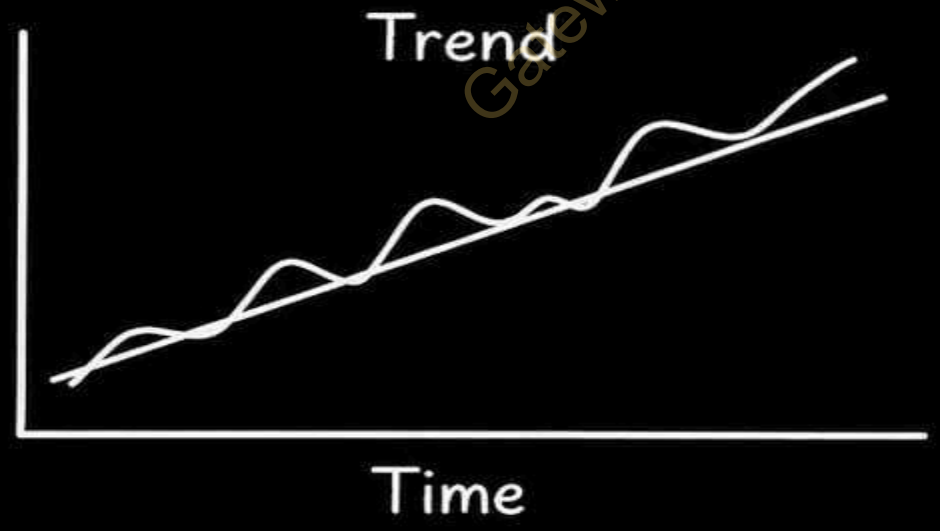
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Components of Time Series Analysis AKTU (2022-23)

1. Trend

- The long term direction of the data over time.
- It may be upward, downward or stable.
- It shows whether the data is increasing , Decreasing , or remaining constant.

Example : A company's sales increasing year after year due to business growth.



Year	Actual sales	Trend
2021	50	Low
2022	70	Inc
2023	60	Inc
2024	90	Inc
2025	100	High

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2. Seasonal Variation (S)

- It is a regular pattern that repeats after a fixed period (day , month, Quarter, or year)
- It is caused by Seasons, Festivals, Holidays, or Weather.

Example : Ice cream sales are higher every year summer.



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3. Cyclical Variation (C)

- Long term fluctuations that occur over several years.
- Usually caused by changes in the business or economic cycle(Boom , recession, recovery)
- Unlike seasonal variation , cyclical patterns do not have a fixed duration

Example : Car sales rising during economic expansion & falling during recession



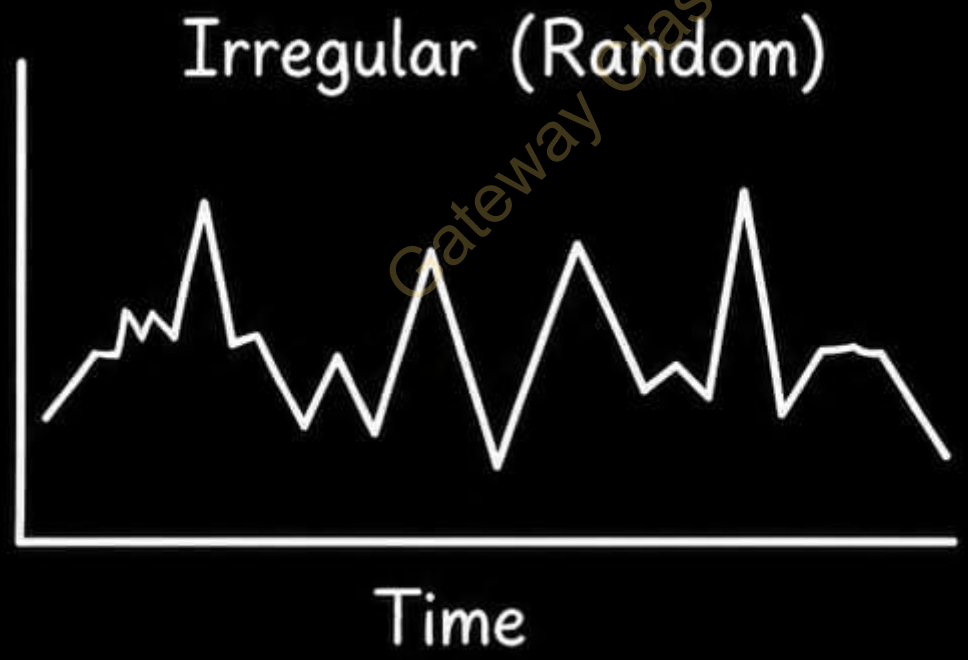
Year	Car Sales
2015	High
2017	Very high
2019	Low
2021	High
2023	Low

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4. Irregular (Random) Variation(I)

- Unpredictable fluctuations caused by unexpected events.
- These cannot be forecast accurately.

Example : Sales dropping due to natural disaster, pandemic , or strike.



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Types of Time Series Analysis

Time series can be grouped based on structure, time interval and statistical behavior. These categories help in selecting the right forecasting method.

1. Univariate vs Multivariate

- **Univariate:** A univariate time series records only one variable over time, making it simpler to analyze and model.
- **Multivariate:** A multivariate time series tracks multiple related variables together to show how they influence each other over time.

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2. Continuous Vs Discrete

- **Continuous:** A continuous time series is observed at every moment or at very high frequency like ECG or sensor signals. Example : Heart Rate monitoring

- **Discrete:** A discrete time series is recorded at fixed intervals such as hourly, daily or monthly and is the most common format. Example : Monthly sales , yearly population etc.

- **3. Stationary vs Non-Stationary**

- **Stationary:** A stationary series has a constant mean, variance and pattern over time with no trend or seasonality.

- **Non-Stationary:** A non-stationary series shows changing patterns like trends or seasonality and often needs transformation before modeling.

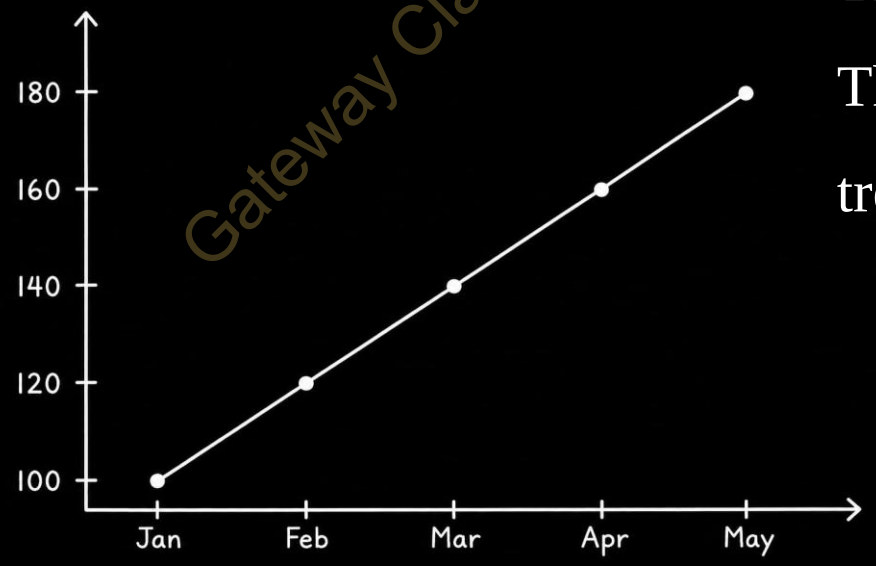
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Linear System Analysis

Linear Systems Analysis is the study of a system where the **output is directly proportional to the input** and follows a straight-line relationship. It is used to understand trends, analyze data, and make future predictions.

Example : Suppose a company record its monthly sales .

Month	Sales(units)
January	100
February	120
March	140
April	160
May	180



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The Increase is constant

This forms a straight - line trend

Characteristics of Linear system Analysis

Characteristics	Description
Linear Relationship	The input & output have a straight line relationship.
Proportional Output	If the input increases or decreases , the output changes proportionally
Constant Rate of Change	The output changes at a constant rate over time
Predictable behavior	Future values can be estimated easily because the pattern is regular
Simple Mathematical Model	It is usually represented by the equation : Y = a + bX

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Equation of Linear System Analysis

Y = a + bX Where, **Y** = Dependent variable(Output)

X = Independent Variable (input)

a = Intercept (Value of Y when X = 0)

b = Slope (Rate of change of Y for every one unit increase in X

Application Linear system Analysis

Sales Forecasting – Predict future sales based on past trends.

Population Growth Analysis – Study changes in population over time.

Business Planning – Analyze business performance and make decisions.

Financial Analysis – Forecast revenue, profit, and expenses.

Demand Forecasting – Estimate future demand for products and services.

Advantages	Limitations
• Easy to understand and apply. • Provides accurate results when the relationship is linear. • Helps in forecasting future values. • Simple mathematical calculations. • Saves time in data analysis and decision-making.	• Works only for linear (straight-line) relationships. • Cannot model complex or nonlinear data accurately. • Assumes a constant rate of change, which may not always be true. • Less accurate when data contains sudden or random changes.

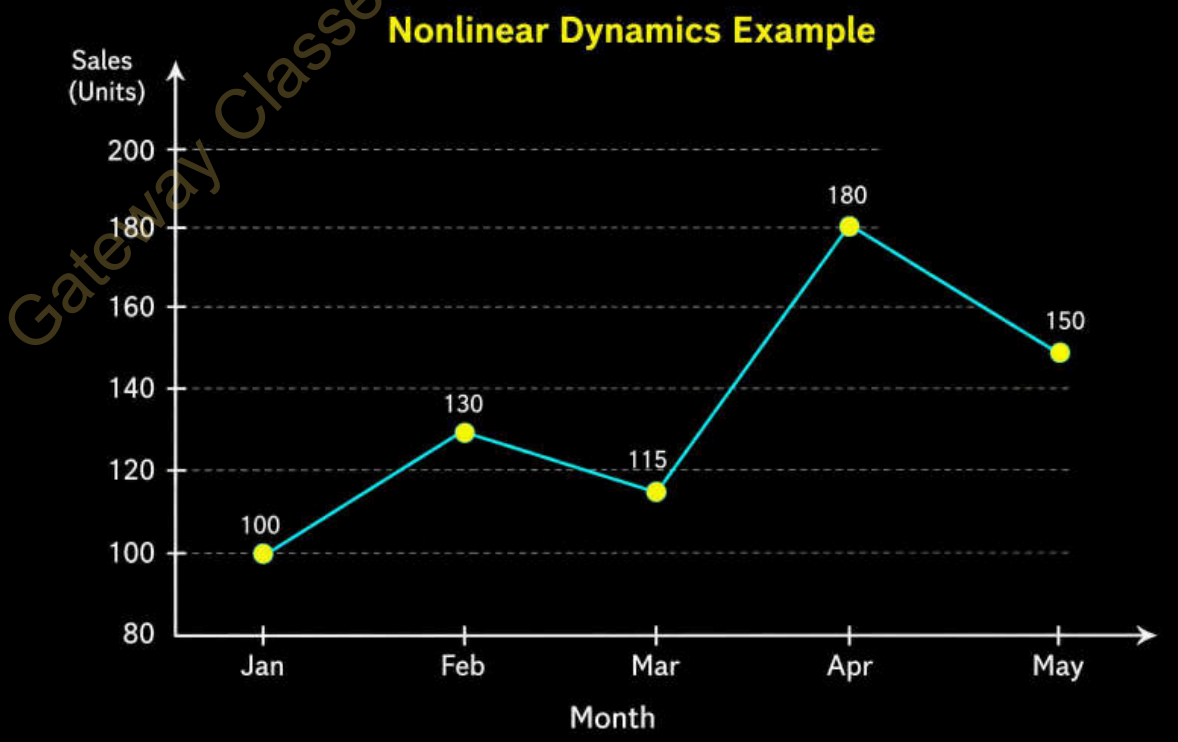
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Non-Linear Dynamics AKTU (2024-25)

A Nonlinear Dynamics is the study of systems in which the relationship between **input and output is not proportional** and does not follow a straight line. Small changes in input may produce large or unpredictable changes in output.

Example : Suppose a Company's monthly sales are :

Month	Sales
Jan	100
Feb	130
Mar	115
Apr	180
May	`50



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Applications

- Weather forecasting
- Stock market analysis
- Population growth modeling
- Traffic flow analysis
- Climate change studies

Advantages :

- Can model complex real-world systems.
- Gives more realistic results.
- Useful for analyzing irregular patterns.
- Improves prediction of nonlinear data.

Limitations :

- Difficult to understand and analyze.
- Requires more calculations.
- Prediction is less accurate for highly chaotic systems.
- Complex mathematical models are often needed.

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Rule Induction AKTU (2022-23)

- Rule Induction is a data mining technique that automatically discovers IF–THEN rules from data to identify patterns, classify data, and make predictions.
- Rule Induction is the process of finding IF–THEN rules from data to help make decisions and predictions.

Example:

IF Attendance ≥ 75% **THEN** Pass

IF Attendance < 75% **THEN** Fail

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Working of Rule Induction – Steps

Step No.	Step Name	Description	What Happens in this Step	Outcome
1.	**Collect Data**	Collect relevant data from various sources.	• Data is gathered from database, files, surveys, sensors, etc. • Data may contain many attributes (features) and a class/target.	Raw data is ready for analysis.
2.	**Prepare Data**	Clean and prepare the data for analysis.	• Remove missing, inconsistent or duplicate data. • Transform data into suitable format.	Clean and consistent data is ready.
3.	**Find Patterns**	Analyze the data to find patterns and relationships.	• Algorithm searches for combinations of attribute values. • It identifies patterns that are strongly associated with a particular class.	Important patterns are identified.
4.	**Generate IF–THEN Rules**	Create rules based on the discovered patterns.	• Convert patterns into simple IF–THEN rules. • Each rule has a condition (IF part) and a result (THEN part).	A set of IF–THEN rules is generated.
5.	**Evaluate Rules**	Check the quality and accuracy of the generated rules.	• Rules are tested using the data. • Weak or incorrect rules are removed.	High quality and accurate rules are selected.
6.	**Use Rules for Prediction**	Use the final rules to classify new data or make predictions.	• New data is matched with the rules. • Based on the rule conditions, prediction/classification is done.	New data is classified or predicted.

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Characteristics of Rule Induction

1. Generates IF–THEN Rules

Rule Induction creates simple **IF–THEN** rules from data.

2. Finds Hidden Patterns

It discovers useful patterns and relationships in the dataset.

3. Easy to Understand

The generated rules are simple and easy for users to read and interpret.

4. Used for Classification

It classifies new data into different categories using the generated rules.

5. Supports Prediction

It helps predict the outcome of new or unknown data.

6. Data-Driven Technique

It learns rules automatically from the available data.

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Types of Rule Induction

1. Classification rule Induction

It is a techniques that generates IF-THEN rules to classify data into predefine categories.

Example :

Study Hours	Attendance	Result
8 hours	90%	Pass
3 hours	50%	Fail
6 hours	80%	Pass

1. Association rule Induction

Association rule induction is a Data mining technique used to discover relationships or associations between items in a dataset by generating IF – THEN rules.

Example :

Customer	Purchased items
C1	Bread, Butter
C2	Bread, Milk
C3	Bread, Butter, Milk

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Applications

- **Easy to Understand :** The generated IF–THEN rules are simple and easy to read.
- **Finds Hidden Patterns :** It discovers useful patterns and relationships in data.
- **Supports Decision Making** :It helps make better decisions based on the generated rules.
- **Useful for Prediction :** It predicts the class or outcome of new data.

Advantages

- Predicts diseases based on patient data.
- Identifies fraudulent transactions.
- Helps banks approve or reject loan applications.
- Groups customers based on their behavior.
- Classifies emails as spam or non-spam

Limitations

- Incorrect or incomplete data can reduce accuracy.
- Large datasets can produce many unnecessary rules.
- It may not capture very complex relationships.
- Better quality data produces better rules and predictions.

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Neural Networks AKTU (2024-25)

A **Neural Network** is a machine learning model inspired by the way the **human brain works**. It consists of connected units called **neurons (nodes)** that learn patterns from data and use those patterns to make **predictions or decisions**.

Example:

Suppose we want to predict whether a student will **pass or fail** based on their **study hours and attendance**.

Input: Study hours = 6, Attendance = 85%

The neural network processes these inputs through its connected neurons.

During training, it learns the relationship between study hours, attendance, and past results.

Output: Pass So, a neural network **learns from previous data and uses the learned patterns to predict the output for new data**.

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Biological Neuron vs Artificial Neuron AKTU (2022-23)

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Aspect	Biological Neuron	Artificial Neuron
1. Definition	A biological neuron is a natural nerve cell found in the human brain.	An artificial neuron is a mathematical model used in a computer and is a basic unit of Artificial Neural Network.
2. Nature	It is a living cell.	It is a mathematical and logical unit.
3. Function	It receives, processes and sends electrical signals.	It receives input values, processes them and produces an output.
4. Structure	It has dendrites, cell body (soma) and axon.	It has inputs, weights, summation function, activation function and output.
5. Input	It receives signals from other neurons through dendrites.	It receives input values (features) through input connections.
6. Processing	Processing is done inside the cell body (soma).	Processing is done using weighted sum and activation function.
7. Output	It sends signals to other neurons through axon.	It produces output which is sent to next neuron or as final result.
8. Learning	It learns from experience and brain activity.	It learns from training data by adjusting weights.
9. Speed	It works very fast (in milliseconds).	It works fast but depends on computational power.
10. Environment	It works in the human nervous system.	It works in an artificial system or computer program.
11. Example	Human brain neuron.	Perceptron, ANN neuron.

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Layers of a Neural Network

A neural network is generally made up of **three main types of layers**:

Input Layer → Hidden Layer(s) → Output Layer

1. Input Layer

- The **input layer is the first layer** of a neural network. It receives the input data from the user or dataset
- Each input feature is usually represented by a **neuron (node)**.
  The input layer receives and passes the input data to the next layer.

2. Hidden Layer

The **hidden layer is the layer between the input and output layers**. A neural network can have **one or more hidden layers**.

The neurons in hidden layers process the input data and learn **patterns and relationships** from it.

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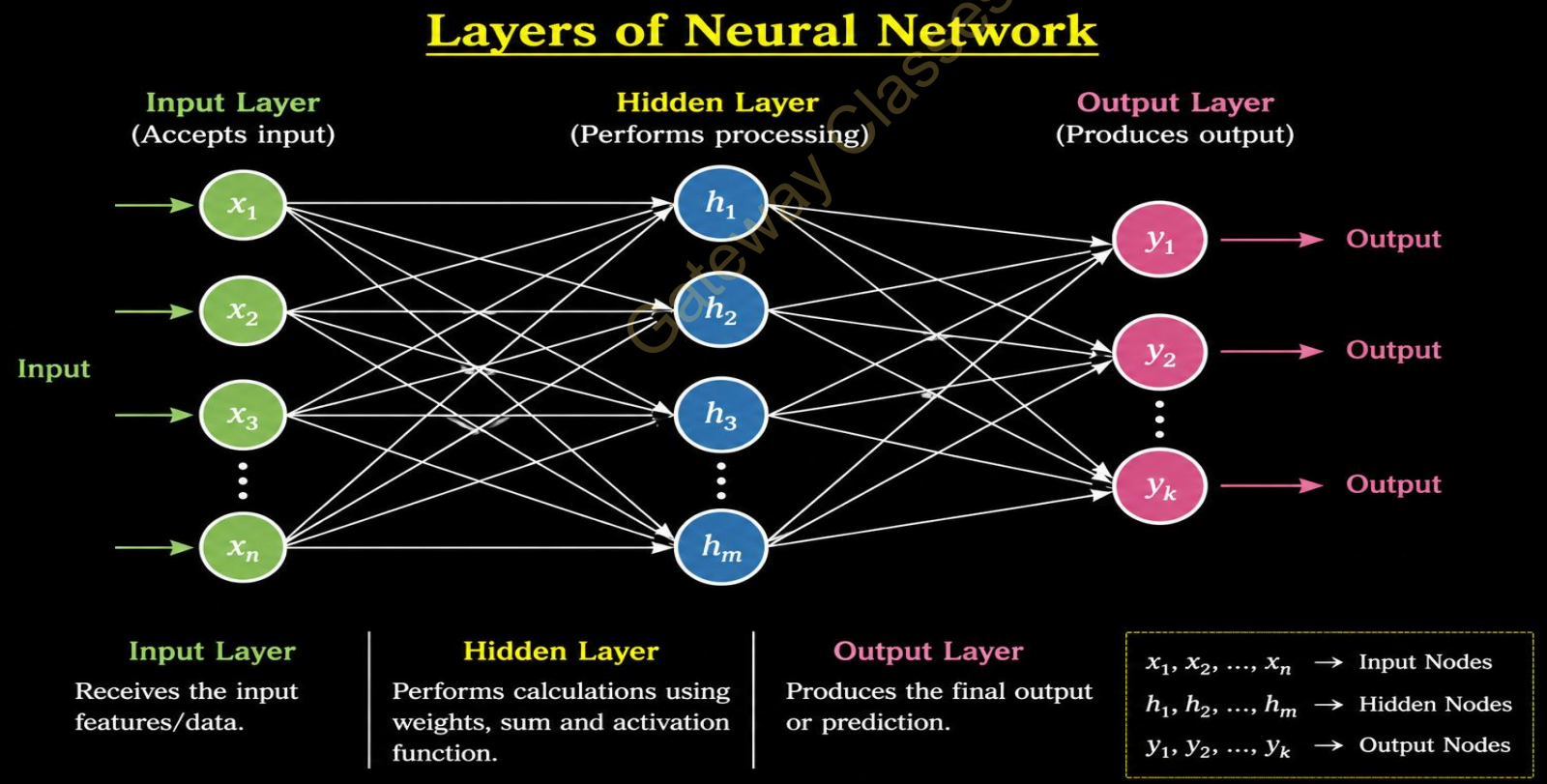
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The hidden layers process the input data and extract useful patterns for making a prediction.

3. Output Layer

The **output layer is the final layer** of a neural network. It provides the **final prediction or result**.

The number of neurons in the output layer depends on the type of problem.



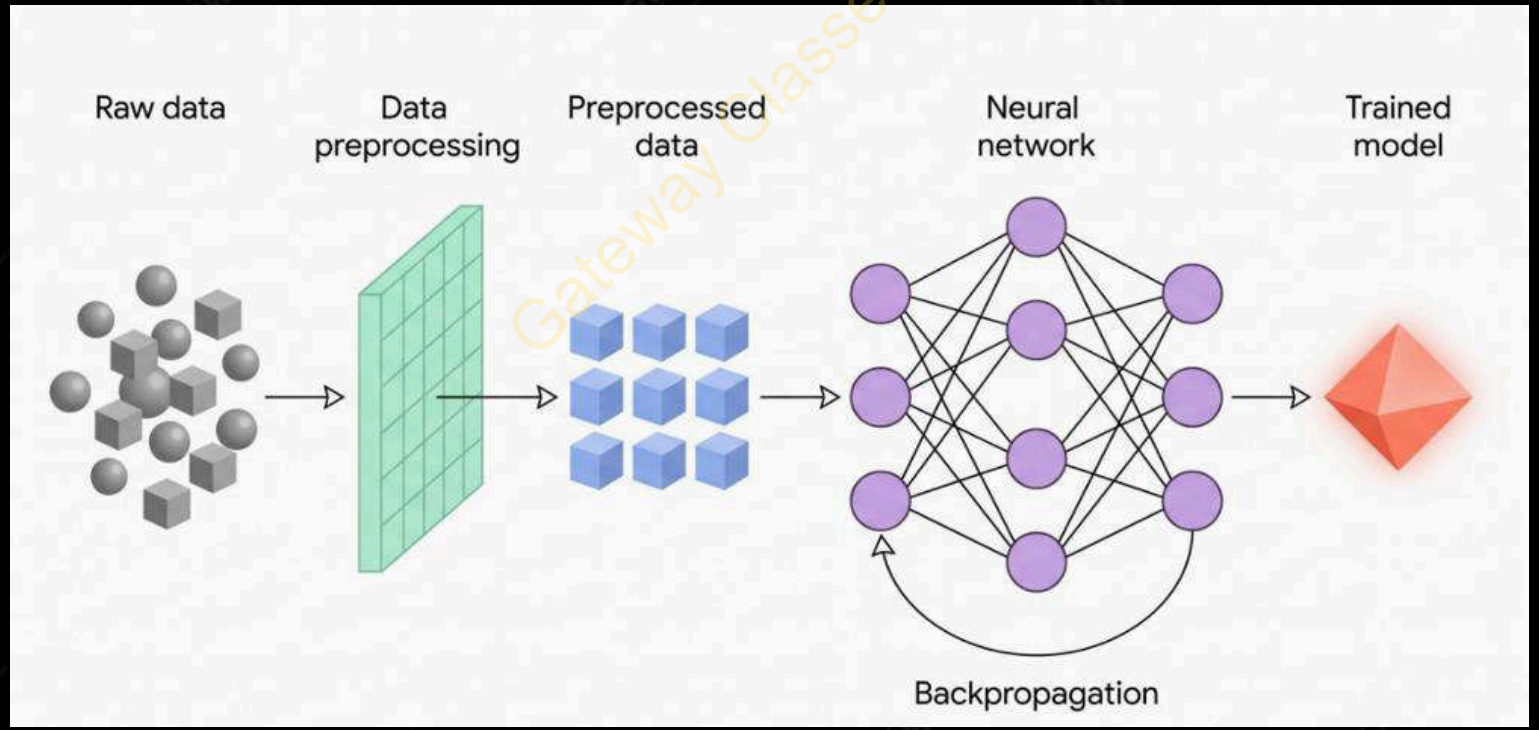
WORKING OF NEURAL NETWORK

1. **INPUT DATA**
   The input data is given to the Input Layer.
2. **ASSIGN WEIGHTS**
   Each input is assigned a weight.
3. **CALCULATE WEIGHTED SUM**
   Multiply each input by its weight and add all the values.
   Add bias to get the final sum.
4. **APPLY ACTIVATION FUNCTION**
   The weighted sum is passed through an activation function
   to decide whether the neuron is active or inactive.
5. **HIDDEN LAYER PROCESSING**
   The hidden layer processes the data, learns patterns,
   and sends the information to the next layer.
6. **GENERATE OUTPUT**
   The output layer produces the final prediction.
7. **CALCULATE ERROR**
   The predicted output is compared with the actual output
   and the error is calculated.
8. **UPDATE WEIGHTS AND BIAS**
   The weights and bias are adjusted to reduce the error
   and improve accuracy.
9. **REPEAT THE PROCESS**
   The process is repeated many times until the error is very small
   and the prediction is accurate.

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Learning in Neural Network

- **Learning is the process in which a neural network learns from training data and improves its predictions by adjusting its weights.**
- A neural network **learns from examples**. It makes mistakes at first, corrects them, and gradually gives more accurate results.



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Types of Learning

1. Supervised Learning

Supervised Learning is a learning method in which the neural network learns from labeled data. The correct output is already known.

Example:

A teacher gives a question and the correct answer. The student learns from both the question and the answer.

2. Unsupervised Learning

Unsupervised Learning is a learning method in which the neural network learns from unlabeled data. The correct output is not given.

Example:

A child is given different fruits and groups similar fruits together without knowing their names.

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3. Reinforcement Learning

Reinforcement Learning is a learning method in which the neural network learns by receiving rewards for correct actions and penalties for wrong actions.

Example:

A dog learns a trick. When it performs the correct trick, it gets a reward. When it performs the wrong trick, it gets no reward and learns to do better next time.

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EXAMPLE OF LEARNING IN NEURAL NETWORK

Example:

Task: Predict Pass or Fail

1. **Raw Data (Input)**
   The system is given students' marks (out of 100) and the correct result (Pass or Fail).

↓

2. **Data Preprocessing**
   Marks are cleaned and prepared for training.

↓

3. **Preprocessed Data**
   Now the data is ready to be used by the neural network.

↓

4. **Neural Network (Learning)**
   - The neural network sees the marks and predicts Pass or Fail.
   - At first, it may give the wrong prediction.
   - It compares the prediction with the correct result.
   - It adjusts its weights to reduce the error.
   - This process is repeated with many students' data.
   - The network learns and its predictions become more accurate.

↓

5. **Trained Model (Output)**
   After learning from imany examples, the model is trained.
   Now it can correctly predict Pass or Fail for new students.

Final Output: Student = Pass

Learning means improving predictions by learning from data.

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Generalisation

Generalisation is the ability of a neural network to apply what it has learned from training data to new, unseen data and give accurate results.

A neural network is trained with pictures of different cats. After learning the features of cats, it can correctly identify a **new cat picture** that it has never seen before. This ability is called **generalisation**.

Example :

A neural network is trained to identify cats and dogs using many images. It learns common features like ears, eyes, and body shape. When it correctly identifies a new cat image that it has never seen before, it shows good generalisation because it can apply its learning to new data.

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Importance of Generalisation in Neural Network

Works on new data – It helps the neural network give correct results for unseen data.

Prevents overfitting – It avoids memorising only training data and improves performance.

Improves accuracy – A well-generalised model provides more reliable predictions.

Saves time and resources – It reduces the need for collecting large amounts of training data.

Makes the model practical – It allows neural networks to work effectively in real-world applications.

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Competitive Learning in Neural Network

Competitive Learning is an unsupervised learning method in which all neurons complete for an input, and only the neuron with the highest response wins and learns.

Example :

Imagine 3 bulbs trying to light up when a switch is pressed.

Bulb A	-	Dim
Bulb B	-	Brightest !!
Bulb C	-	Medium

Since Bulb B glows the brightest, it is the winner. Only Bulb B is allowed to learn (Update its weights). The other two bulbs do nothing.

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Principal Component Analysis AKTU (2022-23)

Principal Component Analysis (PCA) is a technique used to reduce the number of features in a dataset while keeping the most important information. It converts many related features into a smaller number of new features called Principal Components, making the data easier to analyse.

Example :

Suppose a school has the following student data.

Before PCA :

Student	Name	Roll No.	Study Hours	Attendance
A	Aman	101	8	90%
B	Ravi	1022	6	80%
C	Priya	103	3	50%

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After PCA :

Study Hours	Attendance	Marks
8	90%	95
6	800%	85
3	50%	45

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PCA reduce the size of the data while keeping the most useful information.

Fuzzy Logic AKTU (2022-23)

Fuzzy Logic is a technique used to make decisions based on degrees of truth rather than only True (1) or False (0). It allows values to be partially true and partially false, just like human thinking.

Example :

Suppose the room temperature is 28°C.

Classical Logic: Hot or Not Hot (only one answer)

Fuzzy Logic: The temperature can be 70% Hot and 30% Warm at the same time.

So, fuzzy logic does not think in only Yes/No. It also uses partly Yes and partly No.

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Fuzzy Set

A Fuzzy Set is a set in which an element can belong partially to the set. Its membership value can be between 0 and 1.

Example :

Suppose we have a fuzzy set called "Tall People".

Height 190 cm → Membership = 1.0 (Definitely Tall)

Height 175 cm → Membership = 0.6 (Somewhat Tall)

Height 160 cm → Membership = 0.1 (Not much Tall)

Here, a person can be partly tall, not just Tall or Not Tall.

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Membership Function

A Membership Function is a function that shows how much an element belongs to a fuzzy set. It assigns a value between 0 and 1, where 0 means "not a member" and 1 means "fully a member."

Difference between Classical Logic and Fuzzy Logic AKTU (2022-23)

Point	Classical Logic	Fuzzy Logic
1. Values	It uses only two values: True (1) or False (0).	It uses values between 0 and 1. (0 = False, 1 = True)
2. Membership	An element either belongs to a set or does not belong.	An element can belong partially to a set.
3. Decision	Decisions are exact and clear (Yes or No).	Decisions are approximate and based on degrees.
4. Logic Type	Uses precise, fixed rules and conditions.	Uses flexible rules and conditions.
5. Real Life Use	Works well in situations with clear and exact data.	Works well in situations with uncertainty or unclear data.

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Types of Fuzzy Models

1. Mamdani Fuzzy Model

It is the most commonly used fuzzy model.It uses IF–THEN rules to get the output.The output is in fuzzy form and then converted into a final value.

Example:IF temperature is high THEN fan speed is fast

2. Sugeno Fuzzy Model

In this model, the output is a constant value or mathematical function.It is mainly used in control systems and optimization problems.

Example: IF temperature is high THEN fan speed = 80%

3. Tsukamoto Fuzzy Model

In this model, each rule gives a single crisp output value.The final output is calculated by combining all rule outputs.

Example:IF temperature is high THEN fan speed is 80

4. Grid Fuzzy Model

In this model, the input space is divided into small grid regions.A fuzzy rule is created for each grid region. Example:Temperature is divided into Low, Medium, and High, and rules are created for each part.

Gateway Classes

Extract Fuzzy Models from Data

- Extract Fuzzy Models from Data is the process of creating a fuzzy model from available data.
- The system studies the data, finds patterns, and generates fuzzy rules.
- These rules help the system make decisions for new or unseen data.

Example :

Given Data:

20°C → Fan = Slow

30°C → Fan = Medium

40°C → Fan = Fast

New Input: 25°C

The system creates rules such as:

IF Temperature is Low → Fan is Slow
IF Temperature is Medium → Fan is Medium

Gateway Classes

STEPS TO EXTRACT FUZZY MODELS FROM DATA

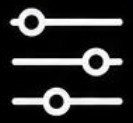
GATEWAY CLASSES

GATEWAY CLASSES

1. 

Collect Data

Collect the required input and output data from different sources.

2. 

Select Variables

Choose the input and output variables that will be used in the model.

3. 

Convert Data into Fuzzy Sets

Convert the collected data into fuzzy values such as Low, Medium, and High.

4. 

Generate Fuzzy Rules

Create IF–THEN rules based on the patterns in the data.

5. 

Build the Fuzzy Model

Combine all the fuzzy rules to create a complete fuzzy model.

6. 

Test the Model

Test the model using new data and check its accuracy.

7. 

Improve the Model

Modify the rules if needed to improve the model's performance.

Gateway Classes

Applications of Extract Fuzzy Models from Data

- **Medical Diagnosis** – Helps doctors make better decisions.
- **Weather Forecasting** – Predicts weather using past data.
- **Industrial Automation** – Controls machines and production systems.
- **Traffic Control** – Manages traffic signals efficiently.
- **Decision Support Systems** – Helps in solving complex decision problems.

Advantages

- Learns patterns from data automatically.
- Works well with uncertain or incomplete data.
- Improves decision-making.
- Easy to update with new data.
- Can be used in many real-life applications.

Limitations

- Requires a large amount of quality data.
- Creating fuzzy rules can be time-consuming.
- Results may depend on the quality of data.
- Complex problems may need many fuzzy rules.

GATEWAY CLASSES
Gateway Classes

Stochastic Search Methods

Stochastic Search Methods are optimization techniques that use random search to find the best or near-best solution to a problem.

Example

Suppose you want to find the shortest path to reach a destination.

Instead of checking every possible path, the system tries different random paths, compares them, and finally chooses the best path.

Gateway Classes

Steps of Stochastic Search Methods

Step 1: Define the Problem

First, identify the problem and set the goal to be achieved.

Step 2: Generate Initial Random Solutions

The system creates one or more random possible solutions.

Step 3: Evaluate the Solutions

Each solution is tested to measure how good or effective it is.

Step 4: Select the Better Solution

The better solution is selected based on its performance.

Step 5: Generate New Solutions

New random solutions are created by modifying the selected solution.

Step 6: Repeat the Process

The search process continues until a better solution is found.

Step 7: Stop the Search

The algorithm stops when the best or a satisfactory solution is obtained.

GATEWAY CLASSES
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Types of Stochastic Methods AKTU (2024-25)

GATEWAY CLASSES

GATEWAY CLASSES

1. Random Search Method-

- Random Search is a simple stochastic optimization method.
- It generates random solutions and selects the best solution among them.
- It does not follow a fixed path for searching.

2. Simulated Annealing-

- Simulated Annealing is inspired by the cooling process of metals.
- It allows some bad solutions in the beginning to avoid getting stuck in a local optimum.
- Gradually, it improves the solution and finds the best result.

3. Genetic Algorithm (GA)-

Genetic Algorithm is based on the process of natural evolution.

- It uses concepts like selection, crossover, and mutation to generate better solutions.
- It is used for complex optimization problems.

Gateway Classes

GATEWAY CLASSES

4. Particle Swarm Optimization (PSO)-

- Particle Swarm Optimization is inspired by the movement of birds and fish.
- A group of particles searches for the best solution by sharing information.
- It is used in optimization and machine learning problems.

5. Monte Carlo Method-

- Monte Carlo Method uses random sampling and probability to solve problems.-
- It estimates the solution by performing many random experiments.
- It is useful for complex mathematical problems.

Gateway Classes

Applications

- Machine Learning
- Data Mining
- Route Planning
- Engineering Design
- Scheduling Problems

Advantages

- Finds good solutions quickly.
- Works well for complex problems.
- Does not require checking every solution.
- Can escape local optimum solutions.
- Useful for real-world optimization.

Limitations

- Does not always find the exact best solution.
- Results may vary because of randomness.
- May require many iterations.
- Can be time-consuming for very large problems.
- Performance depends on the search strategy.

Gateway Classes

Previous Year Important Questions

1. How do stochastic search methods differ from deterministic optimization techniques? Provide use cases for each. (2024-25)
2. What are the various stochastic search method. Explain in detail with suitable example. (2023-24)
3. What are the components of time series? (2022-23)
4. Describe grid-based fuzzy model. (2022-23)
5. Differentiate between Neural Network and Artificial Neural Network. (2024-25)
6. What is rule induction ? (2022-23)
7. Explain multivariate analysis and Bayesian network. (2022-23)
8. Differentiate between Crips logic and Fuzzy logic. (2022-23)
9. Provide a detailed explanation of how fuzzy logic is used to extract models from data. Discuss the advantages of fuzzy modeling in capturing uncertainty and handling imprecise information in comparison to traditional crisp models. **(2023-24)**

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