International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 06 | June - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Real-Time Recommendations for E-Commerce

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ABSTRACT A recommendation system for e-commerce products utilizing collaborative filtering approaches aims to personalize the online shopping experience by analyzing user behavior and preferences. Collaborative filtering operates on the principle that users with similar interests will prefer similar items. There are two primary types: memory-based, which includes user-based and item-based filtering relying on historical user-item interactions, and model-based, which employs techniques like matrix factorization (e.g., Singular Value Decomposition) to uncover latent factors influencing user preferences. These systems analyze data such as purchase history, ratings, and browsing patterns to generate personalized product recommendations. Evaluation metrics like Mean Absolute Error (MAE) and Root Mean Squared Error (RMSE) are commonly used to assess the accuracy of these recommendations. Challenges such as data sparsity, scalability, and the cold start problem are inherent in collaborative filtering systems. To address these issues, hybrid approaches combining collaborative filtering with content-based methods, as well as leveraging big data technologies like Hadoop, have been explored to enhance performance and scalability. Implementing such recommendation systems can lead to increased customer satisfaction, higher engagement, and improved sales for e-commerce platforms. Future enhancements may involve integrating additional data sources, such as user demographics and contextual information, to further refine recommendation accuracy.

Key Words: E-commerce, Recommendation System, Collaborative Filtering, User-Based Filtering, Item-Based Filtering, Matrix Factorization, Singular Value Decomposition (SVD), Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), Data Sparsity, Cold Start Problem, Scalability, Personalized Recommendations, User Behavior Analysis, Hybrid Recommendation Systems.

1.INTRODUCTION

In the digital era, e-commerce platforms have become integral to daily life, offering a vast array of products to consumers worldwide. However, the sheer volume of available items can overwhelm users, making it challenging to discover products that align with their preferences. To address this, recommendation systems have emerged as essential tools, enhancing user experience by providing personalized product suggestions. Among various recommendation techniques, collaborative filtering stands out due to its effectiveness in leveraging user behavior and preferences to predict interests. This method operates on the premise that users with similar tastes will prefer similar items, utilizing patterns in user-item interactions to generate recommendations. Collaborative filtering is primarily categorized into memory-based and model-based approaches. Memory-based methods, such as user-based and item-based filtering, rely on historical data to identify similarities, while model-based techniques, including matrix factorization methods like Singular Value Decomposition (SVD), aim to uncover latent factors influencing user preferences. Despite its advantages, collaborative filtering faces challenges like data sparsity, scalability, and the cold start problem, which can impact recommendation accuracy. To mitigate these issues, hybrid approaches combining collaborative filtering with content-based methods, as well as leveraging big data technologies, have been explored. Implementing robust collaborative filtering techniques in e-commerce platforms can significantly enhance user satisfaction, increase engagement, and drive sales by delivering relevant and personalized product recommendations. This paper delves into the development and evaluation of a recommendation system employing collaborative filtering approaches, aiming to optimize the online shopping experience for users

2.LITERATURE SURVEY

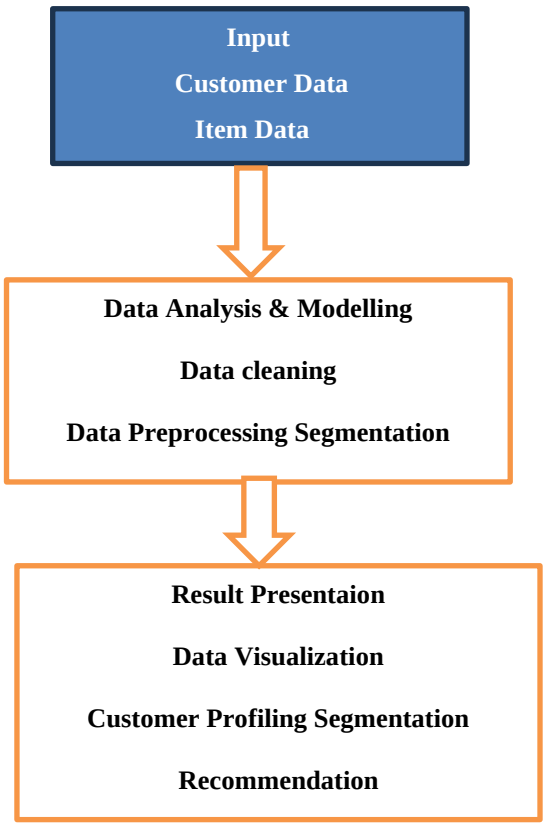
Table -1:

Year	Study/Project	Summary
2022	Dogan, O, Fuzzy Association Rule Mining Approach to Identify E-Commerce Product Association Considering Sales Amount	The paper presents a fuzzy association rule mining (FARM) approach that integrates fuzzy set theory with traditional association rule mining to identify product associations in e-commerce, considering sales amounts.

2023	Kumar, B., E-Commerce Website Usability Analysis Using the Association Rule Mining and Machine Learning Algorithm	This study investigates the usability of e-commerce websites by applying association rule mining and machine learning algorithms.
2024	Sreelakshmi, A, An Optimized Approach Towards Increasing the Sale Rate in a Grocery Mart by Using Association Rule Mining Approaches	This study applies association rule mining techniques to analyze grocery mart transaction data, identifying product associations and customer purchasing patterns to devise strategies aimed at increasing sales rates.

3.METHODOLOGY

3.1 Existing System architecture



Existing Block Diagram

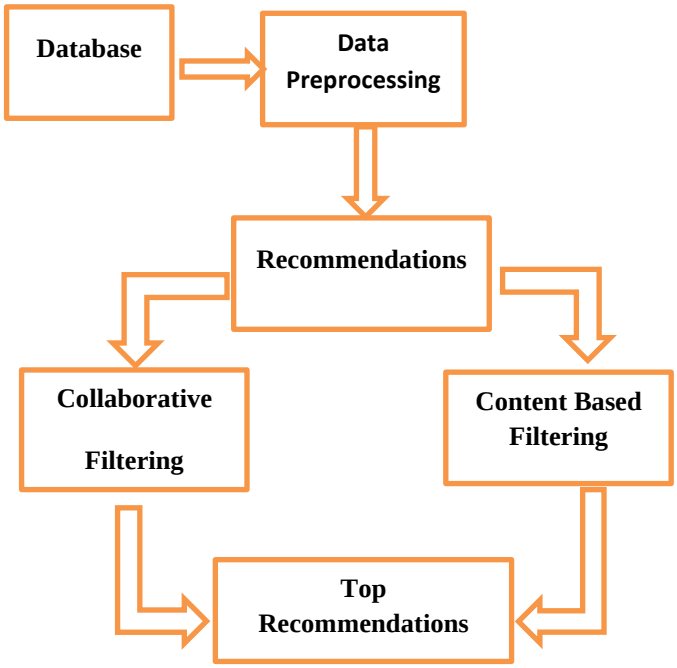
3.2 Data description

1:DataPreprocessing
Raw data comprising user IDs, product IDs, ratings, and timestamps are normalized and structured into a DataFrame.

2:ModelTraining
Collaborative filtering methods (SVD, SVD++, ALS), association rule mining (Apriori, FP-Growth), and clustering algorithms are applied to discover patterns and recommend products.

3:RecommendationandEvaluation
User profiles are segmented through K-Means clustering, and recommendations are generated. Performance is evaluated using metrics such as RMSE (Root Mean Square Error) and MAE (Mean Absolute Error).

3.3 Proposed System architecture



Proposed Block Diagram

3.4 Data description

Database:
The"marketing_sample_for_walmart_comwalmart_com_product_review" dataset from Kaggle comprises 5,000 entries with 31 attributes, including product details like ID, name, category, price, item number, rating (1–5 scale), and user reviews across various categories such as Beauty, Health, and Sports & Outdoors. This dataset aids in understanding user preferences and product popularity, serving as a foundation for developing recommendation systems.

Preprocessing:
Data preprocessing involves loading the dataset using pandas, handling missing values by filling rating gaps with zeros, and removing rows lacking essential fields like product names. Outliers are addressed through removal or techniques like

robust scaling. Singular Value Decomposition (SVD) is utilized to eliminate irrelevant data.

Recommendation:
The recommendation system employs two primary methods: Content-Based Filtering and Collaborative Filtering. Content-Based Filtering suggests products similar to those a user has previously interacted with, based on product attributes and user preferences.

Content-Based Filtering:
This method recommends products resembling those a user has previously engaged with. The process involves compiling product and order data, transforming it into a Compressed Sparse Row (CSR) format, and applying TF-IDF vectorization to assign weights to product features.

Collaborative Filtering Method:
Collaborative Filtering suggests products based on user behavior and preferences, leveraging similarities among users or items. The process starts by importing and preprocessing data to handle missing values and outliers. A utility matrix representing user-item preferences is constructed, with most values initially unknown.

4. ALGORITHMS

Apriori Algorithm
Identifies frequent itemsets by generating and pruning candidate sets based on minimum support. Suitable for interpretable rule creation but less efficient on large datasets.

FP-Growth Algorithm
Builds a compact FP-Tree for frequent pattern extraction without generating candidate sets, reducing computational overhead.

Hybrid (Apriori + FP-Growth)
Combines the clarity of Apriori and the efficiency of FP-Growth. This hybrid reduces execution time drastically (0.0043s compared to Apriori's 0.0761s).

KNN-Based Filtering (KNNBasic)
Calculates item-item similarities to recommend products similar to those the user has liked. It also flags outliers through distance thresholds.

Collaborative Filtering (SVD, SVD++, ALS)

- **SVD**: Matrix factorization method, best for explicit feedback.
- **SVD++**: Extends SVD to handle implicit feedback like clicks and views.
- **ALS**: Alternating Least Squares, good for large-scale datasets and parallel computations.

5. PERFORMANCE EVALUATION

Using cross-validation across three data splits, the performance metrics are:

Table-2:

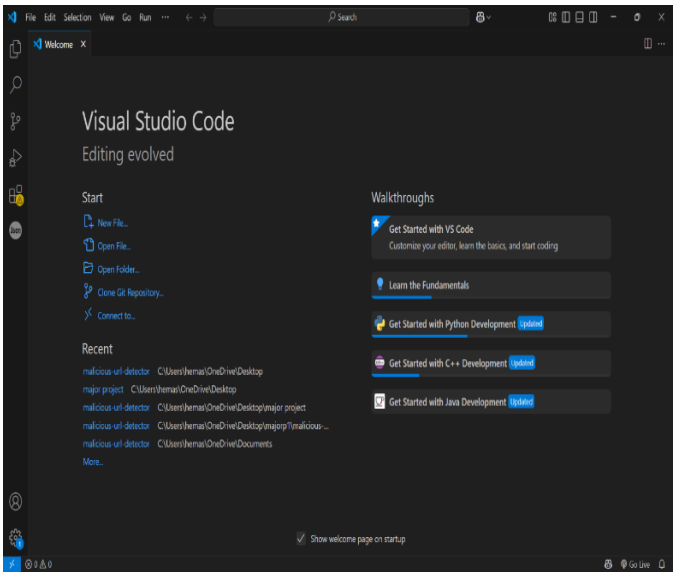
Algorithm	Avg. RMSE	Avg. MAE
SVD	1.3	1.04
SVD++	1.33	1.05
ALS	1.45	1.15
KNN Basic	1.41	1.11

SVD consistently outperforms others in both error metrics. The hybrid Apriori+FP-Growth model complements collaborative filtering by revealing associative rules between products.

6.SOFTWARE USED

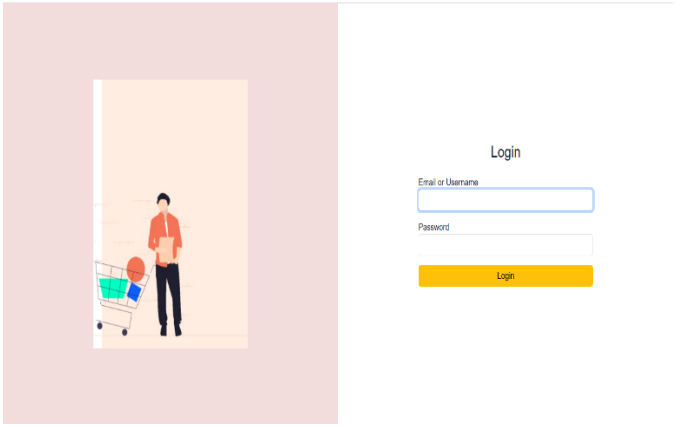
Visual Studio Code

Visual Studio Code (VS Code) is an excellent code editor for machine learning projects, offering powerful tools and extensions that streamline the development workflow. It supports popular ML libraries like TensorFlow, PyTorch, and Scikit-learn, and integrates seamlessly with Jupyter Notebooks for interactive coding. Features like IntelliSense, Git integration, and debugging make it easier to write, test, and manage ML code efficiently. With its flexibility and user-friendly interface, VS Code is a go-to choice for both beginners and professionals working on machine learning projects

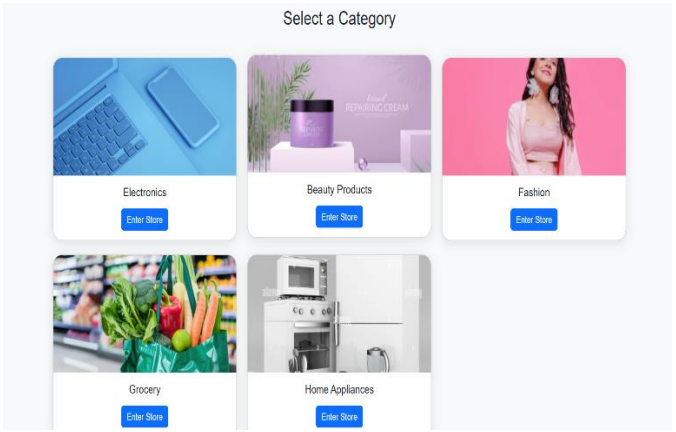


7. RESULTS

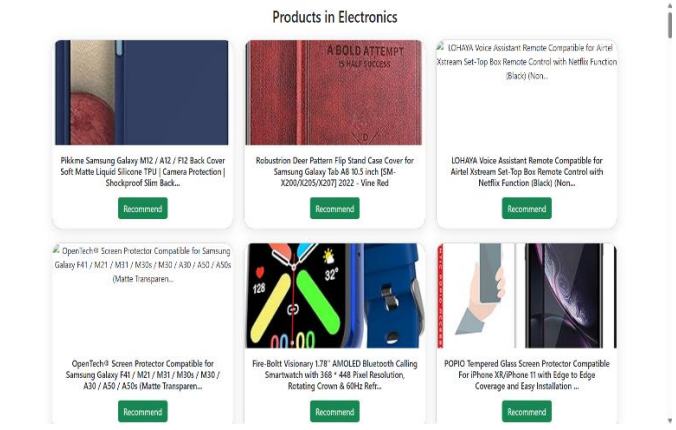
Login Page



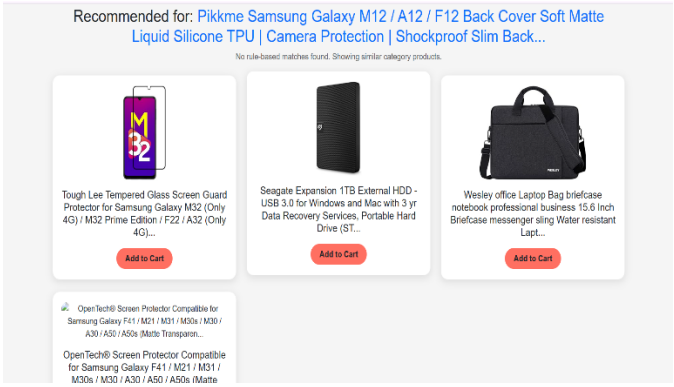
Select Category



Product Selection



Recommended Products



8. CONCLUSION

This research demonstrates the effectiveness of combining collaborative filtering and association rule mining for e-commerce product recommendation. SVD remains the most accurate collaborative filtering method. Collaborative filtering accurately identifies user patterns and similarities, while content-based filtering enriches recommendation variety. The user-friendly interface further underscores the system's efficacy, providing users with a smooth shopping experience. Looking ahead, future research could explore integrating additional data sources and advanced machine learning techniques to enhance the system's adaptability in meeting evolving user needs within the dynamic e-commerce landscape, ultimately driving increased sales and customer retention.The hybrid Apriori-FP-Growth model significantly improves computational efficiency. Clustering and anomaly detection further enhance personalization and system robustness.

9.ACKNOWLEDGEMENT

We would like to express our sincere gratitude to our guide and faculty members for their invaluable support, guidance, and encouragement throughout the development of this project. Their insights and feedback played a crucial role in refining the design and implementation of the Real-Time Recommendations for E-Commerce.

We also thank our institution for providing the necessary resources and environment to carry out this research. Lastly, we appreciate the contributions of all team members whose dedication and collaboration made this project possible.

I deeply grateful to our esteemed faculty mentors, **Dr. Sonagiri China Venkateswarlu, Dr. V. Siva Nagaraju**, from the Department of Electronics and Communication Engineering at the Institute of Aeronautical Engineering (IARE).

Dr. Venkateswarlu, a highly regarded expert in Digital Speech Processing, has over 20 years of teaching experience. He has provided insightful academic assistance and support for the

duration of our research work. Dr. Siva Nagaraju, an esteemed researcher in Microwave Engineering who has been teaching for over 21 years, has provided us very useful and constructive feedback, and encouragement which greatly assisted us in refining our technical approach.

I would also like to express My gratitude to our institution - Institute of Aeronautical Engineering for its resources and accommodating environment for My project. The access to technologies such as Python, Machine Learning and Flask allowed for the technical realization of our idea. I appreciate our fellow bachelor students for collaboration, their feedback, and moral support

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