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Optimal HMM Based Recommendation System For Teaching Faculty

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Abstract— The digital marketing paradigm has seen revolutionary change with the augmentation of recommender systems. The implementation of recommender systems in the fields of e-commerce, entertainment, digital publicity, healthcare, etc has boosted the business many folds. It has also improved the comfort and user experience through appropriate suggestions. However, these recommender systems have not been exploited much in the education field. This paper presents an intelligent recommender system based on machine learning to present a suggestion framework for the teaching faculty. It utilizes various performance indices to derive the recommendations which can greatly improve the overall education sector in terms of student's academic and research performance. The accurate recommendation in this paper is achieved by modified HMM framework where the tuning parameters have been optimized by particle swarm optimization (PSO). The performance of the proposed systems has been verified through the experimental study and the accuracy has been found to be more than 90%.

Keywords- Recommender Systems, Collaborative Filtering, Hidden Markov model, Changing Preference, Dynamic Models, Latent class models, particle swarm optimization.

I. INTRODUCTION

The radical change has been seen in the Education sector over the last few decades due to the advancements in the field of information and communication technologies. The digital transformation of the teaching and learning process has brought very encouraging modifications. The augmentation of conventional teaching methods with the new communication technologies has improved the learning characteristics of the students in terms of imagination and design thinking. The expectations of the students have also switched to very high level which has made the teachers to develop new skills like communication skills, soft skills, emotional quotient, technology friendly, etc apart from knowledge.

It has also changed the perception of educational administrators and academicians towards the teaching fraternity. The under-resourced institutions emphasize on utilize the knowledge and skills of teachers in a best possible ways. This paradigm shift has made the teachers to update themselves with the state of the art information, recent trends and high end technologies. To keep up with these fast paced changes in the education field, teachers need to have the tremendous will, ability and preparation. The challenges are variable depending upon the level of teaching like primary school, secondary school and higher secondary.

The requirements will be very different for professional courses like engineering, medical, pharmacy, management, etc. The theoretical and practical aspects which have to be covered in a subject while teaching are also dependent on the subject's requirements. The diversity in the delivery of content makes the process very complex. The education process followed for multi dimensional curriculum environment is of varying degree and the students taking the respective course are also of different level of intelligence quotient.

The performance evaluation of teachers has been done conventionally only on the basis of students' results. However, the changing paradigm has made it incomplete due to the diversity in the student's quality and their intelligence quotient, the performance evaluation of teachers through the results of students is quite unjustified in most of the cases. Therefore the requirement of a strategy to assess the performance of teachers through direct assessment parameters is the need of the complete teaching learning process.

Recommender systems have gained a lot of attention over the last decade because of its intuitive framework to present suggestions on the basis of the available information. It also offers a more personalized experience to the user. The potential of recommender systems can be exploited in the education field to present a suggestions and recommendations for the teachers. By identifying the areas where a specific teacher is good at and where he needs to improve, right teacher for a specific scenario can be utilized to boost the complete teaching-learning process. However, the dependency of this process of evaluation of teaching process through a recommender system on various parameters makes it a very complex problem.

This paper presents an intelligent recommender system using self adaptive Hidden Markov Model for the performance evaluation of the teachers in the educational institution. It also provides the recommendations on the basis of the evaluation and assessment. Various features like student's assessment, intake quality, innovative practices, experiential learning methods, etc to present a recommendation framework have been used in this work to derive the model for recommender system. The dataset used to train the proposed recommender and evaluate its performance and derived through the ERP of an educational institute. The major contribution of this research work is the implementation of self adaptive HMM based recommender system for the teacher's recommendation. The parameters of the HMM framework have been optimized through PSO so as to reduce the time complexity.

The paper is organized as follows: section II deals with the review of the existing techniques in the field of recommendation systems and teachers performance evaluation methods. The mathematical framework for the collaborative filtering used in the recommender system is given in section III. The proposed self adaptive HMM based recommender system optimized with PSO is discussed in section IV. Section V discusses the effectiveness of the proposed strategy through the analysis of the performance parameters while section VI concludes the paper.

II. RELATED WORK

Many researchers have addressed the complex problem of teacher assessment in the field of education. Various techniques like statistical, stochastic and intelligent frameworks have been proposed over the last few years on the basis of different parameters which can directly or indirectly affect the performance.

Several research papers are discussed in this section to identify the advantages and drawbacks of the various strategies presented in them. The cumulative analysis of the drawbacks results into the research gap and the rationale henceforth. The research work addressing the problem of teacher evaluation and various state of the art decisions making algorithms are discussed below:

Fletcher et. al. [1] proposed a competence evaluation framework on the basis of rewards based model through variety of activities. These activities and parameters reflected the potential of the teacher in their work. Various activities conducted by the authors to evaluate the competence are performance appraisal, performance evaluation and review, performance assessment through measurement, employee evaluation, personnel review, staff assessment, service rating, etc.

The evaluation framework was extended by Grote et. al. [2] to the performance analysis of employees on the basis of a different set of parameters. The analytical process evaluated various aspects of employee's career advancements like pay hikes, promotion, layoff, training and development, etc. The encouraging results of these assessment models have motivated Hamsa et al [3] to implement it to the performance evaluation of employees of educational organizations also. The scenario of some developing countries was taken to show the orientation of education of these nations. They have collected the academic and non academic performance of the students through information technological tools to create a large dataset. These datasets have been used to derive the statistical decision model which reflected the performance of students and teachers.

Iam-On and Boongoen [4] proposed a statistical analysis to evaluate the performance through learning management system (LMS), Student Information Systems (SIS), Course Management System (CMS) and local institute database. The derived model created a formal strategy to continuously keep a track of the progress of the teaching learning process. Migueis et al.[5] have applied data mining techniques to extract the hidden knowledge from the data which are of qualitative importance. Various aspects of education systems like identifying the slow learners and fast learners, deriving strategies for these learners, etc can also be micro-managed to improve the education system.

Altujjar et al. [6] and Zhang et al. [7] merged data mining and education system to proposed a novel term Education Data Mining(EDM). The huge amount of data generated in the educational institutes through the results of students, feedback and reviews of the stakeholders, etc have provided the motivation to implement EDM. The outcomes of these models have also encouraged the developing countries to frame their educational policies.

Pandey and Taruna [8] presented the adaptive technique for the teachers to change their strategies on the basis of the performance evaluation. The depth of data intelligence is explored by the authors to identify the hidden information in the data. Important aspects of EDM from the point of view of students by Thai-Nghe et al.[9]. They presented the benefits of EDM for the students for self evaluation and performance improvement through the analysis of their academic and non academic history to predict the future behaviour. The recommendation for the courses for any students could also be done using this approach.

Helal et al. [10] have used the set of features like scores of high school courses, assignments, grades, etc and compared them with the evaluation sheet of instructors to verify the correctness of the model. The participation of students on social media and their psychological characteristics are also considered to

explore the other dimensions of the features analysis. The detailed collection of features has presented a more accurate estimation of academic performance of students. This in turn could be of use for the teacher's appraisal analysis also.

III. RECOMMENDER SYSTEMS AND COLLABORATIVE FILTERING

The recommender system is an intelligent model to drive the user experience and assist for decision making through the suggestions about the product. These recommendations are derived through the available information about various parameters which are been considered by other users while doing the business in the same domain. The problem of recommendation may be formulated as $f : U \times I \to R$ where f represents the utility function, U and I represent the user space and item space respectively which comprise of the features or attributes of the users and items. R is the set of predicted ratings represented as non-negative numbers. It is generated through the projection of f over the combinations of users and items. The most optimal value of u represented by $u_j^* = \arg Max_{j \in I} f(u, i)$ will be the recommended item for a specific user u.

The recommender systems use collaborative filtering for recommendation framework due to its capability to utilize the ratings of other users for the predictions and recommendations. These ratings and reviews are aggregated and analyzed systematically to present a reasonable recommendation to the active user. It works on the principle of similarity of liking among the clusters of users. Collaborative filtering is classified into two categories: User-user CF and Item-item CF. Concept of classification in user-user CF is the similarity of the ratings of various users. It relies upon the behaviour of user and their orientation towards different items. It can be represented through the similarity function defined by $s : U \times U \to R$. However the time complexity of user-user CF suffers the problem of scalability in case of large number of users. On the other hand item-item CF utilizes the rating patterns of items and the respective similarities to predict the user's orientation towards the items. It is also found to be robust to the scaling issue and independent of the number of users. The similarity function derived in item-item CF is derived as $s : I \times I \to R$. Although both the methods of collaborative filtering are easy to implement and finds applications in various fields with reasonable accuracies, they are subject to some implementation constraints. User based method is found to be more suitable in the situation where the number of items are more than the number of users. However item based methods provide better performance in case where the number of users are more than the number of items. Item-Item CF is used in this research work for the teacher recommendation because the number of parameters used to evaluate the performance of the teachers is less than the number of teachers.

IV. PROPOSED METHODOLOGY

The proposed work comprises of a recommender for teachers of an educational institution depending upon various attributes. These attributes are qualitative as well as quantitative. The nature of these attributes is random because of the behavioral dependency of the stakeholders in the process. Therefore a probabilistic framework using Hidden Markov model is proposed in this paper. The HMM model is modified to make it adaptive in nature. The framework is continuously observed and parameters are modified on the basis of the error values. This way the model is made adaptive so as to deal with the operational dynamic

uncertainties. A stochastic model is presented to resemble the time varying user preferences in terms of joint probability as

$$p(U,I) = \sum_Y p(Y)\,p(U|Y)p(I|Y)$$
$$= \sum_Y p(U)\,p(Y|U)p(I|U) \quad (1)$$

It can be deduced from (1) that the occurrence of user and item within an observation space is independent event if the distribution of latent class (Y) is known for the observation space. This allows us to encode the entire preference of the user over the various items using the latent classes. The varying user preferences are mapped over the dynamic latent class model to derive the Hidden Markov Model (HMM). The overall HMM model is defined using various parameters like the initial state probability distribution for each user (π), transition probability table (A) and respective observation model. The initial state distribution model considered in this paper is derived as

$$\sum_u \sum_n p(Y_u^1 = n \,|\, X; \Gamma^{n-1}) \log \pi_n \quad (2)$$

Where Γ^{n-1} is the parameter estimation of previous iteration, Y_u^1 represents the latent estimate of u[th] user at first iteration and π_n is the probability distribution for nth iteration. $p(Y_u^1 = n \,|\, X)$ represents the summary statistics of the posterior distribution. Similarly the transition model derived in this work is given by

$$\sum_u \sum_{t=2}^{T} \sum_i \sum_j p(Y_u^{t-1} = i, Y_u^t = n \,|\, X; \Gamma^{n-1}) \log A_{ij} \quad (3)$$

where t resembles to the transition instance. The respective observation model is given by

$$\sum_u \sum_{t=1}^{T} \sum_j p(Y_u^t = n \,|\, X; \Gamma^{n-1}) \log p(N_u^t) \quad (4)$$

The three models may now be independently tuned to derive the maximum likelihood estimation. The overall HMM model is derived by adding (2), (3) and (4) which transforms the problem into an estimation of Maximum-a-Posteriori (MAP) estimates. Bayes' theorem can be used further to deduce the maximum posterior distribution. It also resolves the issue of over-fitting of the model with the outliers of the small training samples. The final prediction can be performed using the fine tuned observation model as given in (4). The parameters of the derived HMM model is then optimized using the particle swarm optimization. PSO is an evolutionary algorithm based on stochastic method where each particle is representing the possible solution for the HMM parameter optimization. The parameters are moved in the space after each iteration and the process continues till the best possible solution is not attained. The final solution is considered as the optimal weights of the HMM framework.

The optimal solution in PSO is derived through the following folmulation:

$$v[] = W \times v[] + c_1 \times r \times (p_{best}[] - present[]) + c_2 \times R \times (g_{best}[] - present[]) \quad (5)$$

And $present[] = present[] + v[]$ (6)

Here v[] represent the weight vector, W is the inertia weight, c_1 and c_2 are the acceleration constants. P_{best} and g_{best} represent the individual extremes and global extremes of the algorithms respectively. Variables r

and R are the random numbers ranging from 0 to 1. The weights calculation is done iteratively on the basis of present solutions.

The overall algorithm used in the proposed HMM based teacher recommender system shown below in algorithm 1.

Algorithm 1 HMM based Recommender system Algorithm

1. Collect the user data and Item data for the complete time T.
2. Initialize the model parameters π, A, Γ .
3. Compute the values of initial state distribution using the model given in (2)
4. Evaluate the transition model using (3)
5. Tune the observation model given in (4) through MAP estimates and modify the weights.
6. Derive the final estimates through the PCO model

V. EXPERIMENT ANALYSIS

The performance of the proposed recommender system was evaluated using the real time data of the teachers and other stakeholders from an educational institute. Various attributes of the teachers are collected as primary parameters like Job_skills (Qualification_ID, Exp_ID, Level_ID), User_skills (User_qualification, User_Exp), Research publications, etc. Some secondary parameters like feedback, ratings, student's marks, etc are also considered. The evaluation is performed for 4 teachers over these 10 parameters. The data is collected from over 1000 students and is converted into a large dataset. The qualitative features like the soft skills, communication skills, sensitivity, extracurricular aptitude is also considered while creating the dataset. The dataset is the used to train the proposed HMM based recommender system. The outcome of the proposed model consists of three classes, primary teaching, secondary teaching, higher secondary teaching, college teaching. The recommender system is expected to generate the outcome on the basis of these training attributes and should be able to classify that the respective teacher should be recommended for which level of teaching. For example, a teacher with doctoral degree, rich experience and good publication should be recommended for college teaching, but a teacher with graduate degree should be classified as a secondary or higher secondary teacher. The classes and the respective decision making however, is not a straight forward simple problem. It is indeed a very complex problem in nature due to the time changing behavioral attributes. The performance of the proposed model is evaluated in terms of various metrics like accuracy, precision and recall. It is also compared with the performance of some conventional recommendation frameworks like content based filtering, cost sensitive Collaborative filtering and hybrid recommender. Table 1 shows the comparative analysis of various techniques and shows that the proposed recommender is providing a better performance.

Table 1. Performance Comparison

Technique/metrics	Accuracy	Precision	Recall
Content based filtering	0.473	0.060	0.679

Cost sensitive Collaborative filtering	0.921	0.143	0.132
Hybrid recommender	0.509	0.089	1
Proposed Recommender	0.965	0.150	0.135

VI. CONCLUSION

A recommender system for teachers is proposed in this paper using the HMM framework to deal with the probabilistic distribution of the attributes. The recommendation is proposed on the basis of various primary and secondary parameters which directly and indirectly governs the characteristics of the teacher entity. The parameters like job skills required, user skills attained, research publications, feedbacks, ratings, soft skill, communication skills, students' assessment, etc have been considered in this work to evaluate the class of the teacher. The classification is made under the decision base including the primary level, secondary level, higher secondary level of college level teaching. The parameters of the HM model are optimized using the PCO algorithm to attain the best recommendation solutions. The HMM framework is made adaptive by tuning the weights with reference to the error. The performance of the proposed technique is evaluated in terms of parameters like accuracy, precision and recall. It is also compared with the other conventional techniques and found to be performing better than those techniques.

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