Normalization

Anomalies
Boyce-Codd Normal Form
3rd Normal Form

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Anomalies

- Goal of relational schema design is to avoid anomalies and redundancy.
  - *Update anomaly* : one occurrence of a fact is changed, but not all occurrences.
  - *Deletion anomaly* : valid fact is lost when a tuple is deleted.

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Example of Bad Design

Drinkers(<u>name</u>, addr, <u>beersLiked</u>, manf, favBeer)

name	addr	beersLiked	manf	favBeer
Janeway	Voyager	Bud	A.B.	WickedAle
Janeway	???	WickedAle	Pete's	???
Spock	Enterprise	Bud	???	Bud

Data is redundant, because each of the ???'s can be figured out by using the FD's name -> addr favBeer and beersLiked -> manf.

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This Bad Design Also Exhibits Anomalies

name	addr	beersLiked	manf	favBeer
Janeway	Voyager	Bud	A.B.	WickedAle
Janeway	Voyager	WickedAle	Pete's	WickedAle
Spock	Enterprise	Bud	A.B.	Bud

- Update anomaly: if Janeway is transferred to *Intrepid*, will we remember to change each of her tuples?
- Deletion anomaly: If nobody likes Bud, we lose track of the fact that Anheuser-Busch manufactures Bud.

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Boyce-Codd Normal Form

- We say a relation *R* is in *BCNF* if whenever *X* ->*A* is a nontrivial FD that holds in *R*, *X* is a superkey.
  - Remember: *nontrivial* means *A* is not a member of set *X*.
  - Remember, a *superkey* is any superset of a key (not necessarily a proper superset).

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Example

- Drinkers(<u>name</u>, addr, <u>beersLiked</u>, manf, favBeer)
- FD's: name->addr favBeer, beersLiked->manf
- Only key is {name, beersLiked}.
- In each FD, the left side is *not* a superkey.
- Any one of these FD's shows *Drinkers* is not in BCNF

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Another Example

- Beers(name, manf, manfAddr)
- FD's: name->manf,   manf->manfAddr
- Only key is {name}.
- name->manf does not violate BCNF, but manf->manfAddr does.

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Decomposition into BCNF

- Given: relation R with FD's F.
- Look among the given FD's for a BCNF violation $X \text{->} B$.
  - If any FD following from F violates BCNF, then there will surely be an FD in F itself that violates BCNF.
- Compute X^+.
  - Not all attributes, or else X is a superkey.

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Decompose R Using X -> B

- Replace R by relations with schemas:
  - $R_1 = X^+$.
  - $R_2 = (R - X^+) \cup X$.
- Project given FD's F onto the two new relations.
  - Compute the closure of F = all nontrivial FD's that follow from F.
  - Use only those FD's whose attributes are all in R_1 or all in R_2.

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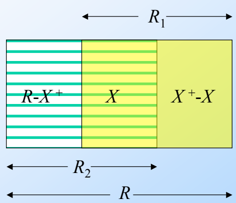
Decomposition Picture



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Example

- Drinkers(name, addr, beersLiked, manf, favBeer)
- *F* = name->addr, name -> favBeer, beersLiked->manf
- Pick BCNF violation name->addr.
- Close the left side: $\{name\}^+$ = {name, addr, favBeer}.
- Decomposed relations:
  - Drinkers1(name, addr, favBeer)
  - Drinkers2(name, beersLiked, manf)

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Example, Continued

- We are not done; we need to check Drinkers1 and Drinkers2 for BCNF.
- Projecting FD's is complex in general, easy here.
- For Drinkers1(name, addr, favBeer), relevant FD's are name->addr and name->favBeer.
  - Thus, *name* is the only key and Drinkers1 is in BCNF.

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Example, Continued

- For Drinkers2(name, beersLiked, manf), the only FD is beersLiked->manf, and the only key is {name, beersLiked}.
  - Violation of BCNF.
- beersLiked$^+$ = {beersLiked, manf}, so we decompose *Drinkers2* into:
  - Drinkers3(beersLiked, manf)
  - Drinkers4(name, beersLiked)

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Example, Concluded

- The resulting decomposition of *Drinkers* :
  - Drinkers1(name, addr, favBeer)
  - Drinkers3(beersLiked, manf)
  - Drinkers4(name, beersLiked)
- Notice: *Drinkers1* tells us about drinkers, *Drinkers3* tells us about beers, and *Drinkers4* tells us the relationship between drinkers and the beers they like.

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Third Normal Form - Motivation

- There is one structure of FD's that causes trouble when we decompose.
- *AB* -> *C* and *C* -> *B*.
  - Example: *A* = street address, *B* = city, *C* = zip code.
- There are two keys, {*A*,*B* } and {*A*,*C* }.
- *C* -> *B* is a BCNF violation, so we must decompose into *AC*, *BC*.

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We Cannot Enforce FD's

- The problem is that if we use *AC* and *BC* as our database schema, we cannot enforce the FD *AB* -> *C* by checking FD's in these decomposed relations.
- Example with *A* = street, *B* = city, and *C* = zip on the next slide.

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An Unenforceable FD

street	zip
545 Tech Sq.	02138
545 Tech Sq.	02139

city	zip
Cambridge	02138
Cambridge	02139

Join tuples with equal zip codes.

street	city	zip
545 Tech Sq.	Cambridge	02138
545 Tech Sq.	Cambridge	02139

Although no FD's were violated in the decomposed relations, FD street city -> zip is violated by the database as a whole.

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3NF Let's Us Avoid This Problem

- 3rd Normal Form (3NF) modifies the BCNF condition so we do not have to decompose in this problem situation.
- An attribute is *prime* if it is a member of any key.
- *X* ->*A* violates 3NF if and only if *X* is not a superkey, and also *A* is not prime.

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Example

- In our problem situation with FD's *AB* ->*C* and *C*->*B*, we have keys *AB* and *AC*.
- Thus *A*, *B*, and *C* are each prime.
- Although *C*->*B* violates BCNF, it does not violate 3NF.

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What 3NF and BCNF Give You

- There are two important properties of a decomposition:
  - *Recovery* : it should be possible to project the original relations onto the decomposed schema, and then reconstruct the original.
  - *Dependency preservation* : it should be possible to check in the projected relations whether all the given FD's are satisfied.

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3NF and BCNF, Continued

- We can get (1) with a BCNF decompsition.
  - Explanation needs to wait for relational algebra.
- We can get both (1) and (2) with a 3NF decomposition.
- But we can't always get (1) and (2) with a BCNF decomposition.
  - street-city-zip is an example.

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