

1NF: no more than  
one value per  
attribute per tuple  
at a time

~~2NF~~

3NF

4NF

5NF

BCNF

guarantee:  
 - no redundancy  
 - no update or  
 del anomalies  
 - lossless



Use the closure algorithm  
and the normal-form  
criteria (for 3DNF or 3NF)  
in our decomposition

- we will need to

= find superkeys ✓

= find keys ✓

= find FD's in a  
projection of a relation

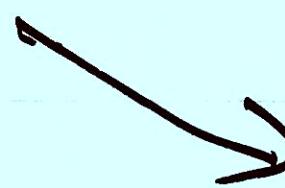


decomposition  
that is not  
lossless:

$$R: \begin{array}{cccc} A & B & C & D \\ \hline 1 & 2 & 3 & 4 \\ 5 & 6 & 7 & 8 \end{array}$$



$$R1: \begin{array}{cc} A & B \\ \hline 1 & 2 \\ 5 & 6 \end{array}$$



$$R2: \begin{array}{cc} C & D \\ \hline 3 & 4 \\ 7 & 8 \end{array}$$

Criterion for a relation  
being in BCNF

(Boyce Codd):

A relation is in BCNF if  
- all its FD's have  
a superkey of the  
relation on the  
left-hand side (LHS)



$R(ABCD)$	<del>FDs</del>
$AB \rightarrow C$	✓
$C \rightarrow D$	—
$D \rightarrow A$	—

[When you start  
(step one)  
- if it is  
sufficient  
to check  
just the given FD]

$$AB^+ = ABCD$$

$$C^+ = ACD$$

$$D^+ = AD$$

If not in BCNF:  
- iterate:

- (a) split using a noncompliant FD
- (b) check if the results are all in BCNF (using all the FDs)



If R is not in BCNF

- picking  $C \rightarrow D$  for the decomposition

The attributes  
in the closure  
of the LHS  
of  $C \rightarrow D$ :

$R1(ACD)$

The remaining  
atts plus  
the LHS  
of  $C \rightarrow D$ .

$R2(BC)$

A 2-attr rel  
is always in BCNF  
 $L(C \& 3NF) \cap BCNF$



Is  $R_1(ACD)$   
in BCNF?

for  $ACD$   
↓ only

LHS a superkey?

$$C \rightarrow D$$

$$C^+ = ACD \quad \checkmark$$

$$D \rightarrow A$$

$$D^+ = AD \quad -$$

$$\underline{C \rightarrow A}$$

$$C^+ = ACD \quad \checkmark$$

$$AC \rightarrow D$$

$$AC^+ = ACD \quad \checkmark$$

$$CD \rightarrow A$$

$$CD^+ = ACD$$

$\Rightarrow R_1$  is not in BCNF  
because of  $D \rightarrow A$



$R1(ACD)$  - decomposing  
into BCNF using  
 $D \rightarrow A$

$\downarrow$   
 $R3(AD)$

$\downarrow$   
 $R4(CD)$

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A decomposition of  
 $R(ABCD)$  with  $AB \rightarrow C$ ,

$C \rightarrow D$ ,  $D \rightarrow A$  into  
BCNF is  $\{R2(BC), R3(AD), R4(CD)\}$

Apply( $\text{SSN}$ , college, name,  
 $\text{HSCode}$ ,  $\text{HSCity}$ , sports)

$\text{SSN} \rightarrow \text{name}$  —

$\text{HSCode} \rightarrow \text{HSCity}$  —

Applications( $\text{SSN}$ , college,  
 $\text{HSCode}$ , sports)

Applicants( $\text{SSN}$ , name)

HSchools( $\text{HSCode}$ ,  $\text{HSCity}$ )



$R(ABC)$  $AB \rightarrow C$  $C \rightarrow B$  // BCNF violation $R1(BC)$  $R2(AC)$ 

$AB \rightarrow C$  can no longer be enforced

(E)

# 3NF decomposition

- use the same BCNF-decomposition algorithm
- = but with a different stopping criterion  
(BCNF + additional condition)



## 3NF criteria:

A relation satisfies 3NF if, for each of its FDs,

- either the BCNF criterion is satisfied
- or the RHS of the FD is part of a key



Students ( $ID$ ,  $addr$ ,  $landph$ )

$ID \rightarrow addr$

$ID^+$  is BCNF OK

$addr \rightarrow landph$

$addr^+$  is not OK

$R(ABC)$	LHS is a Superkey	RHS is part of key (don't look)	(BCNF)
$A \rightarrow B$	✓	✓	
$B \rightarrow C$	—	—	

Decomposition: Same for BCNF & 3NF:  $R_1(AB)$ ,  $R_2(BC)$



$R(ABCD)$ 
 $AB \rightarrow C$ 

LHS is  
superkey

LHS is part  
of key

 $C \rightarrow D$ 

—

✓

 $D \rightarrow A$ 

—

✓

Keys:  $AB, BC, BD$

$\Rightarrow R(ABCD)$  with  $AB \rightarrow C$ ,  
 $C \rightarrow D, D \rightarrow A$  is in 3NF



$R(ABCD)$

$B \rightarrow C$

$B \rightarrow D$

(a) provide a BCNF decomposition of  $R$

$R_1(AB), R_2(BCD)$

(b) provide a 3NF decomposition of  $R$

$R_1(AB), R_2(BCD)$



keys: AB

