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Decision Support System for Furniture Product Recommendation Using Item-Based Collaborative Filtering and Min-Max Normalization

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Abstract: *The increasing variety of furniture products available in the market makes it difficult for consumers to identify products that best match their preferences. Conventional product selection is often carried out manually, requiring consumers to compare product specifications one by one, which is time-consuming and may lead to less appropriate purchasing decisions. This study proposes a web-based decision support system for furniture product recommendation by integrating the Item-Based Collaborative Filtering (IBCF) method with min–max normalisation. The recommendation process utilises historical user ratings to identify similarities among products, while min–max normalisation is applied to standardise product attributes, including price, category, material, colour, and size, into a comparable scale. To address the cold-start problem for newly added products with insufficient rating data, a content-based similarity mechanism is incorporated into the recommendation process. The system was developed using a dataset consisting of 322 furniture products, 50 consumers, and 1,099 rating transactions. System functionality was evaluated using black-box testing, while user acceptance was assessed through user acceptance testing (UAT) involving ten respondents. The evaluation results show that all primary system functions operated as expected and achieved an overall UAT score of 88.0%, indicating that the proposed system is acceptable and capable of assisting consumers in selecting furniture products based on their preferences. This study contributes by integrating collaborative filtering, multi-attribute normalisation, and a content-based cold-start mechanism into a single recommendation framework for furniture product recommendation.*

Keywords: *Collaborative Filtering, Decision Support System, Furniture Recommendation, Item-Based, Min-Max Normalization.*

1. Introduction

The furniture industry in Indonesia continues to experience significant growth, driven by increasing consumer demand for household and office furnishings. According to data reported by the Central Statistics Agency (BPS), the furniture sector has consistently contributed to national exports and remains one of the important manufacturing industries in Indonesia [1]. This development has encouraged furniture businesses to continuously expand their product collections while improving service quality to meet increasingly diverse consumer needs. Consequently, consumers are now offered a wider variety of furniture products with different categories, materials, colors, dimensions, designs, and price ranges. The increasing number of available furniture products provides consumers with more purchasing alternatives but also makes the product selection process more complex. Consumers generally consider multiple factors before purchasing furniture, including price, material, dimensions, color, product category, and design suitability. In many furniture stores, product recommendations are still provided manually based on sales staff experience or product popularity. Such recommendations tend to be subjective and often do not fully represent individual consumer preferences. As a result, consumers need to compare many products before making purchasing decisions, making the selection process less efficient and potentially reducing customer satisfaction [2],[3].

To overcome these challenges, Decision Support Systems (DSS) have been widely adopted to assist users in making more objective and systematic decisions. In recommendation systems, Collaborative Filtering has become one of the most widely used techniques because it identifies consumer preferences based on historical interactions between users and products [4]. Among the available approaches, Item-Based Collaborative Filtering (IBCF) calculates similarities among products according to user rating patterns and subsequently predicts consumer preferences for products that have not yet been purchased or rated [5], [6]. Compared with User-Based Collaborative Filtering, IBCF generally offers better computational efficiency for applications with relatively stable product collections because item similarities can be calculated in advance and reused during the recommendation process.

Although Item-Based Collaborative Filtering has demonstrated satisfactory performance in various recommendation applications, several challenges remain when it is applied to furniture products. Furniture products are characterized by heterogeneous attributes consisting of numerical variables, such as price and rating, and categorical variables, including category, material, color, and size. These attributes cannot be directly compared because they are represented using different measurement scales. Therefore, a normalization technique is required to transform heterogeneous product attributes into comparable values before similarity calculations are performed. Min-Max Normalization is widely used because it converts attribute values into a standardized range between 0 and 1 while preserving the relative relationships among the original data [7], [8].

Previous studies have demonstrated the effectiveness of recommendation techniques in various application domains. Mar'atuttahirah et al. [5] developed an MSME product recommendation system using Item-Based Collaborative Filtering and showed that the method was capable of generating personalized recommendations based on user interaction history. Likewise, Sugiarti et al. [6] implemented Item-Based Collaborative Filtering for computer hardware recommendations and reported that the method effectively identified products with similar consumer preference patterns. Roziqiin and Faisal [9] applied User-Based Collaborative Filtering to an anime recommendation system and demonstrated that user similarity could improve recommendation relevance. Bravo and Indra [10] implemented Item-Based Collaborative Filtering for online news recommendation by utilizing similarities among articles based on user reading behavior. Furthermore, Putra and Rachman [11] compared Content-Based Filtering, Collaborative Filtering, and Hybrid Filtering in a music recommendation system and concluded that hybrid recommendation approaches could improve recommendation quality under certain conditions.

Despite these contributions, previous studies primarily relied on historical user interaction data and generally focused on recommendation performance in domains such as MSME products, computer hardware, and others. Limited attention has been given to integrating normalized heterogeneous product attributes into the recommendation process, particularly for furniture products, where purchasing decisions are strongly influenced by multiple product characteristics. In addition, previous studies rarely discussed mechanisms for recommending newly introduced products with limited historical interaction data within the same recommendation framework. These limitations indicate the need for a recommendation approach capable of combining collaborative filtering with normalized product attributes while maintaining recommendation availability for products with insufficient rating information.

Based on these research gaps, this study proposes a web-based decision support system for furniture product recommendation by integrating Item-Based Collaborative Filtering with Min-Max Normalization. Product attributes, including price, category, material, color, size, and product rating, are normalized before the similarity calculation process to improve the consistency of product comparisons. In addition, a content-based similarity mechanism is incorporated to support recommendations for newly introduced products with limited rating data. Unlike previous studies that mainly focused on either collaborative filtering or attribute-based recommendation independently, the proposed approach integrates both techniques into a unified recommendation framework for furniture products.

The contribution of this research lies in the development of a furniture product recommendation system that combines Item-Based Collaborative Filtering, Min-Max Normalization, and a content-based similarity mechanism within a single decision support framework. The proposed system is expected to provide more objective and personalized product recommendations while assisting consumers in selecting furniture products that better match their preferences. Furthermore, this study contributes practical insights into the implementation of recommendation systems in the furniture retail sector, particularly for businesses managing a large variety of products with diverse specifications.

2. Methods

System Development Method

This study employed a quantitative research approach to develop a web-based decision support system for furniture product recommendation. The system was developed following the Waterfall software development model, which consists of requirements analysis, system design, implementation, testing, and maintenance. The Waterfall model was selected because it provides a structured and sequential development process, making it suitable for recommendation system development with clearly defined requirements [12]. The system architecture was built using the PHP-based Laravel framework as the backend and MySQL as the database. Laravel and MySQL have been used in the development of web-based information systems because they support structured data management and storage [13].

The user interface was developed using HTML, CSS, and JavaScript, while graphic visualizations were built using the Chart.js library. The system runs on a local server using XAMPP and can be accessed through a web browser. Functional testing of the system was conducted using black-box testing to ensure that each function and feature of the system operates according to established requirements [14].

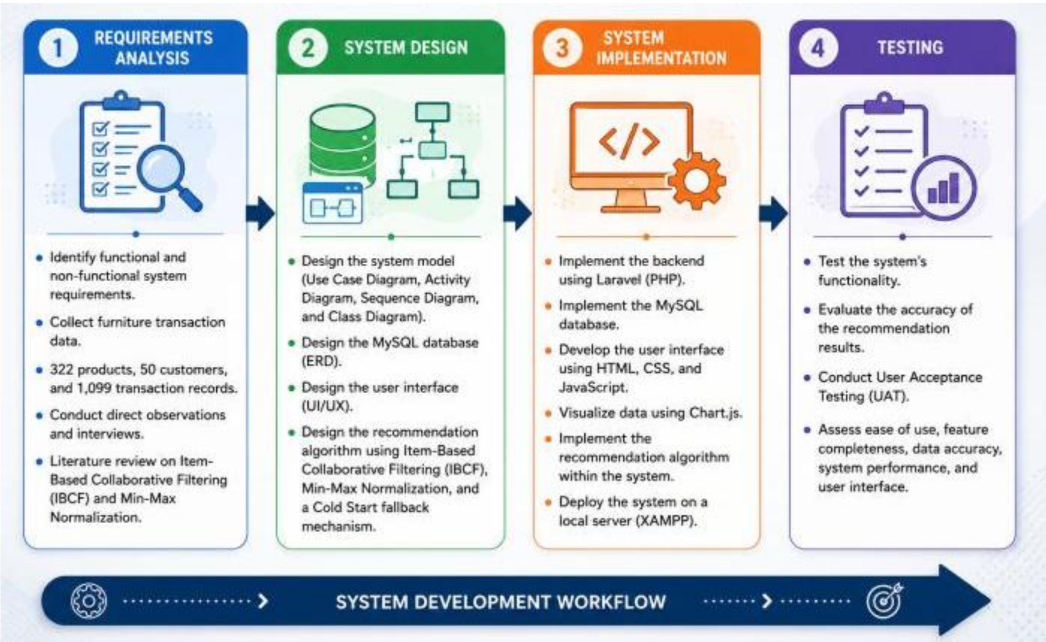

Figure 1. System Development Workflow

Dataset Description

The data used in this study were collected directly from Kamto Rotan Furniture through observation, interviews, and documentation. Observation was conducted to understand the existing product recommendation process, while interviews with the business owner were carried out to identify recommendation criteria and current business requirements. Product and transaction records were collected as supporting data for system development. The dataset consists of 322 furniture products, 50 consumers, and 1,099 consumer rating transactions recorded during 2026. Each product contains several attributes used in the recommendation process, including product category, material, color, size, selling price, and consumer rating.

Historical transaction data were transformed into a user-item rating matrix, which represents interactions between consumers and furniture products. This matrix serves as the primary input for calculating product similarity using the Item-Based Collaborative Filtering algorithm. Since the dataset was obtained from a single furniture business, the findings of this research should be interpreted within the context of the case study. Future studies are encouraged to evaluate the proposed framework using larger datasets collected from multiple furniture businesses to improve result.

Min-Max Normalization

Min-Max Normalization is applied to align multi-criteria product specifications into a uniform scale ranging from 0 to 1 [15], [16]. There are two types of criteria handled:

a. Cost criteria (the smaller the better), namely product price, normalized using equation :

$$Price_{norm} = \frac{Price_{Max} - Price_i}{Price_{Max} - Price_{Min}} \quad (1)$$

b. Benefit criteria (the bigger the better), such as initial rating, number of likes, and number of purchases, are normalized using equation :

$$X_{norm} = \frac{X_i - X_{min}}{X_{max} - X_{min}} \quad (2)$$

c. Categorical criteria (category match, material, color, size) are normalized using equation :

$$Atribut_{(norm)} = \begin{cases} 1, \text{if it matches the user's preference} \\ 0, \text{otherwise} \end{cases} \quad (3)$$

d. The initial consumer preference value is calculated as the weighted average of all normalized criteria using equation :

$$InitialPreference = \backslash sum_{k=1}^{n} (Weight_k \times NormalizedValue_k) \quad (4)$$

Item-Based Collaborative Filtering

The IBCF method works in three main stages: calculating similarity between items, predicting scores, and generating recommendations [17], [18].

a. Cosine Similarity Calculation
The similarity between two products i and j is calculated based on the intersection of consumer ratings evaluating both products using Cosine Similarity in equation :

$$Similarity(i,j) = \frac{\sum_{u=1}^{n} r\,(u,i) r(u,j)}{\sqrt{\sum_{u=1}^{n} r\,(u,i)^2} \sqrt{\sum_{u=1}^{n} r\,(u,j)^2}} \quad (5)$$

Where U is the set of consumers who have rated both products i and j, r(u,i) is consumer u's rating of product i, and r(u,j) is consumer u's rating of product j.

b. Cold Start Fallback

For new products that have never been rated by any consumer (no rating intersection), similarity is calculated based on the weighting of the product's physical attribute specifications using the equation :

$$S_f b(i,j) = 0.40C_i j + 0.20B_i j + 0.10W_i j + 0.10U_i j + 0.20\left(1 - \left|H_i^* - H_j^*\right|\right) \quad (6)$$

c. Recommended Score Prediction

The predicted consumer rating for target product i that has never been purchased or rated is calculated using equation :

$$r_{(u,i)} = \frac{\left(\Sigma_{(j=1)}^{n} sim(i,j) r_{(u,j)}\right)}{\left(\Sigma_{(j=1)}^{n} sim(i,j)\right)} \quad (7)$$

Where S is the set of products that have been rated by consumer u and are similar to the target product i. If the target product has no similarity at all to the products that the consumer has rated, the system uses a fallback prediction using the equation :

$$r_{(fb,i)} = 1 + 4P_i \quad (8)$$

System Design

The system is designed using UML modeling consisting of Use Case Diagram, Activity Diagrams, Sequence Diagrams, and Class Diagrams [19]. The system has two main actors, namely Admin and Consumer. Admin can manage master data (products, consumers, ratings), view SPK calculation visualizations transparently, and export reports in PDF format. Consumers can fill in personal preferences, view personalized product recommendations, rate products, and explore the product catalog with various filter features.

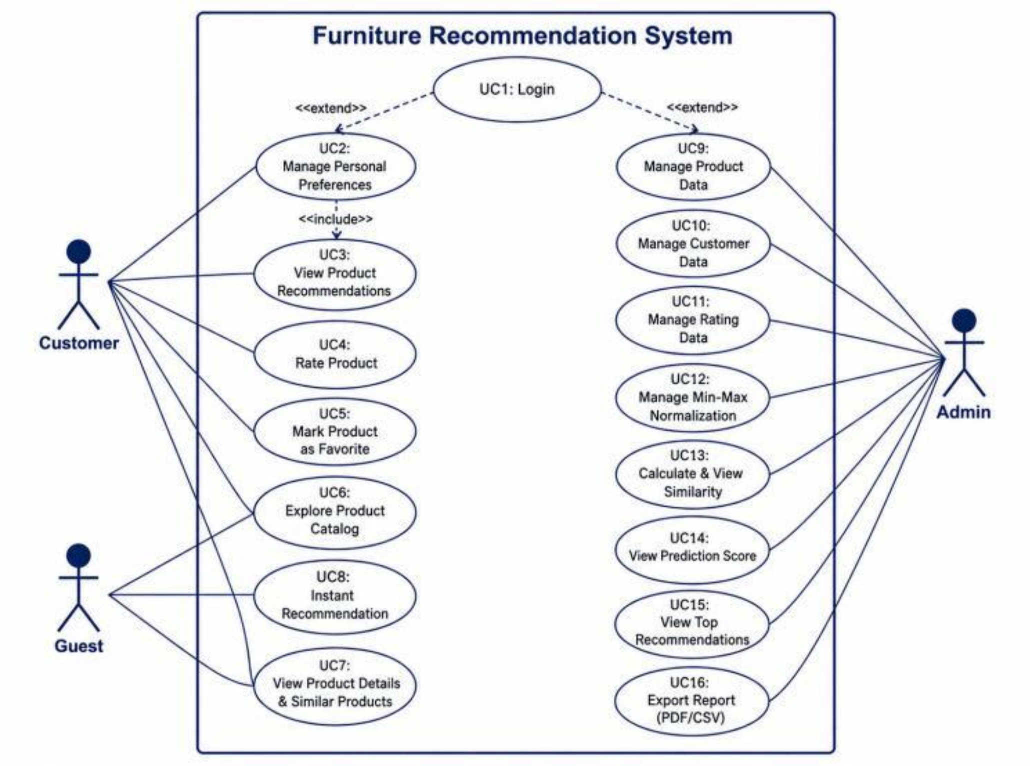

Figure 2. Use Case Diagram

System Testing

System testing was conducted using two methods. First, Black-Box Testing to verify the overall system functionality without regard to internal code, including testing login features, filling in preferences, calculating recommendations, data management, and exporting reports [7], [20]. Second, UAT was conducted by involving 10 respondents consisting of 5 general users and 5 administrators to evaluate the quality of the system using a Likert-scale-based questionnaire with 5 assessment aspects of ease of use, completeness of features, accuracy of recommendations, system speed, and interface appearance [21].

3. Results and Discussion

Data and Normalization

The dataset used in this study consists of 322 unique furniture products spanning eight main categories (chairs, tables, cabinets, sofas, beds, shelves, lamps, and decorations), 50 consumer data items, and 1,099 transaction rating items on a rating scale of 1 to 5. The distribution of product categories and consumer ratings is presented in Table 1.

Table 1. Product Distribution and Ratings per Category

Product Category	Number of Product	Number of Ratings
Chairs	58	218
Tables	52	195
Cabinets	45	175
Sofas	48	183
Beds	42	162
Shelves	38	142
Lamps	22	87
Decoratives	17	57

The Min-Max normalization process was applied to all 322 products. For example, for a price criterion with a minimum value of Rp150,000 and a maximum value of Rp25,000,000, a chair priced at Rp2,500,000 would be normalized to:

$$Price_{(norm)} = (25.000.000 - 2.500.000)/(25.000.000 - 150.000) = 0{,}905$$

The normalization value of 0.908 indicates that the product has a high value from the perspective of cost criteria, meaning that the price is relatively cheap compared to the overall price range of products in the dataset, making it more profitable for consumers.

Cosine Similarity Calculation

The product similarity matrix was calculated for all product pairs in the dataset, resulting in a 322 × 322 matrix with a total of 103,362 product combination pairs. The computation process was performed automatically by the system in an average time of 9 seconds. Table 2 presents an example of the Cosine Similarity calculation results for the top five product pairs with the highest similarity scores.

Table 2. Example of Cosine Similarity Calculation Results for the Top Five Product Pairs

Product i	Product j	Slice Rating	Cosine Similarity
Ergonomic Work ChairA	Ergonomic Work Chair	12 Consumers	0,9847
Teak Wood Dining Table 4-Seater	Teak Wood Dining Table 6-Seater	9 Consumers	0,9712
Sofa L-Shape Gray	Sofa L-Shape Brown	11 Consumers	0,9634
Wardrobe 3-Door White	Wardrobe 3-Door Cream	8 Consumers	0,9581
Bookshelf Minimalist 5-Tier	Bookshelf Minimalist 4-Tier	7 Consumers	0,9423

The calculation results show that the product pairs with the highest similarity are generally products in the same category with similar specifications and have been rated by the same number of consumers. This is in accordance with the basic principle of Cosine Similarity, which measures the cosine of the angle between two rating vectors in a multidimensional space.

Score Prediction and Recommendation Results

As an illustration, the following shows the recommendation score prediction process for Consumer 1 (Budi Santoso) for the target product "Modern Minimalist Work Desk," which has never been purchased or rated. Consumer Budi has previously rated three products that are similar to the target product: Ergonomic Work Chair (rating 4, similarity 0.72), Minimalist Bookshelf (rating 5, similarity 0.58), and Folding Computer Desk (rating 3, similarity 0.85).

$$\text{Prediction} = \frac{(0{,}72 \times 4) + (0{,}58 \times 5) + (0{,}85 \times 3)}{0{,}72 + 0{,}58 + 0{,}85}$$

$$\text{Prediction} = \frac{2{,}88 + 2{,}90 + 2{,}55}{2{,}15} = \frac{8{,}33}{2{,}15} = 3{,}875 \approx 3{,}88$$

A prediction score of 3.88 on a scale of 5 indicates that the system predicts that Consumer Budi will rate the product quite highly, thus placing it in the "Recommended" category (score 3.5-4.49). Table 3 presents an example of the top 10 recommendations generated by the system for Consumer 1.

Table 3. Example of Top 10 Recommendations for Consumers 1

Rank	Product Name	Prediction Score	Category
1	Premium Adjustable Work Chair	4,82	Highly Recommended
2	Modern Minimalist L-Shaped Work Desk	4,71	Highly Recommended
3	Natural Wood Display Shelf 6-Tier	4,65	Highly Recommended
4	Minimalist Gray Sofa 2-Seater	4,53	Highly Recommended
5	Teak Wood Dining Table 4-Seater	4,38	Recommended
6	Wardrobe 2-Door White Modern	4,21	Recommended
7	Natural Rattan Dining Chair	4,17	Recommended
8	Teak Wood Queen Size-Bed	4,09	Recommended
9	Shoe Rack 4- Tier Minimalist	3,95	Recommended
10	Modern Minimalist Work Desk	3,88	Recommended

System Interface Implementation

The system is implemented as a Laravel-based web application accessible through a browser. The following is a display of the system's main interface.

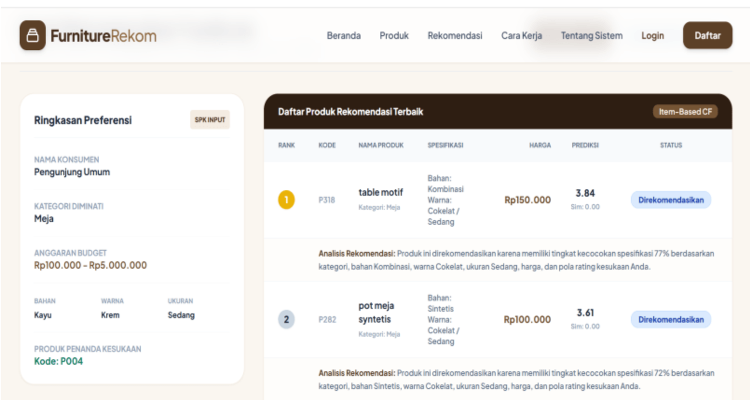

Figure 3. Furniture Product Recommendation Results Page View

The recommendation results page displays a list of products sorted by the highest predicted score. Each product is accompanied by a specification match percentage, a suitability category (Highly Recommended, Recommended, Moderately Recommended, or Less Recommended), and a technical recommendation rationale explaining why the product matches consumer preferences.

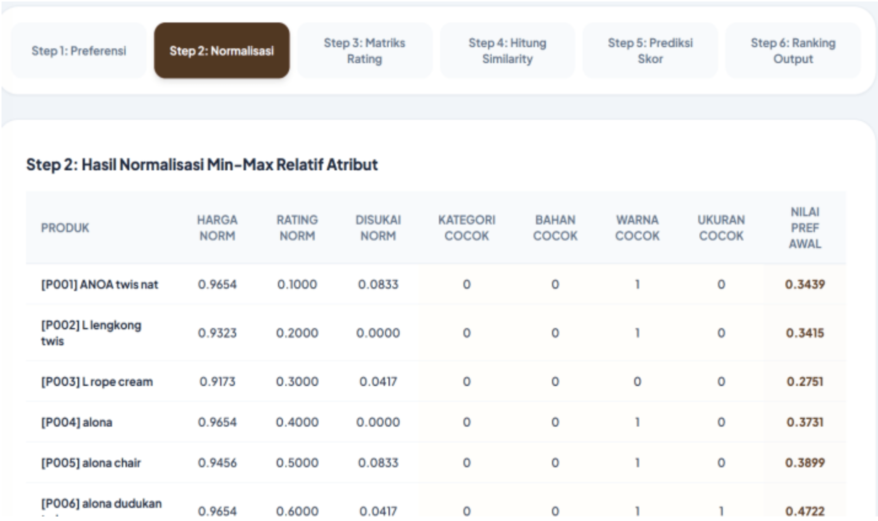

Figure 4. Admin Dashboard View with Transparent SPK Calculation Visualization

The admin dashboard provides a transparent visualization of SPK calculations, including data normalization, a 50×322 rating matrix, similarity calculation results, score predictions, and recommendation rankings. This feature is highly useful for auditing, validation of calculation results, and academic presentations.

Test Result

Black-box testing was conducted on 35 test scenarios covering all system features. The test results showed that 34 of the 35 scenarios successfully executed as expected, with a success rate of 97.14%. One scenario that was not fully met was the response time for recalculating the similarity matrix for large datasets (>10,000 products), which requires further optimization.

Table 4. Summary of Black-Box Testing Results

No	Test Module	Number of Scenarios	Status
1	Authentication and Authorization	5	Successful 5/5
2	Master Data Management	8	Successful 8/8
3	Consumer Preference Input	6	Successful 6/6
4	SPK Calculation & Recommendations	9	Successful 8/9
5	Reports & Exports	4	Successful 4/4
6	Admin Dashboard Visualization	3	Successfule 3/3

UAT was conducted with 10 respondents. The results of the UAT questionnaire assessment using a Likert scale of 1-5 are presented in Table 5.

Table 5. User Acceptance Testing (UAT) results

No	Assessment Aspect	Average Score (1-5)
1	Ease of Use (Usability)	4,6
2	Feature Completeness (Completeness)	4,4
3	Recommendation Accuracy (Accuracy)	4,3
4	System Speed (Performance)	4,2
5	Interface Appearance (UI/UX)	4,5
	Overall Average	4,40 (88,0%)

The UAT results showed an average overall score of 4.40 out of 5, equivalent to an acceptance rate of 88.0%. Ease of use received the highest score (4.6) due to its user-friendly interface and intuitive navigation flow. System speed received the lowest score (4.2), but was still in the very good category, with the caveat that the similarity matrix recalculation process took approximately 9 seconds. Compared with previous studies that primarily relied on historical rating information, the proposed framework extends the recommendation process by incorporating normalized product attributes into similarity computation. This approach is particularly relevant for furniture products because purchasing decisions are influenced by multiple characteristics rather than user ratings alone. Although the proposed system demonstrated satisfactory functional performance and received positive user acceptance, this research has several limitations. The recommendation model was evaluated using transaction data obtained from a single furniture business involving 50 consumers. Consequently, further validation using larger and more diverse datasets is required to investigate the robustness and scalability of the proposed recommendation framework.

4. Conclusion

This study developed a web-based decision support system for furniture product recommendation by integrating IBCF, Min-Max Normalization, and a content-based similarity mechanism. The proposed approach enables the system to recommend furniture products based on consumer preferences while considering heterogeneous product attributes, including price, category, material, color, size, and product rating. The implemented cold-start mechanism also allows newly introduced products to be recommended despite having limited rating data. The developed system successfully performed all intended functions based on Black-box Testing and achieved an overall User Acceptance Testing (UAT) score of 88.0%, indicating good user acceptance in terms of functionality and usability. However, this study was conducted using transaction data from a single furniture store involving 50 consumers. Therefore, future research should evaluate the proposed approach using larger and more diverse datasets and compare it with other recommendation methods to further validate its effectiveness.

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