CURRICULA COMPARISON USING CONCEPT MAPS AND ONTOLOGIES

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Abstract: *Development of tools for automatic comparison of curricula is of special interest and importance in the context of creation of open and dynamic European educational area as they have potential to promote constructive and continuous improvement of study programmes of different educational institutions and their harmonization with requirements of the labor market and international trends in corresponding sectors of economy, which, in its turn, can raise quality of education in general and facilitate student mobility in particular. The authors of the paper have developed an approach that allows comparison of study programmes in automatic way by performing four steps: representation of curricula in the form of concept maps, transformation of the concept maps into ontologies, matching of the ontologies acquired, and visualization of comparison results. The paper presents the first two steps of the approach and discusses the main concepts (concept map and ontology), related works, a general structure of a concept map for a study programme, process for construction of a curriculum concept map, correspondence between elements of concept maps and entities of ontologies, as well as an algorithm for transformation of a concept map into an ontology. Illustrative figures are included in order to show the conceptual structure of concept maps for representation of curricula, a fragment of the created concept map, steps of the approach proposed, and an example of an ontology acquired. At the end of the paper, main activities of future work are specified paying attention to the last two steps of the approach: matching of ontologies and visualization of results.*

Keywords: concept map, ontology, curricula comparison.

Introduction

A number of changes in political, economical, social, and, particularly, educational sectors of the European Union (EU) have been fostered by several documents issued during the last fifteen years. However, the Lisbon Strategy (Lisbon, 2000) is one of the greatest impact because it has defined the further development course of the EU by stressing necessity to become the most competitive and dynamic knowledge-based economy in the world. In 2005, the Council of the EU emphasized that the Lisbon goals of competitiveness and economic growth can only be achieved if young people entering the labor market are properly equipped through qualitative education and training in line with the evolution of society (Council, 2005). Moreover, taking into account movement of the Europe towards open borders and free flow of labor force, it is worth to point out that easy adaptation of new specialists in different labor markets depends not only on the quality of curricula but also on wide opportunities for student mobility (Anohina and Grundspenkis, 2008). According to (Associates, 2001), student mobility and accompanying academic recognition are assumed to be necessary prerequisites for an open and dynamic European educational area that will aid European integration and labor market mobility. In such a context, in order to promote constructive and continuous improvements of study programmes of different educational institutions and to adjust them to requirements of the labor market and international trends in corresponding sectors, as well as to identify possibilities for student mobility it is necessary to harmonize curricula of universities across EU and to develop appropriate tools for comparison of study programmes. 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 relationships and connections between the parts are easily seen (Harden, 2001). Results of such 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 (interdisciplinary and based on best practices), etc.

The paper presents the first part of an approach intended for comparison of curricula on the basis of concept maps and ontologies. The approach proposed includes four main steps: construction of concept maps of curricula, transformation of the concept maps constructed into ontologies, matching of the ontologies acquired, and visualization of matching results. The paper is devoted to the first two mentioned steps. Concept maps allow visualization of the structure of a curriculum and facilitation of its perceiving by non-technical users, such as students looking for possibilities of mobility. Ontologies are used as an input for the matching tool which compares study programmes and displays results of comparison. The algorithm for transformation of concepts maps into ontologies is developed, as well.

The paper is organized as follows. First, definitions of main concepts used in the paper are given. After that, related works are considered and construction of a concept map for a study programme is described. Then, the approach to comparison of curricula is discussed specifying transformation of concept maps into ontologies. At the end of the paper conclusions and directions of future work are given.

Preliminaries

Concept mapping is a pedagogical tool developed by Novak in 1970s (Novak and Cañas, 2008) with the original aim to facilitate student learning by presenting key concepts in a knowledge domain and relations between them in a graphical way. Therefore, a concept map is a semi-formal knowledge representation tool visualized by a graph consisting of a finite, non-empty set of labeled nodes, which depict concepts, and a 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 (Cañas, 2003). Regardless that initially concepts maps were developed for learning purposes, in this paper they are used for representation of a curriculum. That provides the following advantages:

- Concept maps offer a graphical illustration of a study programme and, therefore, facilitate perceiving of the structure of the curriculum which usually is given in textual or tabular format. This advantage is of great importance for non-technical users who are interested in comparison of study programmes, for example, students looking for possibilities of mobility or administration of an educational institution working on a joint study programme;
- The concept map of a curriculum can be easily developed because a study programme, as a rule, has the hierarchical structure of concepts with well-defined levels and the relation "part of" can be used as the main kind of relations between levels.

However, as it was mentioned before, concept maps offer only semi-formal representation, as their semantics is ill-defined and more formal notions are needed to provide fully automated processing of structures displaying curricula. Here it is necessary to note, that concepts maps are very similar to one of the formal knowledge representation schemes called ontologies (Graudina and Grundspenkis, 2008). It is easy enough to make transition from a concept map to an ontology (Graudina and Grundspenkis, 2011) and to use more advanced tools for analysis and matching. Nowadays, the term "ontology" is understood as a thesaurus and a taxonomy, as well as a more expressive knowledge representation schema with classes, their properties, individuals, and logical relations between them (Lassila and McGuinness, 2001). Ontologies have some structural similarity to concept maps, despite the fact that the ontology structure is much more expressive and more complex (Graudina, 2008; Graudina and Grundspenkis, 2008; Graudina and Grundspenkis, 2011). In the context of the paper, "ontology" is a knowledge representation schema formalized in OWL language (http://www.w3.org/TR/owl-features/).

Related works

Nowadays, concept maps are used not only for learning. A number of other application areas have been already explored, inter alia curriculum planning and organization. According to (Novak and Cañas, 2008), in curriculum planning, it is necessary to construct a global "macro map" showing the major ideas planned to present in a whole course, or in a whole curriculum, and also more specific "micro maps" to show knowledge structure for a very specific segment of the instructional program. In this direction, there are research studies concerning not only structuring of curriculum, but also analyzing relationships between subjects and competences (Riesco et al., 2008) and alignment of local curriculum with state standards (Heinze-Fry and Ludwig, 2006). However, comparison of study programmes on the basis of concept maps seems a quite new field, because no corresponding publications were found.

Traditionally, in the context of curricula, ontologies have been used for categorization of competences (Laborde et al., 2008), categorization and description of knowledge used in different study programmes (Chin et al., 2007; Cassel et al., 2008), construction of a study course and learning path, for example, (Kontopoulos et al., 2008; Chi, 2009). Despite this quite wide use of ontologies in area of curriculum and number of research in the field of ontology comparison, matching, and alignment (Ehrig, 2007; Euzenat and Shvaiko, 2007; Lin and Sandkuhl, 2008), 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 (Graudina and Grundspenkis, 2008; Graudina and Grundspenkis, 2011) and already existing number of studies in ontology comparison makes background for research in this paper.

Concept maps and representation of curricula

Due to hierarchical nature of the structure of study programmes, a 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 name of the educational institution, the name of the structural unit implementing the study programme, and the title of the study programme, accordingly. The last one labeled "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 in terms of particular study years;
- 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 study programme;
- 7th - Level of course topics presents specific topics forming a particular study course;
- 8th - Level of concept maps of particular topics.

The described structure of a concept map for a study programme is shown in Fig. 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 study programme is not complete or some concepts are not applicable to the study programme at all, for example, major field. In order to be able to perform comparison of study programmes at least at a shallow level, three levels must be presented: general level, study years, and course titles.

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, groups of courses into major field and so on until inclusion of study years into the whole study programme. Unique linking phrases are "title" on the relation between the node "Study programme" and the node displaying the title of the study programme and "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 in order 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 another course/topic. The linking phrase "one of" can be used between levels of course groups and course titles if it is necessary to indicate that students can study only one course from a specific course group. 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.

Fig. 2 presents a fragment of a concept map developed for the study programme "Computer Systems" offered at Riga Technical University for students of the Faculty of Computer Science and Information Technology. Three levels are omitted in the concept map: major field, course topics, and topic concept maps.

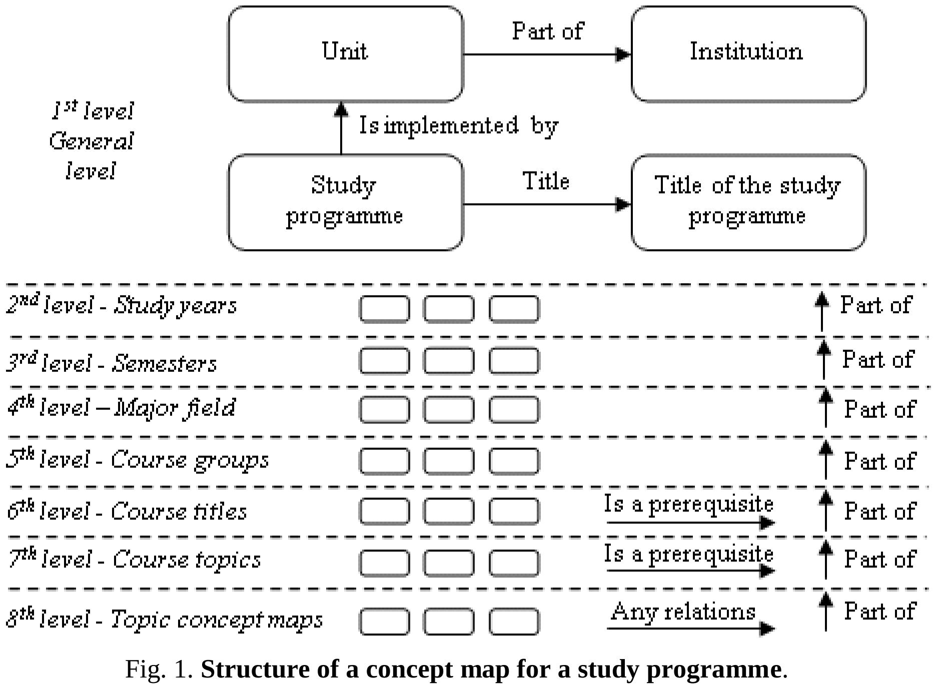

Fig. 1. **Structure of a concept map for a study programme**.

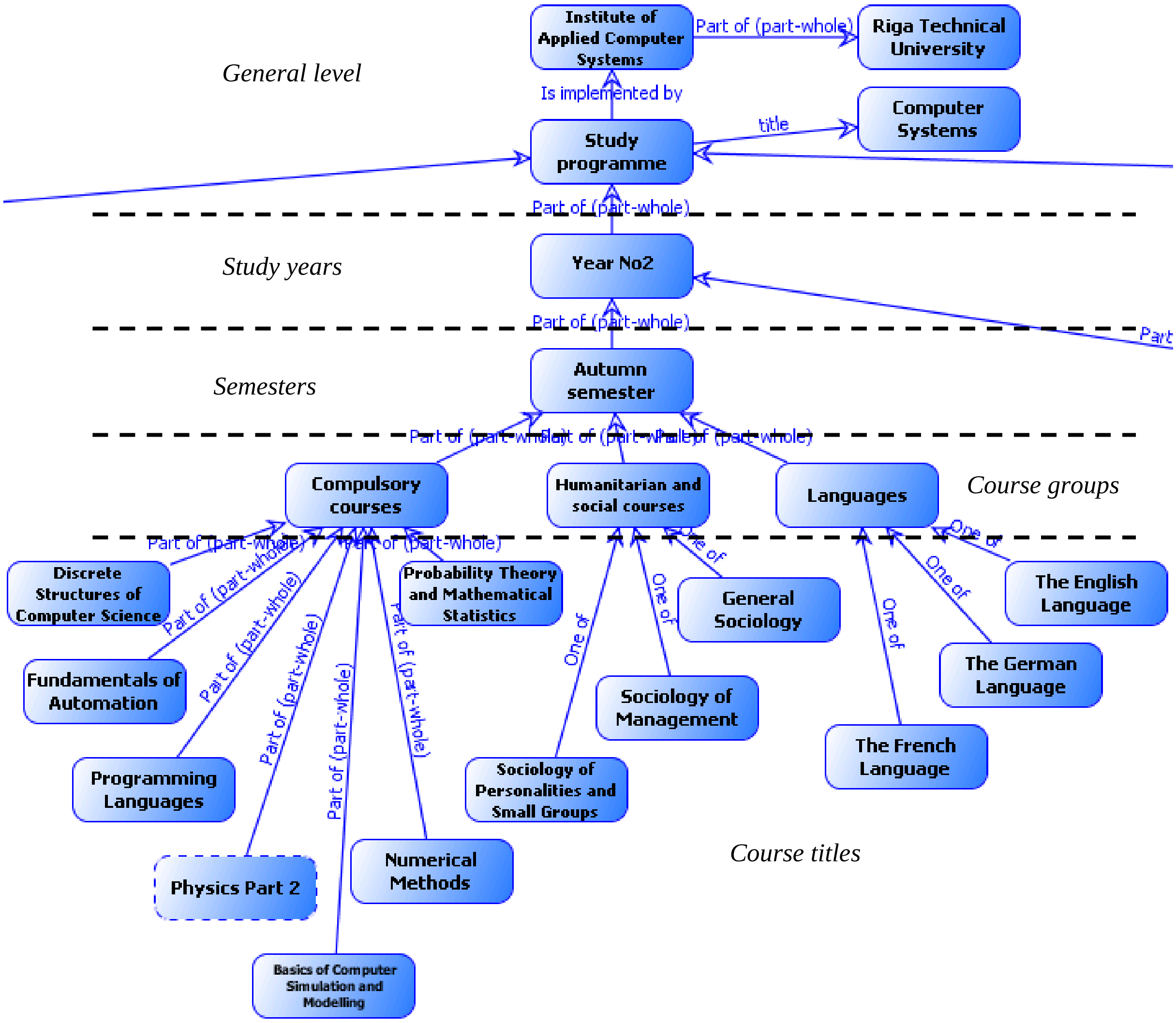

Fig. 2. **A fragment of the concept map for the study programme "Computer Systems"**.

In order to create a concept map for a study programme, the following steps must be realized:

- Acquire the description of a study programme;
- Identify the previously mentioned levels of the study programme;
- Start creation of the concept map with the general level incrementally adding nodes and relating them by relations with the linking phrase "part of" and going to the level of course topics;
- Identify "is a prerequisite" relations (if any);
- Create and add concept maps of topics.

Overview of the approach

Fig. 3 displays the overall approach proposed for comparison of study programmes on the basis of concept maps and ontologies. First of all, using the acquired descriptions of study programmes, concept maps are constructed. Secondly, the concept maps are transformed into ontologies. After that, comparison or, in other words, matching between the ontologies of the study programmes is performed and its results are visualized.

At the moment, the IKAS system (Anohina-Naumeca et al., 2011) is used for creation and transformation of concepts maps. In general, the mentioned system is intended for students' knowledge assessment, but it can be used for other purposes, as well, for example, for creation of concept maps and their translation into XML format and/or ontology. The system provides icon- and drag-and-drop based graphical interface for creation of concept maps. For matching of ontologies, some ontology/schema matching tool must be used. The tool must satisfy the following minimal requirements:

- to accept ontology/schema inputs in XML or OWL format;
- to be able to discover mappings between ontologies;
- to provide visual representation of matching results for identification of related study programmes or making recommendations, for example, to a student, who is looking for possibilities of mobility.

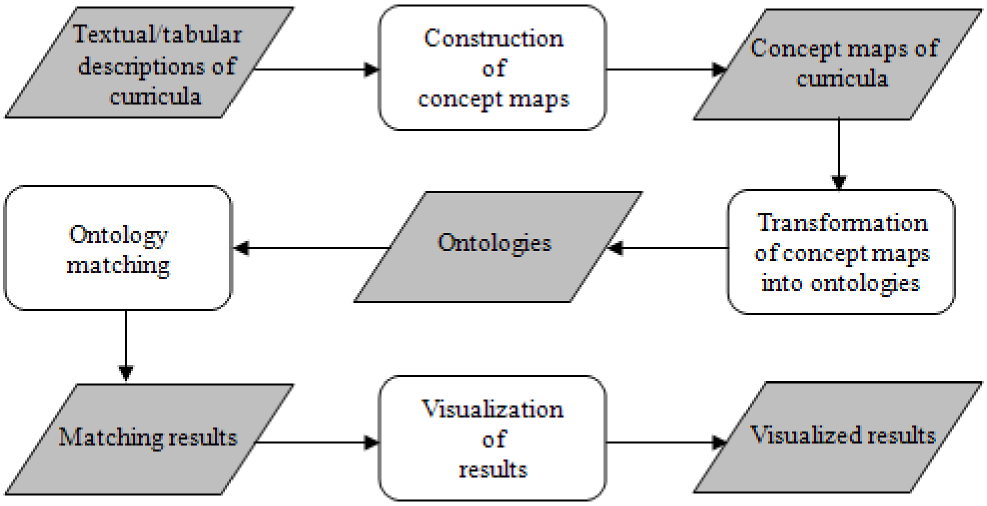

Fig. 3. **The approach for comparison of study programmes**.

Transformation of concept maps into ontologies

Correspondence between elements of the concept map and main elements/entities of OWL ontology is shown in Fig. 4. A concept in a concept map can correspond to a class, an instance, a datatype 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 in the ontology.

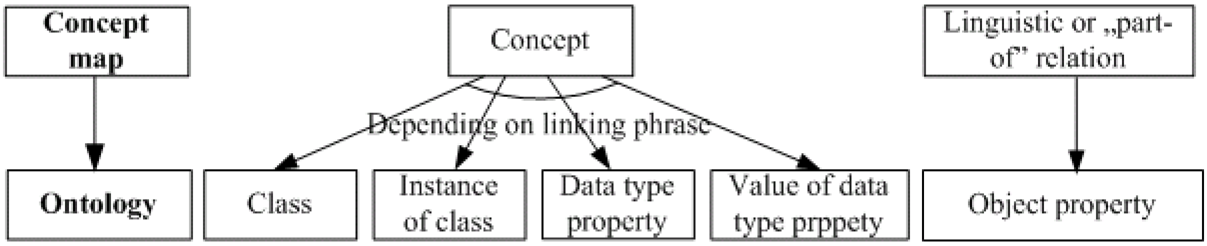

Fig. 4. **Correspondence between elements of a concept map and entities of an ontology** (Graudina and Grundspenkis, 2011).

The algorithm for transformation of a concept map into an ontology consists of seven steps (Graudina and Grundspenkis, 2011) during which all elements of the concept map are handled to determine their correspondence to ontology elements. In result, the appropriate ontology is constructed. The first six steps analyse linking phrases included in the concept map. As a result, types of related concepts are determined and according to them elements are added to the ontology. Step 7 finds synonyms for elements of the concept map because they are not defined directly with relations but are shown as additional information of concepts or linking phrases. The steps of the algorithm are the following:

Step 1: Find all concepts related with hierarchic relations, where two classes are related with linking phrases “is a”, “is a subclass”, “is a subset”, “one of”;

Step 2: Find all concepts related with instance relations, where a class is related to an instance with linking phrases “is an instance of”, “is an example of”;

Step 3: Find all concepts related with property relations, where a class or an instance is related to a property with linking phrases “is characterised by”, “has a property”;

Step 4: Find all concepts related with value relations, where a property is related to its value with the linking phrase “has a value”;

Step 5: Find all concepts related with complement relations, where two classes are related with the linking phrase “not”;

Step 6: Find all concepts related with “part of” or linguistic relations, where two classes are related with the linking phrase “part of” or any other linking phrase defined by a user;

Step 7: Find all synonyms defined for concepts and linking phrases.

According to the determined pair of concepts in each step, appropriate OWL code is written (Graudina and Grundspenkis, 2011), for example, to define a relation between a concept and its property the following OWL code is used:

```
<owl:DatatypeProperty rdf:about="Property_name">
  <rdfs:domain rdf:resource="Concept_name"/>
```

</owl:DatatypeProperty>

In Fig. 5 a fragment of the concept map for the study programme and its corresponding ontology is shown where on the right side of the concept map the code for all "part of", "is implemented by", and "title" relations is given and on the left side definitions of ontology classes and hierarchy are provided.

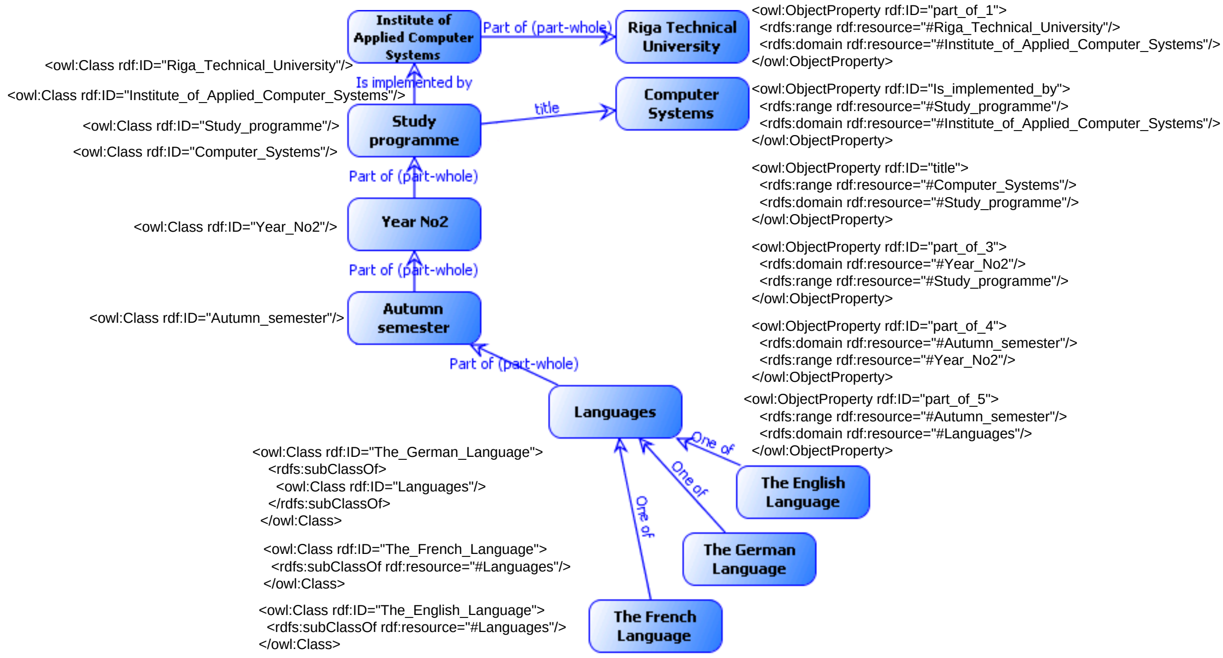

Fig. 5. **A fragment of the concept map for the study programme and the corresponding ontology**.

Before adding linguistic and "part of" linking phrases to ontology, pre-processing of them should be done. It is related to the fact that, on the one hand, there are no formal restrictions for usage of these relations in concept maps and, on the other hand, the same object property cannot link two pairs of different classes in the ontology. To handle such situations, indices are added to phrases. Situations when indices should be added are described below:

- Part-whole relations should be extended with indices which are equal to the number of the level of the structure of the study programme (see numbers of levels in Fig. 1). For example, for the relation at the first level the proposition will be like this "Institute of Applied Computer Systems – Part of_1 – Riga Technical University". An exception is the eighth level which contains several concept maps for different topics, therefore there linking phrases should have not only the index coming from the number of the level but also the index of the use in the particular concept map, for instance, "part of_8_3" means that the linking phrase "part of" is used at eighth level in the third concept map;
- Relations with the phrases "is a prerequisite" also are double indexed: the first index denotes the level and the second one - each unique pair of related concepts;
- Also all other linguistic relations should be indexed if the same phrase relates different concepts and the source and the target of the relation is different.

Matchers used in ontology matching should be set up in such a way that they can identify that "part of_1" is different from "part of _2" despite very close syntactic similarity, because these linking phrases belong to two different levels of the concept map for a study programme.

Conclusions and future work

The paper focuses on the first two steps of the approach for automatic comparison of study programmes: representation of curricula in the form of concept maps and their transformation into ontologies. Concept maps are chosen as the main instrument for visualization of the structure of a curriculum as they consist only of labelled nodes and relations and facilitate perceiving of the structure of the curriculum for non-technical users who are interested in comparison of study programmes. Due to the fact that concept maps are semi-formal knowledge representation with ill-defined semantics and they do not have advanced tools for their comparison, ontologies are used as a main formalism for automatic processing of curricula.

At the moment, the mentioned steps are supported by the IKAS system allowing construction and transformation of concepts maps. However, the approach assumes the use of some matching tool for comparison of ontologies acquired from concept maps and providing possibilities for visualization of comparison results. Therefore, future activities include:

- Creation of a corpus of study programmes offered at different educational institutions across EU;

- Running an experiment on the created corpus of study programmes with aim to check feasibility and applicability of the approach proposed. For this purpose, an ontology matching tool must be used. At the moment, cooperation with researchers from LIRMM-Université Montpellier 2 and use of their tool WebSmatch is considered;
- Analysis of results acquired during the experiment.

In far future, possibility to use some existing categorizations at the level of topics, for example, the one from ACM for the curricula in computer science could be examined.

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