Upgrading Traditional E-Commerce Systems with A Knowledge-Based Recommendation System

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Abstract:
In today's e-commerce, there is a need for intelligent recommendation systems to help consumers choose products. This paper presents an upgrade to traditional e-commerce systems by implementing a knowledge-based recommendation system. The focus is on collaborative filtering, which uses data on consumer preferences to provide personalized product suggestions. A user-user collaborative filtering algorithm is applied, which groups users according to similarities in their choices and suggests products that are popular among consumers with similar preferences.

Keywords:
Recommendation system, e-commerce, collaborative filtering, knowledge vectors, cosine similarity.

1. Introduction

In today's society, which is deeply connected to the Internet and technologies, information systems play a key role in daily activities, especially in electronic commerce. These systems, known as e-commerce information systems, enable easy and efficient trading of products and services over computer networks, such as the Internet [1]. Due to the huge amount of data they operate with, they are ideal for upgrading with intelligent components [2].

Analyzing the data that is generated on a daily basis is a powerful tool for transforming this data into knowledge, gaining invaluable insights, and discovering patterns and trends previously unknown. The acquired knowledge revolutionizes business operations and is an instrument for companies to survive and remain competitive. The benefits that businesses receive from the transformation of data into knowledge are multiple: improved decision-making guided by data and knowledge, better user experience, improved sales and optimization of processes in the organization, that is, increased efficiency and productivity.

For those reasons, the main emphasis in this paper is on the possibilities of upgrading e-commerce systems with a knowledge-based recommendation system and the way to implement such type of upgrade. The focus of the paper is to synthesize new knowledge and identify techniques for upgrading classic e-commerce systems with intelligent components through the analysis of relevant literature and examples, with a special emphasis on knowledge-based recommendation systems. After the introductory part, an analysis of relevant literature from the researched area is made, from where the main idea comes, the implementation of a proposal - a solution that includes upgrading the Reusable system for e-commerce with a recommendation system based on knowledge, which is presented in the third part of the paper. In the final part, concluding observations and future recommendations for further advancement and improvement of the proposed implementation are given.

2. Previous work

A group of researchers highlight two factors as the main ones that determine the future survival and success of organizations, namely electronic commerce [3] and knowledge obtained from consumer data

[4]. They encourage the use of e-commerce and the Internet as a platform for accessing and gathering consumer knowledge.

E-commerce systems abound with diverse data on products, consumers, their orders that can serve to generate knowledge and extend it with intelligent components [5]. Analysis of this data and its transformation into business knowledge will allow a better understanding of customers by analyzing their purchasing preferences. This information can be used to improve marketing campaigns, user experience or product range, but very importantly it can be used for personalized user recommendations. Knowing customers allows them to receive individual product recommendations based on their previous purchases or the purchases of other customers with similar preferences. It leads to customer satisfaction and increased sales by providing relevant products at the right time. Equally, decision makers can determine which of their products perform best in inventory management and can find out whether their prices are attractive to customers.

However, subjective measures of user experience from information systems do not always emphasize the importance of cognitive and "emotional" perceptions, especially in the context of online shopping [6] [7] [8]

In that context, ontologies play a key role, which are increasingly present nowadays. Their number, complexity and the domains they model are constantly increasing significantly. Conversion of databases into ontology is one of the key areas of research in the field of Data Science and Knowledge Science. Ontologies, as structures defining relationships between concepts, are acknowledged in this paper as integral to knowledge representation in recommendation systems. In this work, knowledge vectors are applied as a type of ontology to represent consumer preferences and product relationships.

When data acquires semantic meaning, knowledge can be generated from it in two ways: by creating knowledge graphs or by creating knowledge vectors [9]. Knowledge graphs can often become inefficient and challenging to manage as data volume grows, impacting scalability and performance. For this reason, this paper focuses on knowledge vectors, which represent knowledge mathematically as multidimensional vectors, with each dimension indicating a specific attribute or meaning. By using knowledge vectors, consumer preferences and product relationships are quantified efficiently in the background, making them well-suited to the needs of this recommendation system.

According to Tarus, Niu and Mustafa, in recent years, knowledge vectors are increasingly applied to recommendation systems in order to overcome the problem of lack of consumer-product interaction and to represent the large number of attributes in one ontological structure [10].

Recommendation systems are grouped into three basic classes [11]: collaborative filtering: analyzes the activities of the user and other users with similar interests to predict what he would like and suggest appropriate products; content-based filtering: relies on keywords from product descriptions and content related to the user profile to make recommendations; hybrid filtering: combines techniques from the previous two methods for a wider range of recommendations. Furthermore, collaborative filtering is divided into three subgroups: user–user: based on preferences of similar users; product-product: recommends products similar to previously selected products by the user; combined systems: use data about user preferences for specific products.

3. Upgrade of an e-commerce system with a knowledge-based recommendation system

Reusable e-commerce information system is a system consisting of integrated systems: Airtable, Ongoing, WooCommerce, Refurbed and the Swedish accounting system - Fortnox system. Serving as the central hub, it handles data and information about the products and the orders made and presents them on an intuitive Graphical User Interface (GUI) through which the products are managed before they are published for sale on different platforms and with the orders made. In other words, the system provides an opportunity for quick and easy publication of products for sale on the Reusable or Refurbed site, as well as review, monitoring and editing of orders made by consumers.

Building on methodologies for transforming consumer data into valuable insights, this enhanced e-commerce system goes beyond conventional data processing, converting operational data into meaningful knowledge that greatly increases its practical value. By integrating an intelligent

component, the system now supports knowledge-based recommendations, offering tailored and more effective suggestions for consumers, ultimately boosting both user experience and system performance.

Ontology plays a pivotal role in this context as a foundational framework that facilitates extracting meaningful knowledge from data. It provides a structured representation of concepts and relationships within the data domain, enabling the organization and interpretation of complex information. The ontological framework is a key source of ideas for generating knowledge vectors, effectively encapsulating consumer preferences and product relationships in a mathematically representable format. Knowledge vectors are utilized to represent consumer preferences and facilitate the creation of personalized recommendations based on the semantic meaning derived from data.

To implement a recommendation system that is based on the extracted knowledge about the preferred products by consumers, knowledge vectors were used, which according to Guntars are easy to group by similarity [12], thus giving each consumer a suitable proposal.

Based on the primary classification, the specific recommendation system belongs to the group of collaborative filtering systems and that of the user-user class. Namely, for a certain consumer/user, the system provides a proposal - products based on the products preferred by users with similar preferences.

This recommendation system follows several steps:

- Data loading, preprocessing, and transformation: Relevant data, including product listings, consumer orders, and itemized purchases, is loaded and preprocessed using the SQLAlchemy library. Data cleaning is performed with NumPy to ensure consistency and relevance, after which order data is merged with item details, creating a refined dataset for analysis.
- Construction of consumer-product interaction matrix: an interaction matrix is built, where the rows represent the consumers and the columns represent the products. In the intersection of the row and the column is the ordered quantity of the product by the consumer.
- Extraction of knowledge from data and knowledge vector creation: knowledge vectors are generated in the background from the consumer-product interaction matrix. For each user a vector is created that represents their preferences and for each product a vector is created that represents its "occurrence" in orders or how many it is often commissioned and by whom.
    - **User knowledge vector**: This vector reflects a user's interactions across products. For example, the vector for user ana@example.com is:

$$U_{ana} = [3,0,5,2,1], \quad (1)$$

representing her engagement levels:

1. **Product 3**: High engagement:

$$U_{ana,3} = 5 \quad (2)$$

2. **Product 5**: Minimal interaction:

$$U_{ana,5} = 1 \quad (3)$$

3. **Product 2**: No interaction:

$$U_{ana,2} = 0 \quad (4)$$

    - **Product knowledge vector:** constructed and represented analogously to user vectors, these vectors quantitatively capture engagement levels across users for each specific product.
- Application of the collaborative filtering algorithm: on the obtained knowledge vectors, the collaborative filtering algorithm is applied through:
- Calculation of cosine similarity between consumers: using the Scikit-learn library, the similarity of the obtained knowledge vectors is calculated according to the cosine similarity (with a range of values from -1 to 1) that calculates the angle between two vectors [13]. A lower value simultaneously means a lower similarity in preferences and vice versa.
- Identification of similar consumers: for the given consumer, the most similar ones according to the cosine similarity are found.
- Calculation of average product quantity: purchased by consumers with similar preferences, the average quantity purchased is calculated.

- Exclusion of previously purchased products: products already purchased by the target consumer are excluded, as they are less likely to be repurchased.
- Generation of final recommendations: the system provides recommendations based on the top n products purchased by consumers with similar preferences that the target consumer has not yet bought.

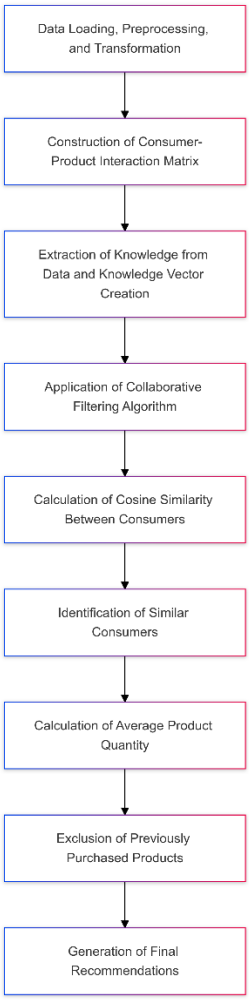

Figure 1: Workflow of the proposed recommendation system
Source: From the Authors

The proposed system is fully functional and allows the generation of product recommendations based on consumers with similar preferences. So for example, for a consumer with email address ana@example.com, product recommendations will be generated based on products consumed by consumers most similar to this consumer. By activating the appropriate system and entering the email address as an input parameter, the system generates recommendations (Figure 2).

```
PS C:\Users\teodo> python knowledge_based_recommendation.py ana@example.com
[{"instance_name":"Microsoft Lumia 950 | 32 GB | black","sku":"10055251-223"},{"instanc
e_name":"REFISHED - SPORTY BAG #FISH yellow | yellow dollar | size S","sku":"refished_4
1261125501121"},{"instance_name":"Microsoft Surface Duo 2 | 8 GB | 128 GB | Single-SIM
| black","sku":"Microsoft Surface Duo 2 | 8 GB | 128 GB | Single-SIM | black B"},{"inst
ance_name":"LG G8s ThinQ | 128 GB | Mirror Black","sku":"LG G8s ThinQ | 128 GB | Mirror
 Black C"},{"instance_name":"Fujitsu Lifebook E546 | i5-6300U | 14\" | 16 GB | 512 GB S
SD | FHD | DVD-RW | Webcam | Win 10 Pro | 4G | DE","sku":"00453-QZ-G-C-12"},{"instance_
name":"CAT S41 | 32 GB | Single-SIM | black","sku":"CAT S41 | 32 GB | Single-SIM | blac
k C"},{"instance_name":"CAT B35 | 4 GB | Single-SIM | black","sku":"CAT B35 | 4 GB | Si
ngle-SIM | black B"},{"instance_name":"Sony Xperia 10 III | 6 GB | 128 GB | Dual-SIM |
black","sku":"SO-XQBT52-128-DS-blk-nw"},{"instance_name":"Samsung Galaxy S20+ | 12 GB |
 128 GB | 5G | Dual-SIM | cosmic black","sku":"35642"},{"instance_name":"iPhone 13 | 25
6 GB | Single-SIM | blue","sku":"IPHONE 13 256GB - AZUL - C"}]
```

Figure 2: Application of the recommendation system
Source: From the Authors

Executing the Python script is from the location where it is placed via the "python" command. The first argument is the name of the script to be executed (recommendations_test.py), while the second argument is the email address of the specific consumer for whom recommendations should be generated (ana@example.com) (Figure 2). By applying collaborative filtering and taking into account the preferences and products ordered by users most similar to this consumer, the system results in 10 products along with their specifications. The specifications include the product name (instance name) and the product code (sku). Recommended products for this consumer include several smartphones, such as CAT S41, CAT B35, Microsoft Lumia, Sony Xperia 10 III, Samsung Galaxy S20+, LG G8s ThinQ and iPhone 13, a laptop backpack (Upcycling Deluxe), as well as two laptops (HP Pro x2 612 G2 and Fujitsu Lifebook E546).

4. Contribution

This paper contributes to the advancement of e-commerce systems by introducing a sophisticated knowledge-based recommendation framework, centered on user-user collaborative filtering. The system leverages knowledge vectors and cosine similarity to identify patterns in consumer behavior, facilitating the generation of precise, personalized product recommendations. By transforming raw transactional data into actionable insights, the proposed model enhances user satisfaction, drives targeted marketing efforts, and improves overall system efficiency. The integration of intelligent components within traditional e-commerce architectures paves the way for more informed decision-making and optimized consumer experiences.

5. Conclusion

The knowledge-based recommendation system successfully upgrades the classic Reusable e-commerce system with an intelligent component, enabling personalized product suggestions. By applying user-to-user collaborative filtering, the user experience is improved through recommendations based on similarities between consumers. More precisely, through the application of knowledge vectors and the calculation of cosine similarity, similar consumers are identified and product recommendations are issued. Focusing on the preferences of similar users while excluding already purchased products enables relevant and targeted recommendations that will meet user preferences. This approach significantly contributes to improving the efficiency of e-commerce, optimizing the product selection process for each individual user.

Future upgrades to the system could also include product-to-product recommendations, where similarity is determined by the characteristics of the products themselves. This approach would offer an even deeper level of personalization, enabling recommendations for products that the user has not purchased, but are similar to those they have been considering. Such a strategy will not only increase user satisfaction, but also significantly contribute to long-term sales growth and customer loyalty, setting the e-commerce system at a higher level of efficiency and competitiveness.

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