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ORIGINAL ARTICLE

A general framework for intelligent recommender systems

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Abstract In this paper, we propose a general framework for an intelligent recommender system that extends the concept of a knowledge-based recommender system. The intelligent recommender system exploits knowledge, learns, discovers new information, infers preferences and criticisms, among other things. For that, the framework of an intelligent recommender system is defined by the following components: knowledge representation paradigm, learning methods, and reasoning mechanisms. Additionally, it has five knowledge models about the different aspects that we can consider during a recommendation: users, items, domain, context and criticisms. The mix of the components exploits the knowledge, updates it and infers, among other things. In this work, we implement one intelligent recommender system based on this framework, using Fuzzy Cognitive Maps (FCMs). Next, we test the performance of the intelligent recommender system with specialized criteria linked to the utilization of the knowledge in order to test the versatility and performance of the framework.

1. Introduction

The main goal of the Recommender Systems (RS) was to help users in their decision making. This area proposes the development of RS to provide high-quality recommendations in different contexts. In general, a recommender system is software which provides suggestions of items for users [15]. Various techniques for recommendation have been proposed. From the domains such as artificial intelligence, data and semantic mining, information retrieval, approaches of RS have emerged. The RS traditionally have been classified as content-based, collaborative, knowledge-based, and hybrid.

A knowledge-based recommender system only exploits the knowledge naively. We argue that a recommender system has an intelligent behavior if it has the next set of capabilities: knowledge representation, learning capabilities, and reasoning mechanisms. The mix of these capabilities can exploit largely knowledge, update them, and infer them, among other things.

Based on these ideas, in this paper we propose a new type of recommender system, called Intelligent Recommender System

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(IRS), which is an extension of the knowledge-based RS. The IRS considers learning algorithms, knowledge representation mechanisms, and reasoning motors, among other aspects. In this paper, we define an IRS, and describe its components, and the relationships among them, among other things.

An IRS can use any intelligent technique (fuzzy logic, ontological approaches, etc.) for its implementation. Additionally, we give an example of its application using the FCMs. The FCMs have been used in different domains [1–3]. The FCMs are based on the Cognitive Maps (CMs) theory, to model systems based on concepts that describe the main characteristics of the modeled system (variables or states of the system), and the causal relationships between them. FCMs are based on the fuzzy logic theory to define their structure and their inference process from a given data input. FCMs have been applied to diverse field such as supporting group-decision, political analysis [2].

In the following section we present some backgrounds about the RS. Section 3 presents the theoretical bases of our approach and then Section 4 presents the IRS framework. Section 5 presents details of the description of the knowledge models of the IRS. Section 6 presents the implementation of IRS using FCMs. Lastly, the next sections present a case study, the utilization of IRS based on FCMs, the experiments, and the analysis of the results.

2. Literature review

In the literature, there are a lot of papers about RS. In this section we present some works, specifically knowledge-based RS or based on intelligent techniques. In [4] the Team Recommender Systems (TRS) is presented, which is a knowledge-based RS that helps organizations define the team needed to carry out a task requiring multiple skills. TRS solves two important problems. First, it manages semantic heterogeneity that occurs when the data describing the same entities are represented in different ways. It manages specialization excess of the objects of highest similarity with the user, leaving out consideration of irrelevant information. Additionally, they develop an ontology used to handle the semantic heterogeneity problem. In [5,6] an overview of knowledge-based RS in different domains, such as restaurants, movies is presented. Additionally, they discuss the strengths and weaknesses of knowledge-based and collaborative-filtering RS, and introduce a hybrid RS that combines the two approaches. In their approach, the knowledge-based RS is the bootstrap of the collaborative filtering engine while the data spool is small, and the collaborative filter is the post-filter of the knowledge-based RS.

In [9] a work to define the profile of the customers is presented. Additionally, algorithms for generating personalized buying proposals, based on the collaborative, content-based filtering, and knowledge-based approaches are presented. The profile is created from the user's nature, and evolves according to the events observed. Also, they present some ideas about RS based on the social web and on the consumer buying behavior theory. In [10] a recommendation system of academic papers is defined. The paper proposes user situation awareness and a recommendation system based on fuzzy clustering analysis and fuzzy cognitive maps. They use fuzzy clustering analysis to describe the correlation between lexical semantics, and FCM to define the qualitative distribution of user interests. The fuzzy clustering analysis introduces the view of the information entropy theory. It carries out a quantitative description of the information in the database, and generates a tree data structure based on this, which is converted into a net data structure used by a FCM for the recommendations. They verify the validity of the algorithm to recommend sites of academic theses. In [12] a recommender system based on fuzzy logic is proposed. This recommender system mines information, in order to provide recommendations to potential buyers about products based on their personal needs. This personalized recommender system driven by fuzzy logic technique mines information about the features of laptop computers, and provides services to potential buyers by recommending optimal products based on their personal needs. They use the Fuzzy Near Compactness concept to measure the similarity between consumer needs and product features. In [13] a Fuzzy linguistic approach to represent the user ratings, and a Fuzzy Multicriteria Decision Making approach, are used to rank the relevant items to a user. Their system handles the uncertainty and fuzziness of human decision making behavior. For that their model of the user ratings considers the subjective, imprecise and vague nature of the user's perceptions and opinions, using fuzzy set paradigm. They test their approach in a Music Recommender system.

In [17] an ontological approach to recommend on-line academic research papers is explored. Research papers are classified using ontology. Recommendation algorithms are used to recommend papers seen by similar people. They create user profiles representing the profiles based on ontology of research issues. Additionally, they use a profile visualization approach, in order to acquire profile feedback. The ontological inference improves the user profiling, and external ontological knowledge is used to bootstrap the recommender system. In [18] an E-Learning RS is presented, based on the use of web mining techniques, to build an agent that can recommend online learning activities or course Web sites, based on the learners' access history, to assist the online learning process. These techniques are integrated on the RS platform. Additionally, they present a Survey about E-Learning RS in the literature. In [19] it is presented a fuzzy-based recommender system for stimulating political participation and collaboration. The recommendation engine is based on a modified fuzzy c-means algorithm, and the Sammon mapping technique is used for visualizing recommendations. Additionally, they develop a framework for eParticipation, which allows to analyze different projects and their development, in order to evaluate the citizens' participation and empowerment. In [20] it is explored the role of cognitive decision effort in RS, using indicators about "information quality" and "service quality", to examine the performance of the RS according to the user opinion, in a internet book store. They conclude that the information quality of the RS has influence in the consumer shopping decision-making process, and that the e-commerce platform provides recommendations and information necessary, but, the recommendation system has not significant influence in the decision-making effort during the process of consumer's shopping decision-making.

In [21] it is determined that collaborative filter-based RS can be improved by incorporating side information, such as natural language reviews. Additionally, they introduce a model of reviews based on the recurrent neural network, and study its effects on collaborative filtering performance. The recurrent

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