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Adaptive Recommendation System to Evaluate Teaching Faculty Performance using HMM based Collaborative Filtering

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Abstract— Recommender systems have completely changed the paradigm of digital marketing over the last decade. These systems have found a vast application in the areas of e-commerce, entertainment, digital publicity, healthcare, etc. The capability of recommender systems to estimate the interest area of consumers and suggest the suitable options have added a completely new dimension in this era of digital market. However, the application of recommender system in the education field has not been explored much. This paper presents an intelligent recommender system for the teaching faculty on the basis of various performance parameters. The recommendation offered by the proposed system can be of great impact on the overall education sector in terms of enhancing the student's academic and research performance. Collaborative filtering has been used in this work to derive the recommendation. 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, Changing Preference, Dynamic Models, Latent class models.

I. INTRODUCTION

Teaching has always been a very important and demanding profession as it plays a very role in the nation building, character building and humanity building. The growth in the information and communication technologies has changed the complete paradigm of education sector. The methods used for teaching has also been changed a lot as compared to the conventional education system. The expectations of the students have also switched to very high level. These expectations have motivated the teachers to develop various characteristics apart from knowledge like communication skills, soft skills, emotional quotient, technology friendly, etc. The perception of the schools or college administrators towards the teachers has also changed a lot over the last decades. The task of teachers becomes even more complex in the under-resourced educational institutions where the high end communication tools are not available to make the process efficient and insightful. These factors have made the teachers to keep on working on various aspects of the teaching-learning process. They have 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 framework used for the teaching of different levels like primary school, secondary school and higher secondary is also of different nature. The process completely switches to another level when it comes to the courses of professional values. 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 most important stakeholder in the teaching learning process is the teacher. The way a teacher is teaching the particular subject or course directly or indirectly governs the learning outcomes and course outcomes afterwards. The quality of delivering the course content is always expected to be in line and in synchronization with the program educational objectives. However, the course content and the complete framework can be finalized and ensured through detailed analysis and review, but the way the content is delivered or communicated cannot be ensured centrally. Therefore, it is utmost important to continuously evaluate the performance of the teachers to ensure the quality of content delivery.

As the educational framework followed conventionally in most of the countries is very much based on the quantitative assessment. The respective evaluation of the teachers efforts in teaching are traditionally been performed indirectly through the marks which the students have received in the examinations throughout the academic year. However, 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.

The role of teacher evaluation is only one component of a comprehensive teacher growth and development system. This system involves many stakeholders whose various roles and responsibilities aim to support and enhance student learning. The development of new systems of teaching and learning that

align student and teacher assessment with the ultimate goal of improving both is the need of the hour. Comprehensive systems of continuous teacher education and professional growth help teachers master content, refine their teaching skills, critically analyze their own performance and their students' performance, and implement the changes needed to improve teaching and learning. Comprehensive performance assessment systems provide targeted support, assistance, and professional growth opportunities based on teachers' individual needs as well as the needs of their students, college/schools, and districts.A recommender system is an intuitive framework to present suggestions to the user on the basis of the available information to offer a more personalized experience. It has been proposed and implemented in many areas like e-commerce, digital marketing, health care, etc. The capability of recommender systems to provide the optimal suggestions can be exploited in the education field to present a recommendation for the teachers for various specific cases and environment. The utilization of right teacher for a specific scenario can boost the complete teaching-learning process. It can even be used to identify the areas where a specific teacher is good at and where he needs to improve. 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 complexity has attracted many researchers to augment some intelligent strategy with the conventional methods to present an effective and efficient system. The quantitative parameters generated during the teaching learning process like the marks obtained by the students, quality of students intake, research efforts by the teachers, experiential learning, innovative teaching process, etc can be used in this system to derive a performance evaluation mechanism. Many statistical, stochastic and machine learning algorithms have been derived over the last decade and have been implemented successfully in variety of applications. The potential of these decision making framework has been proved through many of its applications in different fields of engineering.

This paper presents an intelligent recommender system using Hidden Markov Model for the performance evaluation and enhancement of teachers in the educational institution. This work utilizes various features like student's assessment, intake quality, innovative practices, experiential learning methods, etc to present a recommendation framework. 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 HMM based recommender system for the teacher's recommendation. The impact of the outcome of this recommender has the potential to improve the academic framework and student's performance many folds. Proposed model presents a personalized and customized recommendation to specific stakeholder over a particular time period. The common patterns of the preferences of the stakeholders in the educational framework have been identified in this work to utilize them for the effective and impactful recommendation. Various challenges have also been examined here to incorporate the unobserved preferences of the participants which evolve over time. These challenges are addressed and resolved by HMM which utilizes the adaptive emission component to derive the personalized recommendations using the global preference patterns.

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 HMM based recommender system 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

The importance of assessing the performance of the teachers in the education system has motivated many researchers to derive a framework for performance evaluation of teachers. The researchers have identified the parameters which can directly or indirectly affect the performance. Depending on these parameters, the researchers have presented several statistical, stochastic and intelligent frameworks to solve this problem. However the complexity associated with process due to number of independent variables with different degree has made the process very complex. 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] presented a rewards based performance appraisal model through variety of activities which reflects the competence of the teaching employees in their work. The activities involved in the presented framework are performance appraisal, performance evaluation and review, performance assessment through measurement, employee evaluation, personnel review, staff assessment, service rating, etc. The analysis however, in this work was analytical only without the use of scientific approaches.

Grote et. al. [2] extended this analytical approach to the performance evaluation of employees on the basis of a completely novel set of parameters. The performance metrics considered in this work are used for various organizational and promotional decisions. Various aspects of employee's career advancements like pay hikes, promotion, layoff, training and development, etc are decided through this analytical process. The results of this assessment process have shown very encouraging outcomes in terms of the growth and profits of organization.

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 authors have taken the case study of some developing countries to present an insight to show the direction of these nations in education field. The academic and non academic performance of the students has been utilized 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. Various learning management systems have been derived afterwards using these models.

Iam-On and Boongoen [4] have used the statistical analyzing tools to derive various resources to evaluate the performance through learning management system (LMS), Student Information Systems (SIS), Course Management System (CMS) and local institute database. These models helped in creating a formal strategy to continuously keep a track of the progress of the teaching learning process. However the statistical methods are subject to the disturbances and false information.

Migueis et al.[5] have applied the emerging field of data mining for the analysis instead of conventional statistical method. Data mining techniques have the potential to extract the hidden knowledge behind the data which are of qualitative importance. Various problems associated with the 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] proposed a novel term Education Data Mining(EDM) by merging fast developing interdisciplinary research areas in data mining and education system. The amount of data generated in the educational institutes through the results of students, feedback and reviews of the stakeholders, etc have provided a rationale to implement the potential of data mining with EDM. The performance of EDM however, is very much dependent on the social, cultural and academic behaviors. The outcomes of these models have also encouraged the developing countries to frame their educational policies.

Zhang et al. [7] have explored the potentials of EDM in deriving the strategies of educational policies for the nation building for any developing country. They have identified the importance of EDM in Perfect planning, evaluation, and assessment of their educational programs, changing teaching methods to improve the performance of their students, identifying the learning style of a student, identifying weak students at risk and take the corrective decision to prevent them from failure.

Pandey and Taruna [8] proposed the adaptive methodologies for the teachers to change their strategies on the basis of the performance evaluation. The analysis has helped them to identify the facilities and resources required for the efficient implementation of the strategies. Relevant complex problems have been tried to be solved through the results of EDM. The depth of data intelligence is explored by the authors to identify the hidden information in the data.

Thai-Nghe et al.[9] explored the important aspects of EDM from the point of view of students. 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 authors have also extended the analysis for estimating the best learning path for each student depending upon their performance. The recommendation for the courses for any students could also be done using this approach.

Khasanah [10] presented the various techniques and algorithm to build the recommender system. They also introduced various modern recommendation approaches such as context-aware approaches, Semantic based approaches, cross-domain based approaches, peer to- peer approaches and cross-lingual approaches. Mohamed Ahmeda et.al.[11] proposed a conceptual framework to analyze teacher evaluation. It elaborates on the main components of a comprehensive teacher evaluation model and explains the main aspects to be taken into account for designing a teacher evaluation model.

The idea of the proposed work by Naser et.al. [12] was to investigate and analyze by considering various parameters for predicting the performance of faculty. The parameters considered are Faculty profile, Quality of Teaching, Maintaining Relationships, Learning Assessment, Counseling and Mentoring, Administrative Functions, Research and Development, Organizational Qualities and Outcome. This faculty performance assessment is observed to have helped in identifying better performing as well as poor performing faculty. Also the targets for the subsequent academic year can be set up with clarity and transparency.

Romero and Ventura[13] have extended the applications of EDM to monitor the learning curve of students, cluster the students on the basis of the learning ability, predicting the performance, etc. They have used the outcomes of this analysis to present the real scenario of the teaching learning process to the administrator. It helped in recommending the best suited faculty member for a specific course.

Helal et al. [14] 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 revolutionary growth in the field of e-commerce has made the recommender system a very important part of the process. The recommender system is a very powerful framework to drive the user experience while doing the business. It is an intelligent model to assist the user for decision making through the suggestions about the product which the user may like. The suggestions are based on the information about various parameters which are been considered by other users while doing the business in the same

domain. The design of a recommender system is not only about a software development, but it involves aspects of engineering like user experience, human computer interaction, decision support system, market and consumer behaviour, artificial intelligence, data mining, statistics, etc. Incorporating the features from various domains of business ecosystem to derive a recommender system is a very complex problem. Also the diversity in the respective ecosystem in terms of specific task, information and item domains presents a larger challenge to the problem of recommending as it is not a one-size-fits-all type of problem.

The problem of recommendation may be formulated as 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 will be the recommended item for a specific user u.

Collaborative filtering has attracted the attention of many researchers over the last decade for recommendation framework due to its capability to utilize the ratings of other users for the predictions and recommendations. The ratings and reviews of other users is aggregated and analyzed systematically to present a reasonable recommendation to the active user. The idea behind this method is that if one user of a group liked the quality or relevance of an item, then the other users of the same group are also likely to be interested in those items.

It has been classified into two categories: User-user CF and Item-item CF. The 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 . 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 . 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. 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 is the parameter estimation of previous iteration, represents the latent estimate of uth user at first iteration and is the probability distribution for nth iteration. 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 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 .
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.
6. Derive the final estimates through the MAP tuned 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 softskills, communication skills, sensitivity, extra curricular 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	0.951	0.148	0.130

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 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 performaning better than those techniques.

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