Exercises *Databases*
Session 2: ERD, functional dependencies

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Exercises marked with a (!) are not mandatory. But they are challenging.

ERD

Exercise 6

An ER diagram can be regarded as a graph in several senses. Let us forget about the ISA hierarchies for the moment. Suppose the entity sets are the nodes of an undirected graph and the links are given by the relationships.

(i) What does it mean if such an ER-graph is not connected?

We are going to discuss cyclicity in the graph. In figure 1 you see a cyclic ER-diagram. In case A, we have the following meanings for the relationships:

- teacher t teaches course c
- student s takes course c
- student s takes a course given by teacher t

In case B, we have the following meanings for the relationships:

- teacher t teaches course c
- student s takes course c
- teacher t is the tutor of students s.

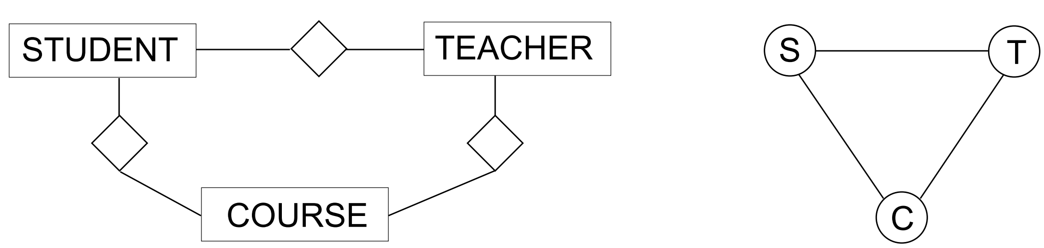

Figure 1: cyclic ER-diagram and ER-graph

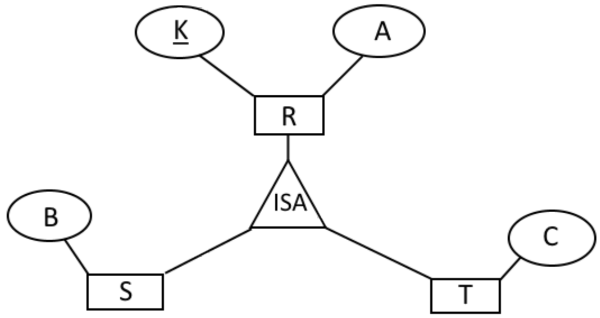

Figure 2: ISA hierarchy

(ii) Does a cyclic ER-diagram make sense in case A? Explain.

(iii) Does a cyclic ER-diagram make sense in case B? Explain.

Next, we suppose we have no relationships, but only ISA-hierarchies. We can associate a directed graph with our ER-model by taking the entites as nodes again, but now we represent ISA-hierarchies with directed links.

(iv) Would you allow cyclicity in such an ER-graph? Explain.

Exercise 7

Suppose we have an ISA hierarchy with supertype A and subtypes B and C. There are two characterisations for ISA hierarchies: *disjoint/overlapping* and *covering/non covering*. Disjoint means that different subtypes do not have elements in common. Covering means that every instance of the supertype can be found in at least one subtype.
For each of the four combinations, show the sets of instances of A, B and C in a Venn-diagram.

Exercise 8

We continue the quest for database schemas derived from ERD's. Suggest a relational schema for the ISA hierarchy in figure 2. Consider all combinations of (non) overlapping and (non) covering subtypes.

functional dependencies

Exercise 9

Explain what the concepts *key* and *FD* have in common. Can one of these concepts be seen as a special case of the other?

Exercise 10

Suppose we have a scheme $R(ABCDEFGHK)$ with FDs $\{A \to BC, CD \to H, CG \to AE, H \to G, B \to D, F \to G\}$. Calculate A^+ and $(BC)^+$. Check whether $BC \to F$ and $BC \to G$ hold.

Exercise 11

Find two keys for R from the previous exercise.

Exercise 12

Check the soundness of the following rules. If the rule is not correct, give a counterexample. If it is, prove it from the Armstrong axioms, or from rules that you have proven to be correct already. *(Hint:* when rewriting rules, you may identify XX with X and XY with YX, because these symbols represent sets of attributes.)

- $X \to Y \Rightarrow Y \to X$ (symmetry)
- $X \to Y, X \to Z \Rightarrow X \to YZ$ (union)
- $X \to YZ \Rightarrow X \to Y$ (right decomposition)
- $XY \to Z, X \to Y \Rightarrow X \to Z$ (left reduction)
- $X \to Y, U \to V \Rightarrow XU \to YV$ (augmentation 2)
- $XY \to Z \Rightarrow X \to Z$ (left decomposition)

Exercise 13(!)

Prove the main decomposition theorem: if the fd $X \to Y$ holds on scheme $R(X, Y, Z)$, the decomposition on $R_1(X, Y)$ and $R_2(X, Z)$ is lossless.

Exercise 14(!)

We want to prove the correctness of the algorithm for calculating the closure of a set of attributes. To achieve this, we have to prove two claims:

1 the calculated attributes for X^+ are indeed functionally dependent on X (soundness)

2 all attributes that depend on X will finally be in the calculated set X^+ (completeness).

Give arguments for the soundness (part 1) of this algorithm. (*Hint:* you can do this by formulating an invariant.)
Prove the completeness.