Relational Database Design

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First Normal Form

- A relation schema R is said to be in 1NF, if the domain of all attributes in R is atomic in nature.
- A domain is atomic if elements of the domain are of indivisible units
- i.e. according to 1NF, there can't be sub-structure within a column and the value present in each attribute is never a set of values or a list of values.
- Examples
  - Sub-structure: address (street, city, state, pin), Name(fname,mname,lname)
  - Set/List of values: multiple phone numbers, mail ids, names etc.

(1NF)First Normal Form

- Atomicity is actually a property of how the elements of the domain are used.
  - Example: Strings would normally be considered indivisible
  - Suppose that students are given roll numbers which are strings of the form *CS0012* or *EE1127*
  - If the first two characters are extracted to find the department, the domain of roll numbers is not atomic.
  - Doing so is a bad idea: leads to encoding of information in application program rather than in the database.

2NF(2nd Normal Form)

- A Relation schema R with FD is said to be in 2NF w.r.t F^+

If there doesn't exist any partial functional dependency in F^+ .

Partial Functional Dependency:- Consider a relation schema that has a composite key k. The relation schema is said to exhibit partial FD of the form x 'determines' y or x->y if x is a proper subset of k(key of R) and y is a non key attribute.

Alt Def: When a part of key (key being composite) functionally determines non key attribute then the functional dependency shall be a partial functional dependency.

2NF(2nd Normal Form) Example

- $R = (A, B, C, D, E)$
  $F = \{A \rightarrow B, C \rightarrow D, AC \rightarrow E\}$
  Key = $\{AC\}$

Verify R satisfy 2NF or not??

Key=AC

There exist partial FDs of the form $A \rightarrow B$, $C \rightarrow D$
Hence it is not in 2NF

??? SO what should we do??

Goals of Normalization

- Let *R* be a relation scheme with a set *F* of functional dependencies.
- Decide whether a relation scheme *R* is in "good" form.
- In the case that a relation scheme *R* is not in "good" form, decompose it into a set of relation scheme $\{R_1, R_2, ..., R_n\}$ such that
  - each relation scheme is in good form
  - the decomposition is a lossless-join decomposition
  - Preferably, the decomposition should be dependency preserving.

2NF(2nd Normal Form) Example

- $R = (A, B, C, D, E)$
  $F = \{A \rightarrow B, C \rightarrow D, AC \rightarrow E\}$
  Key = $\{AC\}$

Decomposition

- $R_1 = (A, B)$ key = A $F_1 = \{A \rightarrow B\}$ key = A
- $R_2 = (C, D)$ key = C $F_2 = \{C \rightarrow D\}$ key = C
- $R_3 = \{A, C, E\}$ key = AC $F_3 = \{AC \rightarrow E\}$ key = AC

This is lossless decomposition because

$R_1 \cap R_2 = A \rightarrow B$ *is the key of* R_1

$R_2 \cap R_3 = C \rightarrow D$ *is the key of* R_2

Its also dependency preserving because

$(F_1 \cup F_2 \cup \ldots \cup F_n)^+ = F^+$

Third Normal Form

- A relation schema *R* is in **third normal form (3NF)** if for all:

  $$\alpha \rightarrow \beta \text{ in } F^+$$

  at least one of the following holds:
  - $\alpha \rightarrow \beta$ is trivial (i.e., $\beta \in \alpha$)
  - α is a super key for *R*
  - At least one attribute in right hand side i.e. β must contain a prime attribute (i.e. a part of candidate key)

  (**NOTE**: each attribute may be in a different candidate key

key→nonkey→nonkey leads to redundancy and hence must be eliminated

Alternative Definition: A relation schema(R) is in 3NF if R is in 2NF and doesn't exhibit any transitive chain of dependency of the form key→nonkey→nonkey

3NF Example

- Relation *dept_advisor*:
  - *dept_advisor (s_ID, i_ID, dept_name)*
    F = {*s_ID, dept_name* → *i_ID*, *i_ID* → *dept_name*}
  - Two candidate keys: *s_ID, dept_name*, and *i_ID, s_ID*
  - *R* is in 3NF
    - *s_ID, dept_name* → *i_ID*

      s_ID, dept_name is a superkey
    - *i_ID* → *dept_name*

      dept_name is contained in a candidate key

Testing for 3NF

- Optimization: Need to check only FDs in *F*, need not check all FDs in F^+.
- Use attribute closure to check for each dependency $\alpha \rightarrow \beta$, if α is a superkey.
- If α is not a superkey, we have to verify if each attribute in β is contained in a candidate key of *R*
  - this test is rather more expensive, since it involve finding candidate keys
  - testing for 3NF has been shown to be NP-hard
  - Interestingly, decomposition into third normal form (described shortly) can be done in polynomial time

3NF Decomposition Algorithm

Let F_c be a canonical cover for F;
$i := 0$;
for each functional dependency $\alpha \rightarrow \beta$ in F_c **do**
  if none of the schemas R_j, $1 \le j \le i$ contains $\alpha\ \beta$
    then begin
      $i := i + 1$;
      $R_i := \alpha,\beta$
    end
if none of the schemas R_j, $1 \le j \le i$ contains a candidate key for R
  then begin
    $i := i + 1$;
    R_i := any candidate key for R;
  end
/* Optionally, remove redundant relations */
repeat
if any schema R_j is contained in another schema R_k
  then /* delete R_j ***/**
    $R_j = R$;
    $i=i-1$;
return $(R_1, R_2, ..., R_i)$

Optional---Erase Unnecessary Tables

3NF Decomposition Algorithm (Cont.)

- Summary of the Above Algorithm:

  1. To Find Canonical Cover F_c for the F.D set.
  2. For each F.D in F_c we create a new Relational schema.
  3. If any schema doesn't contain the candidate key then make a new schema for the candidate key itself.
  4. Remove unnecessary relation schemas

- Above algorithm ensures:
  - each relation schema R_i is in 3NF
  - decomposition is dependency preserving and lossless-join
  - Proof of correctness is at end of this chapter

3NF Decomposition: An Example

- Relation schema:

  cust_banker_branch = (*customer_id, employee_id, branch_name, type*)

- The functional dependencies for this relation schema are:
  1. *customer_id, employee_id* → *branch_name, type*
  2. *employee_id* → *branch_name*
  3. *customer_id, branch_name* → *employee_id*
- We first compute a canonical cover
  - *branch_name* is extraneous in the r.h.s. of the 1st dependency
  - No other attribute is extraneous, so we get F_C =

    customer_id, employee_id → *type*
    employee_id → *branch_name*
    customer_id, branch_name → *employee_id*

  Key= {employee_id, customer_id}

3NF Decompsition Example (Cont.)

- The **for** loop generates following 3NF schema:

  (*customer_id, employee_id, type*)

  (*employee_id, branch_name*)

  (*customer_id, branch_name, employee_id)*

  - Observe that (*customer_id, employee_id, type*) contains a candidate key of the original schema, so no further relation schema needs be added

- At end of for loop, detect and delete schemas, such as (*employee_id, branch_name*), which are subsets of other schemas

  - result will not depend on the order in which FDs are considered

- The resultant simplified 3NF schema is:

  (*customer_id, employee_id, type*)

  (*customer_id, branch_name, employee_id)*

Alternative 3NF Decomposition Algorithm

1. Given R and F.D, we find candidate keys and identify prime and non-prime attributes.

2. Check for 2NF in the functional dependency.

3. If the F.D. doesn't hold 2NF, decompose the schema for the dependency which violates the 2NF

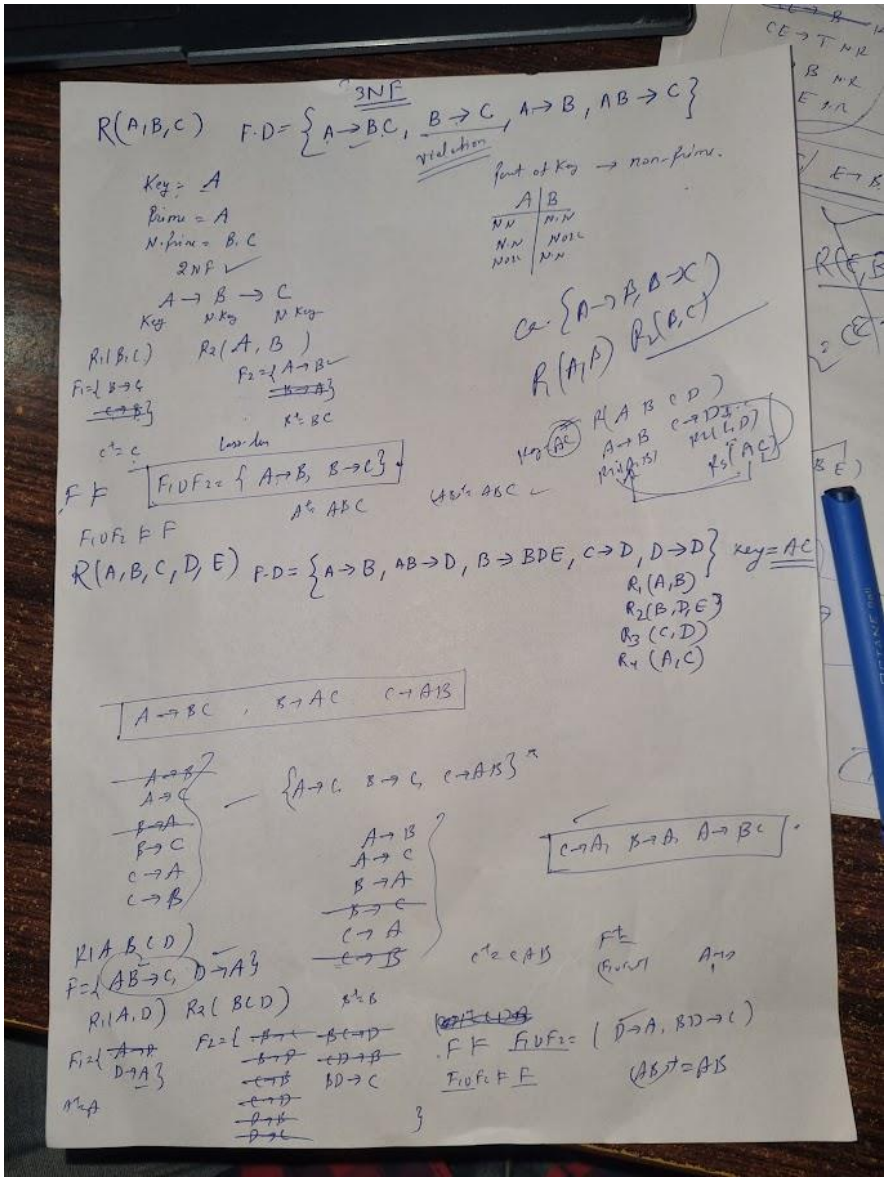
4. Create a new R1 consisting of attributes that violate and new R2 with attributes not in R1+key of R1

5. If the F.D. doesn't hold 3NF, decompose the schema for the dependency which violates the 3NF

6. Repeat step4 for R3 and R4 and check for 3NF again.

- Above algorithm ensures:
  - each relation schema R_i is in 3NF/2NF
  - To check whether the decomposition is lossless-join
  - To check whether the decomposition is dependency preserving w.r.t previous decomposed schema

Example 3NF Decomposition



Redundancy in 3NF

- There is some redundancy in the previous example schema
- Example of problems due to redundancy in 3NF
- J= *s_ID* , *K= dept_name, L= i_ID*
  - *R = (J, K, L)*
    F = {JK → L, L → K }

J	*L*	*K*
j_1	l_1	k_1
j_2	l_1	k_1
j_3	l_1	k_1
null	l_2	k_2

- repetition of information (e.g., the relationship l_1, k_1)
  - *(i_ID, dept_name)*
- need to use null values (e.g., to represent the relationship l_2, k_2 where there is no corresponding value for *J*).
  - *(i_ID, dept_nameI)* if there is no separate relation mapping instructors to departments

Thank You