



# INTERNATIONAL JOURNAL ON INFORMATICS VISUALIZATION

journal homepage : [www.joiv.org/index.php/joiv](http://www.joiv.org/index.php/joiv)



## Applied Fuzzy and Analytic Hierarchy Process in Hybrid Recommendation Approaches for E-CRM

Elham Abdulwahab Anaam<sup>a,\*</sup>, Su-Cheng Haw<sup>b</sup>, Palanichamy Naveen<sup>b</sup>

<sup>a</sup> Faculty of Information Science and Technology, University Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

<sup>b</sup> Faculty of Computing and Informatics, Multimedia University, Jalan Multimedia, 63100, Cyberjaya, Malaysia

Corresponding author: \*anaamelham@gmail.com

**Abstract**—To create a personalized E-CRM recommendation system, the electronic customer relationship management system needs to investigate low accuracy and lack of personalization through applied hybrid recommendation system techniques such as fuzzy and AHP. The main purpose of this research is to enhance the accuracy and deep understanding of common recommendation techniques in E-CRM. The fuzzy and AHP techniques have been used in the current study to the available information of objects and to extend recommendation areas. The findings indicate that each of these strategies is appropriate for a recommendation system in a technological environment. The present study makes several noteworthy contributions to the fuzzy Analytic Hierarchy Process (AHP) and has the maximum accuracy of any of these approaches, with 66.67% of accuracy. However, AHP outperforms all others in terms of time complexity. We advocate the concept and implementation of an intelligent business recommendation system dependent on a hybrid approval algorithm that serves as a model for E-CRM recommendation systems. This recommendation system's whole design revolves on the hybrid recommendation system. The systems additionally incorporate the recommendation modules and the recommendation measurement updating framework. The recommendation modules include the formulation and development of material recommendation algorithms, element collaborative filtering recommendation algorithms, and demography-based recommendation algorithms.

**Keywords**— Hybrid recommendation technique; recommender system; E-CRM; Fuzzy-AHP; hybrid fuzzy.

Manuscript received 5 Dec. 2021; revised 12 Jan. 2022; accepted 28 Apr. 2022. Date of publication 31 Aug. 2022.  
International Journal on Informatics Visualization is licensed under a Creative Commons Attribution-Share Alike 4.0 International License.



### I. INTRODUCTION

Information Technology (IT) plays an important role in E-CRM to facilitate and improve the relationship and interaction of the system. According to Anaam et al. [1] and Khan et al. [2], E-CRM technology facilitates and activates organizational processes. Anaam et al. [1] and Ardyan and Sugiyarti [3] indicated that the part of E-CRM enhances customer information. Companies usually identify E-CRM systems to facilitate workflow and represent a highly qualified process. Classified data is included in the improvement of an additional database and redesigned the system's control of the process. It is crucial to enhance the existing E-CRM standard system. Deldjoo et al. [4] indicated that the organization needs computing technology to process large size of customer data. This includes customer data, customer browsing history, and purchase transactions. This information will carry chances for the companies to create a different business strategy to enhance the organization's needs.

Khan et al. [2] suggested integrating E-CRM marketing with IT to obtain a large size of information on their customers and return this information for strategic business purposes. The literature review very much reaches developed countries as E-CRM is more engaged because they consider it the best way for the competitive world in marketing. As a result, we enhanced the platform recommendation system based on a comparison and methodological research of E-CRM systems [5] to facilitate the selection of the most appropriate E-CRM system, including any organization's goals and configurations, and this is based on an evaluation approach of E-CRM system performance [6]. An additional issue is that traditional E-CRM platforms lack personalization. Regardless of whether they have differing previous information concerning organizational objectives, learners with the same plan have the same content lists for learning [7]. Based on the gap identified in this paper, we offer the functional architecture of the recommendation system for using E-CRM platforms. It consists of two segments:

1) *Formalization of requirements*: the system will make it easier to include an E-CRM system for training distribution, allowing you to pick the one that perfectly suits the training ecology.

2) *The suggested design*: It is divided into two subcomponents. The Semantic-Based System and the Control Elements System. Observation, Learner Profile, Recommendation Storage, and Application Programs are also included in the system. Understanding materials relating to the field is part of a definitional approach. The contributions of this paper are as follows.

- Providing a deep understanding of the recommendation system in E-CRM.
- Review some selected recommendation system techniques.

## II. MATERIALS AND METHOD

### A. Hybrid Recommender System

A hybrid recommender system (RS) results by mixing multiple recommendation algorithms. When evaluating hybrid RS to collaborating or material techniques, a hybrid system often outperforms collaboration or information systems in the context of recommendation efficacy. The rationale for this is a lack of understanding of the area requirements of machine learning and societal perceptions in a content-based system. When combined, one will obtain more common information, allowing one to make better recommendations. It is particularly inspiring when understanding advances to improve fundamental information retrieval techniques with digital information and information techniques with human behavior data. Table 1 depicts the possible types of hybridization methods. The system employs a content/collaborative hybrid that begins with a material recommendations mechanism.

TABLE I  
TYPES OF HYBRIDIZATION METHODS

Hybridization Method	Description
Weighing	A unique recommendation is generated by combining the scores of numerous existing algorithms.
Switching	Based on the circumstances, the system shifts between suggestion strategies.
Mixed	Simultaneously time, a recommendation from numerous separate proposals is offered.
Feature combination	Components from many recommendations from different databases are combined to form a unified classification technique.
Cascade	Each recommended algorithm improves on another's specific suggestions.
Feature augmentation	Each method's outcome has been used to contribute to another's.
Meta-level	Each recommendation algorithm is developed as material for another.

### B. Path Analysis

Path analysis is the most prevalent technique for a company website Figure 1. It could be used to determine the most

popular paths on an online platform. A matrix represents a relationship defined on web pages or other objects. A matrix is typically used to describe the physical web page, with web servers acting as nodes and hypertext links between pages acting as directed edges. The network in the estimation process has generic web addresses as a matrix having two multiple primary categories: Products and Services, within each sub-node PG (Product Groups) and S (Systems).

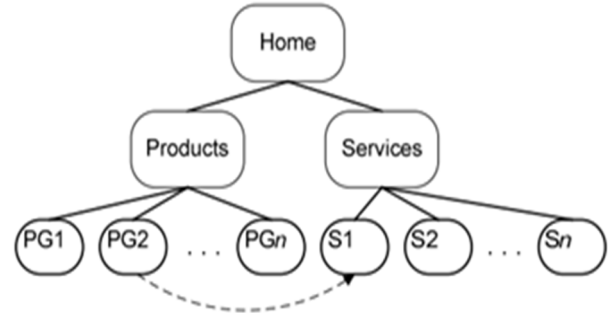


Fig. 1 Platform for tracking users

### C. Important Recommendation System

Expert systems that strongly suggest assets to users are known as RS. A classic RS is depicted in Figure 2. Several variables influence the concerns in Computational Intelligence and Neuroscience.

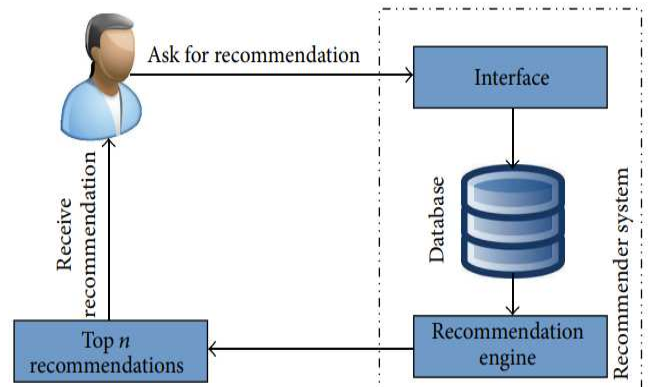


Fig. 2 Recommendation System

Users can decide on the products or services that have been strongly advised. Information system (Positioning relies on data provided by the public, such as websites and social networks. Location information images and systems (GPS) records, recommender. Users benefit from technologies that generate individualized information. Suggestions are beneficial to the users in the process of deciding. An algorithm, filtration approaches, classifications, and datasets are RS's materials and building blocks. Collaboration approaches have shortcomings because RS has little information to provide recommendations. A situation like this is known as a cold start, which is discussed in Table 2. The next subsection goes through the kNN algorithm, most commonly employed in collaboration filtering RS. Many recommendation methods rely heavily on similarities and differences between individuals' activities. Furthermore, several similarity metrics were explained by making comparisons between individuals or products.

TABLE II  
ALGORITHM AND FILTRATION APPROACHES

Benefits of RS	Description	References
Increased sales or conversion	Several strategies stimulate demand without spending lots of money on advertising.	[8]
Increased customer loyalty	Spending considerable time on social media will boost customer knowledge of business models and customer experience.	[9]
Challenges have been minimized, allowing us to address the internet starting difficulty.	Discounted or offers are other low-cost approaches to s clients, and they could be used with advice to boost customer engagement.	[10]–[12]
Increased user satisfies	The quickest path to a payment processing contribution for the customers is because it minimizes their commitments. By supporting a better alternative, proposed methods help to minimize your guest's pathway to the purchase.	[13], [14]
Increasing efficiency, reducing costs on business process	Companies are indeed seeking methods to reduce costs and increase performance. The recommendations mechanism was crucial during this.	[15]

#### D. Analysis of Related Works

The material method and the information retrieval technique are the two main orientations of RS. The version uses the item's information, whereas the latter uses the user's behavior histories. A material strategy aims to find products most "similar" to the participant's model evaluation. As studied by Burke [16], several methods have indeed been devised, including semantic similarity using the term frequency-inverse dense frequency (TF-IDF) word weight, Bayesian classifications, segmentation, and so on. Term frequency The TF is derived from N objects which might theoretically be recommended to the user.

$$Tf_{ij} = \frac{F_{ij}}{\max_{z,j} f_{z,j}} \quad (1)$$

Where  $f_{ij}$ ,  $f_{ij}$  is the number of times keyword  $K_i$   $K_j$  appears in document  $D_j$  and computed maximum  $f_{z,j}$   $f_{z,j}$  is the

frequencies of all keywords  $k_z$  that appear in the document. Keywords that appear in many different documents are not useful when distinguishing between relevant and irrelevant documents.

$$1^D F = \log \frac{N}{n_j} \quad (2)$$

Then we can simply get the weight for keyword  $k_i$  in document  $K_{idj}$  as

$$W_{ij} = TF_{ij} \times IDF_i$$

According to our findings, the material strategy is quite effective for increasing recommendation frequency. A further approach is to make recommendations based on the user's past behavior. Every row inside the consumer sequence is a user's matrix, and each column is an item matrix. The human methodology allows using another user's matrix, sometimes referred to as recollection algorithms in the literature. The online purchase technique is a theoretical method that recognizes the use of the element matrix. Instead of locating similar account neighbors, this approach locates similar item neighbors for items in the user matrix. Table 3 shows the frequent studies that include these Algorithms in their models and empirical studies.

#### E. Electronic Customer Relationship Management

Ali et al. [17] define E-CRM as "the business operation, techniques, and techniques online service (using an essential part of web applications sites and e-mail, data capture, warehouse management, and processing) with a clear goal to locate, develop, and keep improving strong customer relationships to maximize their development opportunities. According to a previous study, important non-exclusive E-CRM fields exist E-CRM markets, E-CRM marketing strategies, E-CRM performance improvement, E-CRM technology, and E-CRM human aspects. The fundamental concept of smart CRM is the implementation of CRM to network e-commerce businesses (E-CRM). According to Burke [16] "e-CRM gives the capacity to obtain, combine, and make available data obtained from the company's website across the business." In the modern environment, an e-commerce system is not limited to a specific platform and instead has evolved to include several channels such as online, web applications, e-mail, PDAs, cellphones, and so on. The e-CRM system aids in the development, selling, and servicing of the rapidly expanding website firm.

TABLE III  
ALGORITHMS USED IN PREVIOUS ACADEMIC

Techniques	Main findings	Techniques/ Algorithms
Neural Networks	[8]	Determine the visualizations that can predict trends in the participant's mouse movement across the screen within the cluster. This demonstrates how keyboard focuses placements, as well as other data such as state and time, and date, can be utilized to boost the top ranks of the search field, as worried visitors seem to be more inclined to investigate the top section of the interface.
	[18]	Individuals are categorized recommend items, and the community development task is finished using a cooperative classification method depending on the user categorization matrices.
K-means	[19]	Streamline Evaluation for the K-Means fuzzy clustering with different amounts of segments is used to study differentiation strategy and categories. The Streamline Scores can be used to assess the Sales Timeliness, Sales Frequently, and Selling Currency, and an optimum solution is obtained.

Factor analysis	[20]	According to the result of this research, incorporating a patient's history in an eCommerce platform's recommendation systems could substantially improve the recommendation system in recommending acceptable items to meet the device's requirements. As shown in the conclusions of this paper, customer feedback backgrounds can be affected by elements such as profile pages, enhanced awareness, neighbors, confidence, and content management systems.
	[21]	The TAM theory was a recommendation as the most conceptual framework for building a conceptual framework for customer repurchase intention in the recommendation system. The investigation, and the survey method effectively forecasts the consumer's means to purchase the advice.
	[22]	In the clustering obtained by different sets of data, the revised SAPK +K-means technique has a low loss. The SAPK+ K-means algorithm achieves a higher predictive influence on customer categorization of e-commerce platforms.
Logistic Regression	[23], [24]	On the validation dataset, the classifier with XGBoost and attribute selection outperforms the Linear Regression method, which does not produce a good estimate. They demonstrate that the model's properties are unlikely linearly related to the objective marking.
	[25]	Shows how the proven classification and clustering approach based on SOM and Kmeans overcomes the limitations of these methods. Their suggested approach not just to solves the fundamental constraints of SOM and K-means, but also improves their potential by introducing a fuzzy user distribution.
	[26]	A self-constructing clustering algorithm was used to minimize the dimensionality associated with the number of products.
	[27]	A most typical application of discovered navigational similarities is to reorganize review sites in addition to enhancing them. E-commerce providers use a recommendation system to recommend products to customers.
	[28]	This research presents the findings of a significant number of studies on the predictive accuracy of data mining algorithms for clustering or recommendation systems. The findings show that Fuzzy systems with decision trees at each node and correlations approaches outperformed Algorithmic segmentation and vector similarities techniques through a range of scenarios.
Bayesian methods	[29]	Combining numerous components evaluations can enhance the recommendations.
Collective intelligence	[30]	Recommending a method for recommending items to a prospective user. Additionally, those whose experiences are unclear due to inadequate purchasing experience. To compare this situation to the new user's demand, the suggested process utilizes the behavior experience of current subscribers with comparable characteristics.
	[28], [31]	The K-Means histogram approach seriously influences the safety aspect of trust in mobile help the business grow. This research reveals that developing a K-means-based algorithm is achievable, adaptable to categorizing customers' trust, and useful in determining its qualifications.
	[32]	They were able to improve the effectiveness of testing and validation by prioritizing acceptance tests using a recommendation systems approach.
Comparing Pre-filtering and Post-filtering	[33]	The importance of specific customer needs as a source of tailored user feedback was emphasized. The initiative was motivated by a need to customize the experiences of unidentified, including first visitors.
Weighted RFM	[27]	The sentiment classification technique has proven to be effective in a variety of applications. To make recommendations, this similar transaction the CF technique with customer requests obtained from widely consumable commodities in every category.
	[20]	They developed a new recommendations system incorporating AHP, segmentation, and correlation guideline approaches. Considering RFM weight lifting probably depends on
	[21]	The ICS paradigm suggests access methods. For ICS application domains, the virtual machine paradigm looks to be appropriate.
	[32]	The findings demonstrate that the bisecting Kmeans strategy outperforms the regular K-means technique and is on par with or outperforms the formal organizational methods.
Singular Value Decomposition (SVD)	[33]	This suggests that Independent Component analysis Decomposition (SVD) may be such a technique in some circumstances. In the instance of a very sparse e-commerce database, the SVD-based method significantly outperformed traditional adaptive algorithms.

#### F. Electronic Customer Relationship Management

Ali et al. [17] define E-CRM as "the business operation, techniques, and techniques online service (using an essential part of web applications sites and e-mail, data capture, warehouse management, and processing) with a clear goal to locate, develop, and keep improving strong customer

relationships to maximize their development opportunities. According to a previous study, important non-exclusive E-CRM fields exist in E-CRM markets, E-CRM marketing strategies, E-CRM performance improvement, E-CRM technology, and E-CRM human aspects. The fundamental concept of smart CRM is the implementation of CRM to network e-commerce businesses (E-CRM). Junior et al. [24],

"e-CRM gives the capacity to obtain, combine, and make available data obtained from the company's website across the business." In the modern environment, an e-commerce system is not limited to a specific platform and instead has evolved to include several channels such as online, web applications, e-mail, PDAs, cellphones, and so on. The e-CRM system aids in the development, selling, and servicing of the rapidly expanding website firm. Figure 3 is a workflow diagram for creating a Product Profile. The business profiles are made up of vector items and integrated product tags. The product profile can have a value of 1 or 0, with 1 indicating that a tag shows on an item and 0 indicating that it does not. This strategy incorporates both content and collaborative data. This strategy employs not just a collaborative and content-based technique, but also a knowledge-based technique and demography.

Based on the consumer profile, a knowledge-based system recommends items. This method employs categorized online sites, which give a platform capable of relieving website visitors from repetitive web browsing to several levels. E-CRM is the system responsible for storing operational data from a data warehouse. It is a database server for data analysis. intermediaries to employ. Interface for data mining as shown in the figure, the three different business aspects are covered when all of the elements work next to each other. The goal of this article is to how a login and access control mechanism is developed on an online platform; after that, higher customer data and e-CRM could be accomplished. We used demographic variables from user data and the RFM algorithm to examine the trend of different customizations and the precise customers. This system was made up of sophisticated modules and three different types of agent functionalities. In addition, Fig. 3 shows the recommendation system's configuration settings.

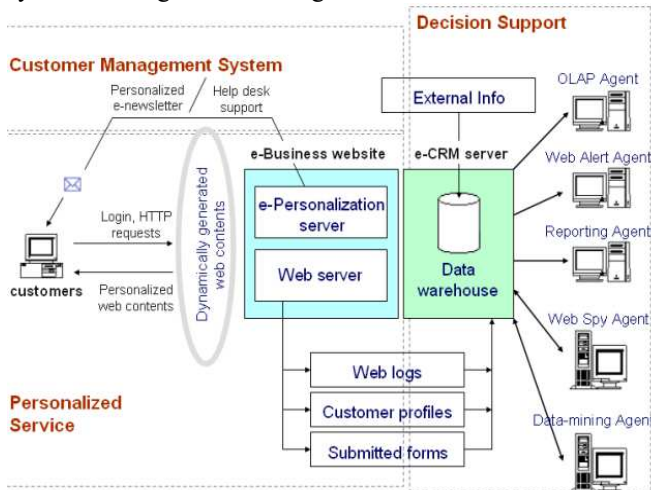


Fig. 3 Recommendation System and E-CRM

### G. Theoretical gap

This study pays particular consideration to the organizational variables related to E-CRM achievement. These organizational variables are drivers of E-CRM practice [25]. Information systems are essential tools which affect the organization as a whole. There are many theories in the field of acceptance of the technology. Many studies have been focused on how to adopt E-CRM effectively [26], [27], [28]. Though there were several guidelines on the adoption method

of E-CRM, the unsuccessful ranks for E-CRM continue perniciously in height. Several types of research have shown that 60% of E-CRM efforts are observed as unproductive adoption in developed countries, while only 40% are observed as achievements [29], [30]. There has been no study on the recommendation system with E-CRM employing both the perceptual cycle model to evaluate differences in satisfaction with service quality.

With its aim of collecting and providing big amounts of information, the E-CRM recommendation system has a lot to offer. Researchers have used the perceptual cycle model as the foundation for their view of human activity recognition, saying that comprehending requires an awareness of the relationship between operating companies and the E-CRM ecosystem. However, the recommendation system might be the main weakness without the right knowledge and capabilities to evaluate and analyze the information. Several obstacles should be overcome before their maximum capabilities may be realized. For starters, it might happen when there is a lack of staff and experience in an organization. Second, it is difficult to track client behavior, particularly in the online world. Following individuals as they transition from brand awareness to conversion. Finally, CRM with Recommendation System may require additional browser IT tools in document processing, particularly when it comes to leveraging data effectively between channels, especially when they do not understand the effectiveness of their efforts in this area. There is no one-size-fits-all answer; employees must incorporate recommendation systems into their initiatives, particularly when it comes to business units, information offerings, and customer journeys. Many CRM teams will continue to look for answers to this problem until such products become accessible. The final problem is information significance, which can be found in Weblog files, social media, enterprise content, transactions, and recommendation system. These data sources may develop the necessary influence of technology to ensure their validity and security. For example, the responsibility of the recommendation system monitors several of our posts or tweets on online platforms.

### H. Proposed Approach

The multiple Kernel Learning (MKL) method is utilized to differentiate feature variables between healthy and sick or organizations and employee data to reduced dimensions. In addition, the input signals are also reconstructed from the output space of coordinates using multi-scale kernel regression.

The proposed fuzzy identification algorithm is being used to determine which organization information fulfills the customers' requirements. Users will be able to learn more efficiently online if a proper E-CRM system is introduced. While learners are allowed to access the material, this research proposes the idea of data uploading to a cloud platform by inputting a question into E-CRM. Filtering user of E-CRM with fuzzy algorithms is the material of an element could be described as follows: we make the  $k_i$  standing for the  $i$ th term of element  $o_i$ , the  $w_{ij}$  standing for the weight of  $k_i$  on  $o_j$ , and finally, the Item  $o_j$ 's contents thrust vector approach could be expressed using the following equations



$$c_{\text{ontet}}(0) = \{w_{ij}, w_{1j}, w_{ij}\} \quad (3)$$

By using a sequential process model, the learner should obtain related data. It categorizes data from a cloud server and then filters the stored information. Similarity-based collaboration segment, the user is recommended relevant data with the aid of a hybrid fuzzy tree. For measuring concept similarity, a fuzzy system matching approach has been presented. According to customers' requirements and the E-CRM system information, as shown in the conception, the fuzzy method is perfectly useful when determining users' needs and recommendations depending on user requirements.

Content-based filtering is many of the most prevalent strategies for developing a recommendation system. Different innovations will be recommended to a user in a content-based RS based on content attributes that are comparable to the items that this user has acted [18]. Figure 3 shows a typical example of how content-based RS works. For example, if a user has viewed an interesting plot, the system will recommend more action movies that the user has not seen previously. Another instance of how content-based filtering works in E-CRM RS is that the technique to identify the significance of effect for employee recommendation is to look at respective content information, including their classifications or essential elements. The three basic elements that make up the high-level approach of knowledge RS are Content Analyzer, Profile Learner, and Filtering and Recommendation.

1) *Content Analyzer*: The content features of structured data can be easily extracted [15]. In extracting content features, pre-processing is required for large amounts of data, including documents [5]. The content analyzer's primary job is to use feature extraction techniques to extract content features of objects from multiple data sources to make future quality very important.

2) *Profile Learner (User Profile Learning)*: The user profile records are utilized to create a user-specific interests' profile, which includes both internal and external comments. For sequential method consumption histories, machine learning algorithms are used to assess recommendation datasets [5].

3) *Filtering and Recommendation*: In this step, the username, password, and element components are matched to provide suggestions. Because content-based approaches rely solely on relevant content, they will be hampered by limited content analysis and over-specialization. The term "limited content analysis" refers to the platform's content-based filtering knowledge being limited.

4) *Method for Item-Based Collaborative Filtering Recommendation*: The key phases of this method are as follows: first, estimate the similarities between materials; second, build a suggestion summary due to the similarities between materials and previous user behavior. In the E-CRM platform, some anxious users have an impact on the calculation of similarity between the items. To lessen the impact of hyperactive users on system correctness, we optimize the estimation of similarities utilizing equations (1): to mitigate the effect of anxious individuals on accuracy and

sensitivity: whereby  $W_{ij}$  represents visitors who preferred items  $j$ , and  $N(i)$  represents visitors who select items  $i$ . After acquiring the resemblance, we construct  $p(u, j)$  representing how the consumer  $u$  like the stuff  $j$ ,  $W(j, k)$  expressing for  $k$  developmental tasks are perhaps the most equivalent to Items

$$j.W_{1j} = \frac{\epsilon u N(i) \frac{1}{\log_1 + N(u)}}{N(i)N(i)} \quad (4)$$

Analytic Hierarchy Process (AHP) is one of the most extensively used decision-making tools based on several variables. AHP is utilized for a corporation with issues, including considering several keys altogether, and AHP has more utilized as a multiple criteria decision-making instrument. The process of AHP does not include cumbersome mathematics but employs essentials of decomposition, pairwise evaluation  $n$ , and significance course generation and combination. Often used in the decision-making method, AHP is known as a concept of quantity; when utilized in the decision-making procedure, it helps  $s$  to break down a multi-criteria decision issue together into a multi-level organizational structure of goal, parameter, sub-criteria, and options available.

### III. RESULTS AND DISCUSSION

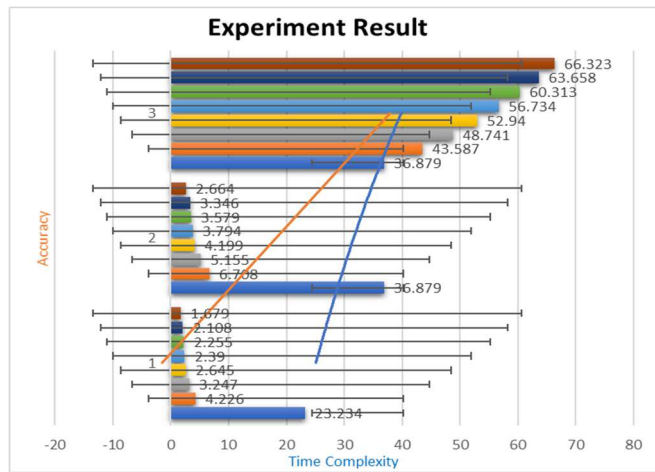
#### A. Evaluation of Performance

The recollection frequency, accuracy, current ratios, and new item ratio are among the significant factors used to evaluate the success of intelligent business recommendation systems [22]. The offline experimental data in this article comes from dangdang.com consumers' shopping data from May to December 2012. The experimental results of recall ratio, accuracy, current ratios, and item advancement ratio were evaluated under different individual classification techniques: content-based recommendation algorithm, item-based collaborative filtering recommendation algorithm, and modeling and simulation-based classification technique. The accuracy of the item-based collaborative filtering recommendation method is high, but the ratio of the new item is poor, as shown by the following statistics. The accuracy of a content-based recommendation method is lower than that of a collaborative filtering algorithm, but it has the maximum recollection as well as availability ratios or may suggest a huge number of new goods. While the coverage and new product ratios are extremely high, the accuracy of the demography-based recommendation method is indeed the weakest. The suggested hybrid recommendation algorithm outperforms the competition to improve accuracy, recollection ratio, and current and new product ratio.

#### B. Experiments Results

The greater the value, the more enthusiastic the user is with the film. Each record in the collection includes details such as the user's ID, the item's ID, the item's user rating value, and the timestamp. Different object ID values correspond to different profiles, and dissimilar employer ID corresponds to different users. We introduce the idea of the sparsity level, defined as the percentage of unrated items in the user rating data matrix, to evaluate the feature space of the total database.

Experiment 1, shown in Fig. 4, analyses the performance of multiple approaches because metrics differ when learning algorithms and experimenting with the dataset, i.e., when database sparsity differs.



- [4] Deldjoo, Y., Schedl, M., Cremonesi, P., & Pasi, G. Recommender systems leveraging multimedia content. *ACM Computing Surveys (CSUR)*, 53(5), 1-38. 2020. <https://doi.org/10.1145/3407190>.
- [5] Mezni, H., & Abdeljaoued, T. A cloud services recommendation system based on Fuzzy Formal Concept Analysis. *Data & Knowledge Engineering*, 116, 100-123. 2018. <https://doi.org/10.1016/j.datak.2018.05.008>.
- [6] Anaam, E. A., Magableh, M. N. Y., & Ridha, A. Key Factors Influence on Decision Making to IoT Adoption in Telecommunication Companies: A Review. *International Journal of Engineering & Technology*, 11(1), 14-19. 2022. [sciencepubco.com/index.php/IJET](http://sciencepubco.com/index.php/IJET).
- [7] Khatter, H., Arif, S., Singh, U., Mathur, S., & Jain, S. Product recommendation system for E-commerce using collaborative filtering and textual clustering. *Third International Conference on Inventive Research in Computing Applications (CIRCA)*. pp. 612-618. September. 2021. IEEE. <https://doi.org/10.1109/ICIRCA51532.2021.9544753>.
- [8] Ardyan, E., & Sugiyarti, G. The influence of e-CRM capability and co-information sharing activity on product competitiveness and marketing performance of small and medium-sized enterprises. *International Journal of Electronic Customer Relationship Management*, 11(2), 158-178, 2018.
- [9] Anaam, E. A., Bakar, K. A. A., Satar, N. S. M., & Kamrul, M. Critical success factors for electronic customer relationship management success adoption: Telecommunication companies case study. *International Journal of Advanced and Applied Sciences International Journal of Advanced and Applied Sciences*, 8(10), 116-130. 2021.
- [10] Koopialipoor, M., Jahed Armaghani, D., Hedayat, A., Marto, A., & Gordan, B. Applying various hybrid intelligent systems to evaluate and predict slope stability under static and dynamic conditions. *Soft Computing*, 23(14), 5913-5929. 2019.
- [11] Anaam, E. A., Khairul, A., Abu Bakar, N. S., & Mohd, S. A theoretical review of a conceptual model for E-CRM success in telecommunication companies. *International Journal of Engineering & Technology*, 10. 2018. <https://doi.org/10.14419/IJET.v7i4.17674>.
- [12] Jain, A., & Gupta, C. Fuzzy logic in recommender systems. In *Fuzzy Logic Augmentation of Neural and Optimization Algorithms: Theoretical Aspects and Real Applications*, pp. 255-273. Springer, Cham. 2018. [https://doi.org/10.1007/978-3-319-71008-2\\_20](https://doi.org/10.1007/978-3-319-71008-2_20).
- [13] Anaam, E. A., Magableh, M. N. Y., Hamdi, M., Hmoud, A. Y. R., & Alshalabi, H. Data Mining Techniques with Electronic Customer Relationship Management for Telecommunication Company. *Amazonia Investiga*, 10(48), 288-304. 2021, <https://doi.org/10.34069/AI/2021.48.12.30>.
- [14] Davagdorj, K., Park, K. H., & Ryu, K. H. A collaborative filtering recommendation system for rating prediction. In *Advances in intelligent information hiding and multimedia signal processing*, 265-271, 2020. [https://doi.org/10.1007/978-981-13-9714-1\\_29](https://doi.org/10.1007/978-981-13-9714-1_29).
- [15] Alshalabi, H., Tiun, S., Omar, N., Abdulwahab Anaam, E., & Saif, Y. BPR algorithm: New broken plural rules for an Arabic stemmer. *Egyptian Informatics Journal* 2022. [Doi.org/10.1016/j.eij.2022.02.006](https://doi.org/10.1016/j.eij.2022.02.006).
- [16] Burke, Robin. Hybrid Recommender Systems: Survey and Experiments, User modeling and user-adapted interaction, Vol 12(4), 331-370. 2018.
- [17] Ali, S., Khalid, N., Javed, H. M. U., & Islam, D. M. Z. Consumer adoption of online food delivery ordering (OFDO) services in Pakistan: The impact of the COVID-19 pandemic situation. *Journal of Open Innovation: Technology, Market, and Complexity*, 7(1), 10, 2020. <https://doi.org/10.3390/joitmc7010010>.
- [18] Zhang, Q., Lu, J., & Jin, Y. Artificial intelligence in recommender systems. *Complex & Intelligent Systems*, 7(1), 439-457. 2021.
- [19] Abderrahmane, D., Moulouki, R., Jihal, H., & Azzouazi, M. Architectural design of trust-based recommendation system in customer relationship management. *Periodicals of Engineering and Natural Sciences*, 6(2), 380-388. 2018. <http://dx.doi.org/10.21533/pen.v6i2.539>.
- [20] Beshir, S., L. A., & Elkhoully, S. The Influence of Applying Mobile Customer Relationship Management (M-CRM) in the Service Sector on Employee's Performance in Egypt. 30th International Conference on Computer Theory and Applications. IEEE. December 2020. <https://doi.org/10.1109/ICCTA52020.2020.9477665>.
- [21] Chatterjee, S., Chaudhuri, R., Vrontis, D., Thrassou, A., & Ghosh, S. K. ICT-enabled CRM system adoption: a dual Indian qualitative case study and conceptual framework development. *Journal of Asia Business Studies*. Vol. 15 No. 2, pp. 257-277. 2020. <https://doi.org/10.1108/JABS-05-2020-0198>.
- [22] Koosha, H. R., Ghorbani, Z., & Nikfetrat, R. A Clustering-Classification Recommender System based on Firefly Algorithm. *Journal of AI and Data Mining*, 10(1), 103-116. 2022. <https://doi.org/10.22044/JADM.2021.10782.2216>.
- [23] Leong, L. Y., Hew, T. S., Ooi, K. B., & Chong, A. Y. L. Predicting the antecedents of trust in social commerce—A hybrid structural equation modeling with a neural network approach. *Journal of Business Research*, Vol 110, 24-40. 2020. <https://doi.org/10.1016/j.jbusres.2019.11.056>.
- [24] Junior, F. R. L., Osiro, L., & Carpinetti, L. C. R. A comparison between Fuzzy AHP and Fuzzy TOPSIS methods to supplier selection." *Applied Soft Computing* 21: 194-209. 2014. <https://doi.org/10.1016/j.asoc.2014.03.014>.
- [25] Hegde, K., Tsai, P. A., Huang, S., Chandra, V., Parashar, A., & Fletcher, C. W. Mind mappings: enabling efficient algorithm-accelerator mapping space search. In *Proceedings of the 26th ACM International Conference on Architectural Support for Programming Languages and Operating Systems*. pp. 943-958. April 2021. <https://doi.org/10.1145/3445814.3446762>.
- [26] Billsus, D., & Pazzani, M. J. Learning collaborative information filters., 98, pp. 46-54. 1998.
- [27] Yang, Y., See-To, E. W., & Papagiannidis, S. You have not been archiving e-mails for no reason! Using big data analytics to cluster B2B interest in products and services and link clusters to financial performance. *Industrial Marketing Management*, 86, 16-29. 2020.
- [28] Al-Ghamdi, M., Elazhary, H., & Mojahed, A. Evaluation of Collaborative Filtering for Recommender Systems. *International Journal of Advanced Computer Science and Applications* Vol. 12, No. 3, 2021.
- [29] Anaam, E. A., Bakar, K. A. A., & Satar, N. S. M. A Model of Electronic Customer Relationship Management System Adoption In Telecommunication Companies. *Amazonia Investiga*. Volume 9 - 35: 61-73, 2020. <https://doi.org/10.34069/AI/2020.35.11.5>.
- [30] Sun, J., Zhang, Y., Ma, C., Coates, M., Guo, H., Tang, R., & He, X. Multi-graph convolution collaborative filtering. *IEEE International Conference on Data Mining (ICDM)* (pp. 1306-1311. November. 2019. IEEE. <https://doi.org/10.1109/ICDM.2019.00165>.
- [31] Rodriguez, M., & Boyer, S. The impact of mobile customer relationship management (MCRM) on sales collaboration and sales performance. *Journal of marketing analytics*, 8(3), 137-148. 2020. <https://doi.org/10.1057/s41270-020-00087-3>.
- [32] L. Honore Petnji Yaya, F. Marimon, en M. Casadesus, Customer's loyalty and perception of ISO 9001 in online banking", *Ind. Manag. Data Syst.*, vol 111, no 8, 1194-1213, 2011, <https://doi.org/10.1108/02635571111170767>.
- [33] Hasan, M.K., Akhtaruzzaman, M., Kabir, S.R., Gadekallu, T.R., Islam, S., Magalingam, P., Hassan, R., Alazab, M., and Alazab, M.A. Evolution of industry and blockchain era: monitoring price hike and corruption using BIoT for smart government and industry 4.0. *IEEE Transactions on Industrial Informatics*. August 2022. <https://doi.org/10.1109/TII.2022.3164066>.