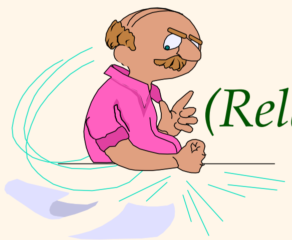
Introduction to Data Management



Lecture #10
(Relational Design Theory, cont.)

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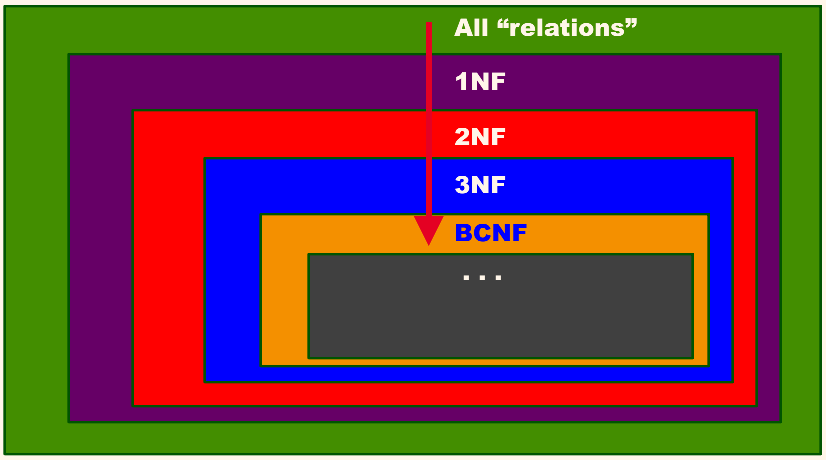
Announcements

- Homework stuff
  - HW #1 is now graded
  - HW #3 is due on Friday
  - HW #4 will come out on Monday (after the exam)
- Exam stuff (time flies!)
  - Midterm #1 is next Monday (**in class**)
  - We'll use assigned seating – come early!
  - You **may** bring an 8.5"x11" (2-sided) cheat sheet
- Today's plan:
  - Relational DB design theory (*IV & Final!*)
  - *Good news*: This should really be the end!… ☺

Reminder: Normal Forms



Dependency Preserving Decomp. *(Review)*

- The decomposition of R into two tables X and Y is *dependency preserving* if $(F_X \text{ union } F_Y)^+ = F^+$
  - I.e., if we consider only dependencies in the closure F^+ that can be checked in X **without** considering Y, and in Y **without** considering X, they ***imply*** all dependencies in F^+!
- Important to consider $\mathbf{F^+}$, not F, in this definition:
  - *Ex:* EmpDeptMix(eid, email, ename, did, dname) with eid→email, email→eid, eid→ename, email→did, did→dname
    - Emp(eid, email, ename) - eid→email, email→eid, eid→ename
    - Dept(did, dname) - did→dname
    - Work(eid, did) - eid→did (instead of email→did)

Must check for both!

- Dependency preserving does ***not*** imply lossless join:
  - *Ex:* ABC with A→B, if decomposed into AB and BC. (*Q:* Key?)

Decomposing a Design into BCNF

- Consider a relation R with FDs F. If **X → Y** violates BCNF, decompose R into R–**Y** and **XY**. *(R-Y has X still!)*
  - Repeated application of this idea will yield a collection of relations that are BCNF, a lossless join decomposition, and guaranteed to terminate. *(Didn't say dependency preserving...)*
- *Ex:* CSJDPQV with C→CSJDPQV, *JP* →*C*, *SD* →*P*, and *J* →*S*.
  - To deal with *SD* →*P*, decompose into SDP, CSJDQV.
  - To deal with *J* →*S*, decompose CSJDQV into JS and CJDQV.
- Note that in general, several of the dependencies may cause violations of BCNF. (And the order in which we process them can lead to different decompositions … only some of which may be dependency preserving!)

BCNF and Dependency Preservation

- In general, there simply may not ***be*** a dependency preserving decomposition into BCNF.
  - E.g., R(CSZ) with *CS* → *Z*, *Z* → *C*.
  - Can't decompose preserving the first FD; not in BCNF...
- Consider again decomposing the relation CSJDPQV into relations SDP, JS and CJDQV:
  - *Not* dependency preserving (*w.r.t. JP* → *C*, *SD* → *P*, *J* → *S*).
  - However, it ***is*** indeed a lossless join decomposition.
  - In this case, ***adding*** JPC to the collection of relations would give us a dependency preserving decomposition.
    - But: JPC data would be used only for FD checking! *(Redundancy!)*

这个就是说JP->C这个没有在那些小relation里面体现出来，我们可以加一个table，但是这会导致Redundancy

Decomposition into 3NF

- The lossless join decomposition algorithm for BCNF can also be used to obtain a lossless join decomposition into 3NF (and might stop earlier).
- One idea to ensure dependency preservation:
  - If X→Y is not preserved in the BCNF decomposition, add relation XY.
  - Problem is that XY may violate 3NF (or even 2NF), so this approach won't work in general.
- The real fix: Instead of using the *given* set of FDs F to guide the decomposition, use a *minimal cover for F*.

Minimal Cover for a Set of FDs

- *Minimal cover* **G** for a set of FDs F such that:
  - Closure of G = closure of F, i.e., $G^+ = F^+$.
  - Right hand side (RHS) of each FD in G is a ***single*** attribute.
  - If we change G by deleting any FD or deleting attributes from the LHS of any FD in G, the closure would change.
- Intuitively: Every FD in G is needed, with G as "*as small as possible*" to have the same closure as F.
- *E.g.*, A→B, ABCD→E, EF→GH, ACDF→EG has the following minimal cover:
  - A→**B**, ACD→**E**, EF→**G** and EF→**H**
- *M.C.*→ lossless-join, dep. pres. 3NF decomposition!

Computing the Minimal Cover

1. Put the set of given FDs in a Standard Form.
   - This turns F into a set G of equivalent FDs with a single attribute on the right-hand side.
2. Minimize the left-hand side of each FD in G.
   - For each FD in G, check each LHS attribute to see if it can be deleted without breaking the equivalence G+ = F+.
3. Delete redundant FDs.
   - For any FDs that remain, check to see if it can be deleted without breaking the equivalence G+ = F+.

And voila – you now have a minimal cover for F…!

Obtaining that 3NF Decomposition

I. Compute the minimal cover G (which is also sometimes denoted as F-).

II. Search for dependencies in F- that have the same attribute set on their left hand side, α:

   a. $\alpha \rightarrow Y1$, $\alpha \rightarrow Y2$, …. $\alpha \rightarrow Yk$
   b. Construct one relation as (α,Y1, Y2, ...Yk)
   c. Repeat this process for all of the FDs' α's
   d. If none of the relations from above contains a candidate key for the original relation R, add one more relation with (just) the attributes of a candidate key for R.
      (Q: Why…?)

Testing Your Understanding…

- Now that you now how to compute BCNF and 3NF decompositions, try it on our earlier examples!
  - *≠2NF*: Supplies(sno, sname, saddr, pno, pname, pcolor)
    with: sno→sname, sno→saddr, pno→pname, pno→pcolor
  - *≠3NF*: Workers(eno, ename, esal, dno, dname, dfloor)
    with: eno→ename, eno,ename→esal, eno→dno, dno→ dname,dfloor
  - *≠BCNF*: Supply2(sno, sname, pno)
    with: sno→sname, sname→sno

Note: I changed the *≠3NF* example's FDs to be equivalent to our earlier FDs but messier to better illustrate the nature of the minimal cover algorithm's operation.

Testing Your Understanding (cont.)…

- *≠3NF*:

Workers(eno, ename, esal, dno, dname, dfloor

with: eno→ename, eno,ename→esal, eno→dno, dno→ dname,dfloor

3NF M.C. step 1:		*3NF M.C. step 2:*
eno→ename		
eno,ename→esal	→	eno→esal
eno→dno		
dno→dname		
dno→dfloor		

Q1: What is the attribute closure of eno – and what does that mean...?

We got lucky!
(No lossy join!)

3NF step II:

Emp(<u>eno</u>, ename, esal, dno)
Dept(<u>dno</u>, dname, dfloor)

Q2: What if the Emp-Dept relationship had been M:N?

Testing Your Understanding (cont.)…

- *≠3NF*:

Workers(eno, ename, esal, dno, dname, dfloor)
with: eno→ename, eno,ename→esal, eno→dno, dno→ dname,dfloor

eno→ename
eno,ename→esal → eno→esal
eno→dno
dno→dname
dno→dfloor

Q1: What is the attribute closure of eno – and what does that mean...?

{eno}
{eno, ename}
{eno, ename, esal}
{eno, ename, esal, dno}
{eno, ename, esal, dno, dname}
{eno, ename, esal, dno, dname, dfloor}

→ That's everything in Workers! (***Therefore***…?)

Testing Your Understanding (cont.)…

- *≠3NF*:

Workers(eno, ename, esal, dno, dname, dfloor)
with: eno→ename, eno,ename→esal, eno→dno, dno→ dname,dfloor

eno→ename
eno,ename→esal → eno→esal
~~eno→dno~~
dno→dname
dno→dfloor

Q2: What if the Emp-Dept relationship had been M:N?

Else we'd have a **lossy join…!**

Emp(eno, ename, esal, ~~dno~~)
Dept(dno, dname, dfloor)

Works(eno, dno)

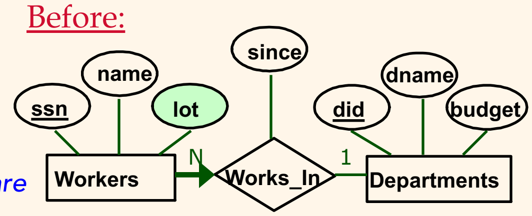
Relational Design Theory Summary

- If a relation is in BCNF, it is free of redundancies that can be detected using FDs. (Trying to ensure that all relations are in BCNF is thus a good goal.)
- If a relation is not in BCNF, we can decompose it into a lossless-join collection of BCNF relations.
  - Are all FDs preserved? If a lossless-join, dependency-preserving decomposition into BCNF is not possible (or is unsuitable for typical queries), consider 3NF instead.
  - Note: Decompositions should be carried out while also keeping *performance requirements* in mind. (More later!)

On Refining ER Based Designs

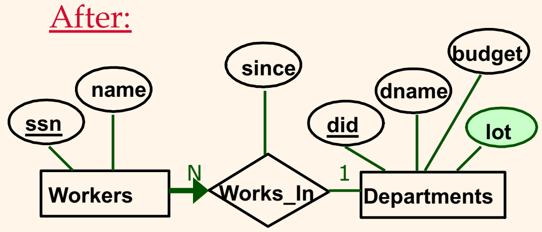
- 1st diagram translated:
  Workers(S,N,L,*D*,S)
  Departments(D,M,B)
  - Lots associated with workers.
- *Suppose all workers in a dept are assigned the same lot: D → L ....*
- Redundancy; fixed by:
  Workers2(S,N,*D*,S)
  WorkersLots(D,L)
  Departments(D,M,B)
- Can further fine-tune this:
  Workers2(S,N,*D*,S)
  Departments(D,M,B,L)

Before:



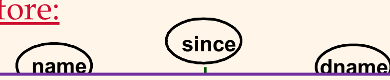
Notice: Lot **wasn't** really a "Worker attribute"!

After:



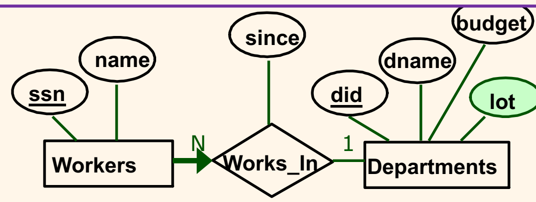
PS: On Refining ER Based Designs

Before:



- 1st diagram translated:
  Workers(S,N,L,D,S)
  Department
  - Lots assoc
- *Suppose all*
  assigned the
- Redundancy
  Workers2(S,
  WorkersLots
  Departments(D,M,B)
- Can further fine-tune this:
  Workers2(S,N,*D*,S)
  Departments(D,M,B,L)

Note:
In many cases the relational translation of an ER design will take you right to 3NF (and BCNF)…!
- Entity key→attributes for entity sets.
- Relationship key→ attributes for relationship sets.
(But problems could arise with FDs within attributes.)



Questions…?