Project Report : Smart E-Commerce System

Team Members:

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Course: Data Structures & Algorithms (CSL2020)

1. Introduction

This project, Smart E-Commerce System, is a desktop-based application that simulates a mini online shopping platform. It is built using:

- **C++** for backend logic and data-structure implementation
- **Python Tkinter** for the graphical user interface
- **File handling** for storing & retrieving product data
- **DSA concepts** for efficient search, filtering, sorting, and cart management

The objective is to design a **real-life application** that demonstrates the usage and importance of Data Structures and Algorithms in handling real-world datasets and operations such as searching, filtering, cart operations, product management, etc.

2. Problem Statement

Modern E-Commerce systems require:

- Fast product search
- Efficient filtering & sorting
- Real-time cart management
- Data consistency
- Scalability for large product lists

The problem is to build a **functional desktop application** that models these requirements while focusing on the **use of data structures and algorithms**.

3. Proposed Solution

The solution is a **Smart E-Commerce System** with:

3.1 Backend (C++)

- Manages all product operations
- Performs search, sorting, filtering
- Handles cart operations
- Reads product data from input files
- Communicates with the GUI using standard input/output

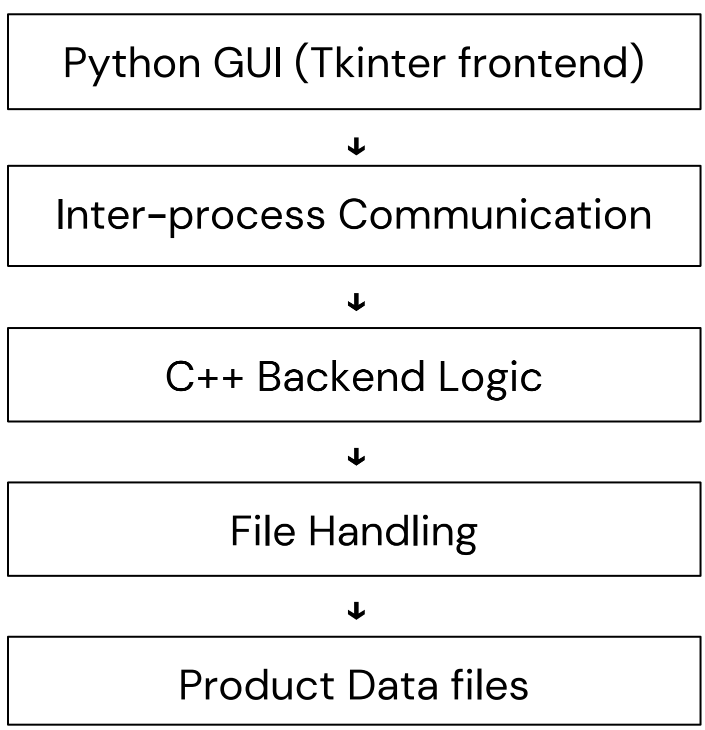
3.2 Frontend (Python Tkinter)

- Displays product catalog
- Applies filters and search options
- Shows product details
- Allows adding/removing items from cart
- Communicates with C++ backend through BackendInterface.py

The combination of **Python GUI + C++ speed + DSA logic** results in a smooth and efficient application.

4. System Architecture

4.1 Architecture Diagram



5. Implementation Details

This section explains **every data structure, algorithm, and design choice** used.

Data Structures & Algorithms

This document provides a complete overview of all Data Structures and Algorithms implemented in the Smart E-Commerce System. Each technique is explained with its purpose, time complexity, and justification for real-world applicability. The goal is to demonstrate a strong, multi-DSA approach suitable for scalable, search-heavy applications.

5.1 Trie (Prefix Tree)

The Trie is used to implement **fast product-name autocomplete** and **prefix-based searching**, making the search bar highly responsive.

Purpose:

- Prefix-based search
- Autocomplete suggestions
- Fast incremental search while typing

Why a Trie?

- Lookup time depends **only on input word length**, not dataset size
- Much faster than scanning the entire product list
- Industry-standard for search bars, browsers, and type-ahead tools
- Perfect for datasets with many textual fields (product names)

Operations & Complexity

Operation	Description	Complexity
Insert	Insert product name	**O(L)**
Search Prefix	Check if prefix exists	**O(L)**
Autocomplete	DFS from prefix node	**O(K × L)**

Where:

- *L* = length of word
- *K* = number of suggestions returned

Since product names are short (10–20 chars), Trie operations are **effectively instantaneous**.

5.2 Fuzzy Search (Edit Distance / Levenshtein-Based Search)

Fuzzy search enhances the system by handling **misspellings**, **typos**, and **near matches**.

Purpose:

- Find results even when user types:
  - “iphon” instead of “iphone”
  - “samsang” instead of “samsung”
- Improve search tolerance and user experience

Algorithm

- **Levenshtein Edit Distance** using dynamic programming
- Measures difference via insertions, deletions, substitutions

Complexity

Operation	Complexity
Edit Distance (single comparison)	**O(m × n)**
Fuzzy search over all products	**O(P × m × n)**

Where:

- *m* = length of input
- *n* = product name length
- *P* = total number of products

Why this is still efficient

- Fuzzy search is a **fallback mechanism** (used only when Trie finds no matches)
- Input sizes are small

- Product names are short
- Search space is reduced when filters or Trie results already narrow down candidates

This achieves a balance between **accuracy** and **speed**.

5.3 Graph (Adjacency List) for Category Relationships

A lightweight graph structure is used to represent relationships such as:

- Similar product groups
- Category connections
- Recommendation adjacency

Structure

```
unordered_map<string, vector<string>> adj;
```

Why Graphs?

- Graphs model relationships far better than arrays or lists
- Ideal for showing “related products” or “similar categories”

Operations & Complexity

Operation	Complexity
Add Edge	**O(1)**
Get Neighbors	**O(K)** (K = number of related items)

Graph operations remain extremely fast due to the shallow and limited category structure.

5.4 Vector-Based Cart Implementation

The shopping cart uses std::vector, optimized for small dynamic collections.

Why a Vector?

- Cart sizes are always small (< 30 items)
- Vector is cache-friendly and fastest for sequential scans
- Minimal overhead compared to maps or linked lists

Operations & Complexity

Operation	Complexity
Add Item	**O(1)**
Remove Item	**O(N)**
Compute Total	**O(N)**

Given the small size of carts, vector operations behave almost constant-time in practice.

5.5 Product Class (OOP Structure)

Products are stored using a dedicated **class/struct**, encapsulating all necessary attributes:

- `id`
- `name`
- `price`
- `category`
- `description`

Advantages

- Clear modularity
- Easy extension for attributes
- Reduced code duplication
- Cleaner interface for frontend–backend communication

Using OOP here strengthens maintainability and clarity.

5.6 Sorting Algorithms

Sorting is implemented using the C++ STL `sort()` function, which internally uses **Introsort** — a hybrid of:

- Quicksort
- Heapsort
- Insertion Sort

Sorting Criteria

- Price (ascending / descending)
- Alphabetical order
- Availability
- Category-based sorting

Complexity

- **O(n log n)** for general sorting
- Highly optimized for real-world usage
- Custom comparator functions control the ordering

5.7 Multi-Layer Filtering Pipeline

Filtering is implemented as a **chained conditional pipeline**, with stages including:

- Category filtering
- Price-range filtering
- Availability filtering
- Tie-in with Trie/Fuzzy search

Why Multi-Layer Filtering?

- Reduces dataset size step-by-step
- Improves search performance
- Makes combined filters efficient

Complexity

- Overall **O(n)**
- Faster in practice because each step shrinks the list

5.8 Hashing (unordered_map)

Hash tables are used for:

- Fast product lookup by ID
- Checking cart item existence
- Quick validation operations

Complexity

- **O(1)** average-case lookup
- Ideal for repeated operations like modifying cart quantities

6. Features Implemented

Product Catalog

Displays all products with attributes:

- Name
- Price
- Rating
- Category
- Stock

Search Function

Search products by:

- Name
- Keyword
- Product ID

Advanced Filtering

- Price range
- Category
- Availability
- Sorting options

Cart Management

- Add item
- Remove item
- Update quantity
- Total price calculation

GUI Features

- Clean Tkinter layout
- Buttons and dropdowns for filters
- Product cards
- User-friendly interface

Backend–Frontend Communication

Python sends commands → C++ processes → Output returned to Python GUI.

7. Code Walkthrough

7.1 main.cpp

- Loads products
- Initializes backend
- Waits for commands from Python
- Executes search/filter/cart logic
- Returns results

7.2 product.cpp / product.h

Defines:

- Product structure
- Functions to display and compare products

7.3 backend_interface.py

Handles:

- Running C++ executable
- Sending input
- Reading output
- Parsing results for GUI

7.4 app.py (Tkinter GUI)

- Contains all UI views
- Calls backend to fetch product lists
- Displays results in TreeView
- Handles user interactions

8. Reproducibility

To run the project:

Step 1 — Compile C++ backend

g++ ecommerce.cpp -o ecommerce

Step 2 — Run Python GUI

python app.py

Step 3 — Ensure product data files are present

Input files must be inside:
src/backend_cpp/
Everything runs automatically once files are present.

9. Repository Structure

```
DSA_Project/
        │
        ├──── assets
        │
        ├──── docs/
        │        ├──── CODE_WALKTHROUGH.md
        │        ├──── ARCHITECTURE.md
        │        └──── DATA_STRUCTURES_AND_ALGORITHMS.md
        │
        ├──── src/
        │       │
        │       ├──── backend_cpp/
        │       │        ├──── product.h
        │       │        ├──── cart.h
        │       │        ├──── trie.h
        │       │        ├──── graph.h
        │       │        ├──── product.cpp
        │       │        ├──── cart.cpp
        │       │        ├──── trie.cpp
        │       │        ├──── graph.cpp
        │       │        ├──── main.cpp
        │       │        └──── products.txt
        │       │
        │       └──── gui_python/
        │                ├──── app.py
        │                └──── backend_interface.py
        ├──── tests/
        │       ├──── test_cpp/
        │       │        ├────test_cart.cpp
        │       │        ├────test_grapht.cpp
        │       │        ├────test_trie.cpp
        │       │
        │       └──── test_python/
        │                ├──── test_app_logic.py
        │                └──── test_backend_interface.py
        │
        ├──── .gitignore
        │
        ├──── Report.pdf
        │
        └──── README.md
```

10. Conclusion

The Smart E-Commerce System successfully demonstrates:

- Application of Data Structures (vectors, maps, sets)
- Implementation of Algorithms
- File Handling and Modular Programming
- A real-world e-commerce workflow
- GUI-Backend integrated architecture

This project is scalable, extendable, and showcases practical usage of concepts learned during our DSA course.

11. Future Scope

- Add user authentication
- Add database integration (SQLite/PostgreSQL)
- Add more product attributes
- Implement recommendation algorithms
- Add cart persistence and order history

12. Team Contributions

All four members contributed significantly to the development of the Smart E-Commerce System.
While each member handled certain specific tasks, everyone participated in the **core DSA logic**, backend algorithms, testing, and discussion.

1. Anushka Mahur

Primary Work: Sorting & Filtering Logic, GUI, Documentation
Detailed Contributions:

- Implemented major parts of the **sorting and filtering algorithms** including price sort, rating sort, category filters, etc.
- Contributed to the DSA design: choosing suitable structures (vector, unordered_map, custom comparators).
- Worked extensively on the **Tkinter GUI**, product display, and user interaction flow.
- Helped integrate GUI with backend outputs consistently.

- Wrote significant parts of the **README** and the **final report**, ensuring clarity and formatting.
- Participated in algorithm debugging, output validation, and complexity checks.
- Collaborated in testing features like search, filter-chain combinations, and cart functions.

2. Harshita Pareek

Primary Work: Fuzzy Search Implementation, Markdown Docs, Backend Contributions
Detailed Contributions:

- Designed and implemented the **fuzzy search algorithm** to improve search accuracy and handle partial matches.
- Worked on the backend search logic using DSA concepts such as string matching, scoring, and efficient iteration.
- Contributed to the writing and structuring of **README and additional markdown documentation**.
- Responsible for improving user experience through enhanced search and lookup logic.
- Helped integrate search outputs with the GUI and maintain consistent formatting.
- Worked collaboratively on testing and validating search correctness and performance.
- Participated in discussions on backend design and data structures.

3. Riya Dhyawna

Primary Work: Backend Functions, DSA Logic, Testing
Detailed Contributions:

- Contributed to backend modules involving **search, filter, and sorting operations**, ensuring proper DSA usage.
- Helped structure and maintain product data storage using vectors, maps, and hashed lookups.
- Actively worked on **testing** end-to-end functionality, especially verifying algorithm outputs and edge cases.
- Helped ensure integration consistency between GUI inputs and backend commands.
- Assisted in dataset preparation, handling missing entries, and validating product attributes.
- Participated in debugging, error-fixing, and refining time complexity of operations.

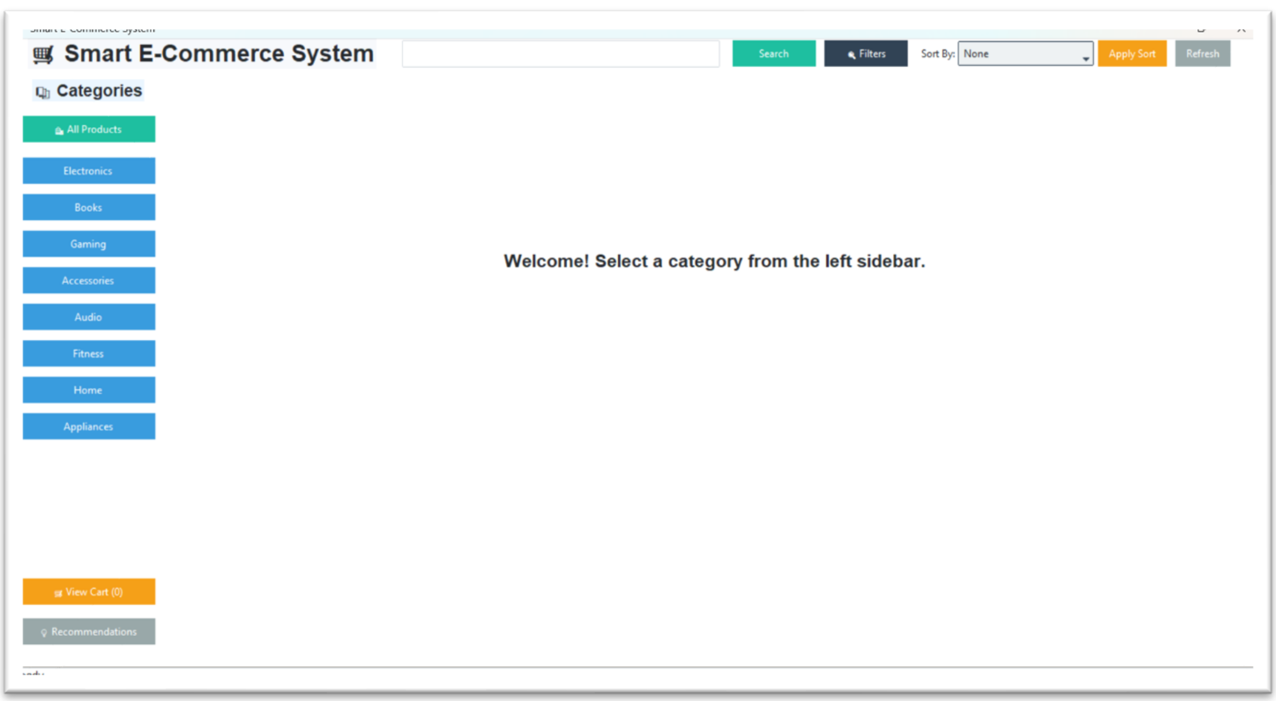
- Contributed to documentation sections related to testing and algorithm explanation.

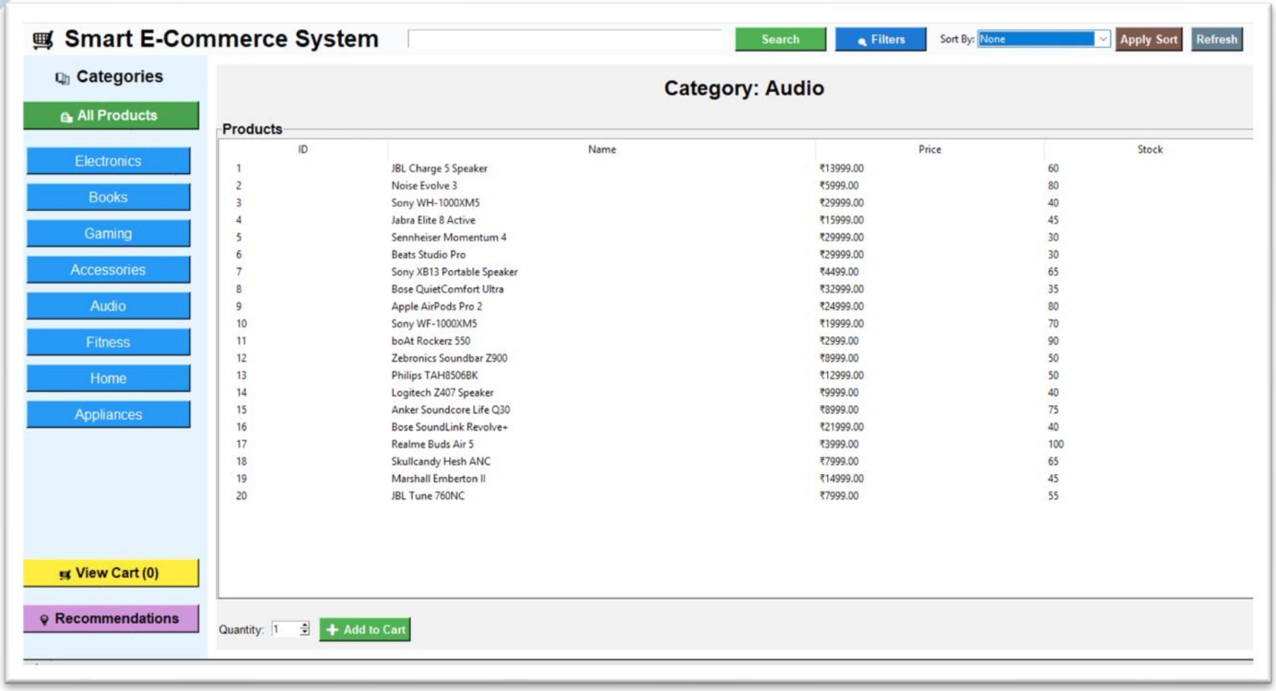
4. Aashma Yadav

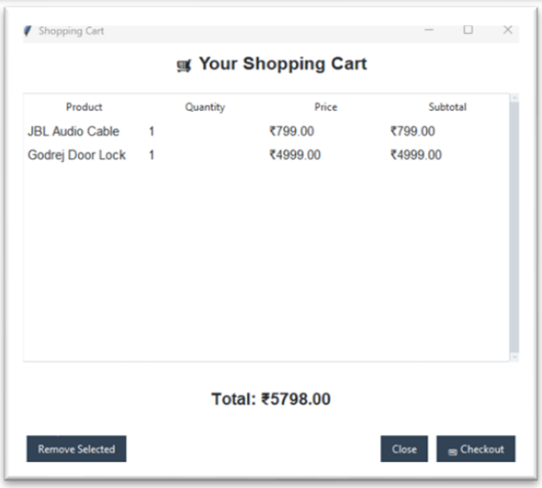
Primary Work: GUI Development, Base Code Setup, DSA Support
Detailed Contributions:

- Worked on **GUI components**, layout design, widget arrangement, and styling for a better user experience.
- Helped set up and refine the **base code structure** for GUI-backend interaction.
- Assisted in implementing several DSA-based features in both backend and frontend logic.
- Helped validate algorithm correctness through manual and automated testing.
- Contributed to refining user workflows, adding buttons, menus, and interaction handlers.
- Assisted in writing documentation and preparing diagrams used in the final report and presentation.
- Participated in debugging integration issues and improving modularity.

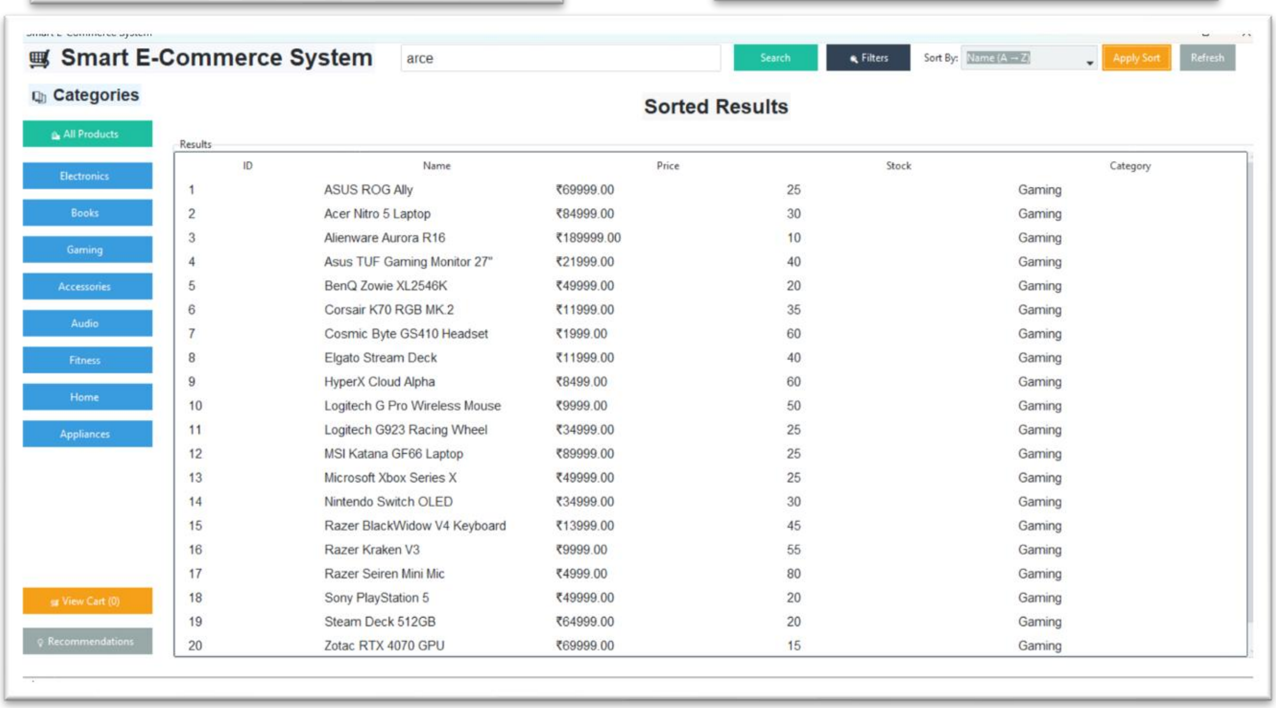
Appendix




Smart E-Commerce System
Search
Filters
Sort By:
None
Apply Sort
Refresh
Categories
All Products
Electronics
Books
Gaming
Accessories
Audio
Fitness
Home
Appliances
View Cart (0)
Recommendations
Category: Audio
Products
ID Name Price Stock
1 JBL Charge 5 Speaker ₹13999.00 60
2 Noise Evolve 3 ₹5999.00 80
3 Sony WH-1000XM5 ₹29999.00 40
4 Jabra Elite 8 Active ₹15999.00 45
5 Sennheiser Momentum 4 ₹29999.00 30
6 Beats Studio Pro ₹29999.00 30
7 Sony XB13 Portable Speaker ₹4499.00 65
8 Bose QuietComfort Ultra ₹32999.00 35
9 Apple AirPods Pro 2 ₹24999.00 80
10 Sony WF-1000XM5 ₹19999.00 70
11 boAt Rockerz 550 ₹2999.00 90
12 Zebronics Soundbar Z900 ₹8999.00 50
13 Philips TAH8506BK ₹12999.00 50
14 Logitech Z407 Speaker ₹9999.00 40
15 Anker Soundcore Life Q30 ₹8999.00 75
16 Bose SoundLink Revolve+ ₹21999.00 40
17 Realme Buds Air 5 ₹3999.00 100
18 Skullcandy Hesh ANC ₹7999.00 65
19 Marshall Emberton II ₹14999.00 45
20 JBL Tune 760NC ₹7999.00 55
Quantity: 1
Add to Cart


Shopping Cart
Your Shopping Cart
Product Quantity Price Subtotal
JBL Audio Cable 1 ₹799.00 ₹799.00
Godrej Door Lock 1 ₹4999.00 ₹4999.00
Total: ₹5798.00
Remove Selected
Close
Checkout


Apple Lightning Cable ₹1499.00
Product Recommendations
Recommendations for:
Apple Lightning Cable
Product Name Price
Apple iPhone 15 ₹79999.00
Samsung Galaxy S24 ₹74999.00
Google Pixel 9 Pro ₹79999.00
OnePlus 12 ₹64999.00
Xiaomi 14 Pro ₹54999.00


Smart E-Commerce System
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Search
Filters
Sort By:
Name (A → Z)
Apply Sort
Refresh
Categories
All Products
Electronics
Books
Gaming
Accessories
Audio
Fitness
Home
Appliances
View Cart (0)
Recommendations
Sorted Results
Results
ID Name Price Stock Category
1 ASUS ROG Ally ₹69999.00 25 Gaming
2 Acer Nitro 5 Laptop ₹84999.00 30 Gaming
3 Alienware Aurora R16 ₹189999.00 10 Gaming
4 Asus TUF Gaming Monitor 27" ₹21999.00 40 Gaming
5 BenQ Zowie XL2546K ₹49999.00 20 Gaming
6 Corsair K70 RGB MK.2 ₹11999.00 35 Gaming
7 Cosmic Byte GS410 Headset ₹1999.00 60 Gaming
8 Elgato Stream Deck ₹11999.00 40 Gaming
9 HyperX Cloud Alpha ₹8499.00 60 Gaming
10 Logitech G Pro Wireless Mouse ₹9999.00 50 Gaming
11 Logitech G923 Racing Wheel ₹34999.00 25 Gaming
12 MSI Katana GF66 Laptop ₹89999.00 25 Gaming
13 Microsoft Xbox Series X ₹49999.00 25 Gaming
14 Nintendo Switch OLED ₹34999.00 30 Gaming
15 Razer BlackWidow V4 Keyboard ₹13999.00 45 Gaming
16 Razer Kraken V3 ₹9999.00 55 Gaming
17 Razer Seiren Mini Mic ₹4999.00 80 Gaming
18 Sony PlayStation 5 ₹49999.00 20 Gaming
19 Steam Deck 512GB ₹64999.00 20 Gaming
20 Zotac RTX 4070 GPU ₹69999.00 15 Gaming