

RESEARCH ARTICLE

# Recommender System for Modelling Subject Combination in Ugandan Senior Secondary Schools

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## Abstract:

Subject combinations at A-level in Ugandan Senior Secondary Schools have made or marred the future career of many prospective students, many students have ended up doing courses they had not planned to do because they made wrong choices at their A-level. This recommender system offers the decision-making process for students based on their subject performance coupled with interest, passion, skills and talents to enable them make right choices. It is person-centred and there are three (3) main actors: the student (who are interested in making appropriate career choice), the documents (which contains available information about interest and passion, skills and talents and subject performances) and access metrics (which aids the student of A-level in extracting knowledge from available resources). A hybrid matrix factorization model using ANFIS and R were used to represent students and subjects as linear combinations derived from their characteristics and interactions, this is combined with rule-based model to offer a unified approach of presenting any student with a list of subjects that will lead to prospective career choices. This offer higher predictive accuracy in career choice matchmaking and overcoming challenges of parental influence, peer influence and others while expanding opportunities of career guidance in Uganda

Keywords: Uganda, Recommender, Subject Combination, Career, Matrix Factorization Model, Decision Making, R

## Introduction

Uganda Education is 7-4-2-3 system, seven years in primary, four years in secondary school, two years A-level in senior secondary school and minimum of three years in the university, to transit from one level to another, national examination are administered for example, at the end of elementary school, pupils are examined in 4 subjects in which all of them are compulsory namely English Language, Mathematics, Basic Science and Health Education, after the completion of O-level, 10 -12 subjects must be chosen out of the available 36 subjects while at the completion of A-level, students are expected to choose 3 subjects out of the possible 36 subjects and additional compulsory General paper[1]. Ugandan Senior Secondary Schools are evolving with several proponents that can improve teaching and learning so as to prepare students for their respective future careers but there are few limitations and challenges to optimally achieve the desired Millennium Development Goals (MDG) in education as a nation[2],[3],[4]. One of the composite functions of MDG and Education For All (EFA) is to make education accessible and available to the populace but this function cannot be achievable without relevant data and information that are to be analyzed in order to observe needs, gaps and missing objectives in the provision of education. One of such gaps or need is the procedure employed in subject selection for upper secondary school students which does not follow documented approach and hence need to come up with an appropriate recommender for students, guardian (parents) and other stakeholders in education. The government of Uganda recognizes education as a basic human right and continues to strive to ensure quality and affordable education is provided, however there are issues with funding, teachers' training, rural populations, inadequate facilities and others which continue to hinder the progress of educational development in Uganda, It is imperative to know that poor performance of A-level students can be reduced optimally if the subject combination matters are handled without prejudices. This research identifies all the existing problems and flaws in subject combination of Uganda Advanced Certificate Examination. Subject-Combination of A-level students in Ugandan schools has many of its attendant flaws which today's advancement in technology intend to improve upon or offer solution(s), many students have ended up enrolling for courses in institutions of Higher Learning which they had not intended to do or studied because they made wrong choices when choosing subject combinations at A-level or the choice are wrongly selected for them. In Uganda, there are three (3) categories of subjects in any combinations for courses in any university in the nation, each combinations has essential, relevant and desirable subjects, essential subjects are multiplied by 3, relevant subjects are multiplied by 2 while desirable subjects are either multiplied by 1 or  $\frac{1}{2}$ , these categories are determined by prospective course of study. For instance, medical student must have biology and chemistry as essential, physics and mathematics as relevant, others science subjects are desirable while law, mass communication are open to all subject combinations. Finding the right choice of career for A-level students is a tedious task considering African communities as one of the most disadvantaged because of corruption and self-centeredness hence a recommender

system is proposed to obliterate these flaws and challenges. Recommender system gives recommendation that is worthy of consideration which distinguishes it from Information Retrieval (IR) and offer personalized and customized responses to their respective users.

This recommender system will offer higher predictive accuracy in career choice matchmaking for students and greater emphasis will be on interest and passion, talents and skills and subject performance while challenges of parental influence, peer influence and others will be expunged, greater opportunities of career choice will be made available to students. It will handle distinct cases of career choice and match-make student which ever before now was only done based on subject performance [5],[6], [7]. Subject performance has only played significant role in choice of guiding prospective student in their future career. The intention of this recommender system is to proffer person-oriented mechanism that will not only consider subject performance but include students' potentials, special capabilities, talents, skills, interest and passion. This person-centered recommender will avail the student the opportunity to be personally involved and participate actively in the decision of what subject-combination can help in their future endeavors. As it was, the decision of subject-combination was always made without student participation which are often based on subject-performance or parental interest and influence. The ability to select subject-combination at A-level by Ugandan student will not only improve the quality of the educational system but also bring satisfaction to all stakeholders and motivate students in their future career. However, it is challenging for secondary school students in Uganda to determine their prospective subject-combination because there is no appropriate procedure which allow them to be solely involved that is, it allows them to make the choice of what subject he/she wants to offer in A-level.

This research aims to assist students, parents, teachers, career counsellor and community at large in transforming challenges in subject combination to opportunity to improve and transform the procedures and previous methods adopted. With this recommender system, career choice will be filtered based on preferences and potentials that a student possesses and it will be done without favoritism, the recommender will explore the three domain of Bloom's Taxonomy that is cognitive (based on subject performance), affective (based on passions and interest) and psychomotor (based on talents, skills and other physical potentials). A recommender makes relevant suggestions to the user depending on the profile of user and other peculiar information needed to make decision(s), these are done using various techniques and algorithms, A-level candidates in Uganda are the user, it will offer suggestion(s) to A-level students on their choice of particular subject combination from the pool of available subjects for different career choices, the idea in this research is to design hybrid system that combines strength of both collaborative and content-based recommender system for students, this is achieve by following parameters for choice of career which are underpinned by subject combination and other preferences.

## Research gap

The growing population in Uganda has place increasing demand on access to quality education and hence need to automate the subject combination of A-level students so as to assist them in making appropriate choices of career. Recommender system will offer and make all complex decision making processes

of subject combination using performance, potentials and interests [8], [9]. One of the challenges of A-level students is high failure rate which is mostly borne out of students offering subject combination outside their capabilities, talents, skills, interest and passion. Other challenges are parental influence, peer influence in offering subject combination without considering academic stamina and other domain of Bloom's taxonomy. Often times, most of A-level students in Uganda go for particular subject combination without prior knowledge of all what it entails whether it will suit their potentials and passion or not and sometime subject combination are selected for students without their consent which in turn greatly boomerang and restrict students to unmerited course of study in any higher institution, this research proposes recommender system that match make subject combination to favour any particular student by considering Bloom's taxonomy.

## Related work

Patient-Doctor Relationship – It does the required match making in any high-risk healthcare domain, with the advent of internet, several people use the internet to get information about diseases, diagnoses and treatments. A hybrid model was used to depict the interaction between patients and doctors and the results were adjudged to be universally acceptable in health care services [5]. This same approach was deployed in this research work but with different inputs in educational sector to proffer solution to prospective students in the choice of the subjects based on the aforementioned parameters.

Crop Recommender System for Farmers - The study contributes to farm yielding and improved productivity by making logical suggestions to farmers on which crop will bring better yielding at a particular location, weather conditions, and other preferences such as pesticides using Mamdani. This work is similar to recommender system for subject combination because suggestion, advice and selection of subjects that prospective student can perform excellently well in it or have the ability and skill for are proposed which invariably reduces the failure rates and increase the literacy level of Ugandans.

Fuzzy Inference Model, this system takes the farmer's location (state and district) and preferences like name of crop, season and other details were used as input which later suggests whether the farmer should go for the crop in that season by predicting the yield of that crop in that season and this is substantiated by the cosine similarity of querying farmer with all the farmers in the database[10]. This method differs from recommender system for subject combination in Uganda because fuzzification and defuzzication approach were not employed.

Implementation of an automated Job Recommender System based on Candidate profiles- It is a recommender system for online job seekers and gives recommendation that is worthy of consideration based on applicants' profiles, CVs, experience etc. It solves the key problem of just making prospective vacancies available online but creates job recommendation using user-based and item-based collaborative filtering algorithm to choose best fit offer for any job applicant that is widely used in IR coupled with method of similarity calculation (Cosine Similarity) and was implemented on Apache-Mahout [11]. The online platform of this recommender was culled out to be implemented in the recommender system for subject combination for the citizens of Uganda to have access to it irrespective of their location in real-time but the methodology differs.

## Research objectives

### *General objective*

To develop a subject combination recommender for A-level students in Ugandan secondary schools using Grover's algorithm for Information Retrieval from unsorted database of subjects.

### *Specific objectives*

- (1) To analyze various challenges facing A-level students in the choice of the subjects to offer out of 36 available subjects
- (2) To design an artefact for students, parents and society that will help in making logical decision on subjects to offer.
- (3) To implement the recommender in R.

## Research methodology

Analysis of the challenges facing A-level students in the choice of the subjects to offer is done, and it shows that performance of student's at A-level has drastically declined in recent year from 2006- till date as observed. Several criteria widely affected the performance of these students, some are scientific while others are not. The inputs in this research methodology were student's interest in particular subject, skills or talents coupled with academic performance in their O'level subjects. The source of the input data are the operational files, documents and educational policies that are found in the secondary schools and ministries supervising education. In this record of files, set of policies for admission, subject competencies, evidence of academic progression, status and procedures are found. The student is given unique ID as Registration/Admission number, their talents and skills, interest and passion were newly added to boost the recommender, interactions between students and subjects and recommend the subject(s) that they can be competent to offer.

A hybrid approach was used in this research in order to overcome many lingering weakness of collaborative filtering and content-based filtering which includes cold starting, data sparsity, overspecialization, scalability, serendipity. This subject combination recommender identified another alternative to help students to find information about subject(s) that can match up with their academic prowess, interests, skills, passion, talents etc. It assumes that there are set of students as Users of a system and set of subjects from all the available subjects for possible subject combination that can be recommended to Ugandan students in their A-level as *Items*, the utility function which measure the appropriateness of worthy option of consideration in subjects to offer or combination that is needed, subject  $i \in subjects$ , student  $s \in users$  which is defined as

R: *Students X Subjects*  $\rightarrow$   $R_0$  where  $R_0$  is represented by non-negative integers or real number. In case of recommending subject combination for each student to be able to get their individual utility functions for the subject

combination and choose one or a set of subjects  $i$  that will match make prospective future career  $R(u,i)$

$$\forall u \in Users, i = \arg \max_{i \in Items} R(u,i)$$

An hybrid matrix factorization model is built to represent subjects (items) and students (users) as linear combinations, we denote  $U$  and  $I$  as the number of users (students) and items (subjects) respectively and the student-subject combination interaction matrix  $Y \in \mathbb{R}^{U \times I}$  as:

$$y_{ui} = \begin{cases} 1, & \text{if interaction (student } u, \text{ subject } i) \text{ exists} \\ 0, & \text{otherwise} \end{cases}$$

Feature vectors are constructed from student and subject metadata, each student  $u$  is described as a set of features  $f_u \subset \mathcal{F}^u$  and each subject  $i$  is given by features  $f_i \subset \mathcal{F}^i$ . For each feature  $f$ , let  $e_f^u$  and  $e_f^i$  represent the  $L$ -dimensional latent embedding vectors for student and subject respectively. The latent representations of students and subjects can be presented as the linear combination of their latent feature vectors

Latent representation of student (user) is  $p_u = \sum e_f^u$  and Latent representation of subject (item) is  $q_i = \sum e_f^i$  and then matrix factorization learns  $p_u$  and  $q_i$  in such a way that the match making of unobserved entries  $y_{ui}$  is given by the inner product of latent student and subject representations:

$$\hat{y}_{ui} = g(u, i | p_u, q_i) \text{ which invariably equal to } g(p_u \cdot q_i)$$

where  $g(\cdot)$  denotes the function that maps student's performance, interests, skills and other natural instincts that invariably add up to select appropriate subject combinations for their future career. This hybrid factorization model offer multidimensional approach which provides additional contextual information on students and subject combination and supports multiple dimensions, profiling information and hierarchical aggregation of subject combination to A-level students in Ugandan secondary schools.

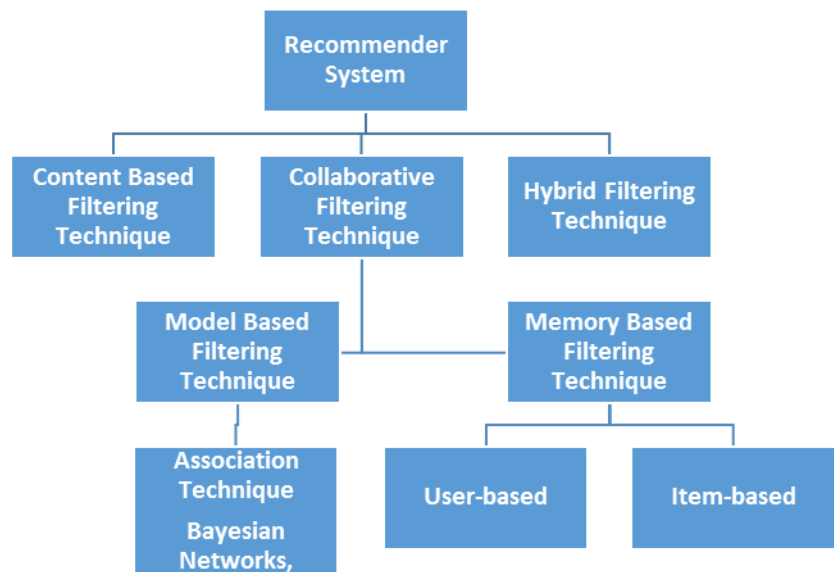


Figure 1: Classification of Recommender System Approaches

Hybrid filtering technique which combines content based and collaborative filtering techniques, many of their individual advantages were harnessed against their limitations [12]. This hybrid approach can be achieved in any of the following ways:

1. Implementation of Content Based and Collaborative Filtering Techniques are done separately and later the obtained results are combined.
2. Employing the properties of Collaborative Filtering Technique in Content Based Filtering method or vice versa
3. Developing a model that combines the properties of both Collaborative Filtering Technique with Content Based Filtering Technique.

As we are aware that the world around us is a large unsorted database and searching from random to exhaustive searching approaches have been archaic with the advances in technology coupled with parallel processing and quantum computation, Grover algorithm can aid searching of unsorted database with reduced computational resources such as time, power and other complexities, the reduction is such that  $O(N)$  queries of conventional searching techniques of  $N$  different entries (subjects) will be  $O(\sqrt{N})$  queries when quantum computational processes are adopted [13]. In this research, if subject for example, mathematics is being searched for in a database with  $N$  different subjects indexed by  $x \in [0, N-1]$  we are looking for  $x_0$  which points to the requested entry  $DB[x_0] = \text{mathematics}$  and consequently recommendation will be made whether to offer the subject or not based on the other parameters of recommender system. In search of better performance, combined recommendation techniques of hybrid recommender is built and adequate comparison of different hybridization of interest and passion and talents and skills are strategically done in R.

## Analysis and discussion

A model that combines the properties of collaborative technique with content based filtering technique is employed and implemented in R as a 3-dimensional plot which is represented with the “*persp*” function as shown in figure 2. The *persp* function requires vector  $u$  and  $i$  containing the coordinates of the grid over the subject combination as the density of bivariate normal distribution and evaluated as function for each pair for  $(x[u], y[i])$

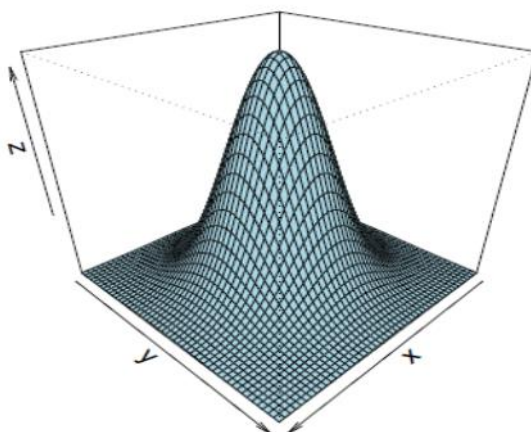


Figure 2: A 3-Dimensional plot represented by Persp function

This handled the inherent problem of information retrieval, subject recommendation overload and other sundry matter of subject selection for A-level candidates. This is done with ANFIS and R to offer personalized and customized services for these prospective candidates of A-level in Uganda. Suggestion on relevant subject that the student is likely to select in their A-level based on their preferences are done. The system generate suggestions for A-level candidate as diagrammatically seen in figure 3 about subject or predict the specific subject(s) based on the input provided which is directly proportional to the preferences of the student(s). The output as seen is either a recommendation or prediction on what is likely going to like or offer as subject(s).

The prediction represents the anticipated opinion of active student for the subject(s) and the recommendation is expressed as a list of N subjects out of 36 available that the active students are expected to offer based on their preferences.



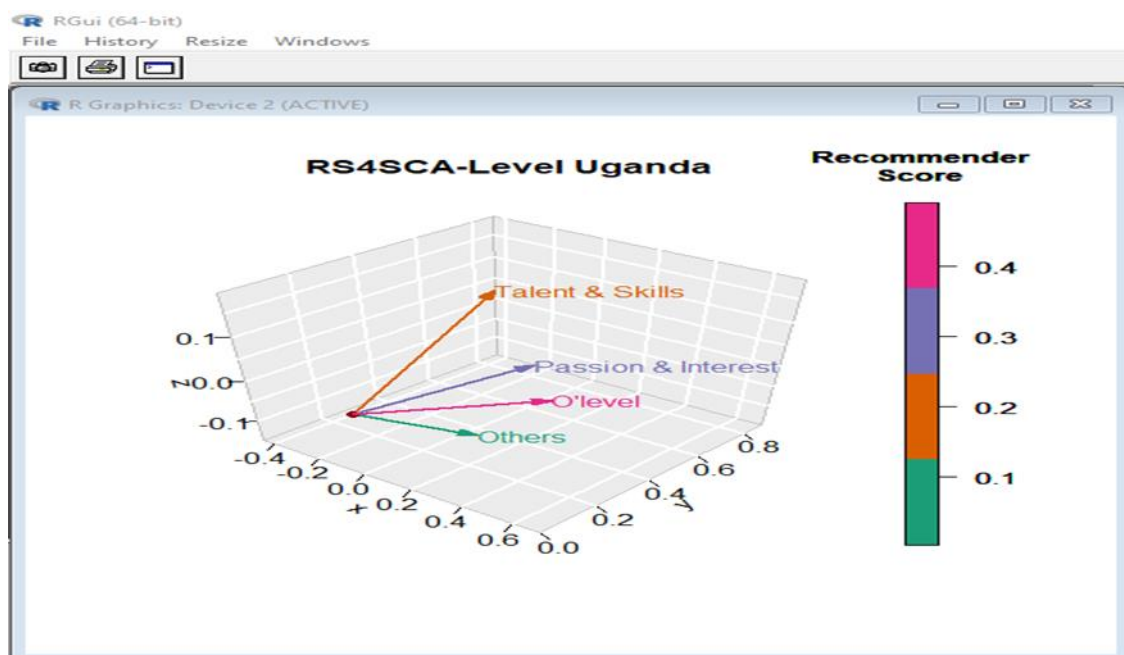


Figure 3: R implementation of Subject Recommender based on inputs

As observed in figure 3, z axis ranges from -0.1 to 0.1, x axis ranges from -0.4 to 0.4 while y axis ranges from 0 to 0.8. It shows that the talents & skills has more numerical value to recommend or predict a particular subject for A-level student for instance, a student with skills and talents of electronics (repair) can have Physics as being likely suggested subject for him/her to offer while passion & interest comes next to numerical strength of talents & skills, O-level subject performance plays lesser numerical significance and other.

## Conclusion

In conclusion, if this recommender system can only be deployed in the educational sector and the Ministry of Education in Uganda adhere to its use in selecting subject combination for A-level students, many of today's challenges in subject combination for A-level candidates will be obliterated and more excellent and person-oriented services will be provided to assist career guidance of future generations using ICT tools. Student-centered educational system as indispensable tool for the achievement of MDGs will be one of the frontiers to improve service-delivery to student, stakeholders and the populace. One of the challenges of transforming education and its delivery into more student-centered education is solved with this recommender system, as recommender system has found its use into all sphere of human lives and day-to-day activities, a scalable user's utility as an overview of recommendation, suggestion or prediction as the case may be are modelled to perform statistical computation seen in this subject combination recommender.

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