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

DESIGNING DATABASES WITH CONCEPT MAPS

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Abstract. We propose the traditional approach to data modeling (using the Entity Relationship model) be augmented with concept maps. A data model can begin as a concept map and if the concept mapper chooses linking phrases carefully the transformation of a concept map to an ER model is facilitated. We propose a set of linking phrases to accommodate many aspects of ER modeling. Students benefit, in general, from using concept maps in any area of study, and so as concept mapping can be integrated into ER modeling the student gains additional benefit from studying ER modeling.

1 Introduction

Concept maps were developed in 1972 (Novak & Musonda 1991); they are graphical tools for organizing and representing knowledge that include concepts, and relationships between concepts indicated by lines connecting (linking) pertinent concepts. The links between concepts are propositions that comprise two or more concepts connected using linking words or phrases that form meaningful statements (Novak & Cañas 2008).

The developer of a concept map has total freedom in choosing concepts and linking phrases which is useful when creating a representation of knowledge. However, discipline is necessary when choosing linking phrases to avoid ambiguity, and when a novice is becoming an expert, the same domain knowledge gets represented by more accurate linking words (Kharatmal & Nagarjuna 2006).

Entity-relationship (ER) models are used in the traditional approach to database design. ER modeling abstractions include entity types, relationship types, attributes, specialization, composite attributes, key attributes, partial key attributes, derived attributes, domains, categories, n-ary relationships, xor relationships (Elmasri & Navathe 2007, Hay 1995, Silverston 2001). (Xiao 2007, Sien & Carrington 2007) showed that concept maps can be used to develop a first domain model from user requirements and that concept maps are useful for helping students develop abstraction skills needed in data modeling. If pertinent link phrases are applied, these concept maps can be transformed into more traditional data models. If an ER model is to be generated, concepts in the map become entity types or attributes according to the link phrases used. Link phrases are also used to determine the type of relationship that exists between entity types. (Xiao 2007) used three classifications of link phrases: (1) to associate attributes to entity types, (2) to accommodate aggregation/ composition relationships and (3) to accommodate generalization/ specialization relationships.

In section 2 we discuss concept maps and ER models and give examples to illustrate the additional link phrases we propose. In section 3 we give our conclusion and suggestions for future work.

2 ER Modeling and Linking Phrases

When a business analyst begins to design a database the analyst starts with rough sketches, jotting down tentative entity types (concepts), and joining them with relationships (linking phrases). A database design often begins as a concept map and at some time is expressed in a more formal manner such as an ER model. The symbols that appear in ER models have precise meanings that reflect business rules in the problem domain. Each rule can be expressed in a natural language statement or as concepts and linking phrases in a concept map. Table 1 summarizes the linking phrases that a concept mapper can use to facilitate the transition to an ER model. Our table extends previous work (Xiao 2007, Sien & Carrington 2007), and proposes additional phrases: “identified by”, “calculation provides”, “subdivided into”, “based on”, “union of”, “e.g.” and “either or” as further refinements for linking phrases related to data modeling.

ER construct	Linking phrase
Entity type - attribute	Described by [#]
Specialization	Is-a
Aggregation/Composition *	Includes
Entity type - key attribute	Identified by
Entity type - derived attribute	Calculation provides
Entity type - composite attribute	Subdivided into
Attribute – domain [+]	Based on
Category	Union of
Relationship type	*Phrase comes from problem domain*
Example [+]	e.g.
XOR Relationships *	"either or" *with phrase from problem domain*
[#] We choose to use "described by" rather than "knows" as done in (Xiao 2007, Sien & Carrington 2007). Anthropomorphism is a natural aspect of object modeling, but in the traditional approach we think of an entity and attributes that *describe* the entity.	
* Strictly speaking, these are not part of the EER model in *Fundamentals of Database Systems* but they can be accommodated with simple extensions.	
[+] Understanding the domains and providing examples are important to ER modeling but they are not included in ER diagrams.	

Table 1: Link Phrases for ER Modeling

Next, we discuss cases to illustrate our proposed linking phrases for ER modeling.

2.1 Entity Types, Attributes, Domains, Examples

An entity type is a definition of a grouping of entities that have common characteristics in terms of attributes and relationships. Consider a Student entity type with attributes student number, gender, phone number, name (first and last), birth date, and age where student number is a key. The concept map in Figure 1 uses linking phrases "based on" and "e.g.", "identified by", "subdivided into", "calculation provides", and "described by". Note that "based on" and "e.g." linking phrases identify information that is not shown in the ER diagram. "identified by" informs us of keys and "subdivided into", "calculation provides", and "described by" inform us of composite, derived, and regular attributes respectively.

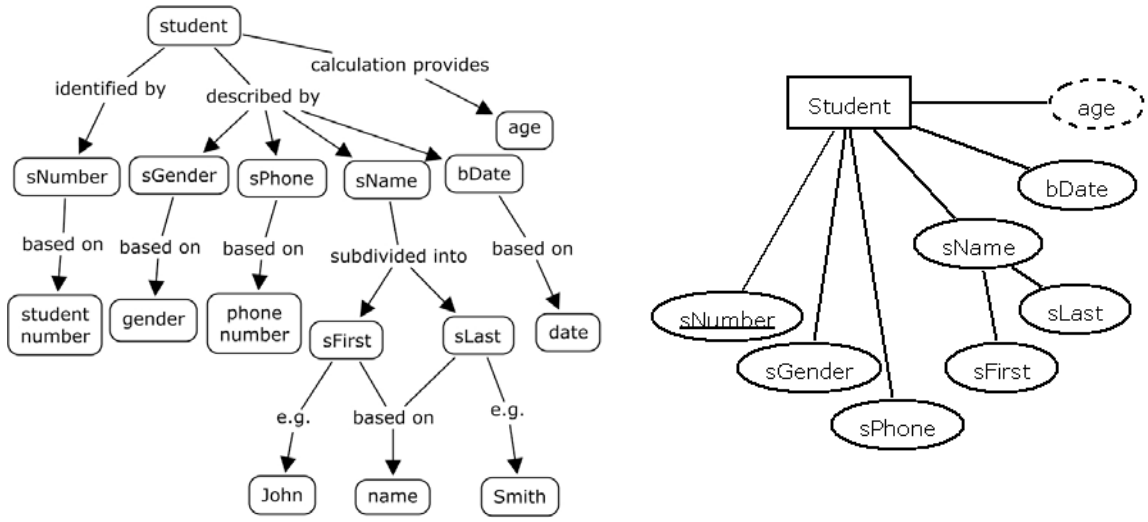

Figure 1. Concept map with attribute-related link phrases and the corresponding ER model

2.2 Weak Entities and Identifying Relationships

Our next example deals with courses and departments at a university. Consider that a department is identified by a department number and that a department offers courses that are identified by both department number and course number. Figure 2 shows the concept map and the ER model it transforms into.

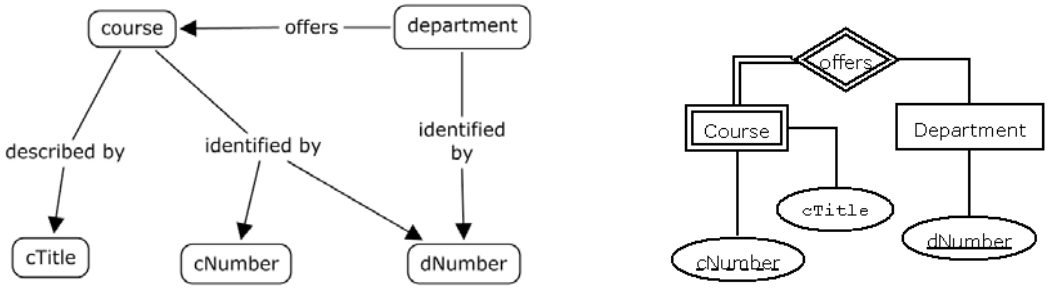

Figure 2. Weak entities and identifying relationships

Due to the representation for identifying relationships, weak entities and mandatory participation in a relationship, the corresponding ER model is complex. In the ER model the relationship is considered *identifying*, Course is a *weak* entity type and Department is a *strong* entity type. This has several implications that can be problematic for a student new to ER modeling: a) the department attribute is not shown as an attribute for Course, b) Course is shown as a rectangle with a double-lined border, c) Course's participation in the Offers relationship is mandatory and so there is a double-lined connector from Course to Offers, and d) Offers is identifying and so it is shown with a double-lined border.

2.3 n-ary Relationships

Previous work (Xiao 2007, Sien & Carrington 2007) considered binary relationships. n-ary relationships, where n>2, involve one relationship type and 3 or more entity types. For example, the ternary relationship "a student may enroll in a course offered during a term" involves the "Enrolls In" relationship and entity types Student, Course, And Term. The concept map and the ER model it transforms into are given in Figure 3.

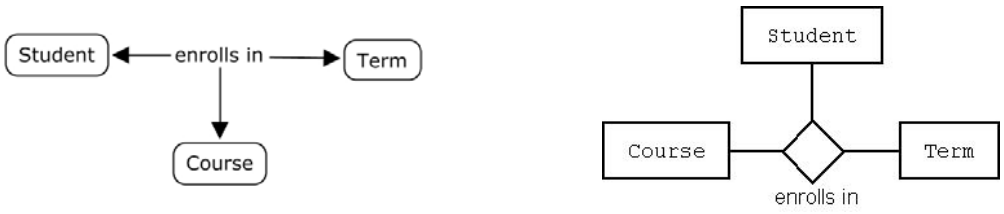

Figure 3. n-ary relationships

2.4 Categories

A category in ER modeling denotes an entity type that represents the union of two or more disjoint sets. For example, consider that a library patron is either a student or a staff, and that a patron borrows books. Note that a student is not necessarily a patron and a staff is not required to be a patron either; this is in contrast to specialization where students and staff would always be considered patrons. See Figure 4.

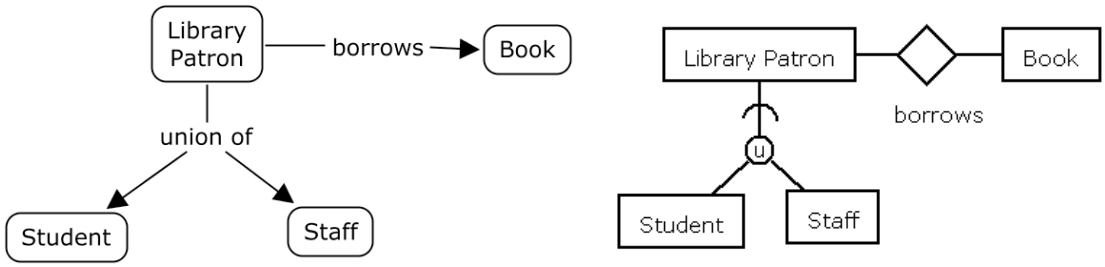

Figure 4. Categories

The category construct appears under-utilized in ER practice (Hay 1995, Silverston 2001) and instead we see models illustrating mutually exclusive relationships. In contrast to Figure 4, the business rules for library patrons are shown in Figure 5 but with mutually exclusive relationships.

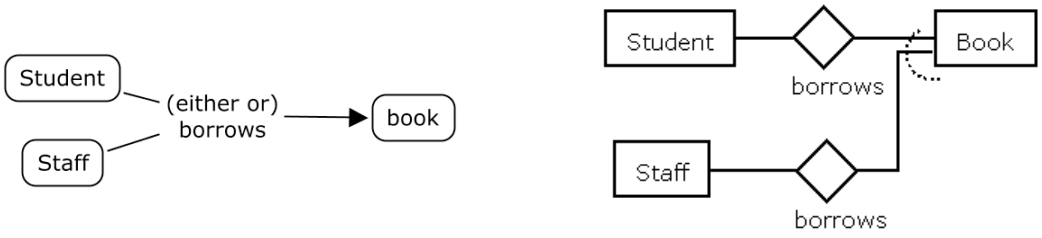

Figure 5. xor relationships

3 Conclusion and Future Work

The procedure for designing a data model begins with creating a concept map. An analyst begins by jotting down ideas/concepts and connecting them with links/relationships. The analyst does not need to be concerned with distinctions between entity types, attributes, domains, and examples in a concept map; they are just concepts which can evolve to attributes, etc., according to the linking phrases used. In one sense, concept mapping is much simpler than ER modeling because there are only two constructs to work with. Thus, concept mapping is the better tool for the novice to start with. Advanced modeling concepts can be introduced to the student as refinements that make our thinking more accurate and consistent. Once the refinements are understood, instruction can introduce ER modeling notation as a further refinement.

In future work we would like to integrate concept mapping and ER modeling in one tool and experiment with this in an educational setting. We would like to investigate the possibilities and issues of moving from a concept map to an ER model and, in the opposite direction, from an ER model to a concept map at any stage of development. It appears attractive to us to be able to view an ER model from different perspectives (layers) in a concept map; for example, some layers could present attribute information, others relationship information. Another area that, in our opinion, gives database students some difficulty is normalization. The topic of normalization includes a discussion of functional dependencies where graphs are used to illustrate dependencies between attributes. We would like to explore the connection between the concept maps as presented here for database design and attribute functional dependency graphs.

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