CONSTRUCTOR UNIVERSITY

Normal Forms

Ramakrishnan & Gehrke, Chapter 17 & 18

The Evils of Redundancy

Dept_id	budget	Emp_id	Emp_name	salary
1	100	1	John Williams	60
1	100	2	Phil Coulter	50
2	200	3	Norah Jones	45
3	300	4	Anastacia	40

- Redundancy at the root of several relational schema problems
  - redundant storage, insert/delete/update anomalies
- Integrity constraints identify problems and suggest refinements
  - in particular: functional dependencies

Functional Dependencies

- Let R be relation, X and Y sets of attributes of R
- Functional dependency (FD) $X \rightarrow Y$ holds over relation R if, for every allowable instance r of R:
  - $t1 \in r,\ t2 \in r$:
    $\pi_X(t1) = \pi_X(t2) \Rightarrow \pi_Y(t1) = \pi_Y(t2)$
  - FDs in example?

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1	100	1	John Williams	60
1	100	2	Phil Coulter	50
2	200	3	Norah Jones	45
3	300	4	Anastacia	40

- K is a candidate key for R means that $K \rightarrow R$
  - $K \rightarrow R$ does not require K to be minimal!
- FD is a statement about all allowable relation instances
  - Must be identified based on semantics of application
  - Given some allowable instance r1 of R,
    we can check if it violates some FD f, but we cannot tell if f holds over R!

Example: Constraints on Entity Set

- Consider relation obtained from Hourly_Emps:
  - Hourly_Emps (ssn, name, lot, rating, hrly_wages, hrs_worked)
- Notation: relation schema by listing the attributes: SNLRWH
  - set of attributes {S,N,L,R,W,H}
  - Using equivalently to relation name (e.g., Hourly_Emps for SNLRWH)
- Some FDs on Hourly_Emps:
  - ssn is key: $S \rightarrow SNLRWH$
  - rating determines hrly_wages: $R \rightarrow W$

Example (Contd.)

- Problems due to R → W :
  - Update anomaly:
    change W in just the 1st tuple of SNLRWH?
  - Insertion anomaly:
    insert employee and don't know the hourly wage for his rating?
  - Deletion anomaly:
    delete all employees with rating 5
    ⇒ lose information about the wage for rating 5!

S	N	L	R	W	H
123-22-3666	Attishoo	48	8	10	40
231-31-5368	Smiley	22	8	10	30
131-24-3650	Smethurst	35	5	7	30
434-26-3751	Guldu	35	5	7	32
612-67-4134	Madayan	35	8	10	40

Wages

R	W
8	10
5	7

Hourly_Emps2

S	N	L	R	H
123-22-3666	Attishoo	48	8	40
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131-24-3650	Smethurst	35	5	30
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Will 2 smaller tables be better?

Normal Forms & Functional Dependencies

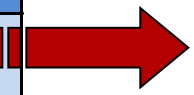
- normal forms avoid / minimize certain kinds of problems
  - helps to decide on decomposing relation
- Role of FDs in detecting redundancy
  - No FDs hold: no redundancy
  - Given relation R with 3 attributes ABC and FD A → B:
    Several tuples might have the same A value; if so, they all have the same B value

It's all about hidden repeating information across tuples

First Normal Form

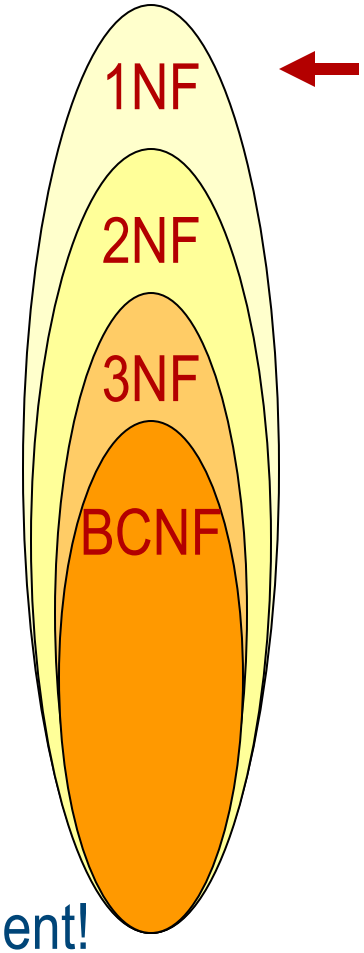
- First Normal Form (1NF)
  - eliminates attributes containing sets = repeating groups
  - ...by flattening: introduce separate tuples with atomic values
- Ex:

id	name	skillsList
1	Jane	{C,C++,SQL}
2	John	{Java,python,SQL}



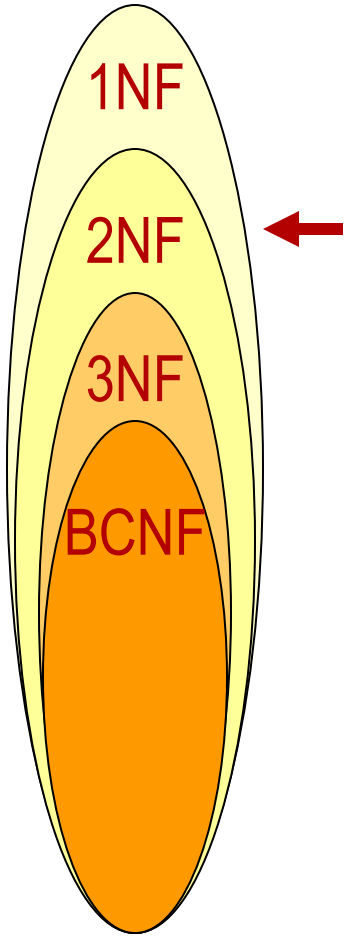
id	name	skill
1	Jane	C
1	Jane	C++
1	Jane	SQL
2	John	Java
2	John	Python
2	John	SQL

  - Skills not f.d. on id, nor name!
- Oops: lost primary key property.
  - Will fix that later.
- Why good? Repeating groups complicate storage management!
  - Experimental DBMSs exist for non-1NF (NFNF, NF^2) tables



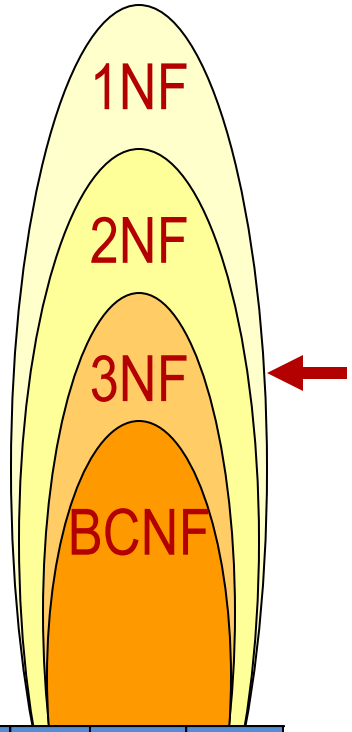
Second Normal Form

- Second Normal Form (2NF):
  - eliminates functional dependencies on a partial key
  - by putting the fields in a separate table from those that are dependent on the whole key
- Ex: ABCD with B→C
  becomes: ABD, BC



Third Normal Form (3NF)

- Relation R with FD set F is in 3NF if, for all $X \rightarrow A$ in F^+,
  - Either $A \in X$ (called a *trivial* FD)
  - Or X contains a key for R
  - Or A is part of some key for R
- In plain words:
  - 3NF eliminates functional dependencies on non-key fields by putting them in a separate table
  - = in 3NF, all non-key fields are dependent on
    the key,
    the whole key,
    and nothing but the key
- Ex:



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Why Is 3NF Good?

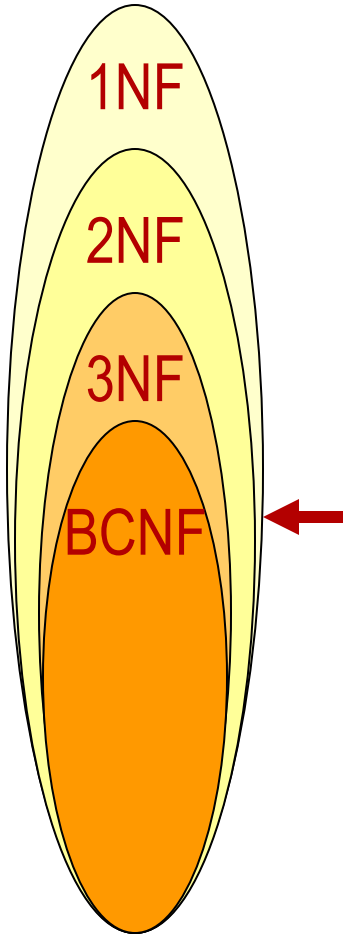
- If 3NF violated by $X \rightarrow A$, one of the following holds:
- X subset of some key K
  - We store (X, A) pairs redundantly
- X not a proper subset of any key
  - Which means: for some key K, there is a chain of FDs $K \rightarrow X \rightarrow A$
  - Which means: we once introduced keys to capture dependencies, but now we have attributes dependent on a non-key attribute!
- …so non-3NF means dangerous updates!

What Does 3NF NOT Achieve?

- Some redundancy possible with 3NF
- Ex: Reserves SBDC, S → C, C → S
  - is in 3NF
  - but S ↔ C means:
    for each reservation of sailor S, same (S, C) pair is stored
- …so we still need to capture "nests" inside the keys

Boyce-Codd Normal Form (BCNF)

- Relation R with FDs *F* is in BCNF if, for all $X \rightarrow A$ in F^+,
  - Either $A \in X$ (called a *trivial* FD)
  - Or X contains a key for R
  - ~~Or A is part of some key for R~~
- In other words:
  R in BCNF ⇔ only key-to-nonkey constraints FDs left
  - ✓ = No redundancy in R that can be detected using FDs alone
  - ✓ = No FD constraints "hidden in data"



Discussion: 3NF vs. BCNF

- Always possible?
  - 3NF always possible, is “nice” (lossless-join, dependency-preserving)
  - BCNF not always possible
- 3NF compromise used when BCNF not achievable
  - Ex: performance considerations
  - Ex: cannot find ``good'' decomp (see next)

Decomposition of a Relation Scheme

- Given relation R with attributes A1 ... An
- decomposition of R = replacing R by two or more relations such that:
  - Each new relation scheme contains a subset of the attributes of R (and no additional attributes), and
  - Every attribute of R appears as an attribute of one of the new relations
- E.g., decompose SNLRWH into SNLRH and RW

Example Decomposition

- SNLRWH has FDs
  S → SNLRWH, R ↔ W, N → SN
- 2nd FD causes 3NF violation:
  W values repeatedly associated with R values (and vice versa)!

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- Easiest fix: create relation RW to store assocs w/o dups, remove W from main schema
  = decompose SNLRWH into SNLRH and RW

Wages

R	W
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5	7

Hourly_Emps2

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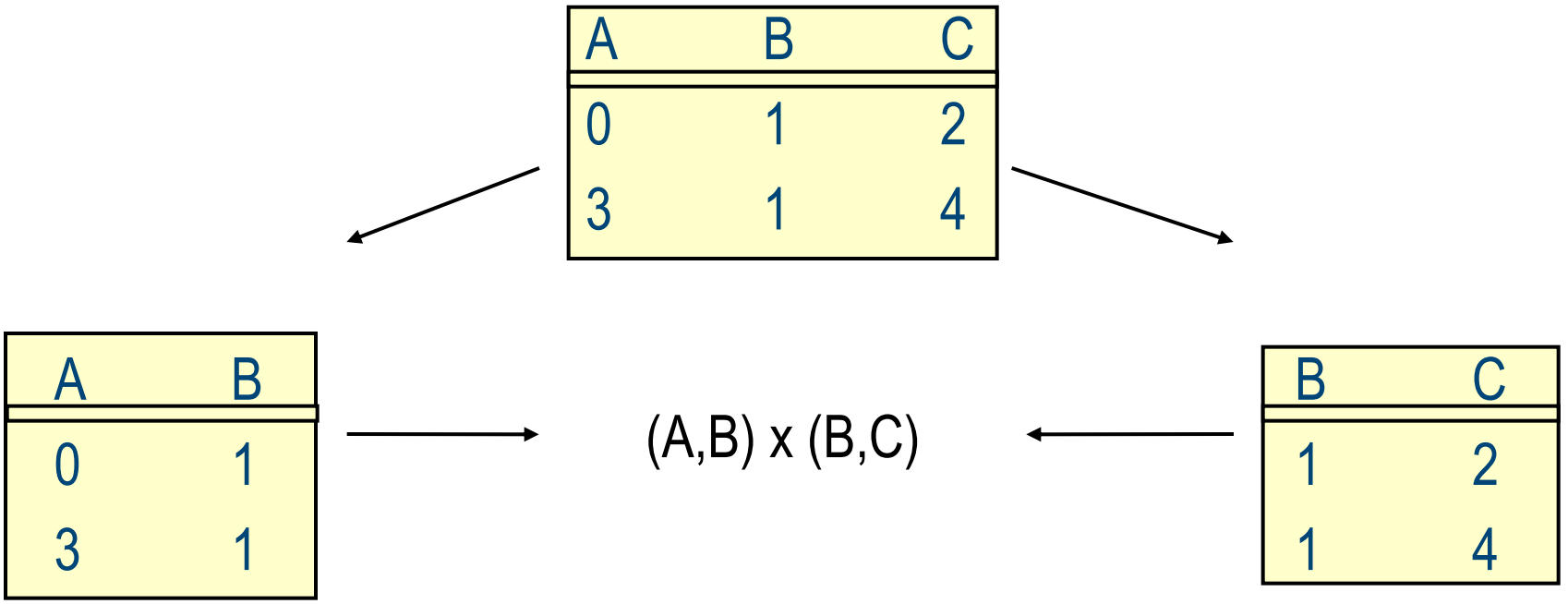
If we just store projections of SNLRWH tuples onto SNLRH and RW, are there any potential problems?

3 Potential Problems with Decomp

- Some queries become more expensive
  - e.g., How much did sailor Joe earn? (salary = W*H)
- may not be able to reconstruct original relation
  - Fortunately, not in the SNLRWH example
  - 

Lossless Join: A Counter Example



What's wrong?

3 Potential Problems with Decomp

- Some queries become more expensive
  - e.g., How much did sailor Joe earn? (salary = W*H)
- may not be able to reconstruct original relation ↳
  - Fortunately, not in the SNLRWH example
- Checking some dependencies may require joining decomposed relations
  - Fortunately, not in the SNLRWH example

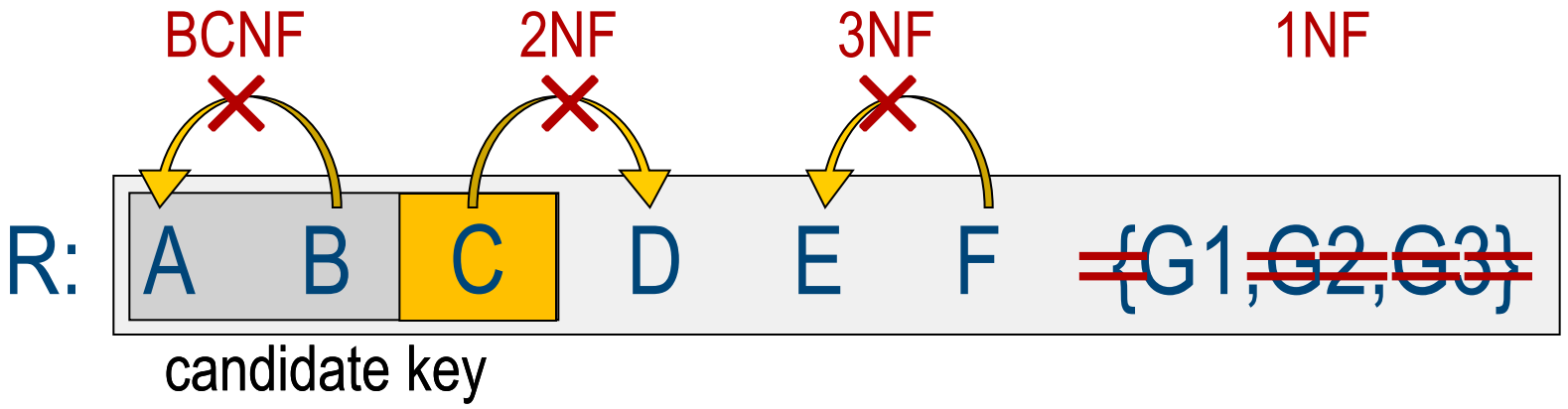
- Tradeoff: Must consider these issues vs. redundancy

Summary of Schema Refinement

- BCNF = free of redundancies that can be detected using FDs
  - BCNF good heuristic (consider typical queries!)
    - *Check FDs !*
  - Next best: 3NF
- When not BCNF?
  - not always possible
  - unsuitable, given typical queries - performance requirements
- Use decompositions only when needed!

↳NF pocket guide

Pocket Guide to NFs



- 1NF = no repeating groups
- 2NF = 1NF + no partial key → non-key
- 3NF = 2NF + no non-key → anything
- BCNF = 3NF + no key → key

Normalization of table R with FD set :

- For all FDs F = „X → Y“:
  - Create additional table $R_F(X,Y)$
  - Remove Y from R, but keep X
- Drop duplicate tables arising from „X → Y, Y → X“ cycles
- Crosscheck all new tables created against all FDs for decomposition need

Example Schemas

Contracts (Cid, Sid, Jid, Did, Pid, Qty, Val)
Depts (Did, Budget, Report)
Suppliers (Sid, Address)
Parts (Pid, Cost)
Projects (Jid, Mgr)

- Contracts = CSJDPQV; ICs: JP $\rightarrow$ C, SD $\rightarrow$ P; C is primary key
  - candidate keys for CSJDPQV?
  - What normal form is this relation schema in?