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Automatic Approach for Comparison of Study Programmes

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Abstract.

This paper presents an approach for comparing study programmes in automatic way by using two software tools: (i) the IKAS system allowing construction of concepts maps representing curricula and their transformation into ontologies and (ii) the WebSmach tool allowing matching of the ontologies and providing visualization of comparison results. The results of our experiment on a real dataset of study programmes in some European universities show the effectiveness of the approach.

Keywords: concept map, ontology, ontology matching, study programmes comparison.

1 Introduction

Open and dynamic European educational area demands modern curricula, wide opportunities for student mobility, and corresponding academic recognition. However, in order to promote constructive and continuous improvements of study programmes across the Europe and to harmonize them with requirements of the labour market, as well as to identify possibilities for student mobility it is necessary to develop tools for comparison of curricula. It is obvious that such tools must be based on some kind of curriculum mapping. The mapping process represents spatially the different components of the curriculum so that the whole picture and the relations and connections between the parts are easily seen [1]. Results of comparison can be used in various ways, for example, for identification of possibilities for student mobility or lifelong education, creation of joint programmes, accreditation of new study programmes, etc.

The paper presents an approach for comparison of study programmes on the basis of concept maps and ontologies. Concept maps allow visualization of the structure of a study programme and facilitation of its perceiving by non-technical users, such as students looking for possibilities of mobility. Concept maps are constructed and then transformed into ontologies by using the IKAS tool [2], which provides a graphical

interface for manipulation of concept maps. Ontologies are used as an input for the matching tool WebSmatch [3] which compares study programmes and displays results. The main contributions of this paper are: (i) representation of study programmes by means of concept maps; (ii) an algorithm for transformation of concept maps into ontologies; (iii) an approach for comparison of study programmes by matching of the corresponding ontologies and visualization of the results in the form of clusters.

The paper is organized as follows. Section 2 describes how to create a concept map for a study programme. Section 3 gives an overview of the approach and describes the techniques used for curricula matching. Results of matching are reported in Section 4. Related works are presented in Section 5. Finally, Section 6 contains the conclusion.

2 Concept Map Based Representation of Study Programmes

Concept mapping is a pedagogical tool developed by Novak in 1970s [4] with the aim to facilitate student learning by presenting key concepts in a knowledge domain and relations between them in a graphical way. A concept map is a knowledge representation tool visualized by a graph consisting of finite, non-empty set of labelled nodes, which depict concepts, and finite, non-empty set of arcs (directed or undirected), which express relations between pairs of concepts. Linking phrases can specify kinds of relations between concepts. A proposition (concept-relation-concept triple) is a semantic unit of concept maps. It is a meaningful statement about some object or event in a problem domain [5]. Due to hierarchical nature of the structure of study programmes, the concept map of a curriculum can be divided into several levels:

- 1st-General level. It can consist at least of four main nodes. Three of them represent the name of the educational institution, the name of the structural unit implementing the study programme, and the title of the study programme. The last one labelled “Study programme” serves as a starting point for comparison process of two study programmes. Moreover, it is possible to add more nodes representing educational institutions or structural units if the study programme is joint by its nature;
- 2nd-Level of study years presents duration of the study programme;
- 3rd-Level of semesters displays incorporation of particular semesters into study years;
- 4th-Level of major field. Sometimes study programmes, after mastering of some general courses, allow students to choose a particular major field, for example, software design, computer networks, and so on. Each major field typically includes different study courses;
- 5th-Level of course groups presents grouping of courses on the basis of students' freedom degree to choose them for studying. Examples of groups are compulsory courses, free electives, restricted electives, and so on;
- 6th-Level of course titles displays particular courses included in the programme;
- 7th-Level of course topics presents specific topics forming a particular course;
- 8th-Level of concept maps of particular topics.

The described structure of a concept map for a study programme is shown in Figure 1. Here, the macro map is provided by levels starting from the general level and finishing with the level of course topics. In their turn, concept maps of particular topics represent micro maps.

It is necessary to note that for presentation of a specific study programme some levels can be omitted if the description of the curriculum is not complete or some concepts are not applicable at all, for example, major field. In order to be able to perform comparison of curricula at least at a shallow level, three levels must be presented: general level, study years, and course titles.

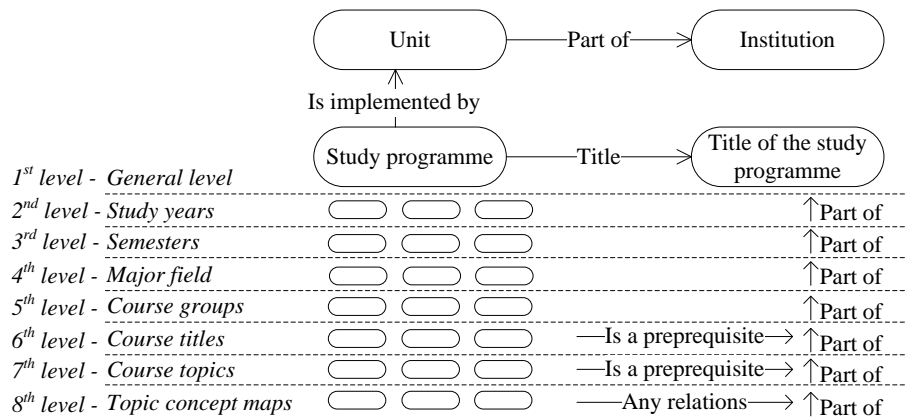


Fig. 1. Structure of a concept map for a study programme

The main linking phrase for relations between nodes at different levels is “part of” representing integration of particular parts into a whole: topics into courses, courses into groups of courses. Unique is the linking phrase “title” between the node “Study programme” and the node displaying the title of the study programme and the linking phrase “is implemented by” between “Study programme” and “Unit”. At the levels of course titles and topics, the linking phrase “is a prerequisite” can be added to relations to show that one course/topic must be learnt before the other one or, in other words, knowledge from one course/topic are essential for understanding of the other course/topic. At the eighth level, relations between nodes can be presented by any linking phrases because concepts of particular topics can be related in a variety of ways using not only standard linking phrases such as “is a”, “part of”, “has a value”, but also any linguistic phrases.

3 Comparison of Study Programmes

Figure 2 displays the proposed approach for comparison of study programmes using concept maps and ontologies. First of all, on the basis of the acquired descriptions of curricula, concept maps are constructed using the IKAS system [2]. The system provides a graphical interface for manipulation of concept maps. Secondly, using the same system, the concept maps are transformed into ontologies. After that, to perform

the comparison or, in other words, the matching between the resulting ontologies and to acquire clustering view, the matching tool WebSmatch [3] is used.

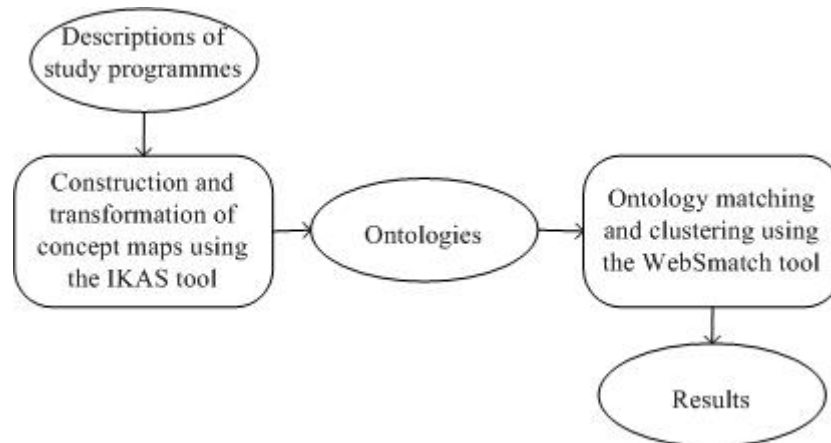


Fig. 2. The approach for comparison of study programmes

3.1 Transformation of Concept Maps into Ontologies

Correspondence between elements of the concept map and main elements/entities of OWL ontology is shown in Figure 3. A concept in a concept map can correspond to a class, an instance, a data type property and its value in the OWL ontology depending on a linking phrase which specifies a relation between two concepts. The linguistic and “part-of” linking phrases agree to the object property. The algorithm for transformation of a concept map into an ontology consists of seven steps [6] during which all elements of the concept map are handled to determine their correspondence to ontology elements. As a result, the appropriate ontology is constructed.

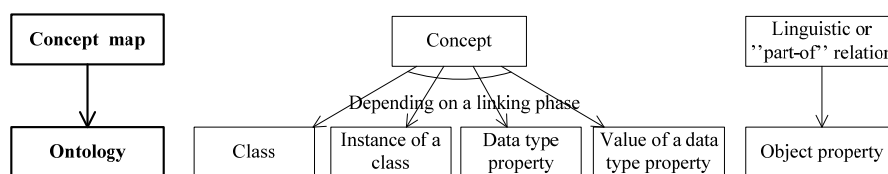


Fig. 3. Correspondence between a concept map and an ontology [6]

3.2 Discovering Correspondences between Study Programmes

Different techniques are used for discovering semantic mappings between ontologies representing study programmes. Each of them corresponds to an individual matcher that implements a single matching algorithm. Next, machine learning techniques are applied to combine individual matchers. Element- and structure-level approaches are

distinguished. The element-level approaches exploit information used to describe entities such as ID, label, and description:

- For ID matching, string and linguistic metrics are utilized to calculate similarity score between two IDs;
- For label matching (chain of words separated by blank spaces), the WebSmatch includes several linguistic metrics;
- For description matching, a profile for each entity in the ontology is constructed by gathering descriptive information of its related entities. A profile is viewed as a vector of weights of terms. Similarity of two entities is calculated by cosine measure of two vectors corresponding to entities' profiles in the vector space model.

The structure-level approaches exploit information about relations between entities. Methods which are used rely on the intuition that elements of two distinct ontologies are similar when their adjacent elements are similar [3]. These criteria are all developed and used as structure-level individual matchers in the WebSmatch tool.

3.3 Clustering Similar Study Programmes

Based on semantic mappings that were previously discovered between ontologies, the WebSmatch tool [3] automatically clusters the set of related documents (ontologies). The clustering process works as follows. First, it computes a distance between each pair of documents. More technically, a bipartite graph is built, where nodes from the left side are the attributes (metadata) of the first document, nodes from the right side are the attributes (metadata) of the second document, and edges are the matches between concepts. The weights over edges are the confidence values of the discovered matches. From this weighted bipartite graph, the maximum matching is computed. Then, this number is normalized by dividing this maximum matching by the minimum numbers of attributes between the first and the second document. From these distances between documents, a minimum energy graph model (adapted from [9]) is built, which represents the cluster structure based on repulsion between documents.

4 Experimental Results

To check the feasibility of our approach, an experiment was conducted over a corpus of sixteen variations of seven study programmes of five European universities (see Table 1). Figure 4 illustrates the result of the clustering service. There are five different clusters. Study programmes (ontologies) are in the same cluster if and only if they share some semantics links. Study programmes in the clusters have different diameters: the larger is the diameter, the more representative of the cluster is the study programme. Therefore, the largest diameter corresponds to the programme which is more related to other study programmes. The variations of the same programme differ only by few courses of restricted electives taken by students and/or information about learning outcomes. For example, in one variation of UR and RTU Business Informatics programmes the course descriptions are supplemented with learning outcomes. It

is therefore not surprising that all of RTU Business Informatics programme variations are considered similar and are included in the first cluster.

Table 1. Study programmes used in the experiment

Institution	Study programme	Number of variations	Names of variations
UR – University of Rostock	Master in Business Informatics	2	SP1; Rostock University, LO
RTU – Riga Technical University	Master in Business Informatics	5	SP3; SP4; SP5; SP6; Business Informatics Outlines, LO
	Bachelor in Computer Systems	5	SP7; SP8; SP9; SP10; Institute of Applied Systems, Bachelor
	Bachelor in Information Technology	1	Institute of Information Technology
UTCluj – Technical University of Cluj-Napoca	Bachelor in Computer Science	1	Cluj-Napoca, Bachelor
VU – Vilnius University	Bachelor in Computer Engineering	1	UV1-B
UL – University of Liege	Bachelor in Computer Sciences	1	UL-B

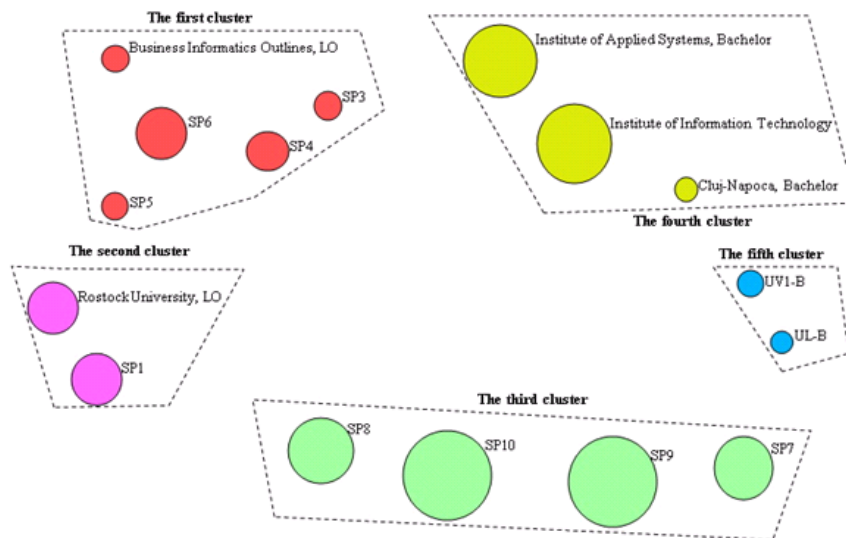


Fig. 4. Results of the experiment in the form of clusters

There is one exception. RTU Computer Systems programme with all restricted electives courses is included in the fourth cluster together with RTU Information Technology and UTCluj Computer Science study programmes. There is a strong simi-

larity between the structure and content of UTCluj study programme and both mentioned study programmes of RTU, which are essentially the same programme during the first two study years. The similarity between these three programmes is evident; however, it would be logical to cluster them together.

The fifth cluster is formed by the study programmes of UV and UL. There are some analogous courses between the mentioned programmes, however, actual similarity between UV and RTU Bachelor study programmes is more pronounced both structure- and content-wise.

5 Related Work

A number of concept map application outside learning have been already explored; inter alia curriculum planning and organization. According to [4], in curriculum planning it is necessary to construct a global macro map showing the major ideas planned to present in the whole course, or in a whole curriculum, and also more specific micro maps to show the knowledge structure for a very specific segment of the instructional program. In this direction, there are research studies concerning not only structuring of curricula, but also analyzing relationships between subjects and competences [8] and alignment of a local curriculum with state standards [18]. However, the comparison of study programmes on the basis of concept maps seems a quite new field, because no corresponding publications have been found.

Traditionally, in the context of curricula, ontologies have been used for competence categorization [10], categorization and description of knowledge used in different study programmes [11-12], construction of a study course and learning path, for example, [13-14]. Despite this quite wide use of ontologies in area of curricula and number of research in the field of ontology comparison, matching, and alignment [7], there is no evidence that ontologies have been applied for comparison of study programmes. Moreover, taking into account progress in development of advanced ontology matching tools, transformation of concept maps (which do not have such tools, but provide intuitive visualization of a problem domain) into ontologies is important in order to use ontology matching tools and methods for matching concept maps. Therefore, combination of ontology and concept map similarity [6] and already existing number of studies in ontology comparison makes background for research in this paper.

6 Conclusion

In this paper, we have proposed an approach that is aimed to perform comparison of study programmes in automatic way by using a matching tool. The approach consists of representing study programmes as concept maps and their further transformation into ontologies. Concept maps are chosen as the main instrument for visualization of the structure of a curriculum as they include only labelled nodes and relations and facilitate perceiving the structure of the curriculum by non-technical users who are

interested in comparison of study programmes. The approach is supported by two software tools: the IKAS system allowing construction and transformation of concepts maps and the matching tool WebSmatch performing matching of ontologies received from concept maps and providing the clustering service. The clustering helps to make results of matching more demonstrative and easier understandable. The results provided by the experiment are very promising and allow believing that this work is one step towards the support of student mobility.

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