A DOCTOR RECOMMENDATION ALGORITHM BASED ON DOCTOR PERFORMANCES AND PATIENT PREFERENCES

YONG-FENG HUANG[1], PENG LIU [1], QIAO PAN [1], JING-SHENG LIN [2]

[1] Department of Computer, Donghua University, Shanghai 201620, China
[2] RuiJin Hospital Computer Center, Shanghai Jiao Tong University School of Medicine, Shanghai 200025, China
E-MAIL: yfhuang@dhu.edu.cn, raining1127@qq.com

Abstract:

A doctor recommendation algorithm is proposed based on the doctor performances model and the patient preferences model, which aims at relieving the problem of doctor information overload and "reservation imbalance" of Shanghai Medical League Appointment Platform and helping patients to schedule a medical appointment successfully. The algorithm is designed via adding the characteristic of patient preferences to the framework of the doctor performances model, which is built with the Analytic Hierarchy Process method. At present, the recommendation algorithm has already been successfully applied to the Shanghai Medical League Appointment Platform. The algorithm is evaluated by patients' operation records and reservation records, and results show that the recommendations are reasonable, and can match the patients' reservation demands effectively.

Keywords:

Analytic Hierarchy Process; Doctor Performances; Patient Preferences; Recommendation Algorithm

1. Introduction

With the popularization and rapid development of Internet, the Internet services have pervaded every aspect of people's lives. Shanghai Medical League Appointment Platform (hereafter called appointment platform) is such a unified appointment platform established for the difficult problem of register [1]. It is set up under the Medical League Project hosted by the development center of Shanghai Shenkang hospital. Now the platform has covered 35 municipal hospitals and 5525 specialists to appointment. However, lots of patients, especially the first time patients, are bothered by how to choose a right doctor when there are so many doctors for reservation online. Besides, the appointment platform has a problem of "reservation imbalance". As the reservation resources are limited, and most of the patients prefer to make an appointment with the few famous doctors, it causes a phenomenon that most patients fail to reserve while there are many other doctors available, and then led to a low appointment rate. To solve these problems, it is urgent to present a valid doctor recommendation method.

Currently, the recommendation methods can be classified into the following three main categories: content-based recommendation, collaborative filtering recommendation, and hybrid recommendation [2]. The first one has a higher degree of accuracy but lack of diversity, and is only suitable for items similar to the ones the user preferred in the past [3]. The second one has a great diversity but needs massive historical data [4]. By combining the above two methods, the hybrid recommendation method is designed to overcome the limitations of each of them, which is studied and used extensively at present [5] [6]. There are three ways to combine content-based recommendation and collaborative filtering recommendation into a hybrid recommender system [7]: (1) Implementing the two methods separately and then combining their predictions. (2) Incorporating one method into the other method. (3) Constructing a general unifying model that incorporates both of them.

According to the analysis of appointment platform, we find that the reserve data is of a high sparseness. At the same time, the recommended item (doctor) has a clear classification as well as data attributes of the doctor's reception and appointment situation. So the paper proposes a new recommendation algorithm based on a hybrid model: at first, we analyze the situations of doctors' reception and appointment to build the doctor performances model using the method of the Analytic Hierarchy Process.; then model the patient preference based on the patient's current reservation and his historical reservation choices; Finally, conclude the doctor recommendation algorithm based on the doctor performance and patient preference models. The algorithm fully considers the characteristics of the appointment platform and avoids unfavorable factors like high data sparseness and cold-start. Most of all, it ensures the accuracy and diversity of the recommended result.

978-1-4673-4685-6/12/$31.00 ©2012 IEEE

Based on the doctor recommendation algorithm, we also design a doctor recommender system, which has been successfully used to the Shanghai Medical League Reservation Platform. The feasibility has already been confirmed by the patients' operation and reservation records. In the following page, we will gradually introduce the doctor performances model, the patient preferences model and the realization and the evaluation of the recommendation algorithm.

2. The model of Doctor Performances

2.1. The Method of Analytic Hierarchy Process

Analytic Hierarchy Process (AHP) is a qualitative, quantitative, systematic and hierarchical analytical method and can be used to resolve complex decision-making problems [8], which is extensively applied to the performance assessment [9] [10].

In this paper, we model the doctor performances based on the AHP model. The calculation steps are as follows:

Firstly, based on the criteria of doctors' reception and appointment situation, select proper performance evaluation index, build the hierarchical structure of the doctor performances model. Then refer to the 1~9 scaling theory, compare those various factors and get a quantitative judgment matrix;

Secondly, use the "root method" to generate the weight coefficients;

Finally, check the consistency of the judgment matrix; the weight coefficients are only valid as the matrix meets the Consistency requirements.

2.2. The Construction of Hierarchical Structure

The time-sharing appointment mechanism is adopted in the reservation platform, which means that patients can reserve the doctor at different time-spans of one day. In this paper, we make doctors' reception and appointment as the criteria level and use four sub-criteria to evaluate the doctors. In the same time period, the four sub-criteria are specified as follows: the reservation resources released by the doctors (referred to as reservation resources C), the appointment number made by patients with doctors (referred to as reservation number D), the number of resources when the doctor is on duty (referred to as the attendance number E) and the reception number of the doctors (referred to as the reception number F).

In this paper, we suppose the doctor performances (R) as the target level, the doctors' appointment(A), the doctors' reception (B) as the criteria level, the reservation resources (C), the reservation number (D), the attendance number (E), the reception number (F) as the bottom level, and the general hierarchical structure is shown in Table 1.

Table 1 the hierarchical structure

Target level	R			
Criteria level	A		B	
Scheme level	C	D	E	F

2.3. The Calculation of the Weight Coefficients

The judgment matrixes are obtained according to the survey and the opinions of experts in Shanghai RuiJin Hospital. In the following figures, ω denotes the weight coefficient calculated by "root method".

Table 2 the judgment matrix of doctor performances in the target level (R)

R	A	B	ω
A	1.0000	0.5000	0.3333
B	2.0000	1.0000	0.6667

Table 3 the judgment matrix of doctors' appointment in the criteria level (A)

A	C	D	ω
C	1.0000	0.1667	0.1429
D	6.0000	1.0000	0.8571

Table 4 the judgment matrix of doctors' reception in the criteria level (B)

B	E	F	ω
E	1.0000	0.1429	0.1250
F	7.0000	1.0000	0.8750

According to the consistency check, we get the consistency index of the above judgment matrix as $CR = CI/RI = 0$, which satisfied the requirement of the consistency check. Now the weight coefficient is valid. We can get the upper level factor by linearly weighting the weight coefficients and the bottom level factors, then repeat until the top level factor is obtained. Finally we gain the formula for the doctor performances as follows:

$$R = 0.0476 * C + 0.2857 * D + 0.0833 * E + 0.5833 * F \quad (1)$$

3. The Model of Patient Preferences

Due to different appointment needs of different patients, we need to model patient preferences to generate personalized recommendation results. In this paper, the patient preferences model is composed by the selected

department and preferred hospital of the patients when making a reservation. The selected department can restricted the recommended doctors in the same department, which can ensure the accuracy of the recommendation. According to the analysis on the historical statistical data of the reservation platform, 98% of the patients has reserved in only 1 or 2 hospitals. Based on those data, we can conclude the patients' preferred hospitals. Next we will grade the preferred hospitals. Considering the transitivity of the patient preferences, we set the patients' usually chose hospitals as the highest grade, followed by other reserved hospitals. Based on the principle of collaborative filtering [4], the hospitals reserved by patients who had made an appointment with the doctors in the same hospital show some correlations, and the higher degree of the correlation reveals the more valuable references. We rank these hospitals as the third grade. The rest are set to the fourth. Based on the degree of preference, we divide the hospitals into four grades (the higher grade means the more the patients prefer):

Table 5 the hospitals preferred by patients

grade	instruction
4	Hospitals chose by patients
3	Hospitals reserved by patients
2	Hospitals reserved by other patients who have reserved the current hospital, and rank by the correlation.
1	Other hospitals

4. The Realization of the Algorithm

In the pilot phase, the algorithm recommends other doctors in the same department to the patient only when chose doctor is not available. Algorithm is as follows:

Algorithm: the doctor recommendation algorithm for Shanghai Medical League Appointment Platform

Input: doctors chose by patients

Output: list of recommended doctors

Process:

(1) Judge whether the chose doctor is available. If it is, end. If not, go to the step 2;

(2)Based on the description of patient preference model in Table 5, figure out the patient's preferred hospital list;

(3)Based on the latest reservation data, calculate the available doctors' performances (in the same department with the chose but unavailable doctor) by formula (1).

(4) According to the results of step (2) and (3), the algorithm returns the list of recommendation doctors ordered by hospital preferred level descending then by doctor performances descending.

5. The results of Evaluation

This algorithm has been integrated in the appointment platform, is now put into use. By analyzing the patients' operation records and reservation records on the recommender system, we evaluate the algorithm.

(1)The analysis of the overall situation

According to the data recorded in the last four weeks, we evaluate the system from 5 aspects, which is shown in the following table.

Table 6 the overall situation

time	A	B	C	D	E
1	35.58%	50.02%	90.75%	18.22%	4.10%
2	35.15%	49.35%	91.22%	19.44%	4.84%
3	35.78%	51.06%	91.59%	19.50%	4.67%
4	36.38%	54.52%	91.00%	19.97%	5.70%

A: the reservation rate B: the ratio of patient's choices for a doctor without a reserved resource to patient's all choices C: the rate of coverage supplied by the recommender system, when there is no reserved resource for the doctor chose by the patient D: the ratio of the number of recommended doctors chosen by patients to the number of recommended doctors recommended by the system E: the ratio of the number of recommended doctors reserved by the patients to the total number of doctors reserved by the patients.

By analyzing the above data, we find that the reservation rate is almost 35% in the last four weeks, i.e. there are still lots of doctors who are not reserved. Besides, nearly 50% of the doctors that patients hope to reserve are not available. This phenomenon suggests two things: on one hand, the majority of the patients would prefer to few famous doctors. On the other hand, the patients are lack of information channel about the doctors. From the above Table, we can know that the rate of doctors' coverage recommended by the recommender system can reach 90% when the doctor chose by the patient is not available, and 20% of recommended doctors can be chose by patients, which suggest that the recommender system is effective. Besides, the ratio of the number of recommended doctors reserved by the patients to the total number of doctors reserved by the patients has grown up from 4.1% to 5.7%, which reveals the doctor recommender system is gradually accepted by more patients.

(2) The analysis of patients' distribution

In this paper, we divide the patients into first time patients and return visit patients. Random sample of the log of one week and the distributions of the patients are shown

as follows:

Table 7 the distribution of the patients

	The recommended doctors chose	The recommended doctors reserved
First time patients	53.4%	61.3%
Return visit patients	46.6%	38.7%

By analyzing the date in Table 7 we know that the first time patients would prefer choosing the doctors recommended by the system, and among the patients who reserve the recommended doctors there are much more first time patients too.

Based on the above analyses, we can conclude that the doctor recommender system proposed in this paper is reasonable, effective and is gradually being accepted by more patients. But for the return visit patients, they are more willing to make an appointment with the doctors who they have reserved before, which to some extent weakens the impact of the recommender system.

6. Conclusion

In conclusion, we have presented a new doctor recommendation algorithm based on the models of doctor performances and patient preferences. It can effectively relieve the problems of doctor information overload and "reservation imbalance". At present, the doctor recommender system has already been successfully applied to the Shanghai Medical League Appointment Platform successfully, and the results show it meets the patients' reservation needs well. The system is beneficial to the patients and can effectively improve the successful-reservation rate.

Acknowledgements

This work is supported by the Central Universities Fundamental Research Funds and Shanghai RuiJin Hospital.

References

[1] Ping He, Jingsheng Lin, and Ming Zuo, "Construction and Practices of Medical Alliance Reservation Services Platform", Journal of Medical Infomatics, vol. 32, no. 10, pp. 27-30, 2011.

[2] Gediminas Adomavicius, and Alexander Tuzhilin, "Towards the Next Generation of Recommender Systems: A Survey of the State-of-the-Art and Possible Extensions", IEEE Transactions on Knowledge and Data Engineering, vol. 17, no. 6, pp. 734-749, June 2005.

[3] Michael J. P, and Daniel Billsus, "Content-based recommendation systems", The Adaptive Web, vol. 4321, pp. 325-341, May 2007.

[4] X. Y Su and Taghi M. Khoshgoftaar, "A Survey of Collaborative Filtering Techniques", Advances in Artificial Intelligence, vol. 2009, 2009.

[5] Burke. R, "Hybrid Recommender Systems: Survey and Experiments", User Modeling and User-Adapted Interaction, vol. 12, no. 4, pp. 331-370, 2002.

[6] Burke. R, "Hybrid Web Recommender Systems", The Adaptive Web, vol. 4231, pp. 377-408, 2007.

[7] H. L Xu, X Wu, X. D Li, and B. P Yan, "Comparison Study of Internet Recommendation System", Journal of Software, vol. 20, no. 2, pp. 350-362, Feb. 2009.

[8] Zhonggeng Han, Methods and Applications of Mathematical Modeling, Higher Education Press, Beijing, 2005.

[9] Yulong Qi, "Research on Performance evaluation system by analytic hierarchy process", Journal of Xi'an Polytechnic University, vol. 22, no. 3, pp. 374-377, June 2008.

[10] Shaomei Yang, "Application of AHP to staff achievements evaluation", Journal of North China Electric Power University, vol. 22, no. 4, pp. 96-98, Jul. 2006.