Job Recommender Systems: A Survey

Zheng Siting, Hong Wenxing*, Zhang Ning, Yang Fan

School of Information Science and Technology

Xiamen University

Xiamen 361005, China

ting718@hotmail.com, hwx2011@gmail.com*

Abstract—**The personalized recommender system is proposed to solve the problem of information overload and widely applied in many domains. The job recommender systems for job recruiting domain have emerged and enjoyed explosive growth in the last decades. User profiles and recommendation technologies in the job recommender system have gained attention and investigated in academia and implemented for some application cases in industries. In this paper, we introduce some basic concepts of user profile and some common recommendation technologies based on the existing research. Finally, we survey some typical job recommender systems which have been achieved and have a general comprehension of job recommender systems.**

Keywords—**job matching, recommendation technology, job recommender system**

I. INTRODUCTION

With the rapid developing of the Internet technology, more and more job seekers release their own personal information whereas enterprises post the jobs on the Internet. Because of the advancement of Web 2.0 technology, there is a dramatic increase in job seekers' personal information and enterprises' recruiting information. As a result, the information becomes overloaded, which lead to the low utilization rate. The job recommender system, which is the online recruiting system with personalized recommendation, has been proposed to handle the aforementioned issue for job seekers and enterprises. As a recommender system, the job recommender system is capable of retrieving a list of job positions that satisfy a job seeker's desire, or a list of talent candidates that meet the requirement of a recruiter by using the recommendation technology, for example, content-based recommender and collaborative filtering recommender which have shown success in different recommender systems. Based on the papers we have studied during our preliminary research, we have identified some issues that have been paid much attention in the job recommender system.

- How to extract the information of jobs and people and contribute the user profile for matching jobs and people well?

- Which recommendation technology is used in the job recommender system based on user profile?

- How to build a job recommender system based on the real data with a certain application background?

In this paper, we survey the existing papers on the job recommender system focusing on three issues above. The first issue is about job and people matching and user profiling. It's the fundamental procedure in the job recommender system. Recommendation technology mentioned in the second issue is very important for job recommender systems. With the need of industry application, the architecture of a job recommender system will tell us how the system is contributed.

The outline of this paper is organized as follows: Some content about the matching between jobs and people are stated in Section Ⅱ; Section Ⅲ introduces the common recommendation technology in the job recommender system, especially reciprocal recommender; In Section Ⅳ there is a survey of job recommender systems which have been investigated for some application cases. Finally, we conclude our paper in Section Ⅴ.

II. JOB AND PEOPLE MATCHING

Job seekers search the job positions whereas enterprises find candidates on the Internet, so the matching in the job recommender system is between jobs and people represented as information.

A. Target User

Considered the diverse needs of users, a job recommender system can be designed for different target users, i.e. job seekers or recruiters. For job seekers, the job recommender system enables them to input their personal information or upload their resumes, and to receive their preferred job positions' information. For recruiters, they can post the recruiting job positions and the information of similarity candidates for their posted jobs can be provided in the job recommender system. A job recommender system generates different user profile and adopts the corresponding recommendation technology based on the characteristics of target users with the same goal of recommending the appropriate jobs or candidates to target users.

B. User Profile

Montaner et al. [1] study the taxonomy of user profiles in general and it's suitable for the job recommender domain. User profile is composed of initial profile and feedback relevance. Initial profile, which represents the target user's basic characteristics, contains some basic feature descriptions of job positions or candidates and the extracted information from the resumes or homepages. Feedback relevance is the user behavior or actions recorded in the system, including explicit feedback relevance and implicit feedback relevance, such as

the numeric rating for items, a binary like/dislike button or textual comments. More information is integrated into user profile, more preferences and interests of target users can be obtained and better matching between jobs and people can be achieved.

The first step of user profiling is information extraction. Some structured or semi-structured data can be collected directly from the database, while unstructured information is stored in the textural form or other forms. So we need to extract the useful information for recommender systems from the textural files. To support automatic resume management and routing, Yu et al. [2] design a cascaded information extraction (IE) framework to obtain the available feature from the job seeker's resume. Figure 1 is the structure of the cascaded hybrid model. In the first stage, with Hidden Markov Modeling (HMM) model the entire resume is segmented into consecutive blocks to extract the general information. Based on the result, the detailed information in the certain block is extracted by different learning technology according to the feature characteristics. Sum up, the detailed information of job seekers which we want to know and be used for further similarity calculation is extracted from the resumes.
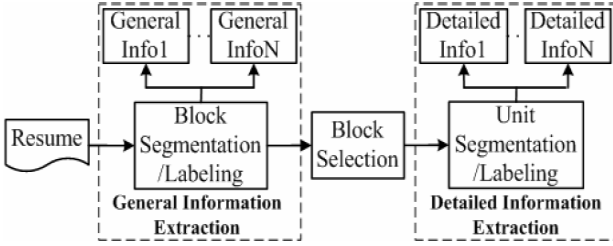

Figure 1.   Structure of cascaded hybrid model [2]

C. Similarity

An important step of achieving matching jobs and people is calculating the similarity or relevance based on their profiles. Several common similarity calculation measures, namely, Constrained Pearson Correlation, Pearson Correlation [3], Spearman Rank Correlation [4], Cosine [5] and Mean Squared Differences in the recommender system. For example, with explicit rating information we can measure the similarity between two users or two jobs by Pearson coefficient which is defined as

$$PCSim_{u,v} = \frac{\sum\limits_{\alpha \in O_{u,v}} (r_{u,\alpha} - \overline{r}_u)(r_{v,\alpha} - \overline{r}_v)}{\sqrt{\sum\limits_{\alpha \in O_{u,v}} (r_{u,\alpha} - \overline{r}_u)^2} \sqrt{\sum\limits_{\alpha \in O_{u,v}} (r_{v,\alpha} - \overline{r}_v)^2}}, \quad (1)$$

where $r_{u,\alpha}$ represents the user u rating for item α and $\overline{r}_u$ represents the average rating of user u. $O_{u,v}$ indicates the set of objects rated by both u and v.

The rating correlation can also be measured by Cosine Index as follow.

$$CosSim_{x,y} = \frac{r_x \cdot r_y}{|r_x| \cdot |r_y|} \quad (2)$$

Where r_x and r_y are the rating vectors in the n-dimensional space for quantifying the similarity between users. Besides, it can be applied in the similarity of items while r_x and r_y represent the vectors consist of item features.

III.   RECOMMENDATION TECHNOLOGY

A. Content-based Recommender

The principle of a content-based recommender is to suggest items that have similar content to ones the target user prefers [6]. In the matching between people and jobs, the content is the personal information and their job desires for people while for jobs, it's the job description posted by recruiters, even including the background description of enterprises.

The process of content-based recommender is selecting the same feature type and comparing them by calculating their similarity for people and jobs. The recommendatory result is a list of job positions or candidates sorted by the similarity index. In short, the two key components of content-based recommender are feature selection and similarity calculation. During selecting feature, not only it's need to select the common feature but also considering its influence on recommendation according to the target user's preferences or the scientific analysis in the job recruiting market. Then the selected features should be represented in an appropriate form, for instance vector space model and their similarity can be calculated.

B. Collaborative Filtering Recommender

Collaborative filtering recommender known as user-to-user correlation method, find similar users who have the same taste with the target user and recommend items based on what the similar user likes. The key step is computing the similarity among users. Collaborative filtering recommender algorithm includes user-based and memory-based and the input data is the division basis.

For user-based, the content i.e. the basic information of users is used to search out the similar users like the similarity calculation in the content-based recommender. For memory-based, the user-item rating matrix is used as input for recommender systems. Applied in the job recruiting domain, some user behavior or actions can generate the user-item rating matrix according to the predefined definitions and transition rules.

C. Reciprocal Recommender

Reciprocal recommender firstly proposed by Luiz Pizzato et al. [7] is a special class of recommender system. The preferences of both users being involved are taken into account and satisfied at the same time. As a result, it achieves a win-win situation for both users and improves the accuracy of recommender systems. It's suitable for the recommender system that matching people and people and it's originally

designed for online dating [8-12] and proposes different algorithms to solve the reciprocal recommendation problems.

In the job recruiting domain, the information of job positions is posted by recruiters. It reflects the preferences and requirements of recruiters actually and the matching between jobs and people becomes the matching people and people from the other side. So the reciprocal recommender can be introduced in the job matching but there is little literature on the job reciprocal recommender system currently.

The difficult point of reciprocal recommender systems is how to satisfy the both users' preferences at the same time. It extends to the problem of bilateral feature representation. As regards the job reciprocal recommender system, a part of preferences of job seekers and requirements of job positions are stored in the database with the textual form, it is difficult to express all the information into the same feature since there is semantic differences and incomplete data. Representing the bilateral features exactly and efficiently is related to the expression of users' information and has impact on the accuracy of calculating the similarity between jobs and people resulting in the final recommendation.

IV. CASES STUDY

In this section, we will introduce several job recommender systems which have been implemented under a certain application background with their architecture and mainly technology.

A. CASPER

CASPER [13] is an intelligent online recruitment service which is designed for originally Job Finder search engine. The architecture of CASPER system is shown in Figure 2. As we see, initial data are composed of the job database and the log files of the Job Finder website. Based on the different type of data, CASPER system takes two approaches, i.e. CASPER Automated Collaborative Filtering (ACF) and CASPER Personalized Case Retrieval (PCR), to generate personalized recommendation for job seekers.
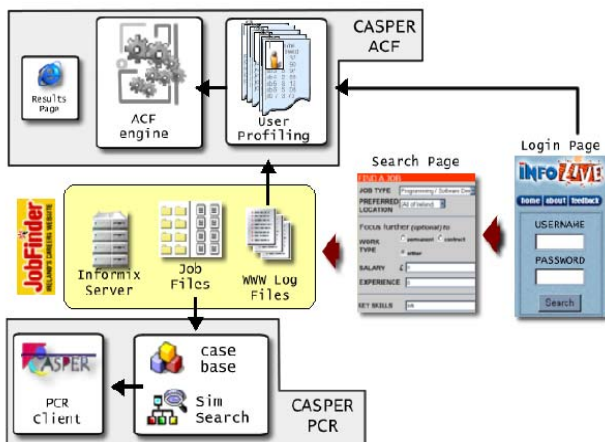

Figure 2.   CASPER System Architecture [13]

In CASPER ACF [14], the first step is user profiling by collecting the user's preferences such as revisit data, read time data and activity data from the log files since the moment that users login to the website. Then, according to the principle of

collaborative filtering technology, the system uses the profile information to find out similar users and what they like, which could be recommended as the target user's preferred jobs.

CASPER PCR [13] uses a two stage personalization process to retrieval relevant results for job seeks and the workflow is shown in Figure 3. The first stage is to select similar jobs to a target query which provided by the user, in short, it is the similarity calculation between query and jobs. Then the job candidates are used for computing the relevance with a target user's profile to update the user profile and sort the recommendation results. But before the two stages, there is the preparatory work for the nature and representation of case-base. No matter user profiles or job descriptions, even the query, contain several features such as salary, location, education background, etc and they are all represented in the form of case which is convenient to match the corresponding feature and calculate their similarity or relevance.
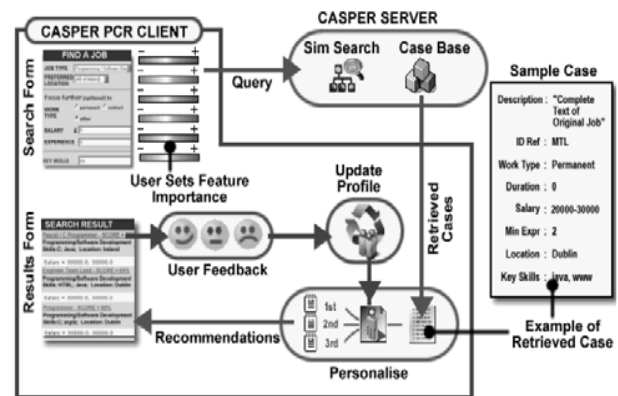

Figure 3.   CASPER PCR System Architecture [13]

B. Bilateral People-Job Recommender

A bilateral people-job recommender system [15] is presented for recommending job positions to people as well as for recommending people to recruiter. Beginning with implementing a CV-recommender and a Job-recommender respectively, the bilateral people-job recommender system shows the fusion results of the two separate recommenders to users.

The job description in the CV-Recommender is represented in a probabilistic latent aspect model as shown in Figure 4 as well the context of Job-Recommender apply the similar model (Figure 5). From the observation, we know that not only the preferences of job seekers but also of recruiters need to be taken into considered while recommending jobs/candidates for job seekers/ recruiters. So the probabilistic CV-Recommender is built based on a convex combination of preference factors from the view of recruiters at first. Then the preferences of jobs seekers are used to contribute a probabilistic Job-Recommender with the help of Expectation Maximization algorithm. After that, a bilateral people-job recommender system is achieved by integrating both two recommenders into a single indicator representing its quality through two stages to improve the match between people and jobs.
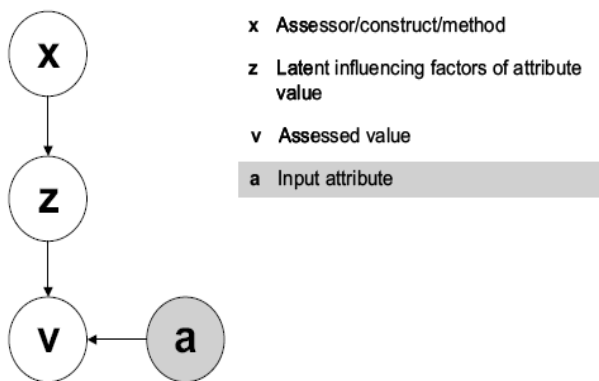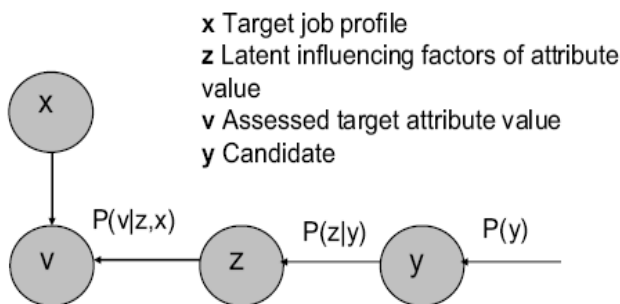
Figure 4. The Probabilistic CV-Recommender [15]

Figure 5. The Probability Job-Recommender [15]

C. Proactive

Proactive [16] is a comprehensive job recommender system developed for different categories of target users. One is who has no definite career purpose and job description but a broad range of preferences and interests, the other is those have clear career goals and narrowed predefined interests. To meet two different user requirements, the Proactive system designs and deploys four different kinds of interfaces: Most Recent Jobs, Advance Search, Recommended Jobs and Preferred Jobs, for job seekers to access information and become a highly user-adaptive system.

Based on the recommendation taxonomy, the job information acquired from online recruiting websites should pass the ontology checker for matching the data ontologies and verifying the classification. The architecture of Proactive system is shown in Figure 6. First of all, ontology for job recommender domain knowledge that explains attributes, relationships and axioms should be predefined for data representations. Job data repository, profile feature repository and preference repository are formed based on ontology. By profile analyzer and preference analyzer, the information in the three repositories are analyzed and compared to generate the preferred and recommended jobs listed on the interface for the target user. Users with diverse information needs can get the relevant job information from different types of interfaces.
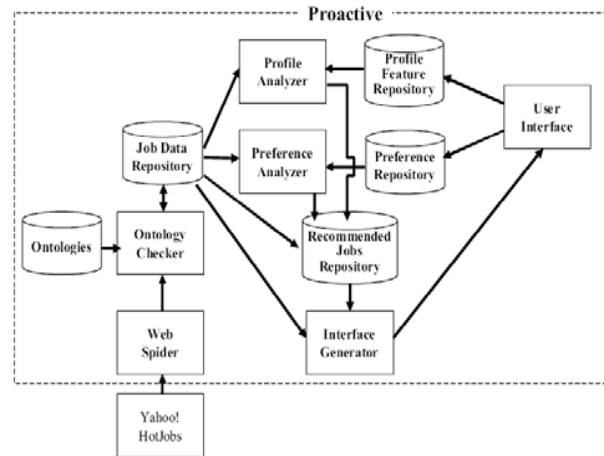

Figure 6. The architecture of Proactive system [16]

D. Absolventen.at

A job recommender for Absolventen.at has been implemented. Its full architecting process is demonstrated in [17], including requirements, architecture, user profiles and recommendation technique. The architecture for the job recommender system is shown in Figure 7. To enhance the performance of the job recommender system, it focuses on the hybrid user profiling. Besides the initial profile extracted from users' resumes, relevance feedbacks including explicit relevance feedback and implicit relevance feedback are integrated into user profile resulting in a hybrid user profile. So there are multiple different data sources for the job recommender system as input, for example the user's personal information and their behavior or actions. The selecting and processing methods of user profile are another key step of enhancing the performance. In this job recommender system, it observes and records the user actions in real time, provides different weights for features or actions based on their influences. At the same time, it should be possible to either ignore outdated actions from the history or to appropriately weight actions according to their interaction date. With the help of the corresponding recommendation technique, the job recommender system will provide a list of job positions which satisfy the job seeker's preferences or interests with more accuracy.
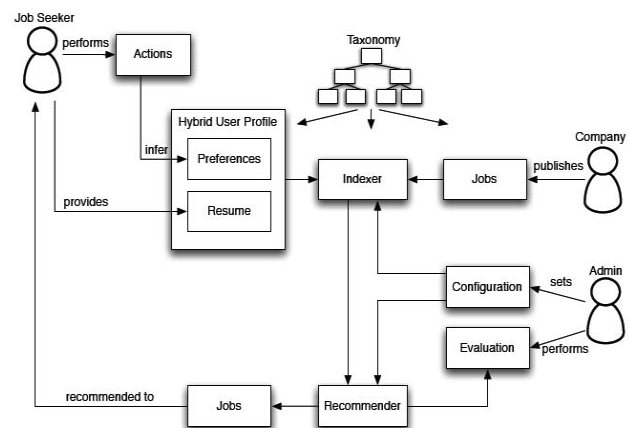

Figure 7. Architecture for job recommender system [17]

V. CONCLUSION

Personalized recommender systems have gained much attentions by researchers and been widely used in many domains in the last decades. The job recommender system is proposed for job seekers who search job positions and recruiters who find candidates on the Internet by applying the concept of personalized recommender systems into the job recruiting domain. With the study by researchers, several job recommender systems which have a certain application background have been implemented and generate the satisfactory recommendation results.

For a job recommender system, researchers focus on the user profile and recommendation technology at the aim of improving the accuracy and performance. User profile is the statistical foundation for the recommender system. For the user of a job recommender system, i.e. job seekers or recruiters, not only their personal information but also their behavior information are indicating their preferences and interests and can both be integrated into a hybrid user profile. The recommendation technology is the implement method of job recommender system. Besides the common recommendation technology, for example, collaborative filtering recommender, reciprocal recommender is an advanced recommendation technology and more and more attentions have been paid by researchers. Because of its advantages and effectiveness, reciprocal recommender will be mainly studied and applied in all kinds of domains, beyond the job recruiting domain.

In the future, we attempt to investigate the useful information about job recruiting and extract as much as possible information to generate the enrich user profile. Then we will study the principle of reciprocal recommender and introduce it into the job recruiting domain to propose a reciprocal job recommender system with the better recommendation performance and accuracy.

ACKNOWLEDGMENT

REFERENCES

[1] M. Montaner, B. Lopez, J. L. D. Rosa, "A taxonomy of recommender agents on the Internet," Artificial Intelligence Review, 19: 285-330, 2003.

[2] K. Yu, G. Guan, and M. Zhou. Resume information extraction with cascaded hybrid model. In Proceedings of the 43rd Annual Meeting on Association for Computational Linguistics, pages 499–506. ACL, 2005.

[3] G. Adomavicius, A. Tuzhilin, "Toward the Next Generation of Recommender Systems: A Survey of the State-of-the-Art and Possible Extensions," IEEE Transactions on Knowledge and Data Engineering 17 (2005) 734-749.

[4] J.L. Herlocker, J.A. Konstan, L.G. Terveen, J.T. Riedl, "Evaluating collaborative fltering recommender systems," ACM Transactions on Information Systems 22 (2004) 5-53.

[5] B. M. Sarwar, G. Karypis, J. A. Konstan, J. Riedl, "Application of dimensionality reduction in recommender system – a case study," In ACM WebKDD 2000 Web Mining for E-Commerce Workshop, 2000.

[6] J. G. Liu, T. Zhou, B. H. Wang, "Advancement of personalized recommender systems," Natural Science, 19(1), 2009.

[7] L. Pizzato, T. Rej, T. Chung, K. Yacef, I. Koprinska and J. Kay. "Reciprocal recommenders." In 8th Workshop on Intelligent Techniques for Web Personalization and Recommender Systems, UMAP'2010, Hawaii, USA, 20-24 June 2010.

[8] L. Pizzato, T. Rej, T. Chung, I. Korinska and J. Kay. "Recon: a reciprocal recommender for online dating." In proceedings of the fourth ACM conference on Recommender Systems, pages 207-214. ACM, 2010.

[9] J. Akehurst, I. Koprinska, K. Yacef, L. Pizzato, J. Kay and T. Rej, "CCR- A content-collaborative reciprocal recommender for online dating," In proceedings of the twenty-second International Joint Conference on Artificial Intelligence, 2011.

[10] F. Diaz, D. Metzler, and S. Amer-Yahia. Relevance and ranking in online dating systems. In Proceeding of the 33rd international ACM SIGIR conference on Research and development in information retrieval, pages 66–73. ACM, 2010.

[11] L. Pizzato, T. Rej, K. Yacef, I. Koprinska, and J. Kay. Finding someone you will like and who won't reject you. User Modeling, Adaption and Personalization, pages 269–280, 2011.

[12] L.A. Pizzato and C. Silvestrini. Stochastic matching and collaborative filtering to recommend people to people. In Proceedings of the _fth ACM conference on Recommender systems, pages 341–344. ACM, 2011.

[13] R. Rafter, K. Bradley, and B. Smyth, "Personalised retrieval for online recruitment services," in Proceedings of the 22nd Annual Colloquium on IR Research, 2000.

[14] R. Rafter, K. Bradley, and B. Smyth, "Automated Collaborative Filtering Applications for Online Recruitment Services," in Proceedings of the International Conference on Adaptive Hypermedia and Adaptive Web-based Systems. 2000.

[15] J. Malinowski, T. Keim, O. Wendt, and T. Weitzel. "Matching people and jobs: A bilateral recommendation approach." In System Sciences, 2006. HICSS'06. Proceedings of the 39th Annual Hawaii International Conference on, volume 6, pages 137c–137c. IEEE, 2006.

[16] D.H. Lee and P. Brusilovsky. "Fighting information overflow with personalized comprehensive information access: A proactive job recommender." In Autonomic and Autonomous Systems, 2007. ICAS07. Third International Conference on, pages 21–21. IEEE, 2007.

[17] M. Hutterer, "Enhancing a job recommender with implicit user feedback," in Fakultät für Informatik. 2011, Technischen Universität Wien. p. 107.