Curriculum GPS: An Adaptive Curriculum Generation and Planning System

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ABSTRACT

In educational systems, there has been an increasing interest for the innovative applications such as educational data mining and predictive analytics. These applications are utilized by the institutions for fulfilling academic missions and for improving the utilization of institutional resources. In this paper, we propose the “Curriculum GPS”, an adaptive curriculum generation and planning system, to provide a quantitative model and an interactive system that assists to grow and maintain programs with high retention and satisfaction rates in college, military or corporate education. The Curriculum GPS is composed of three main components: Curriculum analysis, historical data mining and an adaptive course sequence generation. The existing literature demonstrates how curricular efficiency correlates to student academic success in terms of graduation and retention rates. Therefore we first use an approach from the literature to analyze the curriculum under discussion as a directed graph by considering the conditions among courses such as prerequisite requirements. We conduct network analysis in this graph and compare our results with the catalog of courses currently in use. Then we combine this analysis with the historical data of the students and courses to train our model and develop our system’s database. The resulting system uses this training to create a set of quantitative recommendations for each student depending on her individual data such as passed/remaining courses, grades and time to graduate. The system also allows running what-if scenarios to test the outcomes of different choices by students. Therefore it is advantageous for students, instructors and advisors. The system is being developed for the Information Technology based departments of one of the largest universities in US by using the curricula and student datasets from the last thirty semesters. Initial results suggest this novel system provides both insight and improvement for the institutional education.

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INTRODUCTION

In education and training, there has been an increasing interest for the innovative applications such as educational data mining and predictive analytics. The institutions use these applications to fulfill their missions and improve the utilization of resources. With the advent of web-enhanced learning tools and smart data collectors, the amount and scope of data being collected at institutions has grown to the point of needing sophisticated software to manage it. The collected data is used to find and analyze the indicators of student or trainee success. The graduation and retention rates are two important indicators of a successful program for educational institutions. Therefore, there are various approaches to investigate the factors that affect the student or trainee graduation and retention. The development of support programs, effective assessment, curriculum design and advisory support are a few examples of these factors.

In this paper, we propose the "Curriculum GPS", an adaptive curriculum generation and planning system, to provide a quantitative model and an interactive system that assists to grow and maintain programs with high retention and satisfaction rates in college, military or corporate education. The three main application areas of the proposed approach are as follows:

- **Improving the curricular efficiency:** An important part of our approach is the development of methods for the investigation of the curricula. By detecting crucial courses and analyzing the important features of course networks, this approach helps administrators to make decisions on when to offer certain classes and how to structure the prerequisite relations of courses. This research component involves the adoption of the graph theory approach for curriculum mapping and extension of it according to the findings from the collected data and the requirements of the institution that we apply the model.

- **Determining the correct path for students early:** We develop a method to quantitatively determine the progress of a student according to the current school records. By using this method, the advisors will be able to intervene and redirect students to disciplines that would increase the success chance of the students and consequently the graduation rate of the whole institution. When the success ranking of a student can be expressed quantitatively, the advisors can redirect students to more appropriate disciplines. This proactive filtering increases the success rates of the students by placing them in the suitable discipline.

- **Detecting the student schemes:** We are planning to use the course, grade and graduation data to create different student profiles. The initial parameters of success are determined as the graduation grade point average (GPA) and the time to graduate. Availability of example for successful or unsuccessful student profiles will enable advisors to refer to these profiles when communicating to the students. Additionally, the student course selection paths can be used to examine what-if scenarios for student choices on various factors in college life.

Businesses of all kinds continue to integrate technology into their operations and as business and technology goals increase, demand for computer information systems professionals continue to rise in a vast range of career fields. Therefore institutions of higher education are under mounting pressure to improve their retention and graduation rates in computer and information technology related fields. Hence, the system proposed in this paper is currently being developed for computer science (CS), computer engineering (CpE) and information technology (IT) departments of the University of Central Florida (UCF) by using the curricula and student datasets from the last thirty semesters. The approach is intended to provide a quantitative model that assist universities to grow programs that lead to high-skill jobs in computer-related disciplines and increase the number of students completing programs in these high demand areas. The initial results suggest this novel system provides both insight and improvement for the institutional education.

The remainder of the paper is organized as follows. The next section summarizes the state of the art in the research field of our approach. We provide a detailed description of our approach in the following section. Then we present and discuss the experimental results. In conclusion, we give our concluding remarks and provide our thoughts on possible future work directions.

CURRICULUM MAPPING, ANALYSIS AND VISUALIZATION

The definition of student success broadens from graduation into student retention rates and time-to-degree. These factors are important since a certain portion of funding depends on student success metrics in many states. There have been various studies on the factors affecting the student success in institutions. Some discovered factors include the specific institutional processes and policies that help students graduate while minimizing student's actions.

Tinto (Tinto, 2006) stated that success is dependent on institutional experiences and that those satisfied with their experience persist and graduate at a higher rate than those who are not. Studies have identified the degree to which factors such as learning centers, freshman year programs, dorms, study rooms, etc. contribute to student success (Kuh, Kinzie, Schuh, & Whitt, 2011). Another institutional factor, which hasn't been studied extensively, is the design of the curriculums in the universities. Wigdahl et al. (Wigdahl, 2013) presents a method to show the effect of engineering curricula on the graduation rates, and the number of credit hours accumulated while pursuing a degree. They represent the curriculum as a directed graph, with each class as an individual node, and co/prerequisites as the edges between them. Then the effect of the course streamlining is shown by using network analysis, which has been an effective tool in understanding the connected structure in various education settings (Aldrich, 2015) (Akbas, Avula, Bassiouni, & Turgut, 2013).

The graph-theoretic approaches have been proposed to present the curriculums of raining program or college departments and training programs. There are approaches in the literature, which used this approach to analyze or improve curriculums. In most of these applications, the courses are defined as vertices in the curriculum graph. The edges are formed by the prerequisite and co-requisite relations among the nodes. Therefore, the curriculums form directed acyclic graphs. Lightfood (Lightfoot, 2010) uses a graph-theoretic approach to analyze the curriculum structure in educational institutions and identify the courses where a specific topic must be introduces or reinforced. The Active Curriculum of CS (ActiveCC) is a project of the Faculty of CS at the University of Vienna, where the curriculum is represented with a graph for a transparent curriculum service to students (Kabicher & Motschnig-Pitrik, 2009). Three layers form this graph: Semester, Core Modules and the Application Areas. Each layer is a graph within itself and there are also additional edges between the core modules and the application areas layers. The Curriculum Prerequisite Network by Aldrich also uses the graph theory to visualize the curriculum as a complex system (Aldrich, 2015). In this approach, the prerequisite binding is used as the relation between a parent node and child node in the directed graph. The corequisite binding makes it impossible to model the curriculum as an acyclic directed graph. Additionally, most of the times, the co-registration requirements are flexible and one of the corequisite courses can be taken earlier than the other one. Therefore corequisite binding is also modeled as a directed edge from one course to the other. Then several network analysis methods are used to find isolated groups of courses and the roles of the courses in the curriculum network. These analyses are used to offer curriculum modifications.

There are also approaches focusing on the visualization and the mapping of the curricula. Although they don't use graph theory to visualize or analyze the curriculums, these approaches also use a network structure to define the relationships among the courses. One such method is proposed by Siirtola et al. (Siirtola, Raiha, & Surakka, 2013) to analyze the curriculum overlaps. The method integrates the courses, themes and topics in a network with weighted edges. Siirtola et al. also implemented the approach as an interactive software tool to serve the need for curriculum visualization. However the prerequisite requirements of the classes are not taken into account. Visual Curriculum Advising System (ViCurriAS) is a visualization tool designed to map programs of studies (Zucker, 2009). It is composed of two modules; the course arrangement and the advising. The course management module allows the manual formation of curriculum by using courses and their prerequisite and corequisite relations. The advising module provides the advisor with the ability to enter grades or notes for each course of a student. Hence, it forms a visual map of student's progress in the existing curriculum. CurricVis (Gestwicki & Toombs, 2010) integrates the course network with an information browser by using SWI-Prolog and Graphviz libraries. CurricVis also includes a hypothetical mode to test different cases for course selection. Sommaruga and Catenazzi propose a three-dimensional (3D) visualization tool for the curricula (Sommaruga & Catenazzi, 2007). The tool uses multiple types of data and displays them as a 3D map. However the approach has no link information for the prerequisite requirements among the classes. Software for Target-Oriented Personal Syllabus (STOPS) (Auvinen, Paavola, & Hartikainen, 2014) is a tool created to serve higher education students by mapping their curricula according to learning outcomes. Different than our approach, STOPS mostly focus on the creation of study plans. Therefore the curriculum is modeled as a graph of learning outcomes instead of the only courses. Hege et al. (Hege, Nowak, Kolb, Fischer, & Radon, 2010) propose a similar learning objectives focused approach for Occupational and Environmental Medicine curricula.

CURRICULUM GPS

The Curriculum GPS is composed of three main components: Curriculum analysis, historical data mining and an adaptive course sequence generation. The existing literature demonstrates how curricular efficiency correlates to student academic success in terms of graduation and retention rates. Therefore, we first use the graph theory approach to analyze and visualize the curriculum under discussion as a directed graph and we consider the conditions among courses such as prerequisite requirements. We conducted network analysis in this graph for three higher education programs and compared our results with the catalog of courses currently in use at these programs. Then we combined this analysis with the historical data of the students and courses to improve our model and developed our system's database. The resulting system used this information to create a set of quantitative recommendations for each student depending on the student's individual data such as passed/remaining courses, grades and time to graduate. The system also allows running what-if scenarios to test the outcomes of different choices by students.

The network analysis of courses is conducted to understand the effect of prerequisite requirements. Each node in the network represents a course and a directed edge between two nodes represents a prerequisite requirement. For instance if course A is a prerequisite of course B, then there will be a directed edge from course A to course B in the network. The in-degree of a node is defined as the number of directed edges incident on a node. For instance, in Figure 1 the in-degree of CIS4524 is two. The out-degree of a node is the number of edges going out of a node. The longest path represents the longest sequence of classes that must be taken sequentially in a curriculum. For example, the path length would be two when the students would have to take physics classes in the order of PHY2053 followed by PHY2054. If a student fails in a class that the sequence requires, then she requires one more semester to get back on track. We have also calculated rigidity and identified important courses of IT, CS, CpE departments. The rigidity of a curriculum is calculated by taking the ratio of total number of pre requisites (number of edges) and number of nodes in a course flowchart (Slim, Kzlick, Heileman, Wigdahl, & Abdallah, 2014). As defined by Slim et al., the higher the number of pre or corequisites, higher will be the rigidity in a curriculum. The important courses are defined to have in-degree or out-degree above two or combination of in-degree and out-degree above three. Table 1 shows the rigidity related parameter values of CS, IT and CpE departments of UCF.

Table 1. Parameter values of CS, IT and CpE departments

DEPARTMENT	**CS**	**IT**	**CpE**
Total number of hours	120	120	128
Number of Edges	30	25	38
Number of Nodes	29	24	28
Edges/Nodes	1.03	1.04	1.357

The betweenness centrality is defined as the number of shortest paths from all nodes to all other nodes that pass through the given node. The total path length of a course is obtained by adding all the connections from given course to all other courses. The cruciality value of a course is calculated by multiplying the betweenness centrality of a node with the total path length of a node in course flowchart. (Slim, Kzlick, Heileman, Wigdahl, & Abdallah, 2014)

Figure 1. Network Structure of Courses shows the network structure of IT courses. COP3502, CGS2545, CGS3763, STA2023, MAC1105, MAC1114, MAD2140, PSY2012, PHY2054, PHY2053 are the courses with no pre requisites. PSY2012 is a pre requisite of COP4910 and COP4910 is a pre requisite of CNT4703. The out-degree of MAC1114 is four. The Curriculum GPS takes into account the cruciality value, average grades and the prerequisite requirement of all courses. The cruciality value indicates how critical a course is relative to other courses in the course flowchart (Wigdahl, 2013). For instance if the cruciality value of course A is larger than the course B then it means that the course A is more critical than the course B because of two main factors: (i) the delay in the graduation if student fails course A (ii) the role of the course in the network.

Our approach takes the "crucial classes" approach of Wigdahl (Wigdahl, 2013) and adds multiple options to refine the course selections for students. The Curriculum GPS takes into account the limitations on course offerings of the department and requirements of the program. It also has the flexibility of making recommendations to students with the number of courses that they prefer to take.

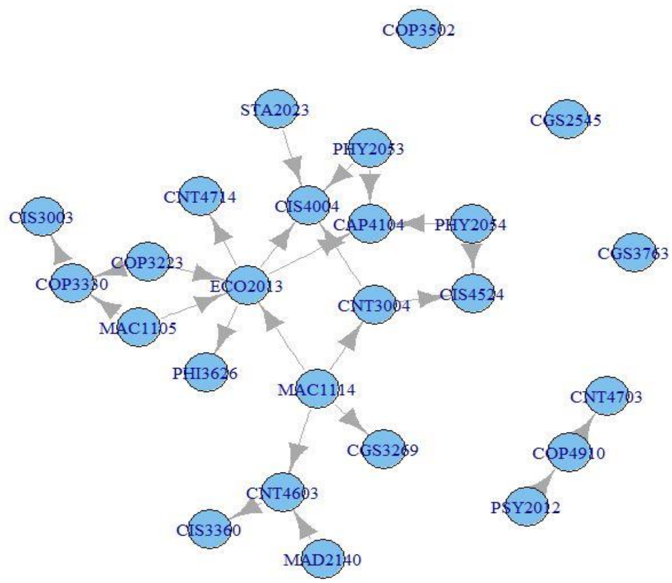

Figure 1. Network Structure of Courses

The current implementation of the curriculum GPS allows students to receive course recommendations in multiple levels based on the number of data types used. There are three main types, which are defined as "levels": (i) Level- 1 GPS: Course recommendation by using the cruciality values (ii) Level-2 GPS: Course recommendation by using the cruciality values and the average grades of the courses (iii) Level-3 GPS: Course recommendation by using both the cruciality values and the average grades with a higher weight on average weights compared to Level-2.

The data analysis complements the graph theoretical approach to create the curriculum GPS levels. For our data analysis, we used data of over 10,000 students of three computer-related programs of UCF. Specifically we looked into the details of the student, course and term data and studied relationships between the student academic progress and the order in which students take the courses. We calculated average grades, average number of retakes and average number of times course failures by a distinct user for all courses. The average grades are calculated by considering A, B, C, D and F grades (Inclusive of +/-) of students from summer 2004 to fall 2013. Withdrawal and Incomplete grades are neglected since they do not have any impact on grades.

Level-1 GPS

Curriculum GPS first finds the courses that has no prerequisites. If a student wants to take (n-2) out of n courses, then Level-1 GPS outputs the suitable courses by considering the cruciality values, the maximum number of courses that the student is allowed to take in a semester and the courses offered in each term. In the current implementation, after finding the courses with no prerequisites, Level-1 GPS checks the cruciality values of the courses and also the course offering term to find out whether the course is being offered in a semester or not. The n-2 courses with highest cruciality value is then presented to the student as the best selections.

Level-2 GPS

Level-2 GPS is an extension of Level-1 GPS. When the cruciality values of two or more courses are equal and courses has no prerequisite then the level-1 GPS picks the courses randomly. In Level-2 GPS, if a student wants to take four courses in a term then the system checks for the courses with no prerequisite and checks the cruciality values of the courses. If the cruciality values of two or more courses are equal then the system will look into the second selected data type. We use the grade point average (GPA) as the example data type. The student is provided with two choices when crucialities of two courses are equal. The student can either select the course with high or low GPA. Thus level-2 GPS simplifies the choices for the student. This course recommendation scheme allows student to complete the courses successfully by lessening the burden of taking difficult courses in a single semester.

Level-3 GPS

The Level-3 adds another type of comparison to GPS. In this level, we consider the percentage range for cruciality values, which gives more flexibility to the course selection compared to the Level-2. Similar to the previous level, if a student wants to take *n* courses, then the system starts execution by checking the prerequisites of all courses. Then the courses with no prerequisites are arranged in decreasing order of their cruciality values. The system takes the cruciality of the n^{th} course and prompts the student or advisor to enter the percentage range to include in recommending courses. The system calculates the cruciality range and selects all of the courses within that cruciality range. Then the courses within this list are advised to be taken according to their average grades. This system also helps 'students at risk', those who are in academic probation because of low GPA. The Curriculum GPS recommends courses with high average grades to those students to improve their GPAs.

Algorithm 1 Level 1 GPS

Define C_n to be the list of courses within a curriculum.
Define M to be the adjacency matrix representation of the curriculum
Let N be the number of courses students want to take in a semester
Let N_c be the number of courses in a curriculum
Initialize $t = N$
while C_n not empty and $t < N_c$ **do**
    Calculate cruciality C for all the courses in C_n
    Choose N courses from C_n with highest cruciality and that do not have any prerequisite
    Remove the chosen courses from C_n and M
end while

Algorithm 2 Level 2 GPS

Define C_n , N , N_c and t as in Algorithm 1
Define G to be the list of GPAs of all courses
while Cn not empty and $t < N_c$ **do**
  Calculate cruciality C for all the courses in C_n
  for all courses with no pre requisites
    if cruciality of courses are not equal **then**
      Choose N courses with highest cruciality
      Remove the chosen courses from C_n and M
    else if cruciality of n courses are equal out of N courses
      Choose *(N-n)* courses with unequal max. cruciality
      Remove the chosen courses from C_n and M
      for *n* courses
        Give options to
        Choose courses according to GPAs
        Remove the chosen courses from C_n and M
      end for
    else
      Give options to choose courses acc. to GPAs
      Remove the chosen courses from C_n and M
    end if
  end for
$t = t + N$
end while

Extensibility of Curriculum GPS and Test Scenarios

The Curriculum GPS considers cruciality value and average grades. The educational or training institutes may want to get course recommendations based on different parameters like course failure rates, course retake rates and course drop rate. The curriculum GPS is designed with a methodology that is flexible to include any number of parameters and their various combinations.

The curriculum GPS can be implemented using parameters like cruciality value and average number of retakes or cruciality value and average number of failures of each course. The system can also have more than three levels. In training environment, we can have the assessment results instead of grades as an additional level. Hence, the curriculum GPS would recommend courses to trainees by using the past assessment results and training requirements. The Curriculum GPS helps training management in deciding the timing to offer different courses and keeping track of curricula.

Algorithm 3 Level 3 GPS System

Define C_n , N , N_c , G and t as in Algorithm 2
while C_n not empty and $t < N_c$ **do**
Calculate cruciality C for all the courses in C_n
for all courses with no pre requisites
Choose the cruciality value C_i of N^{th} course
Create two sets A and B
A: List all the courses that are in the range of x percent of C_i of N^{th} course and (1+x) percent of C_i of N^{th} course
B: List all the courses that has cruciality greater than the C_i of N^{th} course
if N = courses in set B **then**
Choose all the courses from set B
Remove the chosen courses from C_n and M
else if N < courses in set B **then**
Choose all courses in from set B and remaining courses from set A according to GPA
Remove the chosen courses from C_n and M
else
Choose N courses from set B
Remove the chosen courses from C_n and M
end if
end for
$t = t + N$
end while

The Curriculum GPS also considers the cases where students wish to change the majors. By using the student data that we have, we designed Sankey student flow diagrams and noticed that many students change their major from CpE and CS to IT. We calculated the network rigidity for these departments and found that the rigidity of IT is smaller compared to other two departments. Some courses such as computer programming are common for both CS and IT. The Curriculum GPS takes the common courses into account if a student wants to change her major. Then the new path of courses is recommended according to program requirements and courses that the student has already passed.

We compared the results of our Curriculum GPS with the departmental course catalogs. The course catalog of IT suggests student to take courses in order as shown in Table 2. The curriculum GPS course recommendation is as shown in Table 3. The catalog suggests student to complete all the courses in eight terms. But if a student follows curriculum GPS course recommendations then the student will finish all the courses in seven semesters.

Table 2. Catalog Course Recommendation of Information Technology department

TERM 1	TERM 2	TERM 3	TERM 4	TERM 5	TERM 6	TERM 7	TERM 8
COP3223	COP3502	COP3330	CGS3269	CAP4104	CIS4524	CNT4703	COP4910
MAC1105C	ECO2013	PHY2053	STA2023	PHY2054	PHI3626	CIS4004	CNT4714
	PSY2012	CGS2545	CIS3003	CNT3004	CGS3763	CNT4603	
	MAC1114C	MAD2140		CIS3360			

Table 3. Curriculum GPS Course Recommendation of Information Technology department

TERM 1	TERM 2	TERM 3	TERM 4	TERM 5	TERM 6	TERM 7
MAC1105C	ECO2013	COP3330	CIS3360	CNT3004	CIS4004	COP4910
MAC1114C	PSY2012	MAD2140	CGS3269	CIS4524	CAP4104	
CGS2545	PHY2053	PHY2054	COP3502	CNT4714	CNT4703	
COP3223	STA2023	CIS3003	CGS3763	PHI3626	CNT4603	

EXPERIMENTS & RESULTS

Level 1 GPS

The cruciality values and average grades of IT and CS courses are demonstrated in Figure 2 and Figure 3. COP3223 has the highest cruciality value and CNT4603 has the highest average grades. The Curriculum GPS allows students to enter the number of courses that he/she is interested in. For example if a student enters three then the system recommends the student to take MAC1105, COP3223 and ECO2013. The level-1 GPS first looks into the prerequisite requirement and founds those ten courses MAC1105, MAC1114, STA2023, COP3223, ECO2013, PSY2012, CGS2545, MAD2104, CGS3269 and CGS3763 with no prerequisites then the system checks the cruciality values of these courses and then suggests COP3223, MAC1105 and MAC1114. In this way level-1 GPS suggests the courses term wise to the students.

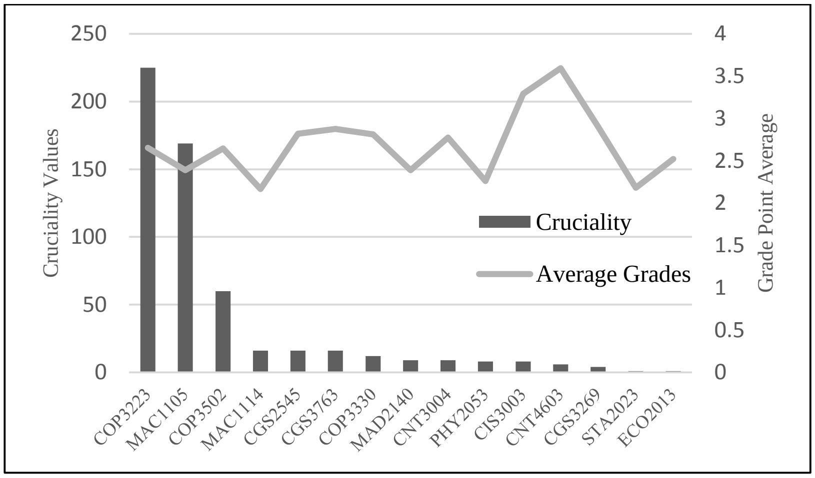

Figure 2. Representation of Cruciality and GPAs of Information Technology Courses

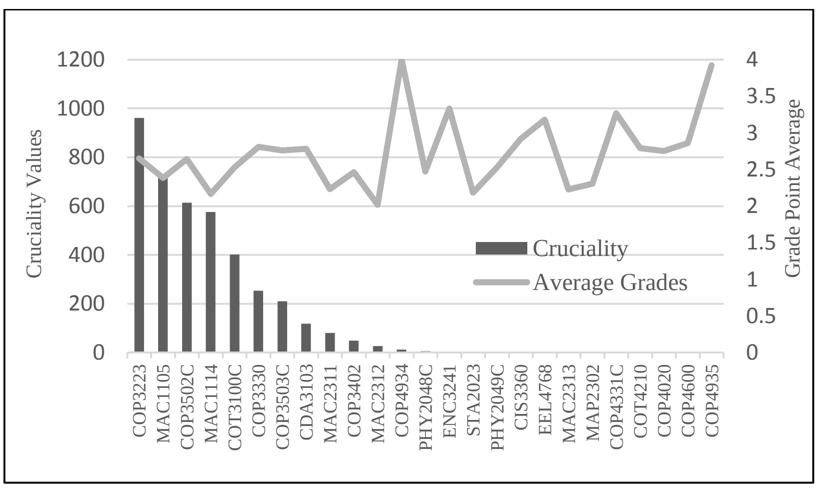

Figure 3. Representation of Cruciality and GPAs of Computer Science Courses

Level-2 GPS

The level-2 GPS first checks the courses with no prerequisites and finds ten courses with no prerequisites as stated in level-1 GPS. Then the system finds the three courses with highest cruciality and then the system checks if any of the cruciality values of these courses matches with the other courses with no prerequisite. In our example system finds that the cruciality value of MAC1114 is same as CGS2545 and CGS3763. Then the system checks the average grades of MAC1114, CGS2545 and CGS3763. The system recommends CGS3763 if student wants to take easy course (the one with highest average grade) and MAC1114 if a student wants to take the one with lowest average grade. Thus the system recommends student to take COP3223, MAC1105 and (CGS3763 or MAC1114) in first semester. Likewise the system recommends the student with appropriate courses for remaining semesters.

Table 4 shows the course recommendations of Level-2 GPS. If a student wishes to take four courses in first term then the system outputs two courses COP3223 and MAC1105 since they have high cruciality values and cruciality value of the MAC1114 in the list equals the cruciality value of CGS2545 and CGS3763. The system looks into the average grades of MAC1114, CGS2545 and CGS3763 and recommends student to take CGS2545 and CGS3763 (assuming student want to take courses with high average grades).

Table 4. Level-2 GPS course recommendations of IT department

Term 1	Term 2	Term 3	Term 4	Term 5	Term 5	Term 6	Term 7
N= 4	N=4	N=2	N=4	N=4	N=2	N=4	N=4
COP3223	MAC1114	COP3502	PHI3626	PHY2054	PSY2012	STA2023	COP4910
MAC1105	COP3330	PHY2053	CAP4104	CIS3360	CNT3004	ECO2013	
CGS3763	MAD2104		CGS3269	CIS4524		CIS4004	
CGS2545	CIS3003		CNT4603	CNT4714		CNT4703	

Level-3 GPS

Let's assume that student wants to take one course in first semester and he wants to consider 0.5 of cruciality value of first course then the system looks into the courses with no prerequisites and for these courses system checks the cruciality values. The system finds ten courses with no prerequisites in first run and since the cruciality value of COP3223 is high, system calculates the 0.5 of cruciality of COP3223. If a student wants to take three courses in the second term then the system finds the courses with no prerequisites and recommends MAC1105 (one with high cruciality value in a list of courses with no prerequisites) and then finds the 0.5 of cruciality value of third course in a list of courses with no prerequisites and recommends CGS3763 and CGS2545. Table 5 shows level 3 GPS course recommendations for IT department, where N is the number of courses per semester.

Table 5. Level 3 GPS course recommendations of IT department

Term 1	Term 2	Term 3	Term 4	Term 5	Term 5	Term 6	Term 7	Term 8	Term 9	Term 10
N= 1	N=3	N=3	N=3	N=3	N=3	N=3	N=2	N=1	N=2	N=1
COP3223	MAC1105	MAC1114	COP3502	CGS3269	CIS4524	CIS3360	STA2023	CNT3004	CIS4004	COP4910
	CGS3763	CNT4603	COP3330	PHY2053	CAP4104	PSY2012	PHY2054		CNT4703	
	CGS2545	CIS3003	MAD2104	PHI3626	CNT4714	ECO2013				

Comparison of level-1, level-2 and level-3 GPS

If a student selects level-1 GPS course recommendation system and he wants to take two courses in each semester then the duration of study will be 13 semesters. But with the level-2 GPS and level-3 GPS with 5% of cruciality value student will finish all the courses in 12 semesters. The level-3 GPS is different from the other two levels since level-3 GPS uses the percentage factor of cruciality value in course recommendation and the percentage factor of cruciality value depends on the student or the trainee that he want to consider in recommending the courses. In Table 6, level 3 GPS with 5% cruciality gives 12 semesters whereas GPS with 50% cruciality value gives 13 semesters.

The level-1 GPS doesn't consider additional parameters such as the average grades. Therefore, the course recommendation with level -2 and level-3 GPS are more detailed than the level-1 GPS. UCF hasn't used Curriculum GPS to change existing course curricula yet. We compared the results of curriculum GPS with the course catalog and noticed that student will graduate in less number of semesters if they follow course recommendations of curriculum GPS. The Curriculum GPS recommends courses with high average grades to those students who has low GPA and thus reduces the burden to students. Also course recommendation with average grade allows student to complete the courses successfully by balancing the number of difficult courses in the curriculum.

Table 6. Comparison of level-1, level-2 and level-3 GPSs

Course Recommendation system	Duration of study (Number of Semesters)
Level-1 GPS	13
Level-2 GPS	12
Level-3 GPS (with 5% of Cruciality)	12
Level-3 GPS (with 50% of Cruciality)	13

Applications of Curriculum GPS in Training

The advances in innovative training tools such as data analytics and simulation technologies have provided training systems with new methods (Farhoomand, 1994) (Soyler Akbas & Waldemar, 2013). In case of higher education, GPA can be considered as the evidence of successful learning. In training environment, certification and job performance are additional evidences of successful learning. The Curriculum GPS can be used to support trainees with the course selection and preferences. To have efficient job performance, training institutes must design curriculum and recommend courses to trainees efficiently. Our approach takes into consideration the average past performances of trainees and recommend courses accordingly. Sometimes trainees end up taking difficult courses in the first term when they have many options and might fail. In order to avoid such problems in course selection, curriculum GPS recommends courses in a balanced fashion in terms of difficulty and supports successful program completion.

The length of the learning process in case of higher education is approximately one to four years but in training the length may vary from several days to months. The Curriculum GPS can help trainees in recommending courses irrespective of the length of training process. The higher educational setting and training programs have series of courses to be taken by student/trainee in order to finish the program successfully. Both in higher education setting and training environment, most of the courses have prerequisite or corequisite requirements and curriculum GPS takes into account these requirements when recommending courses. There are examples for both students and trainees, where they fail to complete their programs because of wrong selection of courses or non-availability of sufficient information.

The curriculum GPS can be used as an advisory system for trainees as it is used in higher educational setting since the system can be arranged to balance the number of courses in each term. For example, curriculum GPS recommends trainees/students with the courses that have high average grades or low average grades. If a trainee wants to take two courses in a single term, then the system firstly recommends him to take the one which is a required core course considering the prerequisite requirements. The other selected class would be the one with high historical average grades. In this way trainee can concentrate on both the courses and can finish the term successfully. The big hurdle for both higher education and training management is the timing to offer certain courses. The curriculum GPS is designed in such a way that it is not only useful for trainees but also for management. Depending on the curriculum GPS course recommendations, the advisors can revise the curriculum and make the required changes.

CONCLUSION

In this paper, we propose the “Curriculum GPS”, an adaptive curriculum generation and planning system, to provide a model and an interactive system that assists to grow and maintain education or training programs with high retention and satisfaction rates. Our approach first analyzes the curriculum under discussion as a directed graph by considering the conditions among courses. In this graph, we conduct network analysis and compare our results with the catalog of courses currently in use. Then we combine this analysis with the historical data of the students or trainees and courses to develop our system’s database. Initial results suggest this novel system provides both insight and improvement for the institutional education. Although the system is being developed for the computer related departments of UCF, it can also be efficiently used in the training programs to improve the ability of management on how early they can predict the trend of a trainee’s performance and eventually improve the success rate and the learning experience. This is particularly important for training programs as they are generally shorter compared to higher education programs. The curriculum GPS recommends courses for trainees irrespective of length of the training and is flexible because the system allows trainees to decide on the duration of the training satisfying the training requirements. In addition to its potential impact on the functioning of institutions, this work addresses the questions of immediate interest both to advisors or the management and the trainees, which could potentially affect the policies at institutions. The system is currently being developed. Therefore, the future work includes the analysis of Curriculum GPS' impact at UCF. Another future direction is the extension of the system with other parameters such as the average number of retakes and average failure rates.

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