

SmartStock Inventory Optimization for Retail Stores

Smart Stock Inventory System – Overview

Introduction

A Smart Stock Inventory System is a digital solution designed to help retail stores track their products automatically. It replaces manual stock counting with technology that updates inventory in real time, reduces errors, and ensures that important items are never out of stock.

Main Objective

- To monitor stock levels accurately and automatically
- To alert store owners about low stock, overstock, or expired items
- To make daily operations faster, smarter, and more organized

Python basics

1. Python Casting

- Casting = data type conversion
 - Common conversions:
 - `int()` → integer
 - `float()` → floating number
 - `str()` → string
 - Example: `float(5) = 5.0`
-

2. Function Initialization (def)

- Syntax:
 - `def function_name():`
 - `# code`
 - Function can have parameters and return values.
-

3. f-string

- f-string =Used to insert variables directly into a string using {}.
 - Fastest & cleanest string formatting.
 - `name = "Mannat"`
 - `print(f"Hello {name}")`
-

4. NumPy

- NumPy = Numerical Python (fast math library).

5. Pandas

- Pandas = data analysis and data cleaning library.
 - DataFrame .
 - Important operations:
 - `df.head()`
 - `df.describe()`
-

6. Matplotlib

- graph/visualization library.
- Graph types:
 - Line → `plt.plot()`
 - Bar → `plt.bar()`
 - Pie → `plt.pie()`
 - Scatter → `plt.scatter()`
- Basic functions:

- plt.title(), plt.xlabel(), plt.ylabel(), plt.show()

AI MODELS

AI models are computer programs that **learn patterns from data** and then use that learning to predict, understand, or generate things on their own.

Company Famous Model Family

Google Gemini

OpenAI GPT (Generative Pre-trained Transformer)

Groq Llama

What is an LLM?

LLM = Large Language Model

It is an AI model trained on huge amounts of text to understand and generate human-like language.

Examples of LLMs

These are all LLMs:

OpenAI

- GPT-5
- GPT-4o
- GPT-3.5

Google

- Gemini
- Gemma

Meta

- Llama 3
- Llama 3.1

LLMs are trained using large datasets.

Chat Completion means using an AI model (LLM) to generate the next response in a conversation.

This is how GPT, Gemini, Groq (Llama), Claude, etc. work.

What is Chat Completion?

It is an API style where you send:

- messages (user + assistant history)
- The model replies with the next message

What is PostgreSQL (Postgres)?

PostgreSQL is an open-source relational database management system (RDBMS).

In simple words:

It stores your data in tables (rows & columns)

Helps you query, insert, update, delete, and manage data

Uses SQL language

1. Type of Database

- **PostgreSQL** → *Object-Relational Database* (supports advanced data types, complex queries).
 - **MySQL** → *Relational Database* (simple structure, very fast for basic queries).
-

2. Speed

- **PostgreSQL** → Slower for simple reads but *faster for complex queries*.
 - **MySQL** → *Very fast for simple read-heavy operations*.
-

Why do we need Vector Databases?

Normal databases (MySQL, PostgreSQL) can't search:

- similar meaning sentences

- similar images
- related documents

They only match *exact words*, not *meaning*.

Vector DBs search using **similarity**, like:

- “Find documents similar to this one”
- “Find images that look like this picture”
- “Find product recommendations”

3 Main Types of Machine Learning

Supervised Learning

Learning with labeled data

The model is given **input + correct output**, and it learns the mapping.

Used for:

- Predicting prices
- Classifying emails (spam/not spam)
- Face recognition

Unsupervised Learning

Learning without labeled data

The model finds **patterns and groups** on its own.

Used for:

- Market segmentation
- Anomaly detection
- Recommendation systems

Reinforcement Learning (RL)

Learning by trial and error

The model gets **rewards** for good actions and **punishments** for bad actions.

Semi-Supervised Learning

Some data → labeled
Most data → unlabeled

Used when labeling is expensive.

Examples:

- Google Photos
- Medical images

1. API (Application Programming Interface)

Definition:

An API is a set of rules that allows two software applications to communicate and exchange data.

Simple meaning:

API works like a **messenger** between two programs. One program sends a request, API forwards it, and returns the response.

Real-life example:

A weather app requests today's temperature using a weather API and displays the result.

Benefits:

- Easy communication between software
- Reuse features without rewriting code
- Saves development time
- Secure, fast, structured communication

2. API Request Methods

GET Method

- Used to **fetch data from the server**.
- **No request body/payload**.
- Example: Getting user details.

POST Method

- Used to **send or create data on the server**.
- Contains payload (JSON data).

- Example: Creating a new user.
-

3. Payload

Definition:

Payload is the **actual data sent inside an API request or response**.

Example:

POST Request Payload:

4. Endpoint

Definition:

Endpoint is a **specific URL path** of an API where requests are made.

Examples:

- /api/users – GET all users
 - /api/users/1 – GET a user by ID
 - /api/users – POST to create a user
-

5. FastAPI vs Flask

Flask

- Lightweight web framework
- Beginner-friendly
- Manually handle validation
- Good for small/medium projects

Example:

```
from flask import Flask, jsonify
```

```
app = Flask(__name__)
```

```
@app.route("/hello")
```

```
def hello():
```

```
    return jsonify({"message": "Hello World"})
```

FastAPI

- Modern & high-performance

Example:

```
from fastapi import FastAPI
```

```
app = FastAPI()
```

```
@app.get("/hello")  
def hello():  
    return {"message": "Hello World"}
```

6. Python :

Create a virtual environment

```
python -m venv venv
```

or

```
python -m venv tenv
```

Activate environment

Windows:

```
venv\Scripts\activate
```

Deactivate

```
deactivate
```

7. requirements.txt

Create requirements file

```
requirements.txt
```

Install from requirements

```
pip install -r requirements.txt
```

Purpose:

Helps install the same packages on any system.

8. Git Commands

git add

- Adds files to staging area.

Add all files:

git add .

Add specific file:

git add filename.py

git commit

Saves staged changes:

git commit -m "message"

git push

Sends your commits to remote repository:

git push

git branch

View branches:

git branch

View all branches (local + remote):

git branch --all

Switch to another branch

git checkout branch_name

Or newer way:

git switch branch_name

Create and switch to a new branch

```
git checkout -b new_branch
```

or

```
git switch -c new_branch
```

git pull

Fetches latest changes and merges them into your branch:

```
git pull
```

git fetch --all

Downloads all changes from remote without merging:

```
git fetch --all
```

Database

A database is an organized collection of data that allows easy **storage, retrieval, updating, and management** of information. Databases help keep data structured and accessible for applications like banking systems, websites, social media platforms, and school management systems.

Why Do We Use a Database?

- To store large amounts of data safely
 - To avoid mistakes and inconsistency
 - To access data quickly
 - To allow multiple users to work at the same time
 - To keep data organized and structured
-

Types of Databases

1. Relational Databases (SQL)

Data is stored in tables with rows and columns. Uses SQL language.
Examples: MySQL, PostgreSQL, Oracle.

2. Non-Relational Databases (NoSQL)

Data stored in documents, key-value pairs, graphs, or wide columns.
Examples: MongoDB, Firebase, Cassandra.

Important Database Terms

- **Table:** Collection of rows and columns
 - **Row (Record):** One entry of data
 - **Column (Field):** Attribute of the data
 - **Primary Key:** Unique identifier for each record
 - **Foreign Key:** Connects two tables
 - **Query:** Command to retrieve or update data
 - **Index:** Speeds up searching
-

Normalization

Normalization is a database process used to organize data, reduce redundancy, and improve data consistency.

It breaks a large table into smaller linked tables so that data becomes clean and easy to manage.

Why Normalization Is Important

- Removes duplicate data
 - Saves storage
 - Ensures consistency
 - Avoids update/delete anomalies
 - Improves performance
 - Makes database structure logical
-

Normal Forms (1NF, 2NF, 3NF)

First Normal Form (1NF)

Rules:

- No repeating columns
- Values must be atomic (single values only)
- Each table must have a primary key

Meaning:

Break multi-valued and repeating data into separate rows.

Second Normal Form (2NF)

Rules:

- Table must be in 1NF
- No partial dependency
(A non-key attribute should not depend on part of a composite key)

Meaning:

Non-key attributes must depend on the whole primary key.

Third Normal Form (3NF)

Rules:

- Table must be in 2NF
- No transitive dependency
(Non-key attribute should not depend on another non-key attribute)

Meaning:

Every column must depend **only** on the primary key.

Summary Table

Normal Form	What It Fixes	Meaning
1NF	Repeating / multi-valued data	Only single values per cell
2NF	Partial dependency	Non-key depends on whole primary key

Normal Form	What It Fixes	Meaning
3NF	Transitive dependency	Non-key depends only on primary key

Git vs GitHub

Git	GitHub
Git is a software/tool .	GitHub is a website/platform .
Used for version control (tracks code changes).	Used for hosting Git repositories online .
Works offline on your computer.	Works online with internet.
Helps you manage project versions .	Helps you share, store, and collaborate on projects.
Only version control.	Provides extra features: issues, pull requests, teams, actions.

git --version is a command used to **check which version of Git is installed on your computer**.

Git Repository

A **Git repository** is a **storage place** where Git keeps all your project files and all the history of changes.

It remembers:

- every file
- every update
- every version
- who changed what

Agentic AI Workflow

Agentic AI is an AI system that can **take actions on its own** to achieve goals, not just answer questions.

It works like a **digital agent** that can plan, decide, and act.

Workflow Steps

1. Goal Definition

- The AI is given a **goal or task** to achieve.

Example: “Book a flight from Delhi to Jaipur.”

2. Environment Perception

- The AI **observes the environment** (data, APIs, or system states).
- It collects the **information it needs** to act.

Example: Checking flight availability or prices.

3. Planning

- The AI decides a **sequence of actions** to reach the goal.
- It may **consider multiple options** and choose the best one.

Example: Compare flights → choose the cheapest → check schedule.

4. Action / Execution

- AI performs the **action** in the environment.
- Can be **automatic tasks** like sending emails, booking tickets, or running scripts.

5. Monitoring / Feedback

- The AI checks if the action worked.
- If not, it adjusts its plan and tries again.

Example: Flight not available → pick next cheapest option.

Agent:

1. check stock levels automatically.

2. Predict when items will be out-of-stock
3. send alert to manager
4. auto-generate purchase orders
5. update demand forecasts daily

Reactive Agent

A **Reactive Agent** is an agent that:

- **Responds immediately to the current situation.**
- **Does not use memory or past experience.**

Robot vacuum → Changes direction when it hits an obstacle

Goal-Driven Agent

A **Goal-Driven Agent** is an agent that:

- **Acts to achieve a specific goal**
- **Can plan its actions instead of just reacting**

A **Multi-Agent System** is a system where **multiple agents work together** to achieve goals.

- **Each agent is independent**
- **Agents can communicate, cooperate, or compete**

How AI Agents Plan, Think, and Act

1. Perception (See/Observe)

- **Agent perceives the environment using sensors or data.**
-

2. Thinking / Reasoning

- **Agent analyzes the information it perceives.**
 - **Uses logic, rules, or models to decide what to do next.**
 - **Can predict outcomes of different actions.**
-

3. Planning

- **Agent makes a plan or sequence of actions to achieve a goal.**
- **Considers multiple options and chooses the best path.**

Example: Self-driving car plans the route to reach the destination safely and fast.

4. Acting / Execution

- Agent performs the chosen actions in the environment.
- The action is designed to move closer to the goal.

Example: Robot moves forward, orders items, or sends alerts.

5. Monitoring / Feedback

- Agent monitors the result of its actions.
- If the goal is not achieved, it replans or adjusts actions.

Example: Stock agent sees a product is still low → sends another alert.

AutoGen Agents

AutoGen frameworks often use **multiple agents** to work together. Two important ones are:

1. User Proxy Agent

- Acts as a **representative of the user**.
 - **Receives instructions or goals from the user**.
 - Communicates the **user's intent to the assistant agent**.
-

2. Assistant Agent

- Acts as the **worker or executor**.
 - **Plans, reasons, and performs tasks** to achieve the user's goal.
 - Can use tools, APIs, or other agents to complete the task.
-

• **pip install openai**

- **pip install openai** is a **command** used to install the OpenAI Python library on your computer.

```
resp = client.chat.completions.create(  
    model="gpt-4o-mini", # replace with an available model like "gpt-4o-mini"  
    or "gpt-4o" or "gpt-5" etc.  
    messages=[  
        {"role": "system", "content": "You are a helpful assistant."},  
        {"role": "user", "content": "Write a two-line poem about chai."}  
    ],  
    max_tokens=120  
)
```

What This Code Does

This code sends a message to an OpenAI model and asks it to generate a reply.

1. resp = client.chat.completions.create(...)

This line **creates a chat completion request**.

Means: “Send my messages to the AI model and give me a response.”

2. model="gpt-4o-mini"

You are choosing which AI model to use.

Example options:

- gpt-4o-mini
- gpt-4o
- gpt-5

Here it means: **Use the gpt-4o-mini model.**

3. messages=[...]

These are the messages we send to the AI.

a) System message

{"role": "system", "content": "You are a helpful assistant."}

This tells the AI:

“Behave like a helpful assistant.”

b) User message

```
{"role": "user", "content": "Write a two-line poem about chai."}
```

This is the actual question we want AI to answer.

4. max_tokens=120

This limits how long the AI's answer can be.

Max 120 tokens (roughly words/parts of words).

from openai import OpenAI mean?

This line is a **Python import statement**.

"From the `openai` library, import the `OpenAI` class."

client = OpenAI() mean?

This line **creates a connection** between your Python program and the **OpenAI API**.

The word `client` means a program that talks to a server (OpenAI).

pip install google-generativeai

This installs Google's AI library (Gemini models).

```
import google.generativeai as genai
```

```
# 1. Configure API KEY
```

```
genai.configure(api_key="YOUR_API_KEY")
```

```
# 2. Create Model
```

```
model = genai.GenerativeModel("gemini-1.5-flash")
```

```
# 3. Send user message
```

```
response = model.generate_content(
```

```
    "Write a short poem about coffee."
```

```
)
```

```
# 4. Get text output
```

```
print(response.text)
```

LLM Text Processing Workflow

Text → Tokens

- Input text is **split into small pieces called tokens**.
 - **Tokens can be:**
 - Words → "Hello"
 - Word parts → "playing" → "play" + "ing"
 - Punctuation → ":"
 - **Purpose:** LLM cannot understand raw text directly, so we break it into manageable units.
-

Tokens → Embeddings

- Each token is converted into a **vector of numbers** called an embedding.
 - Embeddings **capture the meaning of the token** in a numerical form.
 - Example: "chai" → [0.12, 0.88, 0.45, ...]
-

Embeddings → Transformer Layers

- The embeddings are passed through **transformer layers**.
 - Transformer layers **analyze the relationships** between all tokens in the sequence.
 - They contain **multiple sub-layers** like:
 - Feed-forward layers
 - Normalization layers
-

Attention Mechanism

- Attention lets the model **focus on important tokens** in the input.
 - Example: In "I love chai because it is warm", the model understands "chai" is related to "warm".
 - Helps the model **capture context and meaning** across the sentence.
-

Output Generation

- After transformer processing, the model predicts the **next token**.

- Tokens are generated one by one → converted back to text → final response.

Prompt Engineering

What is Prompt Engineering?

- **Prompt engineering** is the process of **designing and refining the input (prompt)** given to an AI model so that it produces the desired output.
- A **prompt** is the text you give the model, e.g., a question, instruction, or request.
- **Rate Limit:** Maximum requests per short period (e.g., per minute).
- **Quota:** Maximum total usage allowed over a long period (e.g., per day/month).

Logistic Regression

- Used for **binary classification**: 0/1, Yes/No, Spam/Not Spam
- Linear equation:

$$z = w_1x_1 + w_2x_2 + \dots + b$$

- Sigmoid function converts z to probability:

$$p = \frac{1}{1 + e^{-z}}$$

- **Prediction rule:**
 - If $p > 0.5 \rightarrow$ class 1
 - Else → class 0
- **Uses:** Fraud detection, Medical diagnosis, Customer churn, Email spam
- **Code:**

```
from sklearn.linear_model
import LogisticRegression
model = LogisticRegression()
```

Decision Tree

- Makes decisions like a **flowchart** (if–else questions)
- Root node → first question
- Branches → answers (Yes/No)
- Leaf nodes → final prediction (Class 0/1, Yes/No)

Is it Sunny?

/ \

Yes No → Play = No

|

Is Temperature Hot?

/ \

Yes No

| |

No Yes

Code:

```
from sklearn.tree

import DecisionTreeClassifier

model = DecisionTreeClassifier()
```

Random Forest

- Ensemble of many decision trees
- Uses random rows + random features for each tree
- Classification → majority vote
- Regression → average of outputs
- Advantages: Accurate, reduces overfitting, works with large datasets
- Uses: Fraud detection, Loan approval, Medical prediction, Stock/Price prediction
- Code:

```
from sklearn.ensemble

import RandomForestClassifier

rf = RandomForestClassifier()
```

KNN – K-Nearest Neighbors

- KNN is a **supervised machine learning algorithm**.
- It can be used for **classification** (class labels) or **regression** (numbers).
- It predicts the output of a **new data point** based on the **closest K neighbors** from the training data

How KNN Works

- Choose a value of **K** (number of neighbors).
- Calculate the **distance** between the new point and all training points (common: Euclidean distance).
- Pick the **K nearest points**.
- For **classification**: Take the **majority class** among neighbors.
- For **regression**: Take the **average value** of neighbors.
-

For two points $P_1 = (x_1, y_1)$ and $P_2 = (x_2, y_2)$:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

- $d \rightarrow$ distance between the points
- $x_1, y_1 \rightarrow$ coordinates of first point
- $x_2, y_2 \rightarrow$ coordinates of second point
-

K-Means Clustering

It is an **unsupervised machine learning algorithm** that groups data into **K clusters**.

- Each cluster has a **centroid** (mean of points in the cluster).
- The algorithm **minimizes the distance** between points and their assigned cluster centroids.

Steps

1. Initialize **K centroids** ($\mu_1, \mu_2, \dots, \mu_K$)
2. Assign each point x_i to nearest centroid ($\min ||x_i - \mu_j||^2$)
3. Recalculate centroid:

$$\mu_j = \frac{1}{|C_j|} \sum_{x_i \in C_j} x_i$$

4. Repeat until centroids don't change

Linear Regression

- A supervised machine learning algorithm.
- Used for predicting a continuous numerical value (regression problem).
- Predicts output y from input x using a linear relationship.
- Formula:

$$Y=mx+c$$

$m \rightarrow$ slope, $c \rightarrow$ intercept

1. IN / NOT IN

IN

Used to match a value with multiple values.

Syntax:

```
SELECT column_name
FROM table_name
WHERE column_name IN (value1, value2, value3);
```

Example:

```
SELECT name
FROM students
WHERE city IN ('Delhi', 'Mumbai', 'Chennai');
```

Meaning → students from either Delhi, Mumbai, or Chennai.

NOT IN

Used to exclude multiple values.

Example:

```
SELECT name
FROM students
WHERE city NOT IN ('Delhi', 'Mumbai');
```

Meaning → show students who are not from Delhi or Mumbai.

2. JOINS

Joins are used to combine rows from two tables based on a common column.

Suppose:

Table 1: Students

std_id name address

Table 2: Subjects

| subject_id | std_id | subject_name |

A. INNER JOIN

Returns only those rows where matching data exists in both tables.

Example:

```
SELECT students.std_id, students.name, subjects.subject_name
```

```
FROM students
```

```
INNER JOIN subjects
```

```
ON students.std_id = subjects.std_id;
```

Shows only students who have subjects.

B. LEFT JOIN (LEFT OUTER JOIN)

Returns all rows from the left table + matching rows from right.
If no match → NULL.

Example:

```
SELECT students.std_id, students.name, subjects.subject_name
```

```
FROM students
```

```
LEFT JOIN subjects
```

`ON students.std_id = subjects.std_id;`

Shows all students, even those who don't have subjects.

C. RIGHT JOIN (RIGHT OUTER JOIN)

Returns all rows from the right table + matching from left.

Example:

`SELECT students.name, subjects.subject_name`

`FROM students`

`RIGHT JOIN subjects`

`ON students.std_id = subjects.std_id;`

Shows all subjects, even if some subjects are not assigned to any student.

D. FULL JOIN (FULL OUTER JOIN)

Returns all rows from both tables, matching or not.

Example:

`SELECT *`

`FROM students`

`FULL OUTER JOIN subjects`

`ON students.std_id = subjects.std_id;`

Every student + every subject, match or no match.

3. GROUP BY

Used to group rows that have the same values.

Example: Count students in each city

`SELECT city, COUNT(*)`

FROM students

GROUP BY city;

Output example:

city	count
------	-------

Delhi	10
-------	----

Mumbai	8
--------	---

4. HAVING Clause

- WHERE → used before grouping (filters rows)
- HAVING → used after grouping (filters groups)

Example: Show cities having more than 5 students

SELECT city, COUNT(*)

FROM students

GROUP BY city

HAVING COUNT(*) > 5;

HAVING applies on aggregate functions like COUNT(), SUM(), AVG().

YOLO (You Only Look Once)

Introduction

YOLO, which stands for You Only Look Once, is one of the fastest and most popular real-time object detection algorithms.

The name describes the core idea — the model looks at the image **only once** in a single forward pass and detects all objects instantly.

Because of its high speed and accuracy, YOLO is widely used in:

- CCTV surveillance
- Traffic and vehicle detection
- Self-driving cars
- Robotics and drones
- Medical imaging
- Gaming and AR/VR
- Industrial automation

What is Object Detection?

Object detection is a computer vision task in which an algorithm:

1. **Identifies** which objects are present in an image (cat, car, person, etc.)
 2. **Locates** them using bounding boxes
-

How YOLO Works

YOLO treats object detection as a **single regression problem** — it directly predicts:

- Object class
- Bounding box coordinates
- Confidence score

It divides the input image into an **S × S grid**.

Each grid cell predicts:

- The probability of an object
- The object's class
- The bounding box (x, y, width, height)

Because the entire image is processed at once, YOLO becomes extremely fast.

Key Features of YOLO

1. Real-Time Speed

YOLO is famous for its speed. It can detect objects at **45+ FPS** (frames per second), while the lighter versions (YOLO-tiny) can go above **150 FPS**.

2. End-to-End Single Network

Unlike old models that required multiple networks, YOLO uses just **one neural network** for detection.

3. High Accuracy

YOLO gives very accurate predictions in real time. Later versions like YOLOv5 and YOLOv8 have reached extremely high precision.

4. Generalization

YOLO sees the entire image at once, so it understands context better and makes fewer mistakes like false positives.

YOLO Architecture

A typical YOLO model contains:

1. **Input Image** (e.g., 416×416 or 640×640)
 2. **CNN Backbone**
 - Extracts features
 - Examples of backbones: Darknet53, CSPDarknet, MobileNet
 3. **Detection Head**
 - Predicts bounding boxes, classes, confidence scores
 4. **Output**
 - List of detected objects with box coordinates and labels
-

Advantages of YOLO

- Extremely fast
 - Works in real time
 - High accuracy
 - Simple end-to-end architecture
 - Good for embedded devices and mobile
 - Can detect multiple objects at the same time
-

Limitations

- Struggles with very small objects
 - Sometimes misses objects that overlap heavily
 - Accuracy depends on good training data
-

Applications of YOLO

✓ Self-Driving Cars

Detects pedestrians, traffic lights, vehicles in real time.

✓ Security & Surveillance

Used in smart CCTV systems to detect breaking rules or suspicious activities.

✓ **Medical Imaging**

Detects tumors, cells, and abnormalities.

✓ **Retail & Industry**

Counts products, inspects defects on assembly lines.

✓ **Agriculture**

Detects plant diseases, animals, crop quality.

✓ **Robotics & Drones**

Real-time navigation, object tracking, and obstacle detection.

Python Concepts

1. strip()

Removes spaces from both sides of the string.

" hello ".strip() Result → "hello"

2. split()

Breaks the string into parts and returns a list.

"a b c".split()

Result → ['a', 'b', 'c']

3. join()

Joins a list of words/letters into one string using a separator.

"-".join(["a", "b", "c"])

Result → "a-b-c"

4. replace()

Changes a part of the string with something else.

`"hello world".replace("world", "Python")`

Result → "hello Python"

5. upper()

Changes the whole string to UPPERCASE.

`"hello".upper()`

Result → "HELLO"

6. lower()

Changes the whole string to lowercase.

`"HELLO".lower()`

Result → "hello"

7. startswith()

Checks if the string starts with a word/letter.

Returns True or False.

`"Python".startswith("Py")`

Result → True

8. endswith()

Checks if the string ends with a word/letter.

Returns True or False.

`"hello.txt".endswith(".txt")`

Result → True

9. find()

Finds the position (index) of a word/letter.
If not found → returns -1.

"hello".find("l")

Result → 2 (because index starts from 0)

10. isdigit()

Checks if the string has **only numbers**.

"123".isdigit()

Result → True

11. isalpha()

Checks if the string has **only letters**.

"abc".isalpha()

Result → True

LIST METHODS

1. append()

Adds **one item** at the **end** of the list.

l = [1, 2, 3]

l.append(4)

print(l)

Result → [1, 2, 3, 4]

2. extend()

Adds **multiple items** (another list) at the end.

```
I = [1, 2, 3]  
I.extend([4, 5])  
print(I)  
Result → [1, 2, 3, 4, 5]
```

3. insert()

Adds an item at a **specific position**.

```
I = [10, 20, 30]  
I.insert(1, 15) # position 1, value 15  
print(I)  
Result → [10, 15, 20, 30]
```

4. remove()

Removes the **first occurrence** of the given item.

```
I = [1, 2, 3, 2]  
I.remove(2)  
print(I)  
Result → [1, 3, 2] (first 2 removed)
```

5. pop()

Removes an item by **index** and returns it.
(Default removes last item)

```
I = [10, 20, 30]  
I.pop()  
Result → removes 30  
I.pop(1)
```

Result → removes item at index 1 (20)

6. index()

Gives the position of an item.

`I = ["a", "b", "c"]`

`I.index("b")`

Result → 1

7. count()

Counts how many times an item appears.

`I = [1, 2, 2, 3]`

`I.count(2)`

Result → 2

8. sort()

Sorts the list in ascending order.

`I = [3, 1, 2]`

`I.sort()`

`print(I)`

Result → [1, 2, 3]

9. reverse()

Reverses the list order.

`I = [1, 2, 3]`

`I.reverse()`

```
print(l)
```

Result → [3, 2, 1]

1. keys()

Gives all **keys** of the dictionary.

```
d = {"name": "Avi", "age": 20}
```

```
print(d.keys())
```

Result → dict_keys(['name', 'age'])

2. values()

Gives all **values** of the dictionary.

```
d.values()
```

Result → dict_values(['Avi', 20])

3. items()

Gives **key–value pairs** together.

```
d.items()
```

Result → dict_items([('name', 'Avi'), ('age', 20)])

4. get()

Returns the **value** of a **key**.
(No error if key doesn't exist)

```
d.get("name")
```

Result → "Avi"

5. update()

Adds or changes key–value pairs.

```
d.update({"city": "Delhi"})
```

```
print(d)
```

Result → {'name': 'Avi', 'age': 20, 'city': 'Delhi'}

6. pop()

Removes a key and returns its value.

```
d.pop("age")
```

Result → removes "age": 20

7. popitem()

Removes the last added key–value pair.

```
d.popitem()
```

8. clear()

Removes everything from the dictionary.

```
d.clear()
```

```
print(d)
```

Result → {} (empty dictionary)

9. fromkeys()

Creates a new dictionary using given keys.

```
keys = ["a", "b", "c"]
```

```
new_d = dict.fromkeys(keys, 0)
```

```
print(new_d)
```

Result → {'a': 0, 'b': 0, 'c': 0}

10. setdefault()

Returns the value of a key.

If key doesn't exist, it adds the key with a default value.

```
d.setdefault("country", "India")
```

Result → adds "country": "India"

DICTIONARY METHODS

1. get()

Used to get the value of a key.

If the key doesn't exist → it returns None (no error).

Example:

```
d = {"name": "Avi", "age": 20}
```

```
print(d.get("name"))
```

Output:

Avi

2. keys()

Returns all keys in the dictionary.

Example:

```
d.keys()
```

Output:

```
dict_keys(['name', 'age'])
```

3. values()

Returns all values in the dictionary.

Example:

```
d.values()
```

Output:

```
dict_values(['Avi', 20])
```

4. items()

Returns key–value pairs as tuples.

Example:

```
d.items()
```

Output:

```
dict_items([('name', 'Avi'), ('age', 20)])
```

5. update()

Adds new key–value pairs OR updates existing ones.

Example:

```
d.update({"city": "Delhi"})
```

Result:

```
{'name': 'Avi', 'age': 20, 'city': 'Delhi'}
```

6. pop()

Removes a key and returns its value.

Example:

```
d.pop("age")
```

Result:

20

Dictionary now becomes:

```
{'name': 'Avi'}
```

7. `popitem()`

Removes the last added key–value pair.

Example:

```
d.popitem()
```

If dictionary was:

```
{'name': 'Avi', 'age': 20}
```

After `popitem()`:

```
('age', 20)
```

Dictionary becomes:

```
{'name': 'Avi'}
```

Set Methods:

- `add()` → Adds an element to the set.
- `remove()` → Removes a specific element (gives error if element not present).
- `discard()` → Removes a specific element if it exists (no error if element not present).
- `pop()` → Removes and returns a random element from the set.
- `clear()` → Removes all elements from the set.
- `union()` → Returns a new set with all elements from both sets.
- `intersection()` → Returns a new set with elements common to both sets.
- `difference()` → Returns a new set with elements in one set but not in the other.

General-Purpose Functions:

- `len()` → Returns the number of items in a sequence (like string, list, tuple, etc.).

- `range()` → Generates a sequence of numbers (often used in loops).
- `print()` → Displays output on the screen.
- `type()` → Returns the data type of a variable or value.
- `id()` → Returns the unique identity (memory address) of an object.
- `sorted()` → Returns a new sorted list from an iterable.
- `enumerate()` → Adds a counter to an iterable and returns it as pairs (index, value).
- `zip()` → Combines multiple iterables element-wise into tuples.

Conversion Functions

Used to convert one data type into another

Function Description	Example
<code>int()</code> Converts a value to integer	<code>int("5")</code> → 5
<code>float()</code> Converts a value to float	<code>float("3.14")</code> → 3.14
<code>str()</code> Converts a value to string	<code>str(10)</code> → "10"
<code>list()</code> Converts iterable to list	<code>list("abc")</code> → ['a','b','c']
<code>dict()</code> Converts sequence of tuples to dictionary	<code>dict([('a',1),('b',2)])</code> → {'a':1,'b':2}
<code>set()</code> Converts iterable to set	<code>set([1,2,2,3])</code> → {1,2,3}
<code>tuple()</code> Converts iterable to tuple	<code>tuple([1,2,3])</code> → (1,2,3)

2. Mathematical Functions

Function Description	Example
<code>abs()</code> Returns the absolute value of a number.	<code>abs(-5)</code> → 5
<code>sum()</code> Returns the sum of all items in an iterable.	<code>sum([1,2,3])</code> → 6
<code>min()</code> Returns the smallest item from an iterable.	<code>min([4,1,9])</code> → 1
<code>max()</code> Returns the largest item from an iterable.	<code>max([4,1,9])</code> → 9
<code>pow()</code> Raises a number to the power of another.	<code>pow(2,3)</code> → 8
<code>round()</code> Rounds a number to the nearest integer or given decimals.	<code>round(3.6)</code> → 4

3. Functional Programming Tools

Function Description

filter()	Selects items from an iterable that satisfy a condition.
map()	Applies a function to each item of an iterable.
reduce()	Combines all items of an iterable into a single value using a function.
lambda	Creates a small anonymous function in a single line.

4. Input & Output

Function Description

input()	Reads data from the user as a string.
---------	---------------------------------------

Example

```
name = input("Enter your name: ")
```

5 Class and Object Functions

Function Description

getattr()	Returns the value of a given attribute of an object.	getattr(obj,'name')
setattr()	Sets a value to an attribute of an object.	setattr(obj,'age',20)
hasattr()	Checks if an object has a specific attribute.	hasattr(obj,'name') → True
delattr()	Deletes an attribute from an object.	delattr(obj,'age')
isinstance()	Checks if an object is an instance of a class.	isinstance(5,int) → True
issubclass()	Checks if a class is a subclass of another class.	issubclass(bool,int) → True

Attribute vs Parameter:

- Attribute is a property of an object (obj.name), whereas a parameter is a value passed to a function (def greet(name):

6. Miscellaneous Functions

Function	Description	Example
globals()	Returns a dictionary of all global variables.	globals()['__name__'] → "__main__"
locals()	Returns a dictionary of all local variables.	locals()
callable()	Checks if an object can be called like a function.	callable(print) → True
exec()	Executes dynamic Python code.	exec("a=5")
eval()	Evaluates a Python expression and returns result.	eval("2+3") → 5

7. Exception Handling

Concept	Description	Example
try-except	Handles runtime errors and prevents program crash.	try: 1/0 except ZeroDivisionError: print("Error")
else/elif	else and elif are conditional statements, not for error handling.	if x>5: print("Yes") elif x==5: print("Equal") else: print("No")

8. Memory and Object Management

Function	Description	Example
del()	Deletes a variable or object from memory.	a=5; del a
gc.collect()	Forces garbage collection to free unused memory.	import gc; gc.collect()

9. Iterables

Function	Description	Example
iter()	Creates an iterator from an iterable.	it = iter([1,2,3])
next()	Returns the next element from an iterator.	next(it) → 1

Key Features of Python

Easy to Learn and Use

Interpreted Language

Dynamically Typed

High-Level Language

Object-Oriented Programming (OOP)

Large Standard Library

Strong Community Support

Portable

Python Data Types

Basic Data Types

- **int** – Integer numbers (e.g., 10, -3)
- **float** – Decimal numbers (e.g., 3.14, -2.5)
- **str** – Text/characters (e.g., "Hello")
- **bool** – True or False

Collection Data Types

- **list** – Ordered, changeable collection (e.g., [1, 2, 3])
- **tuple** – Ordered, unchangeable collection (e.g., (1, 2, 3))
- **set** – Unordered, unique items (e.g., {1, 2, 3})
- **dict** – Key-value pairs (e.g., {"name": "Ram", "age": 20})

Advanced Types

- **NoneType** – Represents 'no value' (None)
- **complex** – Complex numbers (e.g., 2+3j)

- **bytes / bytearray** – Binary data
- **range** – Sequence of numbers (e.g., range(1,5))

PEP 8 =

Python's rulebook for writing clean, readable, and standard code.

Mutable Objects

You can modify the object without creating a new one.

You can add, remove, or replace elements.

Example: (list – mutable)

```
a = [1, 2, 3]
a[0] = 10 # changed the list
print(a) # [10, 2, 3]
```

Immutable Objects

Once created, you **cannot** change them.

If you try to modify, Python creates a **new object**.

Example: (string – immutable)

Indentation in Python

Indentation means giving spaces at the beginning of a line.

Python uses indentation to define **blocks of code** (loops, functions, if statements, etc.).

Instead of { } like other languages, Python uses **indentation level** to show which statements belong together.

How Python Executes a Program

Flow Diagram

Your Code (.py)



Bytecode (.pyc)



Python Virtual Machine (PVM)

↓

Output

Namespace = A container/directory where names are mapped to objects.

How to Make Dictionaries in Python

Python provides 4 common ways to create a dictionary.

1. Using Curly Braces { }

```
student = {
```

```
    "name": "Aman",
```

```
    "age": 20,
```

```
    "city": "Delhi"
```

```
}
```

2. Using the dict() Constructor

```
student = dict(name="Aman", age=20, city="Delhi")
```

3. Creating an Empty Dictionary and Adding Items

```
student = {}
```

```
student["name"] = "Aman"
```

```
student["age"] = 20
```

```
student["city"] = "Delhi"
```

4. Using List of Tuples / Pairs

```
student = dict([("name", "Aman"), ("age", 20), ("city", "Delhi")])
```

Remove duplicates from list

Using set()

```
my_list = [1, 2, 2, 3, 3, 4]
unique_list = list(set(my_list))
print(unique_list) # [1, 2, 3, 4]
```

List Comprehension

List comprehension is a concise way to **create lists** using a single line of code.

It combines **loops** and **conditionals** into a **short, readable expression**.

Feature	Shallow Copy	Deep Copy
Definition	Creates a new object, but nested objects reference the same memory .	Creates a new object and recursively copies all nested objects .
Effect on Original	Changes in nested objects affect the original.	Changes in copy do not affect the original.

Slicing in Python

Slicing is a technique to extract a portion of a sequence (like a list, tuple, or string) using **start, stop, and step** indices.

Syntax

```
sequence[start:stop:step]
```

1. Slice a List

```
numbers = [0, 1, 2, 3, 4, 5]
print(numbers[1:4]) # [1, 2, 3]
```

Frozenset

A **frozenset** is an **immutable version of a set**.

Once created, its elements **cannot be changed**, but you can perform **set operations** like union, intersection, and difference.

*args and **kwargs

In Python, functions can accept **variable number of arguments** using:

1. `*args` → **Non-keyword (positional) variable arguments**
 2. `**kwargs` → **Keyword (named) variable arguments**
-

1. `*args` (**Variable Positional Arguments**)

- Allows passing any number of positional arguments to a function.
- Arguments are received as a tuple.

Syntax

```
def func(*args):  
    for arg in args:  
        print(arg)
```

Example

```
def add(*args):  
    return sum(args)  
  
print(add(1, 2, 3)) # 6  
print(add(5, 10)) # 15
```

2. `**kwargs` (**Variable Keyword Arguments**)

- Allows passing any number of named arguments to a function.
- Arguments are received as a dictionary.

Syntax

```
def func(**kwargs):  
    for key, value in kwargs.items():  
        print(key, value)
```

Decorators

A decorator is a function that takes another function as input, adds extra functionality to it, and returns it.
It allows modifying the behavior of a function without changing its code.

Closures

A closure is a function that remembers the values from its enclosing scope, even if the outer function has finished execution.

- Inner function “closes over” variables of outer function.
 - Useful for data hiding and decorators.
-

Key Points

Definition Inner function that remembers outer function’s variables

Inheritance

Inheritance is a mechanism in Python where a class (child/subclass) acquires properties and methods from another class (parent/superclass).

- Promotes code reusability
- Allows creating hierarchical relationships between classes

Multiple vs Multilevel Inheritance

Feature	Multiple Inheritance	Multilevel Inheritance
Definition	A child class inherits from more than one parent class	A class inherits from a child class, forming a chain of inheritance
Number of Parents	Two or more parent classes	Only one parent class per level
Number of Levels	Single level	Multiple levels (grandparent → parent → child)
Syntax	class Child(Parent1, Parent2):	class Grandchild(Child):
Use Case	Combine functionality from multiple classes	Extend functionality gradually through levels

Polymorphism

Polymorphism means “many forms”.

In Python, it allows objects of different classes to be treated in a similar way, or methods to behave differently based on context.

Abstraction

Abstraction is the concept of hiding the internal implementation details of a class and showing only the essential features to the user.

- Focuses on what an object does, not how it does it.
- Achieved using abstract classes and abstract methods in Python.

Monkey Patching

Monkey Patching is the practice of dynamically modifying or extending a class or module at runtime without altering the original source code.

- Can be used to add, change, or override methods or attributes of existing classes or modules.
- Often used in testing, debugging, or quick fixes.

Syntax Error vs Runtime Error

Feature	Syntax Error	Runtime Error
Definition	Occurs when Python cannot parse the code due to incorrect syntax	Occurs while program is running due to illegal operations
When Detected	Before execution (during parsing)	During execution
Causes	Missing colon, wrong indentation, misspelled keywords	Division by zero, accessing undefined variable, file not found
Program Stops?	Yes, code won't run	Yes, only if exception is not handled
Example	print("Hello" → missing closing parenthesis	x = 5 / 0 → division by zero

What is PIP?

PIP stands for “Python Package Installer”.

It is a tool used to install, upgrade, and manage Python packages and libraries from the Python Package Index (PyPI).

File Reading Methods in Python

Method	Description	Return Type	Example
read(size)	Reads the entire file or up to size characters	String	f.read() or f.read(10)
readline()	Reads one line from the file at a time	String	f.readline()
readlines()	Reads all lines and returns them as a list of strings	List	f.readlines()

Deleting a File in Python

To delete a file in Python, you can use the `os` module.

Steps

1. Import `os` module
2. Use `os.remove()` or `os.unlink()` to delete a file

NumPy Array vs Python List

Feature	Python List	NumPy Array
Type of Elements	Can store different data types	Stores elements of the same type
Performance	Slower for large data	Faster due to vectorized operations
Memory	More memory per element	Less memory, more efficient
Operations	Element-wise operations require loops	Supports vectorized operations ($a + b$, $a * b$)
Functions	Limited built-in mathematical functions	Rich set of mathematical, statistical, and linear algebra functions

Feature	Python List	NumPy Array
Multidimensional	Can create nested lists, but manual handling needed	Supports ndarrays natively (1D, 2D, 3D, ...)
Broadcasting	Not supported	Supported (operate on arrays of different shapes)

Broadcasting

Automatic alignment of arrays of different shapes in NumPy for arithmetic operations is called Broadcasting.

Vectorization in NumPy

Vectorization means performing operations on entire arrays (vectors/matrices) without using explicit loops.

GIL (Global Interpreter Lock)

GIL stands for **Global Interpreter Lock**.

It is a mutex (mutual exclusion) lock in CPython (the standard Python implementation) that allows only one thread to execute Python bytecode at a time, even on multi-core processors.

One-Hot Encoding

One-Hot Encoding is a technique to convert categorical variables into numerical form so that machine learning models can use them.

- Each category becomes a new column
- A 1 is placed in the column corresponding to the category, 0 elsewhere
- **Regex in Python**
 - Regular Expressions (Regex) are patterns used to match, search, and manipulate strings.
In Python, regex operations are performed using the `re` module.

JAVA BASICS

Main Features of Java

- Platform independent (WORA)
- Object Oriented
- Secure
- Robust

- Multithreaded
 - High Performance
 - Portable
-

JDK vs JRE vs JVM

- **JVM** → Runs Java bytecode
 - **JRE** → JVM + Libraries (to run programs)
 - **JDK** → JRE + Development tools (to write programs)
-

Access Modifiers

- **public** → accessible everywhere
 - **protected** → same package + subclass
 - **default** → same package only
 - **private** → same class only
-

Constructor

- Special method to initialize object
 - Same name as class
 - No return type
 - Called automatically
-

Can Constructor be Private?

- Yes
 - Used in **Singleton class**
 - Prevents object creation outside class
-

Abstraction vs Encapsulation

- **Abstraction** → hiding implementation (what to do)
 - **Encapsulation** → binding data + methods (how to protect)
-

Primitive Data Types

- byte, short, int, long
 - float, double
 - char
 - boolean
-

Static vs Non-static Variables

- **static** → class level, shared
 - **non-static** → object level, separate copy
-

final vs finally vs finalize

- final → constant / cannot override / cannot inherit
 - finally → always executes in exception handling
 - finalize() → called by GC before object removal
-

this vs super

- this → current class object
 - super → parent class object
-

String vs StringBuffer vs StringBuilder

- **String** → immutable
 - **StringBuffer** → mutable + thread safe
 - **StringBuilder** → mutable + fast (not thread safe)
-

Why String is Immutable

- Security
 - Thread safety
-

Array vs ArrayList

- Array → fixed size
- ArrayList → dynamic size
- Array → faster
- ArrayList → flexible

Collection Framework

- Used to store & manipulate objects
 - Interfaces → List, Set, Queue, Map
 - Classes → ArrayList, LinkedList, HashSet, HashMap
-

ArrayList vs LinkedList

- ArrayList → fast access
 - LinkedList → fast insertion/deletion
 - ArrayList → uses array
 - LinkedList → uses nodes
-

How HashMap Works

- Stores data as **key-value pairs**
 - Uses **hashing**
 - Allows **one null key**
 - No duplicate keys
-

Checked vs Unchecked Exception

- **Checked** → compile time (IOException)
 - **Unchecked** → runtime (NullPointerException)
-

throw vs throws

- **throw** → throws exception manually
 - **throws** → declares exception in method
-

Multiple Catch Blocks

- **Yes allowed**
 - Order → child first, parent last
-

◆ MULTITHREADING

Process vs Thread

- Process → program in execution
 - Thread → smallest unit of process
 - Thread shares memory
-

Multithreading

- Multiple threads running simultaneously
 - Improves performance
 - Better CPU utilization
-

Deadlock

- Threads waiting for each other forever
 - Conditions → Mutual Exclusion, Hold & Wait, No Preemption, Circular Wait
-

volatile Keyword

- Ensures visibility of variable
 - Does NOT ensure atomicity
 - Used in multithreading
-

Lambda Expression

- Short way to implement functional interface
 - Syntax → (args) -> { body }
 - Checked exception must be handled or declared
-

map() vs flatMap()

- map → one-to-one transformation
 - flatMap → flattens nested structure
-

Inner Classes

- Non-static inner
 - Static nested
 - Local inner
 - Anonymous inner
-

Diamond Problem

- Ambiguity in multiple inheritance
 - Java avoids it using **interfaces**
 - Must override method
-

Method Hiding

- Happens with **static methods**
- Reference type decides method
- Compile time binding

Software Development Life Cycle (SDLC)

1. SDLC Overview

- SDLC is a structured process to develop software efficiently.
 - Phases:
 1. Requirement Analysis
 2. System / Functional Design
 3. Development / Implementation
 4. Testing
 5. Deployment
 6. Maintenance
-

2. Roles & Responsibilities

Business / Functional Side

- **Business Analyst / Functional Consultant**
 - Collects business requirements
 - **Creates Functional Specification (FS)**
 - Maps business needs to software functionality
 - **Product Manager**
 - Defines product vision, roadmap, and features
 - Focus: *What to build and why*
 - **Project Manager**
 - Plans project timelines, resources, and budget
 - Focus: *How & when to deliver*
-

Development Team

- **Developer / Programmer**
 - Writes code based on **Functional & Technical Specs**
 - Creates **Technical Specification Document (TSD)**
 - Performs **Unit Testing**
 - **Documentation**
 - Maintains all project-related documents: BRD, FS, TSD, Test Cases, User Manuals
-

Testing / QA Team

- Creates **Test Cases / Test Scripts** based on FS
 - Performs **Testing: Unit, Integration, System, Regression**
 - Logs defects and verifies bug fixes
-

Administration / Operations Team

- Maintains **network, applications, and databases**
 - Handles **deployment, configuration, monitoring, and backups**
-

Security Team

- Ensures data, network, and application security
 - Performs security monitoring, access control, and compliance audits
-

Support Team

- Provides post-deployment user support
 - Troubleshoots issues and escalates to developers or admin team
 - Maintains knowledge base / FAQs
-

Sales & Marketing Team

- Promotes the product and generates revenue
 - Collects customer feedback
 - Coordinates with Product Manager for improvements
-

Human Resource (HR) Team

- Manages recruitment, onboarding, training, payroll, policies, and employee relations
- Supports project teams by providing skilled resources

Waterfall Model (Software Development)

The Waterfall Model is one of the earliest and simplest SDLC models. It is linear and sequential, meaning each phase must be completed before the next one starts.

Key Characteristics

- Sequential flow: Each phase depends on the deliverables of the previous phase
 - No overlapping of phases
 - Documentation-heavy
 - Easy to understand and manage
-

Phases of Waterfall Model

1. Requirement Analysis

- Gather business and system requirements
- Create **Requirement Specification Document (SRS)**

2. System / Software Design

- Translate requirements into architecture and technical design
- Prepare design documents

3. Implementation / Coding

- Developers write code based on design documents
- Unit testing may also be done

4. Testing

- QA team performs integration and system testing
- Identify and fix defects

5. Deployment / Installation

- Software is delivered and installed at the user site

6. Maintenance

- Fix post-deployment issues
- Provide updates and enhancements

Advantages

- Simple and easy to understand
- Clear milestones and documentation
- Works well for small projects with fixed requirements

Disadvantages

- Inflexible to requirement changes
- Late discovery of defects (testing comes after coding)
- Not suitable for large or complex projects

Agile Model (Software Development)

The Agile Model is an iterative and incremental approach to software development. Unlike Waterfall, it focuses on flexibility, collaboration, and customer feedback.

Key Characteristics

- Iterative development in small cycles called sprints
 - Continuous collaboration with stakeholders and customers
 - Frequent delivery of working software
 - Emphasis on responding to change rather than following a fixed plan
-

Phases / Process of Agile

- 1. Requirement Gathering (High-level)**
 - Collect features for the current iteration (sprint)
- 2. Planning**
 - Define tasks for the sprint
 - Estimate effort and resources
- 3. Design & Development**
 - Develop features in small increments
 - Unit testing by developers
- 4. Testing**
 - QA tests each increment
 - Continuous integration ensures working software
- 5. Review / Feedback**
 - Present working software to stakeholders
 - Incorporate feedback in next sprint
- 6. Deployment**
 - Deliver increments to users frequently
 - Updates done iteratively

Advantages

- Flexible and adaptive to changing requirements
 - Early delivery of working software
 - Close collaboration with customers
 - Reduces risk of project failure
-

Disadvantages

- Requires active stakeholder involvement
- Less predictable scope and timeline
- Needs skilled and motivated team

A* (A-Star) Search Algorithm

A* is an informed search algorithm used to find the shortest path between a start node and a goal node. It is widely used in AI, path-finding, and graph traversal problems.

Working of A* Algorithm

1. Add the **start node** to the **OPEN** list.
 2. Select the node with **minimum $f(n)$** from **OPEN**.
 3. If it is the **goal node**, stop.
 4. Move the node to the **CLOSED** list.
 5. Expand the node and calculate **g , h , and f** for its neighbors.
 6. Add unexplored neighbors to **OPEN**.
 7. Repeat until goal is found or **OPEN** is empty.
-

Heuristic Function ($h(n)$)

A heuristic must be:

- **Admissible** → never overestimates the true cost
 - **Consistent** → satisfies triangle inequality
-

1. Bubble Sort

Idea

Repeatedly compares adjacent elements and swaps them if they are in the wrong order. Largest element moves to the end in each pass.

Algorithm

1. Repeat for all elements:
2. Compare adjacent elements.
3. Swap if left > right.
4. Stop when no swaps occur.

Example

Array: 5 1 4 2

Pass 1 → 1 4 2 5

Pass 2 → 1 2 4 5

2. Selection Sort

Idea

Selects the smallest element and places it at the beginning.

Algorithm

1. Find the minimum element.
2. Swap with the first unsorted position.
3. Repeat for remaining array.

Example

64 25 12 22 11

After 1st pass → 11 25 12 22 64

Complexity

- Best / Average / Worst: $O(n^2)$
-

3. Insertion Sort

Idea

Builds sorted list one element at a time by inserting elements in the correct position.

Algorithm

1. Take next element.
2. Shift larger elements to the right.
3. Insert element at correct position.

Example

8 3 5 2

Stepwise → 3 8 5 2 → 3 5 8 2 → 2 3 5 8

Complexity

- Best: $O(n)$
 - Average: $O(n^2)$
 - Worst: $O(n^2)$
-

4. Merge Sort

Idea

Divide-and-conquer algorithm. Splits array into halves, sorts them, and merges.

Algorithm

1. Divide array into two halves.
2. Recursively sort halves.
3. Merge sorted halves.

Example

38 27 43 3

Split → [38 27] [43 3]

Merge → [3 27 38 43]

Complexity

- Best / Average / Worst: $O(n \log n)$
-

5. Quick Sort

Idea

Divide-and-conquer algorithm using a pivot. Elements smaller than pivot go left, larger go right.

Algorithm

1. Choose a pivot.
2. Partition array.
3. Recursively apply quick sort.

Example

10 80 30 90 40

Pivot = 40 → [10 30] 40 [80 90]

Complexity

- Best: $O(n \log n)$

Different Frameworks under Agentic AI

Agentic AI refers to AI systems that can perceive, reason, plan, act, and learn autonomously to achieve goals. These agents often operate in dynamic environments with feedback loops.

Below are the major frameworks / approaches used in Agentic AI, explained simply (exam-friendly):

1. Reactive Agent Framework

- Agents act only on current perceptions
- No memory of past states

Example:

Rule-based systems, reflex agents

Use case:

Simple games, obstacle avoidance

2. Deliberative Agent Framework

- Agents plan before acting
- Maintain an internal model of the environment

Techniques:

- Search algorithms
- Planning (STRIPS, A*)

Use case:

Robotics, route planning

3. Hybrid Agent Framework

- Combines **reactive + deliberative** agents
- Fast reactions + intelligent planning

Use case:

Autonomous vehicles, smart robots

4. Reinforcement Learning-Based Agents

- Agents learn from **reward and punishment**
- Improve decisions over time

Algorithms:

- Q-Learning
- DQN
- Policy Gradient

Use case:

Games, robotics, recommendation systems

5. Multi-Agent Systems (MAS)

- Multiple agents interact or cooperate
- Agents may be cooperative or competitive

Examples:

- Swarm intelligence
- Distributed AI

Use case:

Traffic control, stock trading bots

Q-Learning in Reinforcement Learning

Q-Learning is a popular [model-free reinforcement learning algorithm](#) that helps an agent learn how to make the best decisions by interacting with its environment. Instead of needing a model of the environment the agent learns purely from experience by trying different actions and seeing their results

Imagine a system that sees an apple but incorrectly says, “It’s a mango.” The system is told, “Wrong! It’s an apple.” It learns from this mistake. Next time, when shown the apple, it correctly says “It’s an apple.” This trial-and-error process, guided by feedback is like how Q-Learning works.

Q-Learning

The core idea is that the agent builds a Q-table which stores Q-values. Each Q-value estimates how good it is to take a specific action in a given state in terms of the expected future rewards. Over time the agent updates this table using the feedback it receives

Key Components

1. Q-Values or Action-Values

Q-values represent the expected rewards for taking an action in a specific state. These values are updated over time using the Temporal Difference (TD) update rule.

2. Rewards and Episodes

The agent moves through different states by taking actions and receiving rewards. The process continues until the agent reaches a terminal state which ends the episode.

3. Temporal Difference or TD-Update

The agent updates Q-values using the formula:

$$Q(S, A) \leftarrow Q(S, A) + \alpha(R + \gamma Q(S', A') - Q(S, A))$$

Where,

- **S** is the current state.
- **A** is the action taken by the agent.
- **S'** is the next state the agent moves to.
- **A'** is the best next action in state **S'**.
- **R** is the reward received for taking action **A** in state **S**.
- **γ (Gamma)** is the discount factor which balances immediate rewards with future rewards.

- α (Alpha) is the learning rate determining how much new information affects the old Q-values.

4. ϵ -greedy Policy (Exploration vs. Exploitation)

The ϵ -greedy policy helps the agent decide which action to take based on the current Q-value estimates:

- **Exploitation:** The agent picks the action with the highest Q-value with probability $1-\epsilon$. This means the agent uses its current knowledge to maximize rewards.
- **Exploration:** With probability ϵ , the agent picks a random action, exploring new possibilities to learn if there are better ways to get rewards. This allows the agent to discover new strategies and improve its decision-making over time.

How does Q-Learning Works?

Q-learning models follow an iterative process where different components work together to train the agent. Here's how it works step-by-step:

Q learning algorithm

1. Start at a State (S)

The environment provides the agent with a starting state which describes the current situation or condition.

2. Agent Selects an Action (A)

Based on the current state and the agent chooses an action using its policy. This decision is guided by a Q-table which estimates the potential rewards for different state-action pairs. The agent typically uses an ϵ -greedy strategy:

- It sometimes explores new actions (random choice).
- It mostly exploits known good actions (based on current Q-values).

3. Action is Executed and Environment Responds

The agent performs the selected action. The environment then provides:

- A new state (S') — the result of the action.
- A reward (R) — feedback on the action's effectiveness.

4. Learning Algorithm Updates the Q-Table

The agent updates the Q-table using the new experience:

- It adjusts the value for the state-action pair based on the received reward and the new state.
- This helps the agent better estimate which actions are more beneficial over time.

5. Policy is Refined and the Cycle Repeats

With updated Q-values the agent:

- Improves its policy to make better future decisions.
- Continues this loop — observing states, taking actions, receiving rewards and updating Q-values across many episodes.

Over time the agent learns the optimal policy that consistently yields the highest possible reward in the environment.

Methods for Determining Q-values

1. Temporal Difference (TD):

Temporal Difference is calculated by comparing the current state and action values with the previous ones. It provides a way to learn directly from experience, without needing a model of the environment.

2. Bellman's Equation:

Bellman's Equation is a recursive formula used to calculate the value of a given state and determine the optimal action. It is fundamental in the context of Q-learning and is expressed as:

$$Q(s, a) = R(s, a) + \gamma \max_{a'} Q(s', a')$$

Where:

- $Q(s, a)$ is the Q-value for a given state-action pair.
- $R(s, a)$ is the immediate reward for taking action a in state s .
- γ is the discount factor, representing the importance of future rewards.
- $\max_a Q(s', a')$ is the maximum Q-value for the next state s' and all possible actions.

What is a Q-table?

The Q-table is essentially a memory structure where the agent stores information about which actions yield the best rewards in each state. It is a table of Q-values representing the agent's understanding of the environment. As the agent explores and learns from its interactions with the environment, it

updates the Q-table. The Q-table helps the agent make informed decisions by showing which actions are likely to lead to better rewards.

Structure of a Q-table:

- Rows represent the states.
- Columns represent the possible actions.
- Each entry in the table corresponds to the Q-value for a state-action pair.

Over time, as the agent learns and refines its Q-values through exploration and exploitation, the Q-table evolves to reflect the best actions for each state, leading to optimal decision-making.

Implementation

Here, we implement basic Q-learning algorithm where agent learns the optimal action-selection strategy to reach a goal state in a grid-like environment.

Step 1: Define the Environment

We first define the environment including the number of states, actions, goal state and the Q-table. Each state represents a position in a 4×4 grid and actions represent movements in four directions.

```
import numpy as np
```

```
import matplotlib.pyplot as plt
```

```
n_states = 16
```

```
n_actions = 4
```

```
goal_state = 15
```

```
Q_table = np.zeros((n_states, n_actions))
```

Step 2: Set Hyperparameters

These parameters control the learning process:

- **learning_rate (α):** How much new info overrides old info.
- **discount_factor (γ):** How much future rewards are valued.
- **exploration_prob (ϵ):** Probability of taking a random action.

- **epochs:** Number of training episodes.

learning_rate = 0.8

discount_factor = 0.95

exploration_prob = 0.2

epochs = 1000

Step 3: Define the State Transition Function

This function calculates the next state based on the current state and chosen action.

We assume:

- 0 → Left
- 1 → Right
- 2 → Up
- 3 → Down

What is a Depth-First Search in AI?

DFS is a traversing algorithm used in tree and graph-like data structures. It generally starts by exploring the deepest node in the frontier. Starting at the root node, the algorithm proceeds to search to the deepest level of the search tree until nodes with no successors are reached.

DFS Working

Depth-first search (DFS) explores a graph by selecting a path and traversing it as deeply as possible before backtracking.

Search operation of the depth-first search

- Originally it starts at the root node, then it expands its one branch until it reaches a dead end. Then it backtracks to the most recent unexplored node, repeating until all nodes are visited or a specific condition is met. (As shown in the above image, starting from node A, DFS explores its successor B, then proceeds to its descendants until reaching a dead end at node D. It then backtracks to node B and explores its remaining successors i.e E.)
- This systematic exploration continues until all nodes are visited or the search terminates. (In our case after exploring all the nodes of B. DFS explores the right side node i.e C then F and and then G. After exploring the node G. All the nodes are visited. It will terminate.

Key characteristics of DFS

In simple terms, the DFS algorithms in [AI](#) holds the power of extending the current path as deeply as possible before considering the other options.

- **Not Cost-Optimal:** DFS is not cost-optimal because it does not guarantee finding the shortest path to the goal. It may find a solution quickly, but that path might not be the shortest or the cheapest one.
- **Stack-Based Search:** DFS uses a stack to remember which nodes to explore next. When DFS visits a new node, it adds it to the stack. It keeps going deeper by exploring neighbors. If it reaches a dead end (a node with no more children), it backtracks by removing nodes from the stack and exploring other possible paths.
- **Backtracking Search:** A variant of DFS is called backtracking search, which uses less memory. Instead of creating all possible paths at once, it generates one child node at a time. It can also modify the current state directly without making a new copy. This saves memory by only keeping one state and the path taken so far.

Depth Limited Search for AI

Last Updated : 23 Jul, 2025

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Depth Limited Search is a key algorithm used in solving problem space concerned with artificial intelligence. But before starting it lets first understand Depth First Search which is an algorithm that explores a tree or graph by starting at the root node and exploring as far as possible along each branch before backtracking. It follows a path from the root to a leaf node then backtracks to explore other paths. This method can be inefficient when dealing with large or infinite trees as it may explore deep branches that do not contain the goal, leading to wasted time and resources.

To learn more about Depth First Search Algorithm refer to: [Depth First Search or DFS for a Graph](#)

Getting Started with Depth Limited Search (DLS)

Depth Limited Search is a modified version of DFS that imposes a limit on the depth of the search.

How Depth Limited Search Works

1. **Initialization:** Begin at the root node with a specified depth limit.

2. **Exploration:** Traverse the tree or graph, exploring each node's children.
3. **Depth Check:** If the current depth exceeds the set limit, stop exploring that path and backtrack.
4. **Goal Check:** If the goal node is found within the depth limit, the search is successful.
5. **Backtracking:** If the search reaches the depth limit or a leaf node without finding the goal, backtrack and explore other branches.

Uniform Cost Search (UCS) in AI

Uniform Cost Search (UCS) is a search algorithm used in artificial intelligence (AI) for finding the least cost path in a graph. It is a variant of Dijkstra's algorithm and is particularly useful when all edges of the graph have different weights, and the goal is to find the path with the minimum total cost from a start node to a goal node.

Introduction to Uniform Cost Search (UCS)

Uniform Cost Search is a pathfinding algorithm that expands the least cost node first, ensuring that the path to the goal node has the minimum cost. Unlike other search algorithms like [Breadth-First Search \(BFS\)](#), UCS takes into account the cost of each path, making it suitable for weighted graphs where each edge has a different cost.

Key Concepts of Uniform Cost Search

1. **Priority Queue:** UCS uses a priority queue to store nodes. The node with the lowest cumulative cost is expanded first. This ensures that the search explores the most promising paths first.
2. **Path Cost:** The cost associated with reaching a particular node from the start node. UCS calculates the cumulative cost from the start node to the current node and prioritizes nodes with lower costs.
3. **Exploration:** UCS explores nodes by expanding the least costly node first, continuing this process until the goal node is reached. The path to the goal node is guaranteed to be the least costly one.
4. **Termination:** The algorithm terminates when the goal node is expanded, ensuring that the first time the goal node is reached, the path is the optimal one.

Bidirectional Search

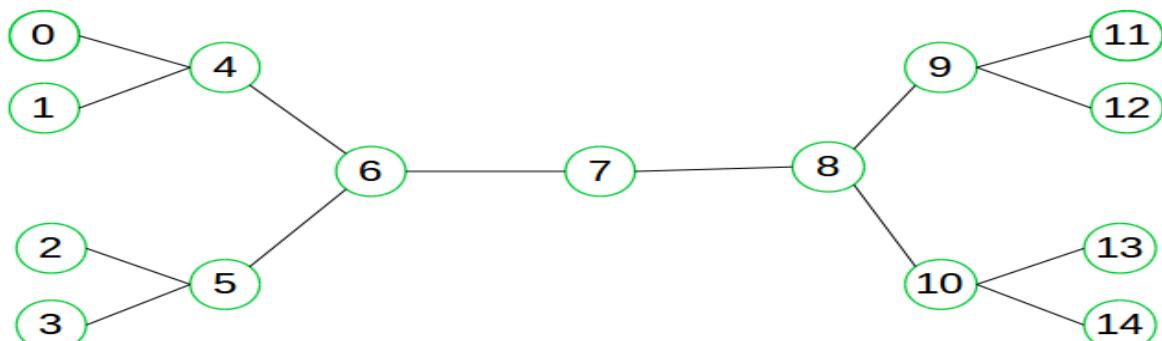
Bidirectional search is a graph search algorithm which finds smallest path from source to goal vertex. It runs two simultaneous search -

1. Forward search from source/initial vertex toward goal vertex
2. Backward search from goal/target vertex toward source vertex

Bidirectional search replaces single search graph (which is likely to grow exponentially) with two smaller sub graphs – one starting from initial vertex and other starting from goal vertex. The search terminates when two graphs intersect.

Just like [A* algorithm](#), bidirectional search can be guided by a [heuristic](#) estimate of remaining distance from source to goal and vice versa for finding shortest path possible.

Consider following simple example-



Suppose we want to find if there exists a path from vertex 0 to vertex 14. Here we can execute two searches, one from vertex 0 and other from vertex 14. When both forward and backward search meet at vertex 7, we know that we have found a path from node 0 to 14 and search can be terminated now. We can clearly see that we have successfully avoided unnecessary exploration.

When to use bidirectional approach?

We can consider bidirectional approach when-

1. Both initial and goal states are unique and completely defined.
2. The branching factor is exactly the same in both directions.

Performance measures

- Completeness : Bidirectional search is complete if BFS is used in both searches.

- **Optimality :** It is optimal if BFS is used for search and paths have uniform cost.
- **Time and Space Complexity :** Time and space complexity is $O(bd/2)$.

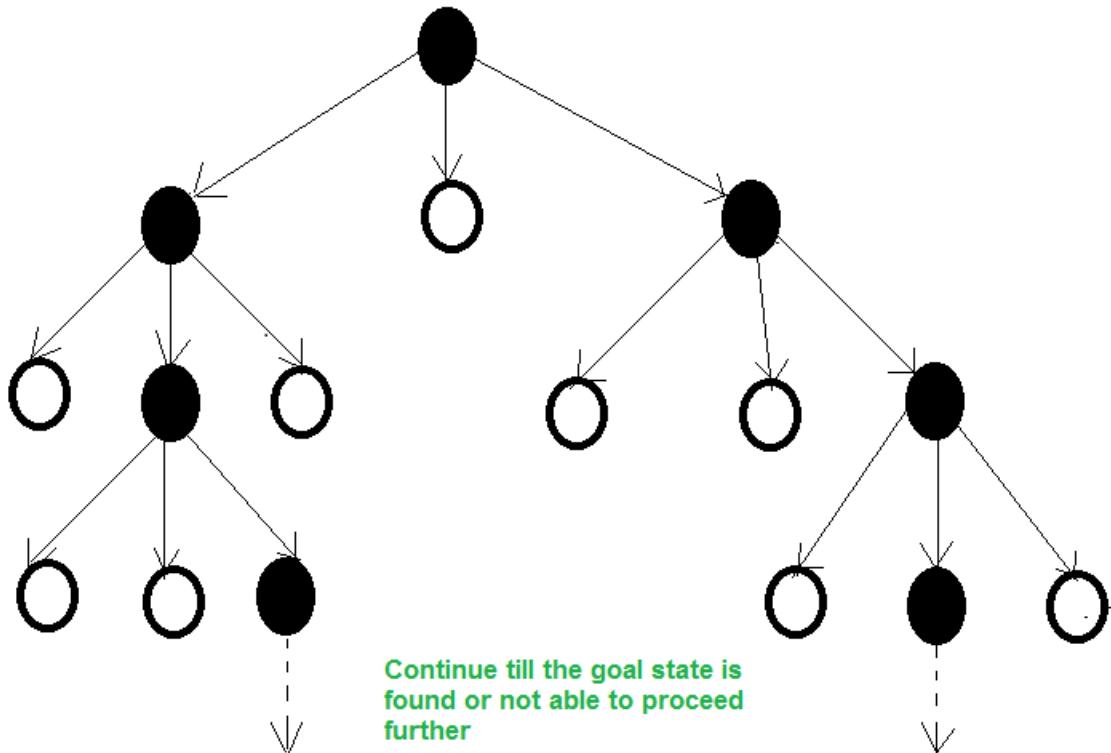
Beam Search Algorithm

Beam Search is a heuristic search algorithm that navigates a [graph](#) by systematically expanding the most promising nodes within a constrained set. This approach combines elements of [breadth-first search](#) to construct its search tree by generating all successors at each level. However, it only evaluates and expands a set number, W , of the best nodes at each level, based on their heuristic values. This selection process is repeated at each level of the tree.

Characteristics of Beam Search

- **Width of the Beam (W):** This parameter defines the number of nodes considered at each level. The beam width W directly influences the number of nodes evaluated and hence the breadth of the search.
- **Branching Factor (B):** If B is the branching factor, the algorithm evaluates $W \times B$ nodes at every depth but selects only W for further expansion.
- **Completeness and Optimality:** The restrictive nature of beam search, due to a limited beam width, can compromise its ability to find the best solution as it may prune potentially optimal paths.
- **Memory Efficiency:** The beam width bounds the memory required for the search, making beam search suitable for resource-constrained environments.

Example: Consider a search tree where $W = 2$ and $B = 3$. Only two nodes (black nodes) are selected based on their heuristic values for further expansion at each level.



Beam Search

How Beam Search Works?

The process of Beam Search can be broken down into several steps:

1. **Initialization:** Start with the root node and generate its successors.
2. **Node Expansion:** From the current nodes, generate successors and apply the heuristic function to evaluate them.
3. **Selection:** Select the top W nodes according to the heuristic values. These selected nodes form the next level to explore.
4. **Iteration:** Repeat the process of expansion and selection for the new level of nodes until the goal is reached or a certain condition is met (like a maximum number of levels).
5. **Termination:** The search stops when the goal is found or when no more nodes are available to expand.

Gaussian Mixture Model

A Gaussian Mixture Model (GMM) is a probabilistic model that assumes data points are generated from a mixture of several Gaussian (normal) distributions with unknown parameters.

Working of GMM

Working of Gaussian Mixture Model

A Gaussian Mixture Model assumes that the data is generated from a mixture of K Gaussian distributions, each representing a cluster. Every Gaussian has its own mean μ_k , covariance Σ_k and mixing weight π_k .

1. Posterior Probability (Cluster Responsibility)

2. Likelihood of a Data Point

3. Expectation-Maximization (EM) Algorithm

4. Log-Likelihood of the Mixture Model

Backpropagation in Neural Network (Easy Explanation)

Backpropagation stands for Backward Propagation of Errors. It is an algorithm used to train neural networks by reducing the error between the predicted output and the actual output.

In this method, the error is passed backward through the network, and weights and biases are updated using the chain rule of calculus. This helps the network learn from its mistakes and improve its performance over time.

Why is Backpropagation Important?

Backpropagation helps neural networks learn efficiently.

- **Efficient Weight Update:**
It calculates the gradient of the loss function with respect to each weight, allowing accurate and efficient weight updates.
 - **Scalability:**
The algorithm works well with multiple hidden layers, making deep neural networks possible.
 - **Automated Learning:**
The network automatically adjusts its weights to minimize error without manual intervention.
-

Working of Backpropagation Algorithm

Backpropagation consists of two main steps:

1. Forward Pass

In the forward pass, the network generates a prediction.

- Input data is given to the input layer
- Inputs are multiplied by their respective weights
- A bias is added
- An activation function (such as ReLU) is applied
- The output of one layer becomes the input of the next layer
- The final layer produces the **predicted output**

This step is used only to compute the output.

2. Backward Pass

In the backward pass, the network **learns from the error**.

- The difference between predicted output and actual output is calculated
- This difference is called **error or loss**
- The error is propagated backward through the network
- Gradients are calculated using the chain rule
- Weights and biases are updated to reduce the error

Error Calculation (Mean Squared Error)

A commonly used loss function is **Mean Squared Error (MSE)**:

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

- Larger difference → higher error
- Smaller difference → lower error

Role of Activation Function

Activation functions play an important role in backpropagation.

- Their **derivatives** are used to calculate gradients
- They decide how much each weight should be updated
- Examples include ReLU, Sigmoid, and Softmax