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Yong Soo Kim
Young J. Ryoo
Moon-soo Chang
Young-Chul Bae *Editors*

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Janusz Kacprzyk, Polish Academy of Sciences, Warsaw, Poland
e-mail: kacprzyk@ibspan.waw.pl

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Preface

Intelligent systems have been initiated with the attempt to imitate the human brain. People wish to let machines perform intelligent works. Many techniques of intelligent systems are based on artificial intelligence. According to changing and novel requirements, the advanced intelligent systems cover a wide spectrum: big data processing, intelligent control, advanced robotics, artificial intelligence and machine learning. This book focuses on coordinating intelligent systems with highly integrated and foundationally functional components. This book consists of 19 contributions that feature social network-based recommender systems, application of fuzzy enforcement, energy visualization, ultrasonic muscular thickness measurement, regional analysis and predictive modeling, analysis of 3D polygon data, blood pressure estimation system, fuzzy human model, fuzzy ultrasonic imaging method, ultrasonic mobile smart technology, pseudo-normal image synthesis, subspace classifier, mobile object tracking, standing-up motion guidance system, recognition structure, multi-CAM and multi-viewer, robust Gaussian Kernel, multi human movement trajectory extraction, and fashion coordination. This edition is published in original, peer reviewed contributions covering from initial design to final prototypes and authorization.

To help readers understand articles, we describe the short introduction of each article as follows;
1. "Qualitative Assessment of Social Network-Based Recommender Systems based on Essential Properties": This paper evaluates and assesses several social network-based recommender systems in terms of robustness, trust, serendipity, diversity, privacy preservation and scalability. It proposes that the observation and analysis can improve the performance of various recommender systems respectively.
2. "Application of Fuzzy Enforcement to Complementarity Constraints in Nonlinear Optimization": This paper presents the application of fuzzy enforcement to complementarity constraints in nonlinear interior point method (NIPM) based optimization. The fuzzy enforcement can provide enough room for the optimality, adequately satisfying complementarity constraints.
3. "iPhone as multi-CAM and multi-viewer": This paper describes catching and watching the real-time images on iPhones or iPads using the WiFi networks. The

resolution of images and frame per second depends on the traffics of WiFi. These systems are widely applicable to home monitoring and baby caring.
4. "Robust Gaussian Kernel Based Approach for Feature Selection": This article incorporates similarity margin concept and Gaussian kernel fuzzy rough sets. It optimizes the Symbolic Data Selection problem. The advantage of this approach features robust function.
5. "Multi Human Movement Trajectory Extraction by Thermal Sensor": This paper proposes a multi human movement trajectories (HMTs) extraction system with room layout estimation by a thermal sensor. The sensor is attached to the ceiling and it acquires 16×16 elements spatial temperatures – thermal distribution. The distributions are analyzed to extract HMTs.
6. "An Energy Visualization by Camera Monitoring": This paper proposes an energy visualization system by a camera. The system applies edge detection and the connected-component labeling to extract numeral regions in counters of a gas mater. Gas consumption is estimated based on shape characteristics of numerals.
7. "Ultrasonic Muscular Thickness Measurement in Temperature Variation": This paper proposes a muscular thickness measurement method using acoustic velocity dependency according to temperature. The authors employ a 1.0 MHz ultrasonic probe, and acquire two kind ultrasonic echoes from same position of body with temperature variation.
8. "Regional Analysis and Predictive Modeling for Asthmatic Attacks in Himeji City": This article predicts the number of asthmatic attacks by a time series data analysis occurred in the areas divided into the coastal place and the inland place in Himeji city.
9. "Analysis of 3D Polygon Data for Comfortable Grip Form Design": This paper describes the method using 3D image processing techniques to extract some features, i.e. positions/directions of fingers and relationships among them, from the 3D polygon data. The research results show that gripping trends can be categorized into 5 classes and the obtained features will be one effective for the mathematical models.
10. "Blood Pressure Estimation System by Wearable Electrocardiograph": This paper proposes a blood pressure estimation system based on electrocardiogram (ECG). The ECG is unconstraintly measured by wearable sensor that provides acquired data to personal computer by wireless communication.
11. "A Fuzzy Human Model for Blood Pressure Estimation": The paper describes a blood pressure prediction model. The model predicts blood pressure of the subject based on trend of the blood pressure, body weight and number of steps.
12. "A Fuzzy Ultrasonic Imaging Method for Healthy Seminiferous Tubules": The authors make cross-section images that consist of multiplying fuzzy degrees depending on amplitude and frequency of line echoes. The images are healthy or unhealthy seminiferous tubules images (HSI or USI) that indicate distribution of healthy or unhealthy seminiferous tubules.
13. "Ultrasonic Mobile Smart Technology for Healthcare": This study designs the mobile medical system to review data prior to patient access. Improved communication can also make the process easy for patients, clinicians, and care-givers.
14. "Pseudo-normal Image Synthesis from Chest Radiograph Database for Lung Nodule Detection": The pseudo-normal image is synthesized from a database containing

other patient's chest radiographs that have already been diagnosed as normal by medical specialists. And then, the lung nodules are emphasized by subtracting the synthesized normal image from the target image.
15. "Low-pass Filter's Effects on Image Analysis using Subspace Classifier": This paper shows an effect for applying a low-pass filter on the performance of image analysis using the subspace classifier. Analysis accuracies depend on if images are filtered or not.
16. "A New Mobile Object Tracking Approach in Video Surveillance: Indoor Environment": This paper deals with mobile tracking object indoors. A new mobile tracking object approaches to the simple operation of extension and contraction on the object window.
17. "Development of a Standing-up Motion Guidance System using an Inertial Sensor": This article presents a standing-up motion guide system for elderly and disabled people. The system consists of a flexion phase, in which the center of gravity (COG) moves forward, and an extension phase, in which COG raises upward. The proposed system is evaluated highly as efficacy in supporting forward COG movement.
18. "A Structure of Recognition for Natural and Artificial Scenes; Effect of Horticultural Therapy Focusing on Figure-Ground Organization": This paper presents a solution of horticultural therapy for the elderly with depression symptom. The therapy in perception-action cycle can enhance motivation, when subjects interact with natural objects. Their experimental results demonstrated a significant difference of eye movements in natural and artificial object cases.
19. "A Study on Fashion Coordinates Based on Clothes Impressions": This paper proposes the fashion coordinates generation system reflecting impressions expressed by an image word. In order to construct the coordinates systems, there are three steps to go through; the analysis of impressions of clothes, the analysis of impressions of the combinations of outerwear and a shirt, and the generation method of initial coordinates candidates.

We would appreciate it if readers could get useful information from the articles and contribute to creating innovative and novel concept or theory. Thank you.

Editors

Yong Soo Kim
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Young-Chul Bae

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Qualitative Assessment of Social Network-Based Recommender Systems Based on Essential Properties

Regin Cabacas, Yufeng Wang, and In-Ho Ra*

Information and Communications Engineering Department,
Kunsan National University
Miryong-dong, Jeollabukdo 573-701 South Korea
{rcabacas,ihra}@kunsan.ac.kr, ywang2@mail.usf.edu

Abstract. Prediction accuracy is the most common metric used to evaluate the performance of traditional recommender systems. However, this might not be applicable with Social Network-based Recommender Systems that uses social connections in creating predictions and suggestions. Other important features should be taken into account in implementing and evaluating them. This paper evaluates and assesses several social network-based recommender systems, in terms of robustness, trust, serendipity, diversity, privacy preservation and scalability. From observation and analysis, we proposed suggestions that can improve the performance of various recommender systems, respectively.

Keywords: social network, recommender systems.

1 Introduction

The rapid increase in the amount of information on the Web brings difficulty for Internet users to obtain desired information. This problem becomes even worse if users do not utilize appropriate search tools. In the past decade, different Recommender Systems (RSs) are proposed to solve this problem. RSs in highly rated sites such as Amazon, Netflix, TripAdvisor, Yahoo and YouTube have played an important role to their success [1]. The key idea is to provide users with items that might be of interest based on previous preferences, transactions and profiles, thus sound decisions can be made.

The integration of social network opens a new field of research in recommender systems. With a number of social networking Web sites such as Facebook, LinkedIn and Twitter, it is most desirable to have a system application that could integrate information from these sources to provide customized recommendation for an individual, a group or community. The idea of incorporating knowledge from social networks (e.g. social influence, social interaction, etc.) originates from the fact that users are often guided with the opinions and recommendations by their friends.

* Corresponding author.

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The first step in selecting an appropriate RS algorithm is to decide which properties of the application to focus upon [2]. Knowing the valuable properties to take into account and understanding their effects will help designers realize the right recommendation system approach and algorithm. A need for careful selection of property should be given importance over the other. In this paper, we provide an overview of a set of properties that are relevant for SNRS. We evaluated several SNRS in terms of these essential properties. The remainder of this paper is as follows: section 2 discusses recommender systems; section 3 presents several existing SNRS methods; section 4 describes essential properties of SNRS, section 5 shows the evaluation and suggestions to improve the performance of SNRS and finally section 6 concludes the paper.

2 Recommender Systems

RSs include software tools and techniques that provide suggestions for items that might be of interest to a given user in the present or near future [1]. The subsections describe RS functions, data sources and commonly used recommendation approaches.

2.1 Functions

RSs are multi-faceted applications commonly employed in an e-commerce site (i.e. Amazon), entertainment sites, which includes movie or DVD recommender (i.e. Netflix, IMDb), services such as travel itinerary (i.e. Tripadvisor) and personalization sites (i.e. Yahoo, Youtube). Authors in [1] argue that to understand recommendation system function, designers should view the application on two perspectives namely: service provider and user perspective. Here are some of the reasons why service providers employ RSs:

- increase the number of items sold
- sell more diverse items
- increase the user satisfaction
- increase user fidelity and
- better understand what the user wants.

On the other hand, in a user's perspective RSs are used to:

- find some good items
- find all good items
- just browsing
- find credible recommender
- improve the profile
- express self
- help others and
- influence others

2.2 Data Sources

Data sources are the bloodstream of RSs. Most of the time, they are the basis of creating recommendations. However in most cases, there are recommendation techniques that are knowledge poor wherein simple and basic data are used such as user ratings and evaluations for items. The following are common data sources used in RSs.

a. Items. Items are the objects that are recommended. Items may be characterized by their complexity and their value or utility. The value of an item may be positive if the item is useful for the user or negative if the item is not appropriate and the user made a wrong decision when selecting it.

b. Users. Users are the person concerned of finding desirable items. Most of the RS retains user profile that contains demographic data (e.g. gender, age) and user preferences.

c. Transactions. Transactions are referred to as recorded interactions between a user and the RS. These are log-like data that store important information generated during the human-computer interaction that are useful for the recommendation generation algorithm that the system is using.

2.3 Approaches

Three main approaches are commonly used in RS namely: Content-Based (CB), Collaborative-Filtering (CF) and Hybrid.

a. Content-Based (CB): This is an approach that recommends items that are similar to the ones a user have preferred in the past. This approach continues to collect users' information and preferences and establishes a user profile. The similarity of items is calculated based on the features associated with the user's profile.

b. Collaborative Filtering (CF): This is an approach that recommends to user similar items that other users liked in the past. CF systems can be classified into two subcategories: memory-based CF and model-based CF. Memory-based approaches make predictions by taking into account the entire collection of previously rated items by a user. Meanwhile, model-based approaches learn a model from collection of ratings and use this model for making predictions.

c. Hybrid: This is an approach that is based on the combinations of the above mentioned approaches. It combines CB and CF, and in most cases it uses the advantages of CF to fix the disadvantages of CB or vice versa. Authors in [3] enumerate different ways to combine collaborative and content-based methods into a hybrid recommender system and classified as follows:

- Separately implementing CB and CF methods and combine their predictions
- CB characteristics incorporated into CF approach
- Incorporating some CF characteristics into a CB approach and construction of general model that incorporates both CB and CF characteristics.

3 Social Network-Based Recommender System

SNRS makes use of the knowledge that can be obtained from social networks to improve the recommendation process. This knowledge includes explicit and implicit social interaction, social influence, trust and social behavioral patterns. Several papers have verified the use of this knowledge in the success of the recommendation [4, 5, and 6]. The following are several SNRS researches that are evaluated in this paper:

a. SOMAR (Social Mobile Activity Recommender)

SOMAR is a social network-based recommender system that recommends activities based on a user's social network, mobile phone data and sensor data in a ubiquitous environment. It supports the user to filter and analyze activities by utilizing social affinities and user interest.

b. FilmTrust

FilmTrust is a web recommender that combines social networks with movie ratings. In this system users can read about movies, rate them, and write reviews. It uses trust ratings within the social network as basis for making calculations about similarities.

c. GLOSS (Group Learning Sharing Own Contribution Search)

GLOSS is a search system that incorporates social network and provides recommendation based on trust weight. It can find out several similar users, revise the trusting weight, and find out potential trusting users using a feedback mechanism.

d. MyPopCorn

MyPopCorn is a Facebook movie RS application that uses unweighted social graph. It requires explicit feedback for movies from the user. Its recommendations are generated from two implementations, one is provided by a traditional user-based RS, where neighborhood is calculated among all users in the database and the other is provided by the social graph where neighborhood is based on the set of active user's friends.

e. SNS (Social Network-based Serendipity Recommender System)

SNS is a system that predicts and recommends items that have not yet been seen by the active user but are of great interest and hard to search. It makes use of social network interactions and access records of items to provide recommendations.

4 Evaluation

Prediction accuracy is the most common performance measure for RSs. Most of the RSs designers put a lot of consideration in the accuracy of predictions whether the approach and algorithm is tested offline or with real user interaction. A basic assumption in a recommender system is that a system that provides more accurate predictions will be preferred by the user [2]. However, works in [7, 8] argued that it is not only the considerable factor to evaluate the total performance of a RS.

Table 1. Comparison of SNRS Researches based on data sources, function and approach

Recommender Systems	Data Sources	RS Function	Approach Used
SOMAR (Zanda et. al)	Facebook, Mobile Data, Sensor Data	Movie	Hybrid
FilmTrust (Golbeck and Hendler)	Own Data Set(User Profile, Preferences, Ratings, Feedbacks)	Professional academic search	Collaborative Filtering
GLOSS (Zhang et. al)	GLOSS User Data(User Profile, Social Network Information)	Movie	Collaborative Filtering
MyPopCorn (de Mello Neto and Nowe)	Facebook, User profile, GroupLens Data Set	Movie	Collaborative Filtering
SNS (Chiu et. al)	Social network interaction, relationship, Access Record, MovieLens Data Set	Social Network Activity	Collaborative Filtering

In this section we compared and assessed SNRS based on a set of properties. We focused on assessing properties such as robustness, trust, serendipity, diversity, privacy preservation and scalability and how they affect the success of the recommendation. Several researches point out the following factors that contribute to the total performance of RSs [2].

a. Robustness

This refers to the stability of the RS in the presence of fake information and attacks. These attacks are commonly in form of profile injections which are made to promote the value of a certain item amongst others.

Robustness measures the performance of the system before and after an attack to determine how it affects the system as a whole. Authors in [9] conducted an experiment in determining the effect of attack models in CF algorithms. Average prediction shift is one of the common measures used in evaluating the robustness of a RS [10]. This measure refers to the change in an item's predicted rating before and after an attack on averaged overall predictions or over predictions that are targeted by the attack. Equation 1 and 2 shows the formula for average prediction shift for an item i for over all users and average prediction shift for all items respectively. Table 2 shows the assessed robustness of each SNRS. High robustness indicates that the system will still provide accurate predictions even threats on data is inherent.

$$\Delta i = \sum_{u \in U_T} \Delta_{u,i} / |U_T| \quad (1)$$

$$\Delta i = \sum_{u \in I_T} \Delta_{u,i} / |I_T| \quad (2)$$

Table 2. Assessed Robustness of SNRS

Recommender Systems	Robustness
SOMAR (Zanda et. al)	High
FilmTrust (Golbeck and Hendler)	Medium
GLOSS (Zhang et. al)	Medium
MyPopCorn (de Mello Neto and Nowe)	Medium
SNS (Chiu et. al)	Low

b. Trust

Trust is the measure of willingness to believe in a user based on his competence and behavior within a specific context at a given time. Humans usually retain a mental map of the level of trust towards a friend's advice.

Work in FilmTrust, GLOSS and MyPopCorn uses trust ratings in a social network as basis for making calculations about similarity. It relies on the notion that there must be a correlation between trust and user similarity. Work in [5] verifies this correlation in an empirical study of a real online community. Work in SOMAR and SNS does not include trust among users in the social network rather social network interaction is given the degree of importance in the recommendation process.

In detail, the social networking component of FilmTrust requires users to provide a trust rating for each person added as a friend. With the collected trust values, they use TidalTrust, a trust network inference algorithm, as basis for generating predictive ratings personalized for each user. In their experiment, the accuracy of the recommended ratings outperforms both simple average rating and the ratings produced by a common RS algorithm. Table 3 shows the use of trust in SRNS.

Table 3. Usage of Trust in SNRS

Recommender Systems	Use of Trust
SOMAR (Zanda et. al)	No
FilmTrust (Golbeck and Hendler)	Yes
GLOSS (Zhang et. al)	Yes
MyPopCorn (de Mello Neto and Nowe)	Yes
SNS (Chiu et. al)	No

c. Serendipity

Serendipity is the measure of how surprising the successful recommendations are [2]. It is the amount of information that is new to the user in a recommendation or basically labeled as the "not obvious" items in the recommendation. Several works on serendipitous recommendation shows that serendipitous items exist in recommendation

lists of different items in different categories than in the lists of similar items. Furthermore, authors in [2] proposed a recommendation method to increase diversity of recommendation lists. In this paper, we aim to identify the need of each SNRS for serendipitous recommendation. Table 4 shows the need for serendipity of each SNRS.

Table 4. Assessed need of serendipitous recommendation

Recommender Systems	Serendipity of Recommendations
SOMAR (Zanda et. al)	Medium
FilmTrust (Golbeck and Hendler)	Medium
GLOSS (Zhang et. al)	Low
MyPopCorn (de Mello Neto and Nowe)	Medium
SNS (Chiu et. al)	Low

d. Diversity

Diversity is a quality of result lists that helps cope with ambiguity. Diversity generally applies to a set of items that is related to how different the items are with respect to each other. Studies in [7, 11] introduced the topic of diversification method to balance and diversify personalized recommendations lists in order to reflect the user's complete spectrum of interests. A trade-off in improving the diversity characteristics of a fixed-size recommendation list is sacrificing its prediction accuracy [11]. Table 5 shows the summary of the need of SNRS for diversification.

Table 5. Assessed need of diversity

Recommender Systems	Diversity
SOMAR (Zanda et. al)	Highly Desirable
FilmTrust (Golbeck and Hendler)	Highly Desirable
GLOSS (Zhang et. al)	Not necessarily needed
MyPopCorn (de Mello Neto and Nowe)	Highly Desirable
SNS (Chiu et. al)	Not necessarily needed

e. Privacy Preservation

Privacy is a critical issue for users. They are reluctant to provide personal details for fear of misuse, and RS administrators are concerned about the legal issues associated with protecting user privacy.

The use of OSN data (i.e. Facebook) is subject to the preservation of user's privacy. Authors in SOMAR handle privacy preservation by implementing the recommendation process in situ or within the user's location, in the mobile phone of the

active user, leaving no traces of passing valuable data to a third party entity. We take into consideration two factors that contribute to privacy preservation in SNRS namely: transparency and anonymity.

- **Transparency**

Users question themselves about the reason behind a recommendation. They are more inclined to accept and evaluate the recommendations better once they understand how an item has been suggested to them.

Authors in [5] have evaluated the role of transparency to the accuracy of recommender systems. They suggest that RSs are mostly not used in high-risk decision-making because of a lack of transparency. The applicability of transparency relies on the domain or function of the RS. Transparency is most likely beneficial for RS such as recommending travel itinerary, investment and real estate. However, most SNRSs mentioned above still operates as a set of black box, leaving the recommending process to the system and never letting the user know how it comes up with that. These SNRS are mainly low level domain type and transparency would likely be not present. However, MyPopCorn users are aware how recommended items are derived either from the user's preferences or similarities with other users or friends.

- **Anonymity**

Being anonymous in an OSN is hard to imagine especially in SNRS where user profiles are stored and used in prediction. Anonymity is associated with transparency. If a user can see how the recommendation has been calculated there would be instances of exploitation of users' data. Data connected with the recommendation can be used maliciously. Like for example in the case of MyPopCorn, friends' similarities could be seen once a recommendation is given to the user. User data obtained from the inference process in recommender systems could be used by perpetrators to commit crime such as harassment, burglary and identity theft. Table 6 summarizes the privacy risk based on the evaluation of transparency and anonymity in SNRS.

Table 6. Privacy risk rated as Low, Medium or High effect on user with risk factors

Recommender Systems	Privacy Risk
SOMAR (Zanda et. al)	Low (in situ processing)
FilmTrust (Golbeck and Hendler)	Medium(Social interactions)
GLOSS (Zhang et. al)	Medium(Social interactions)
MyPopCorn (de Mello Neto and Nowe)	Medium(User profile and Social Interaction)
SNS (Chiu et. al)	Low (Experimental data set used)

f. Scalability

With exponentially increasing users and items, SNRSs or any RSs will likely to suffer serious scalability problems. Social network users normally have hundreds to thousands of friends making the computation of similarity complicated.

In [12], authors stated that users are connected with other users but they do not interact all the same. Users only interact with a small group of friends, normally the closest in the social network structure. SOMAR, GLOSS and MyPopCorn represent this connection in a social graph.

Table 7. Use of Social Graph

Recommender Systems	Use of Social Graph
SOMAR (Zanda et. al)	Yes
FilmTrust (Golbeck and Hendler)	No
GLOSS (Zhang et. al)	Yes
MyPopCorn (de Mello Neto and Nowe)	Yes
SNS (Chiu et. al)	No

In GLOSS, authors state that similarities between friends are in average higher than those non-connected users. This suggests that focusing on the social graph as representative relationship instead of the user's whole social network structure is applicable. Narrowing the data set as used in SOMAR and MyPopCorn solves the problem of scalability. Furthermore, authors in [5] suggest that there is a similarity in focusing on the immediate friends and using the distant friends in the social network as shown in Table 8.

Table 8. Result of Mean Absolute Error (MAE) in prediction using with or without distant friend inference

Type	MAE
With Distant Friend Inference	0.716
Without Distant Friend Inference	0.682

5 Suggestions and Future Work

The popularity of using CF algorithms in SNRS is conclusive that this algorithm is well suited for most SNRS. Authors in [9] conducted and experiment and have demonstrated the relative robustness and stability of model-based CF algorithms over the memory-based approach. This could be basis of using model-based algorithms over SNRS when its focus is its robustness. Robustness should be highly regarded since

profile injection especially for OSN data is prevalent. Certain measures should be done to ensure the credibility of the data being used and no biased items are added that could affect the output of the predictions.

In the evaluation, the use of weighted trust in the social network structure is essential in improving the recommendation process. However, SNRS listed in Section 2 are only considering the calculation of trust from the frequency of social network interaction and explicit rating with mostly no consideration of other social context of trust (e.g. similarity of preferences, proximity of location, community impact factors or reputation). We observed these factors as important to improve the usage of trust in SNRS. FilmTrust could also integrate the use of real-time interactions that can be acquired in any OSN (i.e. Facebook). FilmTrust and SNS could also make use of social graphs as an advantage to enhance their recommendation process.

Serendipity and diversity of recommendation varies with the domain of the RS. On specific domains such as academic research like in GLOSS, serendipity should be of low importance over item similarity or prediction accuracy. However, for entertainment domain such as movie recommender a serendipitous recommendation is highly desirable to present to the users. Diversity could also be a trade-off with prediction accuracy. The dissimilarity of items could be beneficial in some SNRS but not with others. RSs that try to promote items (products, movie, etc.) or events are most likely in need of diversification.

Privacy preservation is lightly tackled in the evaluated set of SNRS. The subject of transparency with the calculation of prediction creates an advantage and disadvantage. It can be used advantageously when transparency create a desirable impact on a user's belief and acceptance of the recommendations. However, it would be a disadvantage if it is used maliciously. Alongside transparency user's information (e.g. user's profile) is implicitly included in the recommendation. Transparency and anonymity should be addressed by explicitly stating the privacy options that a user can have on using the RS. A user should know what data are to be shared and not.

Social neighborhood connections can derive assumptions about a new user's taste, and network of friends can derived specific interest that could be relevant to the active user. Direct or close friends could already be a sufficient social graph data to use in prediction and this could shorten the computation time of making recommendations, which answers scalability problems.

6 Conclusion

In this paper, we have provided an overview of RS, in terms of function, data sources and techniques. We evaluated existing SNRS methods in several domains based on performance measurements i.e. robustness, trust, serendipity, diversity, privacy preservation and scalability. These properties are as essentials as prediction accuracy. However, for the evaluated SNRS most of these properties are not incorporated. A trade-off on prioritizing one property over the other may apparently occur and incorporating all of the properties could be proven effective but would make SNRS more complex. Furthermore, we seek to apply the proposed suggestions to improve future SNRS.

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Application of Fuzzy Enforcement to Complementarity Constraints in Nonlinear Optimization

Hwachang Song

Dept. of Electrical and Information Engr., Seoul Nat'l University of Science & Technology
232 Gongreung-ro, Nowon-gu, Seoul 139-743, Korea
hcsong@seoultech.ac.kr

Abstract. This paper presents the application of fuzzy enforcement to complementarity constraints in nonlinear interior point method (NIPM) based optimization. The fuzzy enforcement can provide enough room for the optimality, adequately satisfying complementarity constraints.

Keywords: complementarity constraints, fuzzy enforcement, nonlinear interior point methods, nonlinear optimization.

1 Introduction

This paper presents the application of fuzzy enforcement to complementarity constraints (CC) as a form of inequality ones for nonlinear interior point method based optimization. Fuzzy enforcement was originally proposed in [1], but it was for general equality and inequality constraints in successive linear programming algorithm. Introducing fuzzy enforcement can adequately deal with the concept of "not too much" violating complementarity conditions, providing enough room for solutions to move to the optimality.

2 Fuzzy Enforcement of Complementarity Constraints

The formulation of nonlinear programming problems with the CC of interest in this paper can be briefly expressed as follows:

$$\begin{aligned} \min \quad & f(x) \\ \text{s.t.} \quad & g(x) = 0 \\ & h_{\min} \le h(x) \le h_{\max} \\ & \left(c_i(x_i) - \alpha_i\right)\left(x_i - \beta_i\right) = 0 \\ & c_i(x_i) - \alpha_i \ge 0,\ x_i - \beta_i \ge 0, \\ & i = 1,\ldots,kc \end{aligned} \tag{2}$$

where x is the vector including control and dependent variables. In (2), $f(\cdot)$ is the objective function; $g(\cdot)$ and $h(\cdot)$ are function vectors for equality and inequality

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