Concept Mapping: Connecting Educators
Proc. of the Third Int. Conference on Concept Mapping
Tallinn, Estonia & Helsinki, Finland 2008

DESIGNING DEGREES: GENERATING CONCEPT MAPS FOR THE DESCRIPTION OF RELATIONSHIPS BETWEEN SUBJECTS

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Abstract. The Spanish University System is carrying out a convergence process towards the model proposed in the European Space for Higher Education. This involves, among other things, the redesign of all degrees and associated curricula. To achieve a coherent design of a degree we need to carefully analyze the relationships between subjects and the competences to be acquired by taking them. These relationships can be formalized using a complex directed graph, but using concept maps facilitates the understanding of these relationships. Due to the high number of concepts and relationships present in a degree, it is not possible to manually construct the concept maps. In this paper we describe a method and tool to automatically generate different concept maps from the raw data of a degree (subjects, competences, and different relationships between them), previously stored in a database. The generated maps will provide helpful information for Students when choosing learning itineraries, and for the School to assure the coherence of the curriculum.

1 Introduction

The Bologna Declaration (CRE, 1999) has fostered a number of changes in the Spanish University System, ranging from organizational aspects to learning and teaching methods. The convergence to the European Space for Higher Education involves, among other things, the redesign of all university degrees and associated curricula.

One of the novelties to consider when designing the new curricula is that they should be based on the acquisition of competences. Therefore, keeping in mind the professional competences a graduate should have, the subjects in the curricula must be directed towards the acquisition of these competences. On the other hand, each subject needs some previous competences of the students in order to understand the contents addressed.

With these relationships between previous competences, subjects, competences contributed by the subjects, and professional profiles, it is possible to establish a dependencies graph representing these relationships.

A quality curriculum will be characterized by a well-structured dependencies graph, where

- All previous competences needed are contributed by subjects already taken.
- All contributed subjects are useful for other subjects or for a professional profile.
- A given competence is not redundantly covered in more than one subject.
- All required professional competences are covered.

Analyzing the dependencies graph we can assure that these conditions are fulfilled, problems can be detected, and appropriate corrective measures can be taken.

2 The Degree Map

In the School of Computing Engineering of the University of Oviedo, the before mentioned dependencies graph of the current Degree in Computing was constructed as a previous step to design the new curriculum. For each subject in the current curriculum, the list of learning objectives has stated, as well as the degree competences associated to each learning objective, and the previous competences needed for the learning of the subject.

All this information was stored in a database. The following direct and indirect relationships, among others, can be extracted from the data:

- Subject - subject relationships.
- Previous competence – subject – contributed competence relationships.
- Competence – competence relationships.
- Competence – professional profile relationships.
- Subject – professional profile relationships.

Figure 1 shows the relationships to be studied. Where necessary, we will use different colours to clearly discriminate the concepts and to stress the level of dependency between some concepts.

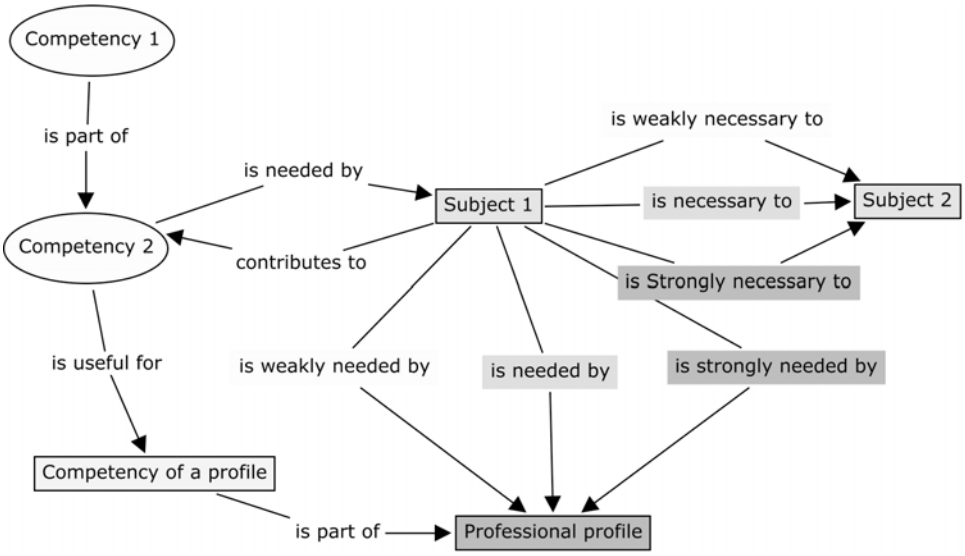

Figure 1. Relationships between subjects, competencies, professional profiles and their competencies

In each case, the meaning of the relationship is different. A subject *depends on* another subject, a subject *needs* a competence or *contributes* to a competence, a competence *is part of* another competence, or a subject *is needed* for a professional profile.

As the volume of data and generated relationships is high, it is necessary to have a graphical representation. A number of directed graphs were produced from the database. However, the comprehension of the graphs is still complex:

- The graphs are not easily to understand without a prior explanation of the meaning of the relationships.
- The graphs are not adequate for expressing more than one type of relationship in the same graph, where each edge can have a different meaning.

To solve these problems we propose to use concept maps, providing more meaning to the relationships and improving the understanding.

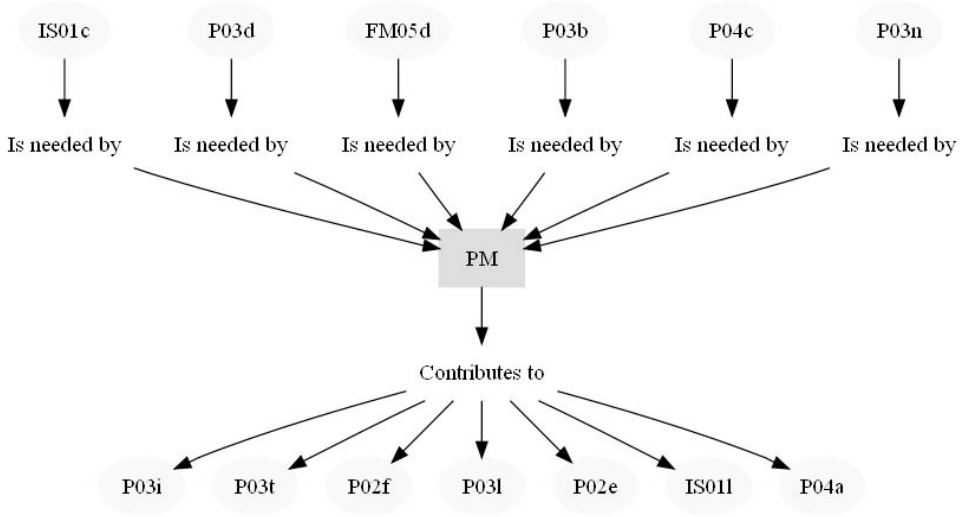

Figure 2. Previous and contributed competences of one subject

Each subject will have a concept map where the previous and contributed competences of the subject are shown. Besides, a concept map will be constructed relating the learning objectives with the associated competences of the degree. Another map will illustrate the other related subjects.

For instance, Figure 2 shows the competences required in order to take the subject “Programming methodology”. The contributed competences are also shown.

Another interesting map can be studied in Figure 3, where the dependency relations between the subjects dealing with programming can be studied. The map shows not only the subject which must be taken first, but also the level of dependency. This map can be generated for all the subjects of the degree, for any subset of them or for only one subject.

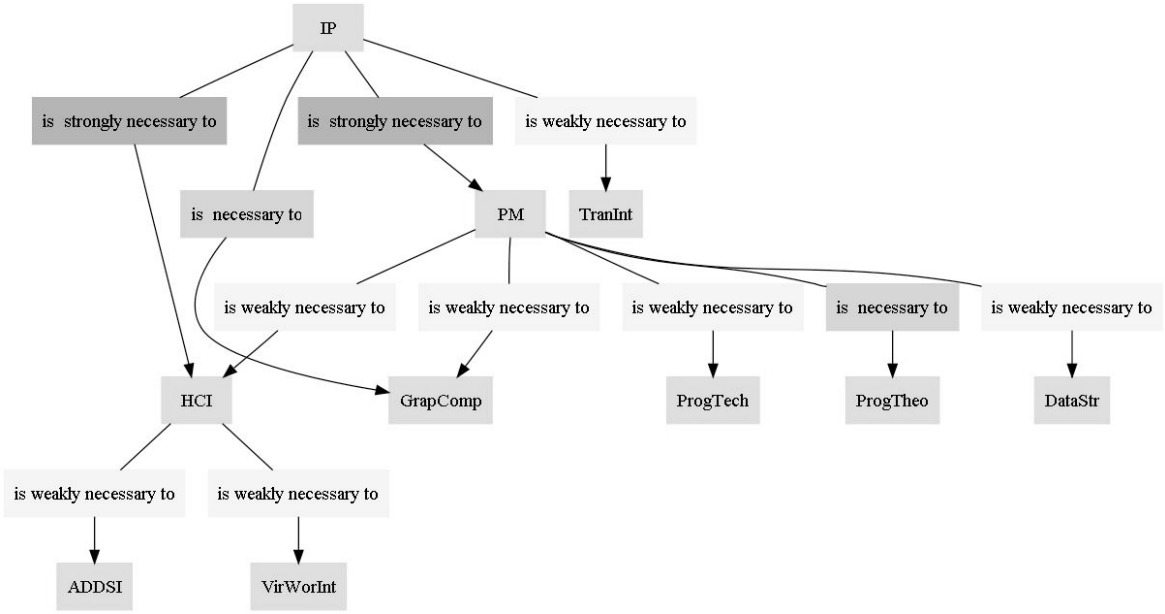

Figure 3. Dependency relationships between programming-related subjects

These maps are much clearer than textual representations or a traditional directed graph. With this representation it will be also possible to join all proposed maps in only one encompassing all relationships. Figure 4 shows the relationships between a set of subjects and with the corresponding professional profiles.

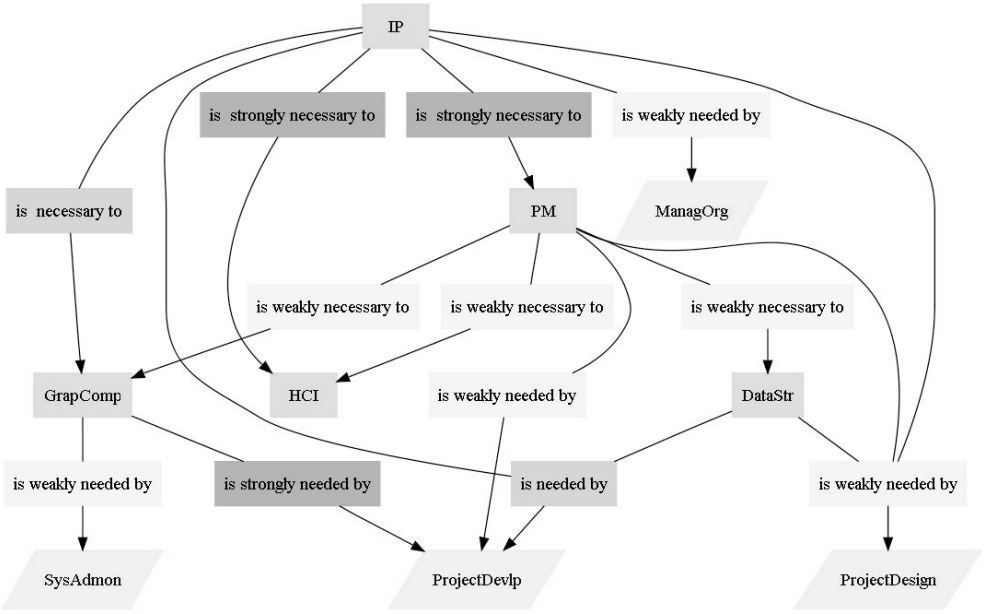

Figure 4. Map with several kinds of relations

Another type of map is needed to complete the description of the degree: a map relating the contributed competences of a subject to the professional profiles.

The set of these concept maps will form the Dependencies Map of the Degree (Degree Map). The Degree Map constitutes an important part of the documentation in the design of a degree.

2.1 Advantages of the Degree Map

The construction of the Degree Map, easily understandable by using concept maps, can be of great importance. Thus

- As it expresses precedence relationships between subjects, the complete Map helps the student with the selection of itineraries, and to decide when to take each subject, facilitating the learning process.
- As it contains all the dependency relationships, the map can be used to check the coherence in the design of the degree, avoiding gaps in competences not covered by any subject, competence overlapping, etc.
- Finally, the map is very helpful as documentation for the accreditation and certification processes of the degree.

2.2 Implementation problems

Due to the data volume involved, it is not feasible to manually construct the maps. It is possible to independently build the map for one subject, but the whole map relating all subjects and competences of the degree would be very difficult to set up. Therefore, an automatic tool to generate the complete map or any of its parts, from the data stored in the database was developed.

3 Generating Degree Maps

As mentioned before, the number of concepts and relationships involved really requires an automated tool to generate the maps from the raw data in the database. For example, in our computing degree there are 71 subjects, 314 subject competences and 1640 relationships between competences, subjects, and profiles existed.

The first step when generating a map is selecting the information to represent. The relationships of interest are:

- Subject - subject relationships.
- Previous competence – subject – contributed competence relationships.
- Competence – competence relationships.
- Competence – professional profile relationships.
- Subject – professional profile relationships.

Once the type of map is selected, and the required parameters (subject or subjects to visualize, type of relation to represent, etc.) a database query is build to select the data.

From this data a file representing the map is created and fed into the *graphviz*[1] (Gansner & North, 1999) application. *Graphviz* is a package of tools for generating graphical representations of graphs.

We had already used this tool to generate the initial dependency graphs referenced before. With this experience and, considering that concept maps are graphs after all, we also used it for building the concept maps.

Both the representation of the concept map (a graphic file in JPEG format) and the detailed description of the concepts involved (subject names, competences and profiles) are visualized in a navigable web page with linked maps. For example, from a map relating subjects it is possible to link to the map with the detailed description of a subject, and then to a map with relationships between subject competences.

[1] graphviz (short for *Graph Visualization Software)* is a package of open source tools, that can be downloaded from www.graphviz.org under the Common Public License.

As the time consumed for the generation of the graphic can be considerable (up to a minute for complex maps), a query cache is implemented so that a repeated query just uses the already-generated graphic.

3.1 Contributions of concept maps to the design of degrees

Generating concept maps to visualize the relationships between the different elements that characterize a degree has a number of advantages. These advantages are based on two basic facts:

- The utilization of concept maps integrates much information in the graphical representation without reducing clarity.
- Generating the maps from the database allows selecting the information of interest for each specific case.

The implemented system has been of great help with two of the fundamental concerns we looked for when initiating the construction of the degree map:

- The relation between subjects and between previous competences-subjects-contributed competences, expressed with the clearness provided by the concept maps, helps the student with the choice of his itinerary.
- The flexibility when reflecting the relationships between the elements selected by the user allowed the Dean and the Board of the School of Computing to analyze the design of the degree, and to discover some problems of coordination between subjects resulting in corrective measures.

3.2 Features to improve

We found some issues to resolve in future versions of the developed tool, and for subsequent studies.

The first drawback is that currently the maps are static. Modifications cannot be done on the map, but only through direct change of the database. Obviously, it is better to have some mechanism to graphically update the information.

The second limitation is that it is not possible to add additional “extra” information to the map, such as linking the subjects with its syllabus, the teaching staff, etc.; just the visualization of subjects and competences is possible.

4 Future Work

To enhance the system it is important to improve the interaction with the generated maps. We are working in two areas:

- Instead of generating maps in graphical format, it would be better to generate them in the format of CmapTools (Novak & Cañas, 2006). This would allow to use these tools afterwards to modify the maps, work collaboratively on them (Cañas et al., 2004), etc.
- Once the map is modified interactively, the changes should be automatically updated in the database for coherence reasons.

5 Conclusions

The usefulness of concept maps to express the design of the curriculum of a degree has been shown. Using concept maps visualizes clearly the dependency relationships between subjects, helping the students decide their itinerary in the degree in a coherent way. Besides, the design of the curriculum is facilitated by the assigning of competences to the subjects, uncovering possible inconsistencies. Concept Maps are also important in the phase of implanting a new degree, as the maps help establishing groups of coordination between subjects.

An automated tool to construct these maps has been developed, using information from a database storing the concepts and relationships between them. This enables the construction of different views according to different interests.

In short, this approach of applying concept maps to the design of a curriculum for a degree is original, and provides appreciable advantages for students, the School and the quality assurance of the degree.

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