Using WordNet to Support Interactive Concept Map Construction

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Abstract

Concept mapping is a knowledge elicitation technique which stimulates learners to articulate and synthesize their actual states of knowledge during the learning process. Several approaches have been proposed for automating the assessment procedure of learners' concept maps based on an expert's map as a reference point. However, these approaches do not handle cases where learners have misspelled a concept or they have used a synonym or a concept related to the appropriate one. In this paper we present an alternative approach in which the process of the error identification is performed through the use of an expert map and of WordNet which is an electronic lexical database containing semantic relationships between words. This way we handle cases such as misspelled concepts, synonyms and related concepts. After error detection WordNet is also employed for providing the learner with appropriate feedback based on the identified errors, with the intention of helping the learner to correct them.

1. Introduction

Concept mapping is the process of organizing concepts in a hierarchical manner and forming meaningful relationships between them. It requires from learners to reflect carefully on their understanding of concepts and their relationships. In this context, concept maps provide a means to capture, elicit and represent qualitative aspects of the learners' knowledge on specific topics [9], [11]. In such a map learners represent meaningful relationships between concepts in the form of propositions. For example, "*Memory* stores *data*" represents a simple concept map forming a valid proposition about the concepts "Memory" and "data".

It is argued that the concept mapping process promotes and assists meaningful learning by encouraging learners to identify concept meanings, establish relationships between concepts, re-arrange the existing relationships, relate new concepts to prior concepts, organize the concepts in a hierarchical and integrated manner and refine the completed map resulting in generalized schemata for certain concepts [4], [9], [10], [11].

There are several tools for constructing concept maps such as those summarized in [5], [8]. Moreover, several research studies have been conducted in automating the assessment of learners' concept maps and providing appropriate feedback [1], [2], [12]. Most of them build on a comparison between the learner's and the expert's concept maps. In [1], the system gives appropriate hints to the learner after analyzing his/her map and comparing it with the one provided by the expert. The hints are provided in a partial proposition type made of the concepts and the relationships in the learners' map. In [2] the system analyzes learners' concept maps and provides learners with hints about specific errors such as missing propositions and concepts (as compared to the expert's map). The hints are predefined and entirely controlled by the expert.

However, these approaches do not handle cases where learners have misspelled a concept or they have used a synonym or a concept related to the appropriate one. Especially in the latter case, this is a useful information about learners' knowledge which could support: (a) the teacher in assessing the learner, and (b) the system in providing appropriate feedback to support learners in reflecting on their concept map and correcting it. We have developed a tool for supporting learners to construct concept maps named COMPASS (COncept MaP ASSessment tool) [6]. COMPASS currently supports the automatic assessment of the learners' concept maps based on their similarity to the experts' concept maps. Moreover, COMPASS assesses learners' maps in order to identify specific types of errors and provide appropriate feedback that will support learners in correcting them [7]. In this paper we propose an approach that will enhance the functionality of COMPASS in assessing learners' maps including the aforementioned cases (misspelled concepts, synonyms, related concepts). To this end, we use an electronic lexical database named WordNet, which is briefly presented in Section 2. Moreover, we present the different options that the proposed approach offers to experts for designing a map (Section 3). In Section 4, we describe the error identification procedure as it is enhanced by the proposed approach. In Section 5 an application example is provided and the paper ends , in Section 6, with concluding remarks.

2. Overview of WordNet

WordNet [3] is an electronic lexical database, which is arranged semantically and contains nouns, verbs, adjectives and adverbs. Words that are synonymous are grouped together in synonym sets, also referred to as *synsets*. Each synset has an associated definition named gloss, which is a short explanation of the meaning of the concept represented by the synset. Many words in WordNet are polysemous i.e. they are included in more than one synsets. For example, the word *computer* can be found in the synset {computer, computing machine, computing device, data processor, electronic computer, information processing system}, which has the gloss “a machine for performing calculations automatically”, and in the synset {calculator, reckoner, figurer, estimator, computer} which has the gloss “an expert at calculation (or at operating calculating machines)”

Synsets are connected to each other through various semantic relations. The most important relations between nouns are the relations of *hyponymy* and *hypernymy*, which are transitive relations between synsets. The hypernymy relationship between synsets A and B means that B is a kind of A. Hypernymy and hyponymy are inverse relationships, so if A is a hypernym of B, then B is a hyponym of A. For example the synset {computer, computing machine, computing device, data processor, electronic computer, information processing system} is a hypernym of the synset {home computer}. Usually each synset has only one hypernym, therefore this relation organizes WordNet into a hierarchical structure. Another pair of inverse relations that hold between nouns are the *meronymy* and the *holonymy* relations. If A is a holonym of B (or in other words B is a meronym of A), it means that B is a part of A. For example, synset {keyboard} is a meronym of the synset {computer, computing machine, computing device, data processor, electronic computer, information processing system}.

WordNet was initially developed for English in Princeton University and that is currently the largest WordNet available. However, afterwards, WordNets have been developed for numerous other languages. In the course of the EuroWordNet project [14] WordNets were developed for Dutch, Italian, Spanish, German, French, Czech and Estonian, and currently in the framework of the BalkaNet project [13] WordNets are being developed for the Balkan Languages (Bulgarian, Czech, Greek, Romanian, Serbian and Turkish). We currently work with the Princeton WordNet in order to assess the effectiveness of the proposed approach, as it is the most extensive and most complete one. In the near future we intend to use the Greek WordNet in order to investigate the extensibility of our approach to languages other than English.

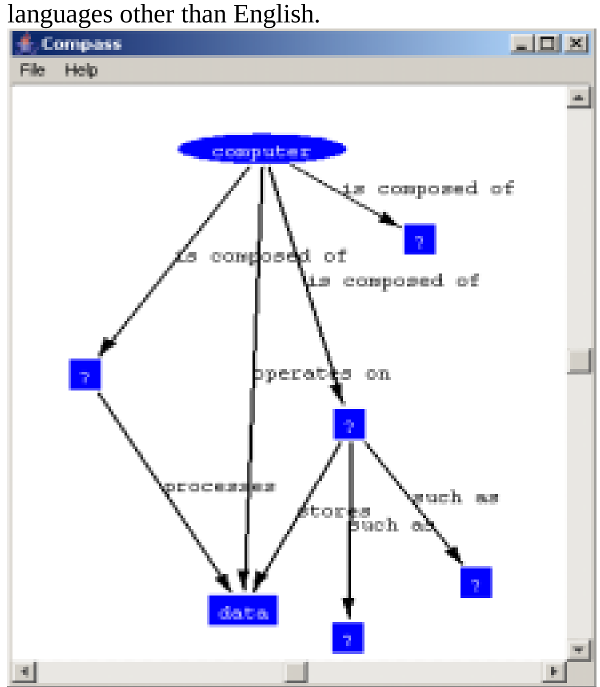


Figure 1. The main screen of COMPASS as it appears to the learner who starts working on a “concept list completion” task. Concepts to be filled appear with a question mark.

2. The Options Provided to Experts for Designing a Map

In this section we give a brief description of the concept mapping tasks that COMPASS supports as well as the different options provided to experts based on the exploitation of WordNet.

COMPASS supports various concept mapping tasks such as (i) the construction of a concept map from scratch (“free construction” task), and/or using an available list of concepts (“concept list construction” task), and/or using an available list of concepts and relationships (“concept-relationship list construction” task), (ii) the free evaluation of a concept map (“free evaluation” task), and/or using an available list of concepts and relationships (“concept-relationship list evaluation” task), (iii) the extension of a concept map from scratch ("free extension" task), and/or using an available list of concepts ("concept list extension" task), and/or using an available list of concepts and relationships ("concept-relationship list extension" task), (iv) the free completion of a concept map ("free completion" task), and/or using an available list of concepts ("concept list completion" task) and/or using an available list of relationships ("relationships list completion" task) and/or using an available list of concepts and relationships ("concept-relationship list completion" task).

Specifically the "concept list completion" task on which we shall concentrate in this paper, addresses assessment outcomes of the Comprehension level (see in Fig. 1 the "concept list completion" task as it appears to a learner). In this type of concept mapping tasks, the structure of the concept map, with all the relationships between the concepts, the central concept of the concept map, and a list of concepts (not all of them can be used) are given to the learners. Learners' task is to fill the empty boxes with the names of the concepts that they consider to be the most appropriate. The expert is the one responsible for designing activities for the learners. Usually, this process includes the construction of a specific map that is the target map of learners' activity (the expert's map), as well as a map on which learners will work on. When designing the latter concept map for a "concept list completion" task, the expert should fully specify the structure of the map, all the relationships between concepts and for each concept s/he should define whether that concept will be given to the learner or not.

In the proposed approach the expert does not specify a target map, but for concepts not given to the learner, the expert should somehow denote what answers of the learners will count as correct. In order to achieve this, the proposed approach offers the expert with three options. The first and most simple option, is to give a word that is the name of the concept. This is quite inflexible since the learners' answer will be considered correct only if it is identical to what the expert had in mind. However if that particular concept does not exist in WordNet, this is the only option for the expert. The second option is to define a concept as a WordNet synset. This is far more flexible and furthermore it is more intuitive since WordNet synsets are a better representation of concepts than single words are. The third option, is by defining a concept as any synset that has a specific relation to a another certain synset, e.g. "any meronym of the synset {computer, computing machine, computing device, data processor, electronic computer, information processing system}". In the current state of COMPASS, in order to make these selections the expert should have some knowledge of the structure of WordNet and of the available synsets. However, in our future research we intend to add an authoring interface to COMPASS that will work as a front-end between the expert and WordNet, and will therefore free the expert from the burden of learning about WordNet. In the following section we will present in greater depth, how these methods of defining concepts are being put to use so as to support the process of concept mapping.

In Fig. 2 appears an example of a concept map designed by the expert.

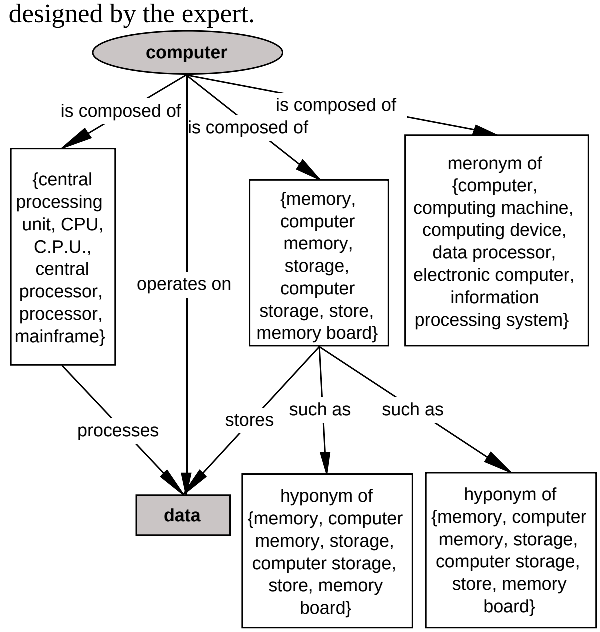


Figure 2. A concept map as it was designed by the expert. The gray concepts are the ones given to the learner. Some concepts are defined as WordNet synsets, while others are defined as a relationship with a WordNet synset.

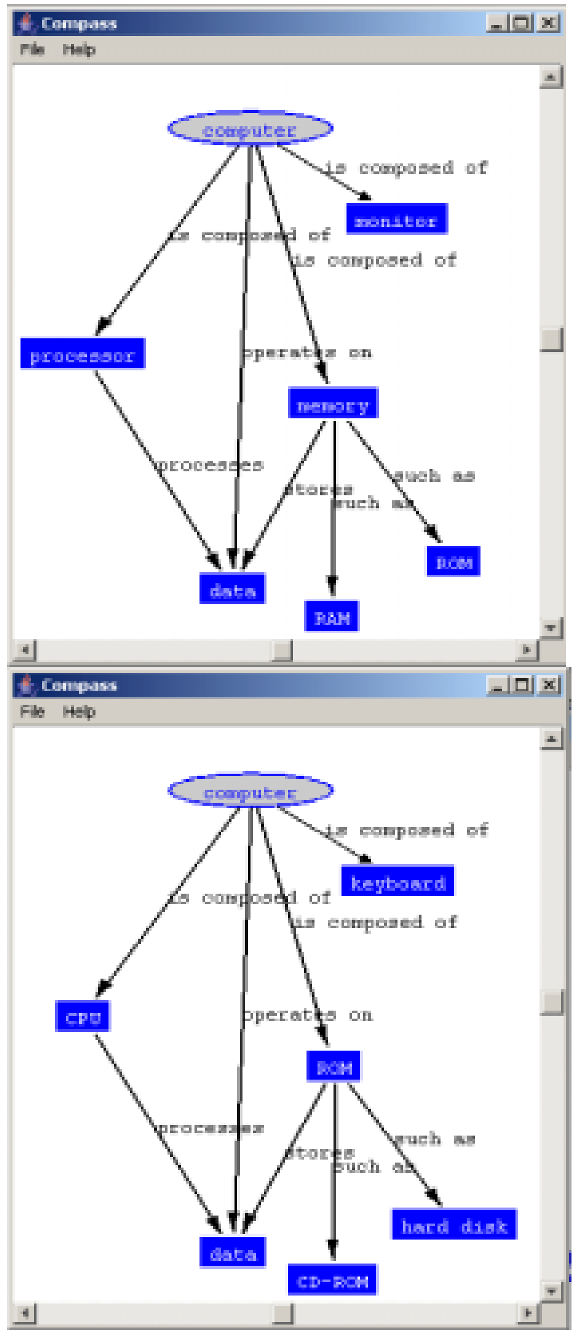
3. How WordNet Enhances the Functionality of COMPASS

We propose that WordNet can be a valuable resource for assessing concept maps designed by learners and for supporting the learner in his/her attempt to design concept maps for three reasons. Sets of synonyms can offer flexibility in assessing learners' answers, the WordNet ontology allows the teacher to define multiple possible correct answers and finally WordNet can be used to provide meaningful feedback targeted at the learners' specific mistakes.

Specifically, the synsets in WordNet can provide flexibility when comparing an answer given by a learner to the correct concepts provided by the expert. A problem of automatic correction of concept maps is that often a learner has provided the correct answer, but the system will not accept it because it has not been phrased in the way the system expected. By using synsets it is possible to check whether the learner's and the expert's map actually refer to the same concept in different words. For example, if a concept in the expert's map is the {central processing unit, CPU, C.P.U., central processor, processor, mainframe} synset, it makes no difference whether the learner phrases the answer as *processor* or *CPU* or *C.P.U.*, because all these answers will be considered as correct.

Secondly, WordNet offers an extensive ontology, that the expert can use in order to define entire classes of correct concepts, rather than just one correct concept. For example in the expert's concept map the relationship "is composed of" may exist between the concept *computer* and a concept that the learner should fill out. Then if the learner gives as an answer any part of the computer, that answer should be considered correct, regardless of the specific part. We would like all the answers *keyboard, monitor, memory* etc. to be considered correct. This can be implemented through WordNet's meronymy relation. Once the expert has defined the correct answer as any meronym of a certain synset, the system can assess the answer of the learner by searching for it in the synsets that are meronyms of the given synset. In this way a large number of acceptable answers can be defined by simply stating their common property and not by listing them explicitly. In fact, this seems to be well suited for concept maps, since a number of relationships that appear often in concept maps, correspond to WordNet relations. For example, the concept map relationship "is composed of" corresponds to meronymy and the "is a kind of" relationship corresponds to hypernymy.

Finally, WordNet's ontology and relationships may further be exploited so as to provide the learners with meaningful feedback that will be targeted at the specific errors they have made, instead of just generic messages such as "Wrong Answer" and "Try Again". We claim that this is possible, since through WordNet the system is able to find out the relationship that holds between the concept given by a learner as answer and the concept expected by the teacher. Based on that relationship we can provide the learners with the most appropriate feedback that will hint them towards the correct answer. For example, if the correct concept expected by the teacher is defined as the synset {memory, computer memory, storage, computer storage, store, memory board} and the answer of the learner is *RAM*. Using the WordNet ontology it is easy to find out that the synset {random-access memory, random access memory, random memory, RAM, read/write memory}, which contains RAM is a hyponym of the correct synset. Through this knowledge the system can provide informative feedback to hint learners towards using the general category to which RAM belongs, i.e. "memory". In the same way it is possible to also use other of the WordNet relations, such as the *meronym-holonym* relation.



(a)

(b)

Figure 3. The completed concept maps of two different learners (a) and (b) working with COMPASS.

4. An Application Example

In this section we give an example of how the proposed approach is actually incorporated in

COMPASS. In Fig. 3a (Learner A) and 3b (Learner B), we give examples of two concept maps constructed by two learners after using COMPASS, whilst in Fig.2 appears the corresponding expert's map. We can make the following observations concerning the way the system handles and assesses those concept maps.

- Given the relationship "processes" between an unknown concept and "data" both learners have given the correct answer, even through they have typed different words (*CPU* and *processor*). Both answers are treated as correct by COMPASS, since both of them belong to the synset defined by the expert.
- Given the relationship "is composed of" between "computer" and an unknown concept the two learners have given two different answers (*keyboard* and *monitor*). Nevertheless, COMPASS considers both answers as correct, because both answers are meronyms of the {computer,...} synset. Intuitively, this is a correct assessment since computers are indeed composed of both keyboards and monitors.
- Given the relationship "stores" between an unknown concept and "data", learner A correctly answers with *memory*, but the answer of learner B (RAM) is too specific to be considered correct. The response of the system in this case is to offer feedback that will hint the learner towards using a more general concept.

So, the assessment mechanism of COMPASS offers flexibility to the assessment procedure enabling experts and learners to provide alternative concepts/answers and include multiple perspectives in one map.

5. Conclusions

Concept mapping enables learners to externalize their understanding of a domain. This process requires from learners to reflect carefully on their knowledge of important concepts and their interrelations. A common concept map completion task is organized by an expert asking learners to complete a given concept map where several concepts are missing. However, the way learners will fill the map is not always predictable. Thus, when experts assess the final product of learners' activity, they should consider many different perspectives and possible correct answers. This process becomes even more complicated when a system undertakes the assessment of the map. In this context, we propose an automated concept map assessment approach that extends the assessment procedure to handle a variety of learners' responses such as synonyms, concepts with hypernyms/hyponyms or meronyms/holonyms relations based on the electronic lexical database named WordNet. Moreover, this approach offers the expert the option to define the concepts in the expert's map as sets of concepts (instead of one concept) based on specific relations in WordNet.

Acknowledgements

This research is supported by the BalkaNet project, which is funded by the European Commission in the framework of the IST Program (IST-2000-29388).

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