

Intelligent E-commerce Product Recommendation System using Machine Learning.

Mr. Kuldip Dilip More¹, Asst. Prof. Chetana M. Kawale²

Research Scholar, Department of Computer Applications, SSBT's College of Engineering & Technology Jalgaon,
Maharashtra, India¹

Assistant Professor, Department of Computer Applications, SSBT's College of Engineering & Technology Jalgaon,
Maharashtra, India²

Abstract: Today, online shopping websites have millions of products. When a customer buys a main product, like a laptop or a smartphone, they often need accessories like a mouse, a bag, or a keyboard. However, finding accessories that are both affordable (within their budget) and technically compatible (matching the exact features) is very confusing and takes a lot of time. Traditional recommendation systems fail here because they only show items based on "what other people bought". They do not check if the accessory fits the customer's personal budget or if it actually connects with their specific device. To solve this real-world problem, this project introduces the "Intelligent E-commerce Product Recommendation System using Machine Learning". This system acts like a smart digital shopkeeper. Instead of showing random popular products, it uses Machine Learning (ML) algorithms to intelligently analyze two main things: the technical specifications of the selected primary product and the exact budget limit set by the user. By matching these details, the system filters the database and suggests only the most perfect, compatible, and pocket-friendly accessories. The project is built with a strong technical foundation, utilizing a relational database structure to safely store user and product details. To plan the software architecture perfectly, comprehensive UML models have been designed, including Use Case, Sequence, ER, Activity, Class, and Deployment diagrams, ensuring the web application is robust and logical. In conclusion, this intelligent system completely upgrades the online shopping experience. For the customers, it saves their valuable search time and provides highly personalized, cost-effective suggestions. For the e-commerce platform owners, it acts as a powerful tool to increase their daily sales and profit (cross-selling) by automatically showing the right product to the right user at the right time.

Keywords: Machine Learning, E-commerce, Product Recommendation System, Cross-selling, Collaborative Filtering, Content-Based Filtering, Personalization.

I. INTRODUCTION

The rapid development of e-commerce has significantly changed the way people search for, compare, and purchase products. Online shopping platforms provide customers with access to a large variety of products from different categories, brands, and price ranges. Although the availability of a wide range of products provides greater choice, it also creates a challenge for customers because finding the most suitable product can require considerable time and effort. This has increased the importance of intelligent recommendation systems in modern e-commerce applications.

A product recommendation system is an information-filtering technique that analyzes available product and user-related information to identify products that may be relevant to a particular customer. Instead of requiring users to search through a large number of products manually, a recommendation system can present a personalized list based on the user's previous activities, preferences, ratings, and interactions. Such systems can improve the product discovery process and provide a more personalized shopping experience.

Traditional recommendation approaches may depend on a single source of information, such as product similarity or user ratings. However, relying on only one factor may not always produce sufficiently relevant recommendations. Two products may be similar in their description or category but may not match the user's budget or previous preferences. Similarly, recommendations based only on ratings may not consider the actual similarity between products. Therefore, combining multiple sources of information can provide a more comprehensive recommendation approach.

This research proposes an Intelligent E-Commerce Product Recommendation System that combines user history, product similarity, ratings, and user interaction information to generate personalized product recommendations. The proposed system also considers practical factors such as product category, budget, accessories, and compatibility. By considering these factors together, the system aims to recommend products that are not only similar to previously preferred products but are also relevant to the user's requirements.

The system maintains information related to users, products, ratings, and interactions using a relational database. User activity and product-related information are processed to identify relevant patterns and similarities. Based on these factors, the recommendation mechanism generates suitable products for individual users. The approach is intended to reduce the effort required to search for products and assist customers in identifying products that better match their preferences and requirements.

The proposed system can be useful for different types of e-commerce platforms where a large product catalogue makes manual product discovery difficult. It can support personalized shopping by adapting recommendations according to user behaviour and product characteristics. The combination of multiple recommendation factors provides a foundation for developing flexible and intelligent e-commerce recommendation solutions. Overall, this research focuses on developing a personalized recommendation approach that integrates user preferences, product characteristics, ratings, and interaction history to improve recommendation relevance, simplify product discovery, and enhance the overall online shopping experience.

II. LITERATURE REVIEW

E-commerce recommendation systems can use different levels of information to understand user preferences. Explicit information, such as ratings, reviews, and stated preferences, directly represents the user's opinion about a product. In contrast, implicit information is obtained from user activities such as product searches, page views, clicks, cart additions, and purchases. Implicit interactions are useful because users may not provide ratings for every product they view or purchase. Combining explicit and implicit information can therefore provide a broader understanding of user behaviour.

User history plays an important role in personalized recommendation. Previous purchases can indicate the types of products preferred by a user, while browsing and search history can indicate current interests. For example, a user who frequently searches for laptops may receive recommendations related to laptops and compatible accessories. However, historical information should be processed carefully because older activities may not always represent the user's current requirements. Considering recent interactions along with previous history can make recommendations more relevant.

Product similarity is another important factor in recommendation systems. Similarity can be determined using product attributes such as category, brand, specifications, features, and description. When a user shows interest in a particular product, the system can identify other products with similar characteristics. This approach is useful when sufficient information about the products is available, even if detailed information about other users is limited. Ratings and user interactions provide additional information for evaluating product preference. A highly rated product may indicate better acceptance among users, while repeated interactions with a particular product may indicate stronger interest. However, ratings alone may not always be sufficient because users can have different requirements and budgets. Therefore, ratings can be combined with other factors such as user history, product similarity, price, and category.

Budget-based filtering is particularly useful in practical e-commerce applications. A product may match a user's interests but still be unsuitable if its price is outside the user's preferred range. Applying a budget constraint before generating the final recommendation list can reduce irrelevant results. This makes the recommendation process more aligned with the actual purchasing conditions of the user.

Compatibility is another factor that can improve product recommendations, especially for electronic products and accessories. Products may have technical or functional relationships with other products. For example, an accessory may need to be compatible with a particular laptop, mobile phone, camera, or other device. Considering compatibility can help avoid recommendations that are attractive based on similarity but are not practically usable by the customer.

The cold-start problem remains a common challenge in recommendation systems. New users may have little or no interaction history, while newly added products may have few ratings or interactions. In such cases, relying only on historical behaviour can reduce the ability of the system to generate personalized recommendations. Product categories, features, specifications, and general popularity can provide additional information when sufficient user history is unavailable.

Another challenge is maintaining recommendation diversity. A system that repeatedly recommends products very similar to previous choices may limit the user's exposure to alternative products. A useful recommendation system should provide relevant products while allowing some variation within the user's preferred category and requirements. This can help users explore additional choices without receiving completely unrelated recommendations.

Data quality is also important for the effectiveness of recommendation systems. Incorrect product information, missing attributes, duplicate records, or incomplete interaction data can affect the recommendation process. Data preprocessing can therefore be used to organize the collected information before applying similarity analysis, filtering, and recommendation generation. The overall recommendation process can be viewed as a sequence of data collection, preprocessing, preference analysis, product similarity identification, requirement-based filtering, and recommendation generation. Each stage contributes to the final recommendation result. Integrating these stages in a single system can provide a more structured approach to personalized e-commerce recommendations. Based on the reviewed approaches, the proposed Intelligent E-Commerce Product Recommendation System focuses on combining behavioural information with product-level and practical requirements. User history, ratings, interactions, product similarity, category, budget, accessories, and compatibility are considered together to generate personalized recommendations. This integrated approach forms the basis for the proposed system discussed in the following sections.

Table I. Comparison of Recommendation Approaches

Approach	Information Used	Main Benefit	Limitation
Collaborative Filtering	Ratings, purchases, user interactions	Understands user preferences	Cold-start problem
Content-Based Filtering	Product features and category	Finds similar products	Less recommendation variety
Hybrid Recommendation	Multiple recommendation techniques	Combines different information sources	More complex
Proposed System	User history, similarity, ratings, interactions, budget and compatibility	Personalized and requirement-based recommendations	Requires multiple data sources

III. RESEARCH METHODOLOGY

The proposed Intelligent E-Commerce Product Recommendation System follows a structured methodology for generating personalized product recommendations. The main objective of the methodology is to collect and organize relevant user and product information, analyze user preferences, identify suitable products, and generate recommendations according to individual requirements. The methodology combines user history, product similarity, ratings, user interactions, and practical factors such as product category, budget, accessories, and compatibility.

A. Data Collection

The first stage of the proposed methodology is data collection. The system requires information related to users, products, and user-product interactions. User-related information may include previous purchases, browsing activity, searches, ratings, and other interactions with products. Product information includes product name, category, description, features, specifications, price, and other relevant attributes. This information provides the basic input required for the recommendation process.

The collected data can be organized into separate logical entities such as users, products, ratings, purchases, and interactions. Maintaining structured information helps the system retrieve the required data during recommendation generation. The availability of both user-related and product-related information allows the proposed system to consider different factors rather than depending on a single recommendation parameter.

B. Data Storage and Database Management

The collected information is maintained using a relational database. A relational database provides a structured method for storing user, product, rating, purchase, and interaction information. Different entities can be represented using tables and connected through appropriate relationships.

For example, user information can be associated with purchase or interaction records, while product information can be associated with categories, ratings, and related products. This structure helps in retrieving user history and product information during the recommendation process. It also supports organized data management and reduces unnecessary duplication of information.

C. Data Preprocessing

Before generating recommendations, the collected information needs to be prepared for analysis. Data preprocessing includes organizing records, handling incomplete information, removing unnecessary or duplicate data, and maintaining consistent product and user attributes.

For recommendation generation, the system requires meaningful information about products and user interactions. Proper preprocessing helps improve the quality of the input data and supports more reliable analysis. Product attributes such as category, price, features, and compatibility information can be standardized so that they can be used during filtering and similarity identification.

D. User History Analysis

User history is an important component of the proposed recommendation methodology. The system analyzes information related to previous purchases, product views, searches, ratings, and other available interactions to identify user preferences.

For example, if a user repeatedly interacts with products from a particular category, this information can be used to identify the user's interest in that category. Previous purchases can provide information about long-term preferences, while recent interactions can provide information about current interests. The resulting preference information is then used as an input for identifying suitable products.

E. Product Similarity Analysis

Product similarity is used to identify products that have characteristics similar to products preferred or interacted with by the user. Product attributes such as category, features, specifications, description, and other available characteristics can be considered during similarity analysis.

When a user shows interest in a particular product, the system can identify other products with related characteristics. This allows the recommendation process to provide alternatives instead of recommending only the exact product previously viewed or purchased.

F. Rating and Interaction Analysis

Ratings and user interactions provide additional information about product preferences. Ratings can indicate the user's opinion or level of satisfaction with a product, while interactions such as viewing, searching, clicking, purchasing, or other available activities can provide information about user interest.

The proposed methodology considers these signals together with user history and product information. Combining multiple interaction signals can provide a broader representation of user preferences than relying only on product ratings.

G. Requirement-Based Filtering

After analyzing user preferences and product information, the system applies practical requirements before generating the final recommendation list. The main filtering factors considered in the proposed system are product category, budget, accessories, and compatibility.

Category filtering ensures that recommendations belong to the product category required by the user. Budget filtering removes products that do not fall within the user's preferred price range. Accessory consideration helps identify related or complementary products that may be useful with the selected product. Compatibility filtering helps ensure that recommended products or accessories are suitable for the user's selected product.

This filtering stage helps reduce irrelevant products and makes the final recommendation more suitable for practical purchasing requirements.

H. Recommendation Generation

After user preference analysis, similarity identification, rating and interaction analysis, and requirement-based filtering, the system generates the final product recommendations. Products satisfying the required conditions can be selected and arranged according to their relevance to the user.

The recommendation process therefore does not depend on only one factor. User history provides information about previous preferences, product similarity identifies related products, ratings and interactions provide preference signals, and practical filters ensure that the products satisfy requirements such as category, budget, accessories, and compatibility.

I. Personalized Recommendation Output

The final output of the system is a personalized list of recommended products. The recommendations are generated according to the available user information and selected requirements. Instead of presenting the same products to every user, the system attempts to provide recommendations based on individual preferences and product requirements.

The recommendation output can include suitable products along with relevant product information such as product name, category, price, rating, and compatibility or accessory information, depending on the available data.

J. User Feedback and Continuous Improvement

User interaction with recommended products can provide additional information for future recommendations. When users view, select, purchase, or rate recommended products, these activities can be stored as new interaction information. This information can subsequently become part of the user's updated history. Therefore, the recommendation process can follow an iterative cycle in which new user interactions provide additional information for future recommendation generation. This approach can help the system adapt to changing user interests over time.

K. Overall Methodology Flow

The complete methodology can be represented as a sequence of interconnected stages: Data Collection → Database Storage → Data Preprocessing → User History Analysis → Product Similarity Analysis → Rating and Interaction Analysis → Requirement-Based Filtering → Recommendation Generation → Personalized Recommendations → User Feedback.

The methodology integrates both behavioural and product-related information with practical purchasing requirements. This provides a structured framework for developing an intelligent e-commerce recommendation system that can generate personalized and requirement-based product suggestions.

Fig. 1. Proposed Methodology of the Intelligent E-Commerce Product Recommendation System

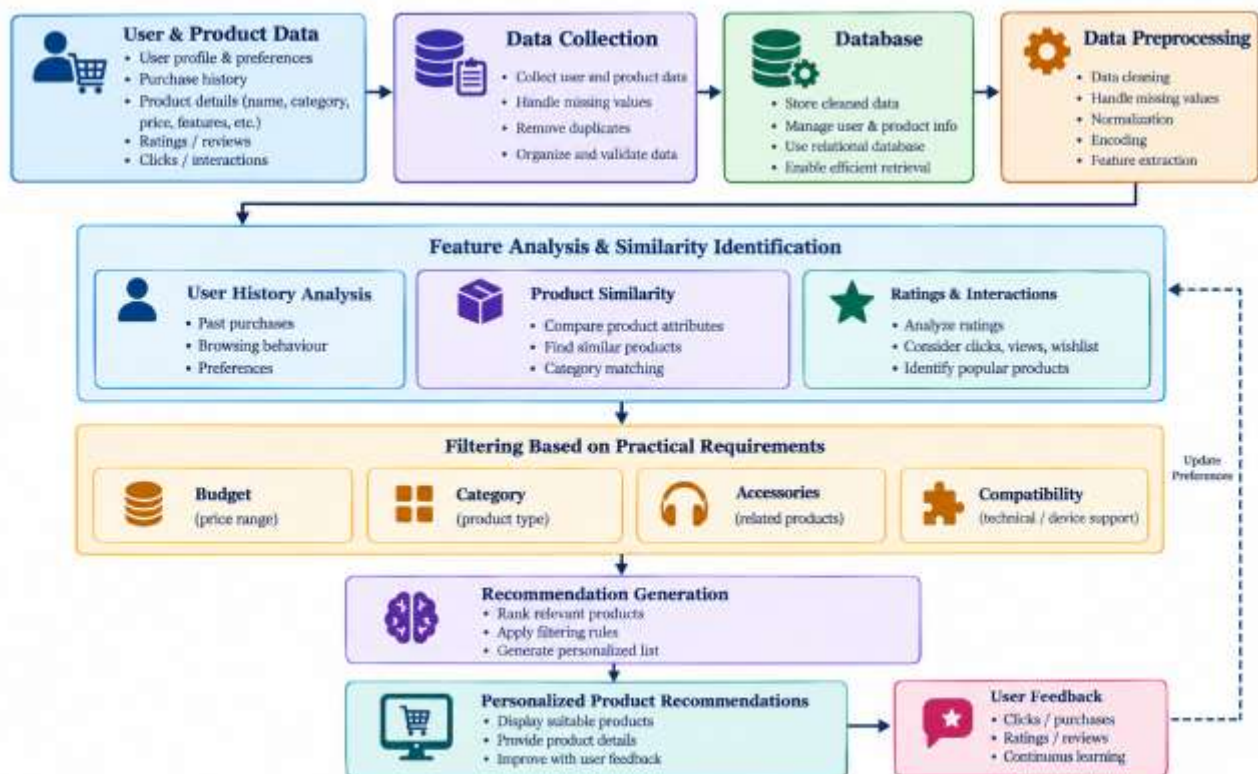


Fig. 1. Proposed Methodology of the Intelligent E-Commerce Product Recommendation System

IV. RESULTS

The proposed Intelligent E-Commerce Product Recommendation System generates personalized product recommendations by using different types of user and product information. Instead of depending on only one factor, the system combines user history, product similarity, ratings, and user interactions. This allows the system to understand the user's interests from different perspectives and identify products that are more suitable for the user.

The analysis of user history helps the system understand the products in which a user has shown interest in the past. Purchase history, browsing behaviour, searches, and other available interactions can provide useful information about user preferences. For example, if a user frequently searches for products from a particular category, the system can use this information while generating future recommendations.

Product similarity helps the system identify products that have similar characteristics to products preferred or viewed by the user. Product category, features, specifications, and other available product attributes can be considered for this purpose. As a result, users can receive alternative or related products instead of seeing only the exact products they have previously viewed or purchased.

Ratings and user interactions provide additional information about product preference. Ratings can indicate how users respond to products, while activities such as viewing, searching, clicking, or purchasing can indicate user interest. Combining these signals with user history provides more information for generating recommendations than using ratings alone. The system also applies requirement-based filtering before producing the final recommendations. Product category helps ensure that the recommended products belong to the required category. Budget filtering helps remove products that are outside the user's preferred price range. Accessories can be considered to identify related products that may be useful with the selected product. Compatibility helps ensure that recommended products or accessories are suitable for the user's selected product.

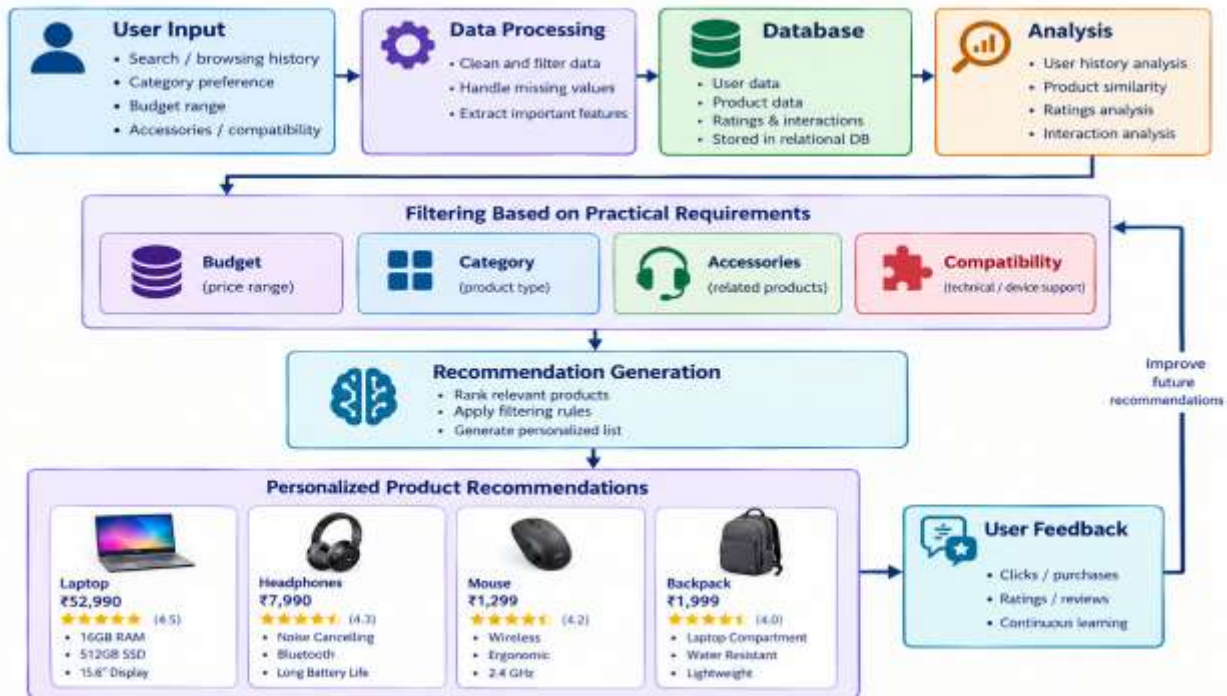
The use of a relational database helps organize and retrieve user and product information in a structured manner. User records, product details, ratings, purchases, and interaction information can be maintained systematically. This supports the recommendation process by providing the required information for user preference analysis, product similarity identification, and filtering. The overall result shows that combining multiple recommendation factors can provide more relevant and personalized product suggestions. The proposed approach can reduce the effort required by users to search through a large product catalogue. Instead of manually checking many products, users can receive recommendations based on their preferences and specific requirements.

The inclusion of practical factors such as budget, category, accessories, and compatibility makes the recommendations more suitable for real-world e-commerce usage. These factors help the system move beyond simple product similarity and consider whether a recommended product is actually suitable for the user's requirements. Therefore, the proposed system demonstrates a structured approach for personalized e-commerce product recommendation. The results provide a foundation for further improvement using larger datasets, more user interactions, and advanced recommendation techniques. Quantitative performance evaluation using standard recommendation metrics can be conducted in future work to measure the effectiveness of the system more precisely.

Table II. Result Analysis of the Proposed System

Parameter	Result / Observation
User Preference Analysis	Identifies products based on user history and interactions
Product Similarity	Finds products with similar characteristics
Rating Analysis	Uses ratings to understand product preference
Budget Filtering	Removes products outside the specified price range
Category Filtering	Provides recommendations from the required product category
Compatibility	Considers compatibility between products and related components
Personalization	Generates recommendations according to individual user requirements

Fig. 2. Results and Recommendation Process of the Proposed System



V. DISCUSSION

The proposed Intelligent E-Commerce Product Recommendation System demonstrates how different sources of information can be integrated to generate personalized product recommendations. Traditional recommendation approaches may depend mainly on ratings, product similarity, or previous user behaviour. In the proposed system, these factors are considered together. User history provides information about previous preferences, product characteristics help identify similar products, while ratings and interactions provide additional information about the user's interest in different products.

An important feature of the proposed system is the consideration of practical purchasing requirements. A recommendation may be relevant to a user's interests but may not be suitable because of its price, category, or compatibility. Therefore, the system considers factors such as budget, product category, accessories, and compatibility before generating the final recommendations. This can help reduce irrelevant products and provide suggestions that are more suitable for the user's actual requirements.

The use of user interactions also supports continuous improvement of recommendations. Activities such as viewing, searching, purchasing, or rating products can provide additional information about user preferences. As new interaction information becomes available, it can be included in the user's history and used for future recommendation generation. This allows the system to consider changes in user interests over time rather than depending only on older information. The proposed approach also has some limitations. The quality of recommendations depends on the availability and accuracy of user and product data. New users may have limited history, while new products may have insufficient ratings or interactions. In addition, incomplete product information can affect similarity analysis and requirement-based filtering. These limitations indicate the need for sufficient and well-structured data for effective recommendation generation.

Overall, the discussion shows that combining user behaviour, product information, ratings, interactions, and practical requirements provides a structured approach to personalized e-commerce recommendation. Further evaluation using larger datasets and real user interactions can help measure the performance of the proposed system using suitable recommendation evaluation metrics.

VI. CONCLUSION

The Intelligent E-Commerce Product Recommendation System provides a personalized approach for helping users select suitable products from a large number of available choices. The proposed system combines user history, product similarity, ratings, and user interactions to understand user preferences and generate relevant product recommendations. By considering multiple sources of information, the system can provide recommendations that are more closely related to the individual user's interests.

The system also considers practical requirements such as product category, budget, accessories, and compatibility. These factors are important because a product may match the user's interest but may not be suitable for their price range or specific requirements. Including these conditions helps reduce irrelevant recommendations and makes the recommendation process more practical for real-world e-commerce applications. The use of a relational database also provides structured storage and retrieval of user and product information.

The proposed approach shows that combining behavioural information, product characteristics, ratings, and practical requirements can provide more personalized and requirement-based product suggestions. However, the effectiveness of the system depends on the availability and quality of user and product data. Therefore, larger datasets and real user interactions can be used in future evaluation to measure recommendation performance more accurately.

In the future, the system can be enhanced using machine learning, deep learning, intelligent product ranking, real-time user behaviour analysis, and advanced personalization techniques. These improvements can help the system adapt more effectively to changing user preferences and provide better recommendations. Overall, the proposed system provides a structured foundation for developing an intelligent and personalized e-commerce product recommendation solution.

REFERENCES

- [1]. G. Adomavicius and A. Tuzhilin, "Toward the Next Generation of Recommender Systems: A Survey of the State-of-the-Art and Possible Extensions," *IEEE Transactions on Knowledge and Data Engineering*, vol. 17, no. 6, pp. 734–749, 2005.
- [2]. G. Linden, B. Smith, and J. York, "Amazon.com Recommendations: Item-to-Item Collaborative Filtering," *IEEE Internet Computing*, vol. 7, no. 1, pp. 76–80, 2003.
- [3]. F. Ricci, L. Rokach, and B. Shapira, "Recommender Systems: Introduction and Challenges," in *Recommender Systems Handbook*, Springer, pp. 1–34, 2015.
- [4]. F. Ricci, L. Rokach, and B. Shapira, Eds., *Recommender Systems Handbook*, 2nd ed., Springer, 2015.
- [5]. S. Zhang, L. Yao, A. Sun, and Y. Tay, "Deep Learning Based Recommender System: A Survey and New Perspectives," *ACM Computing Surveys*, vol. 52, no. 1, pp. 1–38, 2019.
- [6]. M. H. Alshammari, A. Alshammari, and others, "Item-Based Collaborative Filtering and Association Rules for a Baseline Recommender in E-Commerce," *IEEE Conference Publication*, 2021.
- [7]. "Development of Product Recommendation Engine by Collaborative Filtering and Association Rule Mining Using Machine Learning Algorithms," *IEEE Conference Publication*, 2020.
- [8]. "An Intelligent Exploratory Approach for Product Recommendation Using Collaborative Filtering," *IEEE Conference Publication*, 2021.
- [9]. "Personalizing Product Recommendations Using Collaborative Filtering in Online Retail: A Machine Learning Approach," *IEEE Conference Publication*, 2023.
- [10]. "Two Decades of Recommender Systems at Amazon.com," *IEEE Internet Computing*, vol. 21, no. 3, pp. 12–18, 2017.