Concept of Recommender System for Building an Individual Educational Profile

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Abstract. The paper is dedicated to two issues connected with managing information and knowledge at higher educational institutions: students' decision-making processes; and individualization of these decision and, hence, of students' education. The author has made an attempt of developing a concept of a recommender system that should assist university students in making decisions as for their educational future (study programs, courses, research projects, scientific circles, etc.). The novelty of the recommender system is provided by combination of the algorithms used in its development, which are knowledge graph and text mining. The system's additional value for universities is guaranteed by the fact that it will contain a mechanism for evaluating the level of individualization of education at a particular university and provide recommendations on its increase. The paper presents author's suggestions as for the scale containing individualization levels and the set of criteria used for evaluation of individualization and level selection.

Keywords: Recommender System, Knowledge Graph, Text Mining, Individualization of Education, Student's Profile.

1   Introduction

In today's world, where education plays significant role in building a successful future of an individual, people of all ages are provided access to a variety of educational opportunities. Apart from higher educational institutions, large number of courses (online as well) and trainings are offered. However, traditional institutions like universities have not yet been replaced and are still the major source of knowledge acquisition for youth and adults.

Having a possibility to start university education (e.g. being able to pay for studies or having them free of charge; having high grades; having passed all the exams, etc.) does not mean having no problems with selecting a study program to enroll in. In order to make decision on such an important step in life, an applicant for studies (as well as a student) has to have access to all the information necessary for the decision-making. Besides, this information should be presented in a form that is clear and easy to be analyzed. Finally, a student needs to have freedom on drawing conclusions out of this information and making his/her individual decisions.

The author's motivation to study the problem of students' decision-making is justified by two factors. Firstly, higher educational institutions, trying to keep up with the pace of developing labor market, have recently introduced quite a few new study programs. Some of the topics studied within these programs may seem overlapping, which may be confusing for students when they make their choices. Secondly, with all the possibilities of work and education given to young people today, they feel the need of certain flexibility and freedom when making their individual decisions on what, where and even when they would like to study.

These factors lead to statement of two major problems the author would like to solve in the doctoral study. The first research problem considers the issue of helping students make their decisions by assisting them in their search of information on study programs, courses and other important things connected with their education. To solve this problem the author will try to answer the set of research questions: 1) What tool could be used to assist students in their decision-making process? 2) What functions would this tool fulfill? 3) How it will be implemented into the educational process at any university? 4) What will be the technical background of this tool?

The second research problem is connected with students' individual decisions on their individual education. When solving this problem, the author will try to answer the following research questions: 1) Can universities, in the forms they presently exist, provide students with individual education? 2) What could be the forms of individual education at higher educational institutions? 3) What are the ways of evaluating how individual the education is? 4) What are the ways of increasing the level of individual education provided by universities?

In order to solve the first research problem, the author is going to develop a prototype recommender system (hereinafter – RS or System) to be implemented into the didactic process of higher educational institutions. The author suggests development of the RS with application of two components: knowledge graph (hereinafter – KG or Graph) and text mining algorithms (hereinafter – TM). Combination of these methods is so far not very well studied in literature, that is why it is supposed to be the element of novelty in the doctoral research. This research paper is an attempt to answer the questions 1, 2 and partially – 4, of the first research problem. The paper presents the major functions of the recommender system and its general concept.

With the objective to solve the second problem set in the research, the author introduces the notion of individualization of student's educational profile: the degree to which students are enabled to make their own decisions and choices as for their education. In today's scientific literature individualization of education is discussed from a totally different perspective: mostly considering development of individual educational programs for children and adults with special needs. That is why research of individualization of students' decision-making within the educational process is also a novelty of this doctoral research. The paper is the author's attempt to answer the question 3 of the second research problem.

This research paper is structured as follows. In section 2 the author explores the major findings in literature on two topics: 1) development of knowledge graph applying text mining algorithms, and 2) individualization (and its evaluation) of education at

higher educational institutions. In section 3 the author describes concept of the recommender system for students and the major components of this system. Section 3 also presents the author's idea on using the recommender system for evaluating student's education individualization; the author's understanding of individualization is described. In section 4 the author highlights the major contributions of the research, points out limitations and inaccuracies, draws final conclusions and discusses directions for further research on the topic.

2   Literature Review

The author sees the novelty of the research not in development of the recommender system itself, but in two other issues: 1) data processing approach, applied in the system; 2) evaluation of individualization of education at higher educational institutions, which will be performed by the recommender system apart from its first function – assisting students in their decision-making process. That is why, the literature review focuses on two research issues: 1) combination of knowledge graph and text mining algorithms, which is planned to be applied in recommender system development; 2) individualization of education at higher educational institutions, which is planned to be analyzed and evaluated with the help of the developed recommender system. Results of the literature review and the revealed (if any) gaps will allow to state whether it is reasonable to develop the recommender system containing the above-mentioned functions.

2.1   Knowledge Graph and Text Mining

Since the key components of the recommender system (see part 3.2) are the knowledge graph and text mining algorithms, the author decided to focus firstly on reviewing scientific papers dedicated to the combination of KG and TM and to find out whether this topic is widely-considered in today's literature and, moreover, whether there is a gap in the topic which is possible to be filled.

To gather literature on the topic, the author investigated the scientific citation service Web of Science (WoS). In WoS two types of search were conducted (for publications in English language, from 2009 to 2019): 1) key words "knowledge graph" and "text mining" to occur together in the title of publication (TI=(knowledge graph AND text mining))[1]; 2) key words "knowledge graph" and "text mining" to occur together in the topic of publication (TS=(knowledge graph AND text mining)). With the 1st search option 4 research papers were found, while the 2nd one revealed 182 papers. In the second step of literature analysis the author examined titles, and then – abstracts of all the publications to find out whether each of them actually fits into the topic. Such filtering by abstract has reduced the number of papers in the 1st search section to 1 (from 4), and to 2 (from 182) – in the 2nd search section. Eventually, in the third step of literature analysis all the selected papers were thoroughly read and conclusion from

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[1]   Query within the framework of Web of Science Advanced Search rules.

each was drawn. In this step the total number of papers left after filtering was 3. These papers are enumerated in Table 1 along with short descriptions of their authors' contributions.

Table 1. Results of literature analysis (KG and TM)

Authors(s)	Contribution
[1]	Entity analysis for semantic knowledge graph development. Texts with entities are analyzed with TM algorithms.
[2]	Music knowledge graph. TM techniques applied to process large corpora of music-related documents.
[3]	Sematic graph built of key words to visualize document's nature. TM used to prepare texts for further processing.

The research papers selected by the author in the literature analysis (Table 1) are dedicated to the development of various knowledge graphs. In [2] the Graph is developed to represent texts about flamenco, Renaissance music schools and music criticism, while in [1] and [3] the Graphs are not claimed to cover any specific area. In these three research works algorithms of text mining are applied to process the selected set of texts (in one language, dedicated to one particular topic; in TM terminology referred to as a [text] corpus): to extract keywords, calculate word frequency and co-occurrence.

The author admits that the literature analysis conducted in the paper is not complete and suggests that with engagement of more databases more relevant research papers would be found. However, the fact that exploration of a highly-ranked scientific service gave so few results on the connection of knowledge graph development with text mining algorithms allows to state that so far this topic has not been researched well enough. This gap, in turn, allows the author to make an attempt to develop a new version of "KG+TM" combination and to apply it in the recommender system in educational sphere.

2.2 Individualization of Education

The second part of the literature review is dedicated to the issue of individualization of student's education and, first of all, to evaluation of its degree (see part 3.3). To explore literature on this topic, the following word queries were created in the WoS search engine (for publications in English language, from 2009 to 2019): 1) key words "individualization" and "education" to occur together in the title of publication (`TI=(individualization AND education)`); 2) derivatives of the word "individual" to occur together with the "education" in the title of publication (`TI=(individual* AND education)`). In the second step, as well as in part 2.1, the author examined titles and abstracts of all the publications. In the third step all the selected papers (from both queries) were thoroughly read, and conclusions were drawn. The 1st query gave 11 works, yet the second step reduced this number to zero. The 2nd query revealed 739 papers, and filtering in second step resulted in zero as well.

Such results are conditioned by the fact that the notion "individualization" is rather wide and can be both understood and used in various aspects. A large number of works found by the author in the Web of Science service are addressing the words "individual" (as an adjective), "individualized" and/or "individualization" in the two following aspects: 1) development of individual educational programs for people with mental and physical disabilities (as, for instance, in [4] and [5]) or with some other specific needs (as in [6] and [7]); 2) individual programs for children at schools or those being at homeschooling for different reasons (e.g., [8] and [9]).

Another group of research papers, distinguished by the author, covers the topic of development of individual approach towards education: interactive teaching methods, intensive work, various forms of motivation, etc. (for example, [10], [11], [12] and [13]).

It is clear that much research is done on the problem of individual education – the education adjusted to student's needs (physical, mental, moral, emotional or any other). Yet the author has not revealed any research works connected with individualization (and its evaluation) in a way the author considers it (see part 3.3). This opens to the author a large field of research and gives chances to come up with a new valuable idea. However, at the same time the author does not exclude the possibility that further research would include certain alterations in author's theory on individualization of education in order to specify what particular kind of individualization the author is exploring.

3 Recommender System in Education

3.1 Students' Individual Profile

The major objective of the authors research is to develop an information system, aimed at assisting students of higher educational institutions when building their individual educational profiles (hereinafter – Profile). Under the notion Profile the author suggests understanding student's portfolio, which covers: (1) description of the study program selected by a student; (2) obligatory courses within this program and (3) elective courses the students selects during the studies; (4) information on conferences the student attends and research papers he/she writes (if any); (5) topics of bachelor and master thesis and other research projects; (6) information on membership in any scientific circles; and (7) notes of other interests a student develops within the framework of his/her education.

This information system is supposed to be developed as a recommender system, that filters data in order to narrow down the information relevant for a user (student): based on his/her query [14], on his/her previous search results and/or on the data provided in his/her user's profile – for instance, age, year of studies, study program, topics of interest [15], etc. The RS is to help students by suggesting study programs, courses or any other educational activities on the basis of their preferences and, what is also important, by presenting all the available information in a clear and transparent form to make it easy for comprehension and analysis. By fulfilling the above-mentioned task, the RS

will enhance the knowledge management process at university from the point of view of students' decision-making.

In order to get a better view of the recommender system suggested by the author, firstly it is reasonable to consider its architecture in brief.
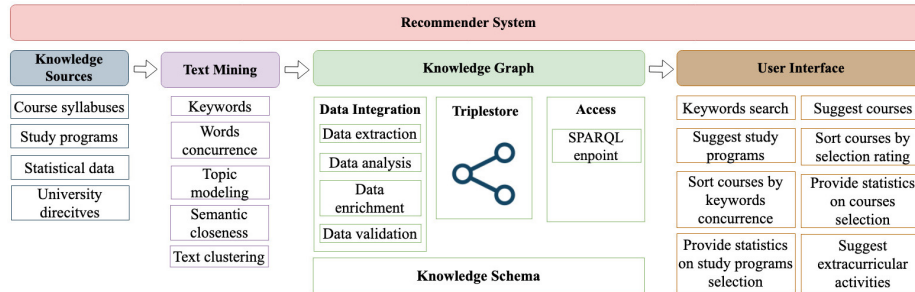
3.2 System architecture

Through the years of development of the theory about recommender systems, three major generations of the Systems have been formed [16]. The first-generation RS (1995-2005) are based on three major approaches: content filtering, collaborative filtering and hybrid methods. Its methods are statistical and do not consider users' personal preferences. The second-generation RS (2003-2014) are based on the context such as time, place, features like ratings of groups of users, etc. Research on this generation of RS are still being done, yet the third-generation RS are growing to be more and more interesting. These RS focus on semantic models of representation and use of all the knowledge components involved in the process of making recommendations.

The concept of a recommender system (as it is described further) applying text mining algorithms and taking into consideration user's preferences, as well as processing a large number of documents to cover all the information gaps, allows to state that the RS suggested by the author belongs to the third generation of recommender systems.

The users of the recommender system are students of higher educational institutions. Their preferences have major influence on the set of functional requirements that the System possesses. Except for a number of functions initially suggested by the author, the knowledge on important functions will be elicited from the questionnaire surveys conducted with university students. The stakeholder of the System is a university (represented by employees of an administration sector) where this system is implemented.

The architecture of the RS (as presented in Figure 1) contains four major blocks: Knowledge Sources, Text Mining [algorithms], Knowledge Graph and User Interface, which in the end form the System. Knowledge sources are the set of *input data* required for the RS development. These data include: *syllabuses of all courses* conducted at the particular educational institution; descriptions of all *study programs*; *statistical data* (number of students that selected a particular course or specialty, number of elective courses offered vs. actually conducted, etc.); *directives of an educational institution* as for developing and conducting courses and study programs, offering elective courses, gaining ECTS credits, etc. All these documents are gathered and systematized in advance.
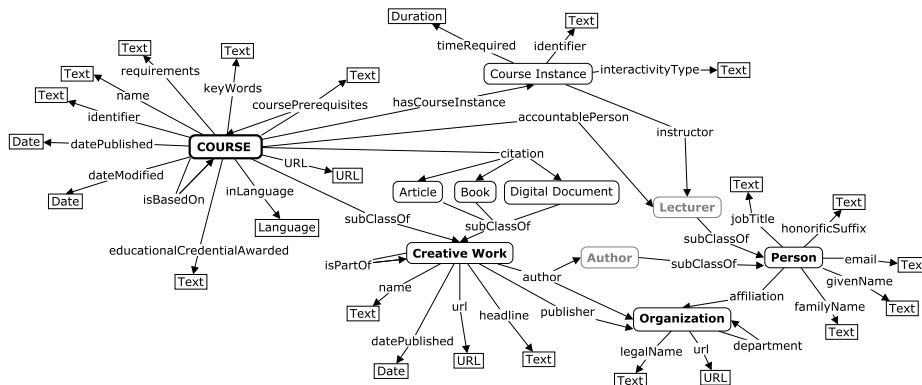
Fig. 1. Building student's educational profile: information system architecture
Source: own, based on [19] and [20]

The database of knowledge sources is further transferred to be processed by the text mining tools. Text mining is used to analyze documents from the source database and apply the results for performing user's queries in the RS. The TM algorithm may conduct the following tasks within the framework of the KG: contextual *keywords* selection, *word concurrence* retrieval (revealing the documents, in which particular words stand together more frequently), *topic modelling* (revealing the major abstract topics in each document), *semantic analysis* (finding the contextually close documents) and *text clustering* (creating groups of documents on the basis of their content similarity). Necessity to perform any of the above-listed operations depends on the type of query set by a user, as well as on the functions offered by the RS.

Once the data are prepared with the help of text mining algorithms, the knowledge graph comes into operation. It is the knowledge base of the RS [17]. The process of KG administration includes a set of tasks, which are performed successively or simultaneously. First, the input database is analyzed, and the necessary entities of data are extracted and relations between them are assessed. This is done to form the triples (subject-predicate-object) which are stored and retrieved in the database called Triplestore (also RDF Store). In the process of KG development, testing and improvement these data triples are also corrected and/or enriched. This can be a repeatable process since with the growth of number of users their requirements may increase, and it will require the input data to be updated. The update will be necessary in case of changes in any of the source documents.

To visualize the relations of entities in the Triplestore, the knowledge schema, which is referred to as a meta-layer of KG, is constructed. Such knowledge schema contains all the data about courses, study programs, university regulations, etc. (from the block Knowledge Sources). Figure 2 presents a draft knowledge schema, developed on the example of a concept of a university course. The schema is built using the Schema.org vocabulary of entities and their relations (RDF triples "subject-predicate-object").

Duration — timeRequired — Course Instance — identifier — Text — interactivityType → Text

Text — requirements — keyWords
Text — name
Text — identifier — coursePrerequisites — hasCourseInstance — accountablePerson — instructor
Date — datePublished — COURSE — citation
dateModified — URL → URL
Date — isBasedOn — inLanguage
Language — subClassOf — Article — Book — Digital Document — Lecturer — jobTitle — Text — honorificSuffix — Text
educationalCredentialAwarded — subClassOf — subClassOf — Person
Text — isPartOf — Creative Work — Author — subClassOf — email → Text
name — author — givenName
Text — url — headline — publisher — affiliation — familyName — Text
datePublished — Organization — Text
Date — URL — Text — legalName — url — department
Text — URL

Fig. 2. Knowledge schema of a university course concept
Source: own, modification of [17]

In order to make the knowledge graph actually work, a program code is further written, which contains a sequence of instructions, statements that generate triples, and, if necessary, some comments [18]. One of the options for such program code is to use the Terse RDF Triple Language, which is often used for presenting data in RDF models.

When the knowledge graph is built, the *Recommender System* is ready to be applied. What the users (students) get is a web application or a website, which offers a possibility to create personal user profile and provide information connected with the studies and/or personal interests. These data, as it was mentioned above, will be used by the RS to suggest the most relevant search results. The RS for building an educational profile has the following list of capabilities offered to a user (in his/her *user interface*), which actually make this system a recommender one: searching for courses and study programs by *keywords*; *suggesting courses and study programs* on the basis of student's interests and/or some keywords selected by him/her; show search results *sorted by frequency of a particular word* occurring in a course syllabus; show search results *sorted by frequency of selection by other students*; present *statistical data* on courses and study programs; suggest additional scientific and practical activities connected with a particular study program or course (*extracurricular activities*).

As it was discussed above, the recommender system is being developed as a helpful tool for students, especially those who face certain doubts when making choices as for their educational paths (study programs, elective courses, etc.). But, furthermore, the author supposes this RS to possess another function, which will not be visible for students (nor be used by them in any way) yet will be of use for university's knowledge management processes.

In connection with the above-stated, the author's further research on the recommender system architecture will be: 1) Expanding the architecture by developing the block responsible for evaluation of individualization (see part 3.3); 2) Preparing a complete set of documents to fill the Knowledge Sources block.

3.3 Evaluating Profile Individualization

The author supposes that the second function of the recommender system would be enhancing knowledge management at university from the point of view of individualization of education. Here it is necessary to refer to the above-mentioned individual educational Profile of a student. When we say "individual Profile" we mean some information describing a particular student (an individual) and we hardly could say that a student's profile is "more" or "less" individual. However, the author suggests measuring individualization of such a Profile, and, consequently, individualization of student's education. Under the notion *individualization* (in literature could also be referred as personalization [21]) the author suggests understanding the degree to which students get a possibility do make their own decisions as for their educational paths. This degree can be evaluated by answering a set of questions (a list to be completed): How many courses can students select based on their preferences? How many elective courses are they offered? What choices can they amend and how many times? How complete is the information provided by university's online resources? How relevant (up-to-date) is this information? What is the limit of ECTS credits? Can they modify their course schedule? How flexible can their class hours be? How can they fit extracurricular activities into their schedule?

The author suggests referring to this set as a list of *criteria of individualization.* The list of this criteria will be expanded by the author during further research. Yet, after being completed by the author, the content of the list still would be subject for verification and amendments, since it will be used by different universities. There is no doubt that these universities will differ by specialization, number of students and, for instance, language. At the same time, they will have different rules and procedures as for organization of didactic process. To adjust the recommender system to their demands universities will need to adjust the list of criteria se well – to select the most relevant and negate (or eliminate) the least important. Therefore, it can me stated that individualization of student's Profile is a multicriterial indicator.

Once this indicator is adjusted for a university, the RS will evaluate the level of individualization of a student's profile. As the result of evaluation, it will: 1) present the information in the textual and graphical form (data diagrams); 2) provide the administrator with recommendations as for the possible ways of changing (most likely – increasing) the level of individualization. The levels of individualization of student's educational Profile, as they are suggested by the author (a draft version), will form the following scale: 0 – Zero individualization; 1 – Initial individualization; 2 – Weak individualization; 3 – Medium individualization; 4 – Strong individualization; 5 – Absolute individualization.

This scale is based on the 1 to 5 Likert scale [22] yet is modified to match the particular evaluation process. The scale starts with *level 0* for universities with *zero individualization*: where students are not provided with any possibilities for making individual decisions. From level 1 to level 5 the scale evaluates the actual individualization – beginning from the very little steps taken by a university in this direction. *Level 1* characterizes universities with the *initial level of individualization* – when a university has only began implementing a certain policy on individualization and students already

have certain freedoms as for their educational path. Universities that have reached *level 5*, in turn, would have the *absolute level of individualization*: giving their students total freedom in selecting courses, forming their own schedule, choosing extracurricular activities, etc.

The author's further research on the evaluation scale will be dedicated to answering three major questions: 1) What are the qualitative and quantitative characteristics of the criteria of individualization? 2) How are these characteristics distributed between the individualization levels? 3) How are these characteristics transformed into recommendations for each of the levels?

4   Conclusion

The research paper presents the concept of a recommender system, developed to assist students of higher educational institutions in their decision-making process as for building their individual educational profile (portfolio). Approach to data processing, applied in the recommender system, is discussed in the paper, along with the major functions it will fulfill when implemented by a university.

The literature review on the issue of developing knowledge graphs with the usage of text mining algorithm has revealed that this topic has not been widely explored so far. This finding gave the author a gap in general research on knowledge graphs, which the author attempts to fill by suggesting application of knowledge graph and text mining in development of a recommender system for universities. In this suggestion the author sees the first contribution of the paper. This suggestion also allows to obtain preliminary answers to the questions 1 and 4 of the first research problem, stated in section 1 of the paper: what tool assists students' in their decision-making process and what is its technical background.

The second contribution consists in the fact that the prototype recommender system, concept of which is introduced in the paper, not only fulfills its main function (assisting students in the decision-making process), but also provides recommendations for university's administration as for the level (and ways of increasing) of individualization of education at the particular institution. Here the question 2 of the first research problem (functions of the tool) is answered.

It is necessary to add that the concept of a recommender system, in its present state, has a few minor limitations to be discussed. The major limitation the author sees so far is the specificity of each university were the recommender system can potentially be implemented. Even though the set of knowledge sources to be processed in the recommender system is set by the author, there is no doubt that these sources (in particular, course syllabuses and study programs) differ in their structure (template) and even content. In the stage of analysis of these knowledge sources the algorithm should be flexible enough to adjust quickly to the differences in the processed documents. The same above-mentioned specificity might be a minor limitation at the stage of evaluation of individualization. As it was stated, the System will be evaluating the level of individualization on the basis of criteria of individualization. Regardless the fact that these criteria will be defined in advance by the author, there will be a need to adjust them for a

particular university (e.g. number of students, rules for elective courses, etc.). Therefore, the recommender system settings should also be flexible in the stage of individualization criteria analysis.

The third contribution of this paper covers the scale of evaluation of individualization and (a draft) set of criteria for such evaluation. At the same time, this part definitely requires further development and verification. Thus, it is the first step of the author's further research. The scale needs to be completed with characteristics for each of the levels, and initial verification (on a small sample of universities) needs to be conducted. However, in this paper the author answers the question 3 of the second research problem, suggesting a draft set of criteria and a scale for evaluation of individualization.

There is a need to highlight one more important issue, discussed in the paper – the notion of individualization of education and its usage (and understanding) in today's research literature. Presently the author sees the major limitation of the research in the fact that the definition of individualization is rather broad and varies in literature (as it was revealed in the literature review, part 2.2). At the same time, this forms the major inaccuracy of the authors research idea. Further research on this problem as supposed to let the author come up with a precise notion that will represent what the author understands as the degree to which a student is given a possibility do make his/her own decisions as for the educational path (part 3.3).

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