A hybrid quantum-induced swarm intelligence clustering for the urban trip recommendation in smart city

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ABSTRACT

The development of internet technologies has brought digital services to the hands of common man. In the selection process of relevant digital services to the active target user, recommender systems have proved its efficiency as a successful decision support tool. Among many successful techniques incorporated to generate recommendations, collaborative filtering has been widely used to make similarity-based predictions for the recommendation of the relevant list of items to the users. As an advancement, utilizing clustering mechanisms with collaborative filtering for grouping similar users as clusters can enhance the efficiency of the recommendation generated. Though many clustering mechanisms have been employed to group similar users in the existing works, incorporation of bio-inspired clustering has yet to be explored for the generation of optimal recommendations. In this paper, a novel user clustering approach based on Quantum-behaved Particle Swarm Optimization (QPSO) has been proposed for the collaborative filtering based recommender system. The proposed recommendation approach has been evaluated on real-world large-scale datasets of Yelp and TripAdvisor for hit-rate, precision, recall, f-measure, and accuracy. The obtained results illustrate the advantageous performance of proposed approach over its peer works of recent times. We have also developed a new mobile recommendation framework XplorerVU for the urban trip recommendation in smart cities, to evaluate the proposed recommendation approach and the real-time implementation details of the mobile application in the smart-cities are also presented. The evaluation results prove the usefulness of the generated recommendations and depict the users' satisfaction on the proposed recommendation approach.

1. Introduction

Recommender Systems (RS) predict interesting personalized items for target user among a large collection of available items. To make predictions, the main goal of an RS is to match better items to user's requirements and interests. The general term items can be classified as any user consumables such as food, books, music, movies, e-services, etc. The emerging popularity of e-commerce web portals, e.g. Netflix.com, TripAdvisor.com, Amazon.com, Flipkart.com, etc. - have created massive interests in RS research to provide effective recommendations to end users. The demand of RS has attracted many researchers to the field and progressive research has been conducted in recent years in a wide manner [1–14].

Generally, the RSs are classified based on the techniques used and the major classifications are hybrid, Content-based, Collaborative filtering [15,16]. Among all other techniques, Collaborative Filtering (CF) is widely used with RSs and very successful with its prediction performance [17,18]. In the Collaborative Filtering Recommender System (CFRS), the prediction of items for the target user is made through the assessment of ratings provided by other users for items. Based on the assessment and prediction model, the CFRS can be divided into the item-based and user-based model. As an enhancement to CFRS, clustering techniques were exploited to generate personalized recommendations to meet user's requirements [19–22]. In the user-based CFRS, the clustering technique employs a similarity measure to group the users based on the similar item-ratings given by different users. The items organized based on similarity ratings in a particular cluster of users is recommended to any new user who has similar preferences to the user group. There are many clustering techniques used to generate personalized recommendations in user-based CFRS such as K-means, SOM, fuzzy c-means, etc. But still, bio-inspired clustering

techniques are not explored for user-based CFRS. This article has attempted to employ a novel bio-inspired swarm intelligent model for clustering of users in user-based CFRS, and the obtained results are compared with recommendation models with other existing clustering techniques.

In recent years, research on the development of clustering techniques has attained notable attention in various data mining applications such as web analysis, information retrieval, text mining, pattern recognition, visualization, and image segmentation [23–26]. With the development of real-time clustering based recommender systems, the information processing problems make the recommendation process more complex. The utilization of traditional clustering algorithms such as K-means clustering has some drawbacks in obtaining optimal solutions for large-scale application problems [27–31]. The formal logics-based traditional clustering algorithms fail to help the recommendation algorithms to generate recommendations in fast and efficient manner. To overcome such drawbacks of traditional clustering algorithms, the recent researchers have introduced bio-inspired swarm intelligence for clustering technology. Many researchers have developed many nature-inspired intelligent algorithms to solve real-life engineering problems to generate better optimal solutions [32–39]. Bio-Inspired meta-heuristic approaches are better than traditional models as they are ecologically inspired and their meta-heuristics are specifically designed to tackle complex a large scale problems. Bio-inspired algorithms are very familiar in solving the optimization problems which traditional approaches failed to have an effective or an efficient solution. In many real-world practical problems, the bio-inspired algorithms have proved its performance and recognized as the best solution providing method due to its exploitation of nature-inspired meta-heuristics. The recent trends in the development of hybrid techniques for complex real-world problems, bio-inspired algorithms are highly preferred to solve modern day global optimization problems. Swarm Intelligence inherits the characteristics of biological systems and produces promising results for data analytical models. With the proven efficiency over solving global optimization problems, swarm intelligence models were studied in depth, and the obtained results pave the path for new ideas. As an example, the combinational clustering models of PSO (Particle Swarm Optimization) with C-means and K-means have achieved better clusters over conventional algorithms [40–42].

The new clustering algorithms based on swarm intelligence have a better correlation of data and results with better quality of clusters through attaining great adaptability and rapid convergence. The swarm intelligence based clustering algorithms were adopted by various domains such as neurocomputing, decision-support systems, pattern recognition and big data to experience its enhanced performance [43–53]. With the above line, this article proposes a novel clustering ensemble method with swarm intelligence for recommender systems to solve information overload problem. In this work, we propose a new user clustering approach based on Quantum-behaved Particle Swarm Optimization (QPSO) for better clustering through addressing the drawbacks of traditional clustering based RSs. Quantum-behaved Particle Swarm Optimization (QPSO) is new swarm intelligence algorithm with improved ability over PSO by producing an effective solution for global optimization problems with fewer adjustable parameters [54,55].

The recommendation mechanism of an RS is based on the user's feedback data on the items which are already purchased or consumed. The explicit user ratings are used to generate recommendation list as input along with the implicit user behavior such as user purchase pattern, browsing history, links, etc. The modeling of user preference from their numerical ratings is most commonly used approach. The users' ratings on the 5 point rating scale represent the users' feedback for the particular item as 5 for "most loved" and 1 for "completely hated". The online giants such as Amazon and Netflix analyze the users' rating pattern in their past to predict users' preferences and needs for their upcoming choice of items. After predicting the ratings for non-purchased items, the recommender system organizes the predicted ratings and then ranks accordingly from highly estimated predicted ratings. Finally, the list of top-n items with highly predicted ratings may be recommended to the users. For the enhancement of the recommendations, the traditional recommendation models are combined to frame a hybrid recommendation approaches. Two or more recommendation approaches are combined to form a hybrid recommender system. The hybrid recommender systems have lesser drawbacks over the individual recommendation approaches. In most cases, collaborative filtering based recommendation models are combined with other techniques as a hybrid recommendation approach to overcome ramp-up problem. There are many variants of hybrid recommender systems based on the hybridization method used. The familiar hybridization methods of the recommender systems include weighted, switched, mixed, cascade, meta-level, feature combination and augmentation.

1.1. Need for travel recommender systems in a smart city

In the travel and touristic context, Smartphones help users to overcome navigational difficulties by searching and organizing the required information. In the e-tourism domain, the recent research focuses on mobile technology based recommender systems to provide recommendations on the go. The main aim of the research is to exploit user data and social context to enhance the user acceptance of the generated recommendations. The utilization of mobile technologies for providing travel services benefits both end users and service providers. The development of mobile apps is considered as a significant investment by the travel service providers and helps them to maintain real-time connections with their users. The travel mobile apps are the cost effective solutions than traditional web-based applications by means of enhanced usability, intuitiveness, and attractiveness. Travel destination is the geographical location, which is the important entity of the travel services. With the recent development of Information Communication Technology has changed the prediction mechanism for determining the relevant destination for the active target user. The destination is an area or place that makes a decision to plan a travel trip. In the real-world scenario, a single destination or multiple destinations are determined to generate travel recommendations based on user interests.

With the rapid development and utilization of social networks has helped travel recommender systems to learn the changing user interests for the improvement of the quality of travel related services. The massive user generated data on the online social media is considered to be a significant challenge to grab relevant information for the particular travel. Many existing approaches specifically focus on recommending attractive locations to the users. But still, there is a huge gap yet to be explored for the generation of personalized travel recommendations. Generally, the travel information comprises of heterogeneous data such as images, texts, and videos. For making tailored travel recommendations, the RSs need to be capable of processing the heterogeneous data from social media. The explicit user feedback collection is termed as an active approach, and implicit user feedback collection is known as the passive method for mining the user's interests. For the travel applications, implicit user feedback plays a significant role in predicting relevant-attractive locations for the users. As an effective decision support tool, RSs are widely used as the travel management applications to organize travel and destinations. With employment of hybrid prediction strategies, RSs increases the user sophistication