Design an Intelligent Multi-agent Computer-aided Model for Recommender Systems

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Abstract–Increasing the information and services available on the web, providing tools such as recommender systems to websites and applications for users to find information and services according to their interests, seems necessary.Therefore, providing appropriate guidance and suggestions to users in different choices, according to the user's priorities, has found a special position in different fields. Recommender systems proactively recommends items that usersmay prefer. We proposed, a multi-agent recommender system that can provide suitable recommendations as a shopping assistant in the purchasing process. To analyze the proposed model, the sales dataset of an online store has been used.According to the results, in this evaluation, the accuracy of the proposed model was better than common models such as Naïve Bayesian and artificial neural networks.By combining multi-agent systems, multi-agent recommender systems were proposed that can provide suitable recommendations as a purchasing assistant in the purchasing process. The results of applying the proposed model on the data related to the purchase history of the customers of an online shopping showed that the proposed model has a good efficiency in evaluating the parameters used in comparison with the common methods in this property field.

Keywords: Intelligent agents, Computer-aided System, Machine learning, Multi-agent systems (MAS), Recommender systems

1. Introduction

Nowadays, it is very important to provide appropriate guidance and suggestions to users in different choices, according to user priorities in various fields, from electronic commerce to online advertising, from social networks, YouTube, and Amazon to many other web services. Explosive growth in the amount of digital information in existing operating environments and the number of Internet visitors and the number of social network users has created the potential challenge of loading information, which prevents timely access to the items of interest to the users of these environments.The goal of recommender systems is to suggest relevant items to users. These systems prioritize and personalize the content by creating and redrawing the existing content system based on the user's interests and preferences. With this approach, the demand for recommender systems in operational environments has increased [1].

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Artificial intelligence is the study of designing and implementing artificial logic agents. Many applied approaches in artificial intelligence are focused on the use of logical agents.A logical agent can understand the environment through its sensors and influence the environment through its tools.Also, logical agents such as humanoid robots, soccer player agents, medical assistant agents, shopping assistant agents, and software agents always try to maximize the efficiency standard that shows the agent's performance in the environment.But in practice, it rarely happens that a single and independent agent can work with maximum efficiency in a complex operational environment[2]. In many cases, an intelligent agent interacts with other agents in different ways.Agents such as software agents on the Internet, soccer player robots, which include a group of agents that interact and communicate with each other to achieve a goal, are called multi-agent systems[1].In these systems, a combination of problem-solving agents solves problems together and as a group.In the community of agents, each autonomous agent may have its own goals, beliefs, capabilities and characteristics[3].

2. Recommender systems

Recommender systems predict whether a particular user prefers an item or not based on the user's specifications and

[1]MAS: multi-agent systems

requests to help them search and select the desired items. These systems reduce the costs of finding and selecting items in an operational environment such as online shopping by collecting various information related to users' tastes and items in the system [4]. Recommender systems improve the decision-making process and the quality-of-service delivery.In the e-commerce environment, systems increase the income of business owners.These systems are used in various domains such as online stores, assistant systems, medical diagnosisand other environments to provide and offer suitable services. These systems have also played a vital and very important role in the Internet of Things[2] industry.The main goal of recommender systems is to provide the most attractive items and services to users or objects.Due to the increasing growth of the IOT in small and large devices, it is very necessary to use approaches that have made the complexity of access and providing services to users simpler and more fluid. The use of these systems in the IOT has caused this technology to grow and expand significantly [5]. The general classification of recommender systems is shown in Figure 1.

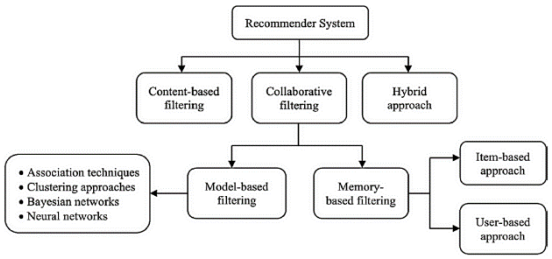

Fig. 1. Types of recommender systems[6]

Collaborative recommender systems are one of the most widely used recommendation methods[7]. This filter recommends items to users by determining the items that similar users have given a positive score or selected. For example, if two users are similar in their interests and behavior, the system recommends the items purchased by one to the other [8]. Hybrid recommender systems allow systems to gain benefits from different methods, which improves performance and increases recommendation accuracy.The combined recommender system combines different data sources that are used with other recommender systems and will lead to more favorable results, and due to the use of different data sources, it is more popular than other methods [9],[10].

[2] IOT: Internet of Things

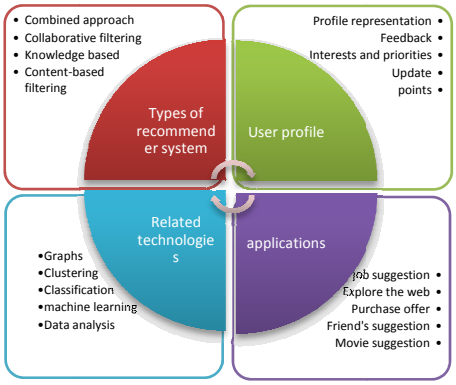

Fig. 2. Intelligent recommender systems

Types of recommender systems, applications, profile information of users in these systems and technologies related to these systems are shown in Figure 2.

3.Multi-agent systems

A multi-agent system is a system that consists of two or more interacting intelligent agents.A multi-agent system has a number of agents, each of which in turn performs its internal interactions and interacts and communicates with the outside environment and cooperates with each other. These systems have created new ways to solve various problems.Decision making in these systems is done in a distributed manner.A multi-agent system (self-organizing system) is a computer system that consists of several interacting intelligent agents. Multi-agent systems can solve problems that are difficult or impossible to solve for a single agent or an integrated system [9]. Intelligence may include methodical, functional, procedural, algorithmic search, or reinforcement learning approaches. Despite the considerable overlap, a multi-agent system is not always the same as an agent-based model. An agent-based model aims to seek explanatory insight into the collective behavior of agents (which do not necessarily need to be intelligent) following simple rules, typically in natural systems, rather than solving specific practical or engineering problems. Applications where multi-agent systems research may provide a suitable approach include online commerce, disaster response, target surveillance, and social structure modeling[10,11].

4. Review of previous works

In 2019, Pinto et al. proposed a case-based reasoning[3] recommender system combining multi-agent systems for intelligent energy management in buildings that recommends the amount of energy reduction to be applied

[3]CBR:case-based reasoning

in a building at any given moment by learning from previous similar cases. The results show that the proposed approach, by comparing its results with the previous approach based on particle swarm optimization (PSO) and with the actual reduction in the past cases, can provide appropriate recommendations in the field of energy reduction [12]. In 2022, Neto et al. conducted a thorough review of the use of recommender systems based on multi-agents. This review shows the variety of applications of multi-agent systems in recommender systems [13]. In [14], a conceptual framework of a multi-agent based recommender system is proposed to provide active support for accessing and using project knowledge and information in software engineering ontology. The software engineering ontology was developed to enable efficient collaboration and coordination between distributed teams working on related software development projects across sites. In this research, it was shown that with the help of the multi-agent system and the meaning-based recommendation approach, creating a common work environment for accessing and manipulating data from the ontology and performing reasoning, as well as creating expert recommendation facilities for software teams scattered across sites, in an integrated format will be provided. In the research of Pandey and Singh in 2015, a multi-agent-based e-learning framework is presented that is able to provide a personalized experience to the person under training. This system advises the person how to study the course materials based on their wishes and goals. In this research, a recommender agent framework based on fuzzy logic is presented to provide suggestions to the learner to increase satisfaction and provide advanced learning experience[15]. In the research of Keykhaee et al., a tourism recommender system was proposed using self-organizing artificial neural networks, Bayesian network, and meta-heuristic algorithms. In this research, the statistical information of the year 2015 of tourist roads and places in Yazd city has been used in order to organize a trip for 100 tourists. This research showed that the designed system based on neural network, Bayesian network and meta-heuristic algorithms in routing can play an important role in tourists' decision-making in choosing tourist attractions and travel planning, according to their interests, preferences and demographic information [16]. In Teimouri 's research in 2015, while introducing multi-agent systems and comparing its characteristics with single-agent systems, the structure and architectures of multi-agent systems and communication methods between agents were investigated. In this research, the purchasing assistant multi-agent system was introduced by stating the structure, architecture and communication method of the agents[17]. Mohammadiet al. 2018, , in research titled implementing hotel recommender systems using user preferences, recommender systems based on Twitter social network data using various interfaces, content analysis methods with techniques Computational Linguistics and Algorithm of Nation Modeling topic were presented. The results of this research showed that, after examining the depth of the objectives, the methodologies of this article will help those interested in the development of the travel recommender system and also facilitate future research[18]. Neto et al., 2022, in research investigated the context-based multi-agent recommender system, supported in the IOT, to guide building occupants in the event of a fire. In this research, it is suggested that instead of focusing on modeling the occupants' behavior, it focuses on conditioning this behavior by providing real-time information on the most efficient evacuation routes. It is achieved by using a context-based multi-agent recommender system based on textual data obtained from IoT devices, which recommends the most efficient evacuation routes at any given time. The obtained results show that the proposed solution can improve the efficiency of evacuation of buildings in case of fire[19]. Forestieroin research, investigated the multi-agent recommender system in the Internet of Things. Proposing useful objects in the Internet of Things environment is an important task for many applications such as urban computing, smart cities, health care, etc., which should be carefully investigated. In this research, a multi-criteria algorithm using the self-organization and decentralized strategy is presented to create a distributed suggestion system in the Internet of Things environment. The research results confirm the validity of this method[20]. Marivate etal., 2018, in research, investigated a multi-agent intelligent recommender system to increase human capacity. In this research, a multi-agent approach to the problem of recommending training courses to engineering professionals is presented. In the suggested recommendation system, through user modeling and data collection from a survey, collaborative filter recommendation is implemented using intelligent agents. Agents work together in recommending meaningful training, and by updating course information, this system uses user profiles and course keywords to rank courses. The research results showed that the proposed recommender system is scalable and compatible and further improvements can be made by using clustering and recording user feedback [21].

5. Methodology

Recommender systems are information systems that assist in the decision-making process by modeling the behavior of users in operational environments in ranking, comparing, selecting and choose items by users, narrowing the information search through high-quality and accurate recommendations. In this research, a multi-agent recommender system has been proposedas an intelligentshopping assistant in the process of buying suitable offers. The proposed recommender system includes several subsystems, and each subsystem will be responsible for performing a predefined task and is modeled using a set of agents. According to Figure 3, a subsystem consists of agents that have specific goals and determine what the

subsystem intends to do.

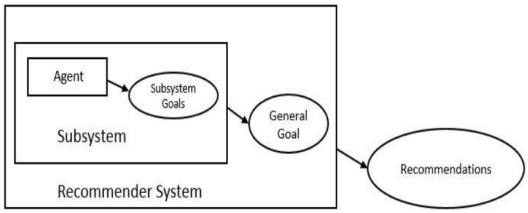

Fig. 3. Combination of agent and subsystem to create recommender system

One of the advantages of a multi-agent system is the distribution of execution, which provides the possibility of increasing the overall performance. Moreover, the failure of one agent does not necessarily mean the failure of the entire system. The robustness provided by the multi-agent system is increased with repetitive capabilities. This repetition is activated by having several agents with the same or similar capabilities. In such cases, when an agent with certain capabilities becomes unavailable, another agent with similar capabilities may be referred.

5.1 Introduction of agents

There are the following agents in multi-agent systems for intelligent shopping assistant:

- Buyer agent
- Sales agent
- Postagent
- Accountant agent
- Bargaining agent
- Auction agent
- Recommending agent

Below we describe the duties of agents[17].

5.1.1 Buyer agent

The buyer announces his request to buy the items to the seller. After the seller announces that the product is available in the system, the price of the product is announced to the buyer. If the price announced by the seller is less than or equal to the price desired by the buyer, he accepts it and the purchase is made. If it was more than the target price, the buyer bargains with the seller. And the seller reduces the price of the product according to a certain criterion and informs the buyer. This cycle continues until the buyer and the seller reach an agreement or until an agreement is not reached and the sale is canceled. This agent is based on usefulness. It means that whenever the price of items decreases, it will benefit the buyer.

5.1.2 Sales agent

The seller sees the buyer's request and then informs the buyer if the desired product is available in the system.If the inventory of the requested product is less than the requested quantity, the request will be rejected.Otherwise, if the inventory is sufficient, the agent will announce the price to the buyer.If the buyer accepts the price, the sale is made. Aaccording to the buyer's request, they haggle over the price to reach an agreement.The seller also reduces the price to a certain amount according to his criteria and if there are two purchase requests at the same time and both request the same product, then the seller can increase the price of the product, that is, put the product up for auction.If the price is agreed with the buyer, he will reduce the inventory amount from the sold amount.This agent is also based on usefulness.But the utility of this agent is the opposite of the utility of the buyer.

This intelligent agent will benefit as much as it can raise the price of the items.

5.1.3 Post agent

If the buyer and seller reach an agreement, the purchase and sale take place.In this case, the items will be delivered to the buyer by the post agent according to the choice of the shipping method, and the buyer will pay the purchase amount of the items according to the selected payment method in cooperation with the accounting agent.The architecture of this agent is a simple reactive agent.

5.1.4 Accountant agent

In case of an agreement between the buyer and the seller, the desired itemsare announced to the accountant, and the accountant calculates their total price and informs the seller. The seller also shows the total price to the buyer. Also, if the buyer wants to pay online, this is the responsibility of the accountant. The architecture of this agent is a reactive agent and a learning agent.

5.1.5 Bargaining agent

This agent is part of the seller agent. The seller first announces the real price of the items to the buyer. If they do not agree on the price, the seller will reduce the price to a certain amount and negotiate with the buyer. The architecture of this agent is also based on usefulness.

5.1.6 Auction agent

If the number of buyers was two or more at the same time and the number of items was less than the number of applicants, then the seller can increase the price of the items and put the items up for auction. This increase is increased according to a certain criterion so that a buyer reaches an understanding with the seller. The architecture of this agent is also based on usefulness.

5.1.7 Recommending agent

In the proposed architecture, a collaborative recommender agent is used. This agent interacts with the seller's agents, based on the interests of the users from among the items in the item database, by determining the items that similar users have given a positive score or selected, they recommend items to the users. In this case, if two users are similar in their interests and behavior, the system will

recommend the items purchased by one of the users to the other user.

5.2 Proposed Multi-agent Recommender System

The electronic sales system is not a complex system, so in this system, the structure of agents is flat.The architecture of the proposed model is shown in Figure 4. According to this figure, all agents are on the same level and each agent can communicate with other agents. The buyer agent has a direct and unmediated relationship with the seller agent.The seller's agent also includes three agents, accountant, bargaining and auction.And if buying and selling takes place, then the postman agent will be used.The recommending agent, in connection with the buyer and seller agents, after receiving the buyer's preferences, will suggest the best items to the buyer for selection according to the offered items.The internal classes of each type of agent are determined based on a number of pre-defined components and their combination. In the system of electronic sales of items, the type of reactive architecture is suitable for each of the seller and buyer agents.In the reactive architecture, the agent responds to the messages received from the environment based on the rules specified for it.

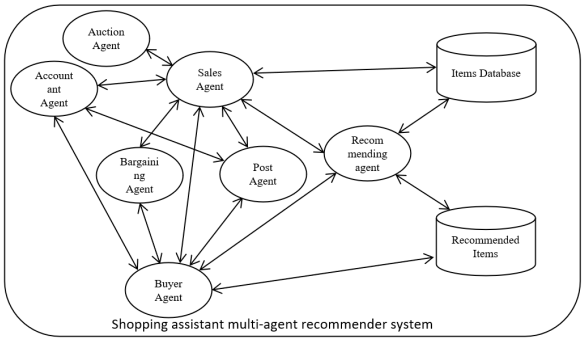

Fig. 4. The structure and architecture of the proposed multi-agent recommender system

Considering that the specified strategies for the seller and the buyer in the system are specific and predetermined rules, reactive architecture is suitable for these agents.

5.3 Evaluation method

Evaluation of the efficiency and performance of the proposed multi-agent recommender system architecture is done based on various criteria. The most common evaluation criteria of recommender systems are accuracy criteria and recall [22]. In the evaluation stage, the confusion matrix is used to check the success and validation of the proposed model in prediction and classification. The confusion matrix calculates the performance of a model based on the comparison of the actual value and the estimated value. One of the results of the confusion matrix and the most important criterion for determining the efficiency of a classification algorithm is the calculation of accuracy or classification rate. Accuracy is one of the most important design goals in recommender systems. The ratio of the number of correct samples selected by the proposed model from a specific user to the total number of samples that the model has selected and recommended in that category, either correctly or incorrectly, shows the accuracy [23]. This criterion shows how many percent of the entire set of records has been correctly selected by the designed model. Also, one of the most important evaluation criteria of the recommender model is precision, which means the ratio of the number of samples that were classified in the positive selection to the total number of samples that the class model correctly predicted [24,25].The components of the confusion matrix are:

True positive TP: indicates the number of records whose true category is positive and the classification algorithm correctly recognized their category as positive.

True negative TN: It means the number of records whose true category is negative and the classification algorithm correctly recognized their category as negative.

False positive FP: It means the number of records whose true category is negative and the category classification algorithm falsely recognized them as positive.

False Negative FN: Indicates the number of records whose actual category is positive and which the category classification algorithm mistakenly recognized as negative.

The calculation of accuracy, precision, coverage or recall and the F-Measureof the classifiers is obtained based on relations 1 to 4:

$$Acuracy = \frac{(\mathrm{TN} + \mathrm{TP})}{(\mathrm{TN} + \mathrm{TP} + \mathrm{FN} + \mathrm{FP})} \quad (1)$$

$$\mathrm{Precision} = \frac{\mathrm{TP}}{(\mathrm{TP} + \mathrm{FP})} \quad (2)$$

$$Recall = \frac{TP}{(TP + FN)} \quad (3)$$

$$\mathrm{F-Measure} = \frac{2 * (\mathrm{Precision} * Recall)}{(T\mathrm{Precision} + Recall)} \quad (4)$$

In this research, the stated criteria will be used to compare the performance and efficiency of the proposed model.

5.4 Dataset

To analyze the proposed model in this research, the sales data set of a UK-based store containing 1,067,371 records of online sales data has been used. This dataset contains 1067371 records of online sales data obtained from 2009 to 2011. The variables that used include: invoice number, unique number of each transaction, product code, unique number for each product, product name, number of products that states how many products in the invoices have been sold, description, date and invoice time, product price, unique customer number and customer address.

6. Result and discussion

Today, multi-agent systems are used to solve various problems in the fields of industry, medicine, trade, education and military fields. These applications have high complexity in terms of size, nature, components, distribution of components and their interactions. For this reason, multi-agent systems also need engineering like other software systems. According to the nature of the investigated problem, buying assistant needs to consider different parameters compared to physical buying and selling, and gaining expertise in choosing each of the parameters requires experience. A multi-agent system, according to the characteristics of our problem, can be used. On the other hand, due to the growth of the volume of data and services related to online shopping and online, it is necessary to use recommender systems for timely access to the data and services of interest. In order to obtain information and services according to the interests of users in providing smart shopping assistant services, a multi-agent recommender system architecture is proposed.In the proposed architecture, to implement a multi-agent system, it is necessary to define intelligent agents and how to arrange and communicate between intelligent agents. For the implementation of this system, the required agents were designed and by examining the types of architecture of multi-agent systems, considering the problem of the structure of an architecture, it was proposed.

Due to the structure of the recommender system based on multi-agents proposed, this system can be used in all interactive environments that deal with buying and selling or trading. The proposed model in this research was simulated in MATLAB software version 2022 and the results of applying the proposed model on the data related to the sale of an online store were analyzed. The comparison of evaluation parameters in the proposed model with common methods in the analysis of recommender systems, including neural networks, KNN, SOM Ensembles, Weighted item-based, Global Top-N and Naïve Bayesian, is shown in Table 1 and Figure 5.

Table. 1. Comparison of evaluation parameters in the proposed model with other methods

Model / Evaluation Criteria	Accuracy	Precision	Recall	F-Measure
Neural Network	86.41	91.21	62.78	69.41
KNN	73.32	93.25	55.38	68.41
SOM Ensembles	74.38	76.48	32.21	35.17
Global Top-N	69.78	66.41	42.94	34.81
Weighted item-based	72.31	73.25	46.37	59.34
Naïve Bayesian	59.68	89.41	24.31	38.54
Proposed Method	91.58	93.21	72.41	75.41

By simulating the proposed model, the results of applying the model to the relevant data were analyzed. The proposed model in this research was simulated in MATLAB software version 2022 and the results of applying the proposed model on the data related to the sale of an online shopping were analyzed. As shown in Table 1, according to the results, in this evaluation, the accuracy of the proposed model was 91.5% on average, compared to the neural network model, it was 86.41%, compared to the KNN model, 78.32%, compared to the SOM Ensembles model, 74.38%, compared to the Global Top-N model, 69.78%, compared to the Weighted item-based model, 72.31%, and compared to The Naïve Bayesian model has an accuracy of 59.68%, a higher accuracy in the right suggestion to users. Figure 5 shows the comparison of evaluation parameters in the proposed model with other proposed methods in the form of a diagram.

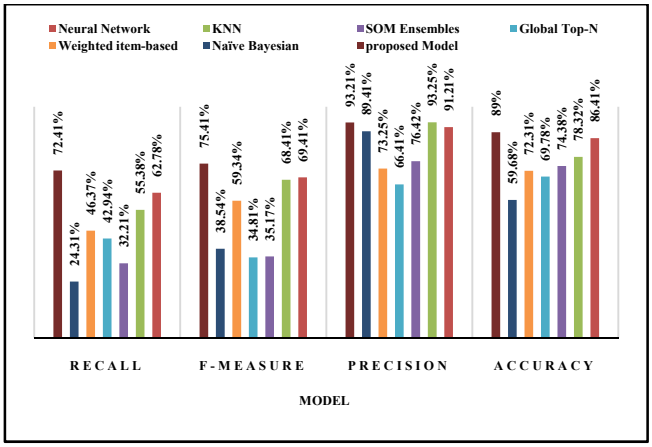

Fig. 5. Comparison of evaluation parameters in the proposed model with other methods

As shown in Figure 5, according to the obtained results, in this evaluation of the accuracy of the proposed model compared to the neural network model, KNN, SOM Ensembles model, Global Top-N, Weighted item-based model, and Naïve Bayesian model. respectively, it has 5.09, 13.18, 17.12, 21.72, 19.19 and 31.82 percent higher

accuracy in the appropriate offer to users. The effectiveness of the proposed model in comparing other evaluation parameters is shown in Table 1.

7. Conclusion

In this research, while studying recommender systems, the challenges in this field were examined and multi-agent systems were used to provide suggestions and recommendations with high accuracy and quality in ranking, comparison, selection and preferences of users' items in the decision-making process in operational environments. By combining multi-agent systems, multi-agent recommender systems were proposed that can provide suitable recommendations as a purchasing assistant in the purchasing process. The results of applying the proposed model on the data related to the purchase history of the customers of an online shopping showed that the proposed model has a good efficiency in evaluating the parameters used in comparison with the common methods in this property field. Due to the increasing amount of information and services available on the web, it is necessary to provide tools such as recommender systems to websites and applications that can help users find information and services that suit their interests. For this reason, providing appropriate guidance and suggestions to users in different choices, according to the user's priorities, has found a special position in different fields. Recommender systems are information systems that help in the decision-making process by modeling the behavior of users in operational environments in ranking, comparing, selecting and preferring user items, by limiting the search space through high-quality and accurate recommendations. In this research, a multi-agent recommender system was proposed that can provide suitable recommendations as a shopping assistant in the purchasing process. To analyze the proposed model, the sales dataset of a UK-based store including 1067371 records of online sales data has been used. According to the results, in this evaluation, the accuracy of the proposed model was 91.5% on average. By combining multi-agent systems, multi-agent recommender systems were proposed that can provide suitable recommendations as a purchasing assistant in the purchasing process. The results of applying the proposed model on the data related to the purchase history of the customers of an online shopping showed that the proposed model has a good efficiency in evaluating the parameters used in comparison with the common methods in this property field.

Conflict of interest

The authors of the article declare that this research does not have any conflict of interest.

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