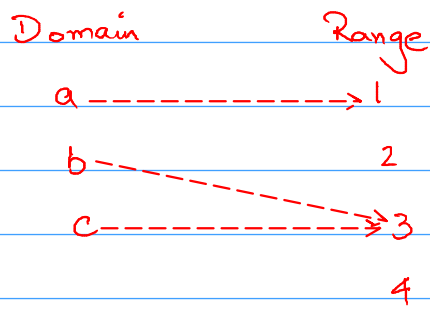


Functional Dependency FD



```

y = square(x)
int square(int x)
{
    return x * x;
}
    
```

If for every unique value of X
I get the same value for Y
the X functionally defines Y
or Y is functionally dependent on X

$$X \rightarrow Y$$

x	y
3	9
4	16
3	9
5	25
-3	9
1	1
0	0
-1	1
-3	9

attributes

A	B	C	D	E
a1	b1	c1	d1	e1
a2	b1	C2	d2	e1
a3	b2	C1	d1	e1
a4	b2	C2	d2	e1
a5	b3	C3	d1	e1

row/records

Table R

$$C \rightarrow D \quad \checkmark$$

$$D \rightarrow C \quad \times$$

$$B \rightarrow E \quad \checkmark$$

$$A \rightarrow B \quad \checkmark$$

$$B \rightarrow A \quad \times$$

$$BC \rightarrow D \quad \checkmark$$

$$Bc \rightarrow A \quad \checkmark$$

$$CD \rightarrow A \quad \times$$

Armstrong Axioms

1. If $B \subseteq A$ then $A \rightarrow B$
 Reflexivity
 $A \rightarrow A$
 name, age, address \rightarrow age
2. If $A \rightarrow B$ then $AX \rightarrow BX$
 Augmentation
 name \rightarrow sex
 name, age \rightarrow sex, age
3. If $A \rightarrow B$ and $B \rightarrow C$ then $A \rightarrow C$
 Transitivity
 roll# \rightarrow name
name \rightarrow sex
 roll# \rightarrow sex
4. If $A \rightarrow B$ & $A \rightarrow C$ then $A \rightarrow BC$
 Union
 roll# \rightarrow name
roll# \rightarrow address
 roll# \rightarrow name, address
5. If $A \rightarrow B$ & $X \rightarrow Y$ then $AX \rightarrow BY$
 Composition
 roll# \rightarrow s.name
cid \rightarrow t.name
 roll#, cid \rightarrow s.name, t.name
6. If $AX \rightarrow BY$ then $AX \rightarrow B$ & $AX \rightarrow Y$
 Decomposition
 reverse of Union
roll#, cid \rightarrow s.name, t.name, grade
 roll#, cid \rightarrow s.name
 roll#, cid \rightarrow t.name
 roll#, cid \rightarrow grade
7. If $A \rightarrow B$ & $BC \rightarrow D$ then $AC \rightarrow D$
 Pseudo Transitivity

$R(A, B, C, D, E, F)$

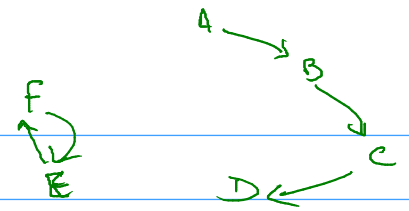
$A \rightarrow B$

$B \rightarrow C$

$C \rightarrow D$

$E \rightarrow F$

$F \rightarrow E$



$A \rightarrow A$

Reflexivity

$A \rightarrow B$

given

$A \rightarrow C$

transitivity

$A \rightarrow B, B \rightarrow C$

$A \rightarrow D$

transitivity

$A \rightarrow B, B \rightarrow C, C \rightarrow D$

$A \rightarrow E$

not possible

$AF \rightarrow E$

$A \rightarrow A$

Reflexivity

$F \rightarrow E$

Given

$AF \rightarrow AE$

Composition

Decomposition $\left\{ \begin{array}{l} AF \rightarrow A \\ AF \rightarrow E \end{array} \right.$

$AE \rightarrow ABCDEF$

A

$\left\{ \begin{array}{l} A \rightarrow A \\ A \rightarrow B \\ A \rightarrow C \\ A \rightarrow D \end{array} \right. \begin{array}{l} \text{Reflexivity} \\ \text{Given} \end{array}$

E

$\left\{ \begin{array}{l} E \rightarrow E \\ E \rightarrow F \end{array} \right. \begin{array}{l} \text{Reflexivity} \\ \text{Given} \end{array}$

Unions

$A \rightarrow ABCD$

$E \rightarrow EF$

$AE \rightarrow ABCDEF$ composition

Closure

$R(A, B, C, D, E)$

$A \rightarrow BC$

$C \rightarrow B$

$D \rightarrow E$

$E \rightarrow D$

①

$A^+ \rightarrow ABC$

$B^+ \rightarrow B$

$C^+ \rightarrow CB$

$D^+ \rightarrow DE$

$E^+ \rightarrow ED$

②

$AB^+ \rightarrow ABC$

AC^+

$AD^+ \rightarrow ADBCE$

$AE^+ \rightarrow AEBCE$

BC^+

$BD^+ \rightarrow BDE$

BE^+

CD^+

CE

DE^+

③

ABC^+

ABD^+

ABE^+

ACD^+

ACE^+

ADE^+

BCD^+

BCE^+

BDE^+

CDE^+

④

$ABCD^+$

$ABCE^+$

$ABDE^+$

$ACDE^+$

$BCDE^+$

⑤

$ABCDE^+ \rightarrow ABCDE$

of possible combinations = $2^n - 1$

Superkey: Set of attributes whose closure contain all attributes of Relation

HW-1

① $R(A, B, C, D, E)$

$A \rightarrow BC, C \rightarrow B, D \rightarrow E, E \rightarrow D$

② $R(A, B, C, D, E)$

$A \rightarrow B, B \rightarrow C, D \rightarrow C$

Find closure of all possible combinations

also identify superkeys

$R(V, W, X, Y, Z)$

$SK = \{ \overset{(2)}{VY}, \overset{(2)}{VZ}, \overset{(3)}{VWY}, \overset{(3)}{VWZ}, \overset{(3)}{VXY}, \overset{(3)}{VXZ}, \overset{(4)}{VWYZ}, \overset{(4)}{VWXZ}, \overset{(5)}{VWXYZ} \}$

$CK = \{VY, VZ\}$

Size of Superkey: # of attributes in the SK

Default Superkey: set of all attributes of the relation

Candidate key: Superkeys with smallest size

Primary key: One of the candidate key

$R(S, T, U, V, W)$

$S \rightarrow T \quad T \rightarrow U \quad U \rightarrow V \quad V \rightarrow W \quad W \rightarrow S$

$S^+ \rightarrow STUVW \checkmark$

$T^+ \rightarrow TUVWS \checkmark$

$U^+ \rightarrow UVWST \checkmark$

$V^+ \rightarrow VNSTU \checkmark$

$W^+ \rightarrow WSTUV \checkmark$

$CK = \{S, T, U, V, W\}$

$R(A, B, C, D, E)$

$D \rightarrow E, E \rightarrow D$

$R(W \ X \ Y \ Z)$

$Z \rightarrow WXY \quad X \rightarrow W$

$W^+ \rightarrow W$

$X^+ \rightarrow XW$

$Y^+ \rightarrow Y$

$CK = \{Z\}$

$Z^+ \rightarrow ZWXY \quad \checkmark$

$R(A \ B \ C \ D \ E)$

$A \rightarrow C \quad C \rightarrow B \quad B \rightarrow E \quad E \rightarrow D \quad D \rightarrow A$

$A^+ \rightarrow ACBED \quad \checkmark$

$B^+ \rightarrow BEDAC \quad \checkmark$

$C^+ \rightarrow CBEDA \quad \checkmark$

$CK = \{A, B, C, D, E\}$

$D^+ \rightarrow DACBE \quad \checkmark$

$E^+ \rightarrow EDACB \quad \checkmark$

$R(A \ B \ C \ D \ E)$

$A \rightarrow C \quad E \rightarrow D \quad B \rightarrow C$

$ABE^+ \rightarrow ABECD$

$CK = \{ABE\}$

\overline{D}	D
A	C
B	D
E	

$R(V \ W \ X \ Y \ Z)$

$Z \rightarrow WXY \quad X \rightarrow W \quad Y \rightarrow Z$

$V^+ \rightarrow V$

$VW^+ \rightarrow VW$

$VX^+ \rightarrow VXW$

$VY^+ \rightarrow VYZWX \quad \checkmark$

$CK = \{VY, VZ\}$

$VZ^+ \rightarrow VZWXY \quad \checkmark$

\overline{D}	D
V	W
	X
	Y
	Z

$R(A\ B\ C\ D\ E)$

$A \rightarrow C\ C \rightarrow B\ B \rightarrow D\ D \rightarrow E\ E \rightarrow A$

$A^+ \rightarrow ACBDE \checkmark$

$B^+ \rightarrow BDEAC \checkmark$

$C^+ \rightarrow CBDEA \checkmark$

$D^+ \rightarrow DEACB \checkmark$

$E^+ \rightarrow EACBD \checkmark$

$CK = \{A, B, C, D, E\}$

\overline{D}	D
	A
	B
	C
	D
	E

$R(A\ B\ C\ D\ E\ F\ G\ H\ I\ J)$

$AB \rightarrow EF\ A \rightarrow C\ B \rightarrow DGH I\ H \rightarrow I\ AE \rightarrow BDFGHI$

$A^+ \rightarrow AC$

$AB^+ \rightarrow ABCDGHIEF \checkmark$

$AE^+ \rightarrow AECBDEFGHI \checkmark$

$AH^+ \rightarrow AHC I$

L	B	R	\overline{D}	D
A	B	C	A	B
J	E	D	J	C
	H	F		D
		G		E
		I		F
				G
				H
				I

$CK = \{AB, AE\}$

Prime Attributes: Any attribute that appears in any CK

Non Prime Attributes: Any attribute which not a prime attribute

$AS^+ \rightarrow ASC$

$ASB \rightarrow ASBCDGHIEF \checkmark$

$AJE \rightarrow \checkmark$

$ASH \rightarrow$

$CK = \{ASB, ASE\}$

$P.A. = \{A, J, B, E\}$

$NPA = \{C, D, F, G, H, I\}$

$R(A, B, C, D, E, F, G, H)$

$AB \rightarrow C\ AC \rightarrow B\ AD \rightarrow E\ B \rightarrow D\ BC \rightarrow A\ E \rightarrow G$

11. R(A B C D)

$AB \rightarrow C$

$AB \rightarrow D$

$C \rightarrow A$

$D \rightarrow B$

L	B	R
	A	
	B	
	C	
	D	

$A^+ \rightarrow A$

$AB^+ \rightarrow ABCD \checkmark$

$B^+ \rightarrow B$

$AC^+ \rightarrow AC$

$C^+ \rightarrow CA$

$AD^+ \rightarrow ADBC \checkmark$

$D^+ \rightarrow DB$

$BC^+ \rightarrow BCAD \checkmark$

$BD^+ \rightarrow BD$

$CD^+ \rightarrow CDAB \checkmark$

$CK = \{AB, AD, BC, CD\}$

P.A = $\{A, B, C, D\}$

N.P.A = $\{\}$

Item	Color	Price	Tax	Qty
T-Shirt	Red, Blue	12.00	0.60	5, 3
Polo	Red, Yellow	15.00	0.60	8, 2
T-Shirt	Red, Black	12.00	0.60	5, 9
Sweatshirt	Blue, Black	25.00	1.25	12, 2

Database Design Guidelines

1. Table should have relevant data
2. Avoid redundancy — anomalies
 - insert
 - update
 - delete
3. Avoid NULL values
4. Avoid generation of spurious records (when using natural join)

Normalization

0 - Normal Form (0NF)

You should have table with data

1st Normal Form (1-NF)

Data must be in 0-NF

AND

no complex or multivalued data in the table

OR

-table should have FDs

OR

table should have PK

2nd Normal Form

Table must be in 1-NF

AND

All non prime attributes must be fully functionally dependent on whole primary key

OR

No partial dependency between Non prime attributes and portions of PK

3rd Normal Form

Table must be in 2nd Normal Form

AND

All non-prime attributes must be directly functionally dependent on the primary key

OR

No transitive dependency is allowed in the table b/w non-prime attributes and the PK.

Item	Color	Price	Tax	Qty
T-Shirt	Red, Blue	12.00	0.60	5, 3
Polo	Red, Yellow	15.00	0.60	8, 2
T-Shirt	Red, Black	12.00	0.60	5, 9
Sweatshirt	Blue, Black	25.00	1.25	12, 2

Item	Color	Price	Tax	Qty
T-shirt	Red	12.00	0.60	5
T-shirt	Blue	12.00	0.60	3
Polo	Red	15.00	0.60	8
Polo	Yellow	15.00	0.60	2
T-shirt	Red	12.00	0.60	5
T-shirt	Black	12.00	0.60	9
S-shirt	Blue	25.00	1.25	12
S-shirt	Black	25.00	1.25	2

Item \rightarrow Price
Price \rightarrow Tax
Item, Color \rightarrow Qty

$(\text{Item, Color})^+ \rightarrow \text{Item, Color, Price, Tax, Qty}$

L	B	R
Item	Price	Tax
Color		Qty

$CK = \{(\text{Item, Color})\}$
 $PK = (\text{item, color})$

$R1(\underline{\text{item}}, \underline{\text{color}}, \text{price}, \text{tax}, \text{qty})$

$R1$ is in 1NF

ABC
A Prime attributes = {item, color}
B Non Prime Attr = {~~price~~, ~~tax~~, qty}

C $\text{item}^+ \rightarrow \text{item price, tax}$ $R2(\underline{\text{item}}, \text{price}, \text{tax})$
AB $\text{color}^+ \rightarrow \text{color}$ $R3(\underline{\text{item}}, \underline{\text{color}}, \text{qty})$
AC

BC $R2 \ \& \ R3$ are in 2NF

$$A \rightarrow x$$

$$B \rightarrow y$$

$$C \rightarrow w$$

$$AB \rightarrow z$$

$$BC \rightarrow v$$

PK: ABC

$R1(\underline{A}, \underline{B}, \underline{C}, v, w, x, y, z)$

$$A^+ \rightarrow Ax$$

$$B^+ \rightarrow By$$

$$C^+ \rightarrow Cw$$

$$AB^+ \rightarrow ABxyz$$

$$AC^+ \rightarrow ACxw$$

$$BC^+ \rightarrow BCyvw$$

P.A: {A, B, C}

$\neg P.A: \{y, w, x, z, v\}$

$R2(\underline{A}, x)$

$R3(\underline{B}, y)$

$R4(\underline{C}, w)$

$R5(\underline{A}, \underline{B}, z)$

$R6(\underline{B}, \underline{C}, v)$

$R7(\underline{A}, \underline{B}, \underline{C})$

R2 (item, price, tax)

R4 (item, price)

R5 (price, tax)

R3 (item, color, qty)

R3, R4 & R5 are in 3NF

R4

<u>item</u>	price
T-shirt	12.00
Polo	15.00
S-shirt	25.00

R5

<u>price</u>	tax
12.00	0.60
15.00	0.60
25.00	1.25

R3

<u>item</u>	<u>color</u>	qty
T-shirt	Red	5
T-shirt	Blue	3
Polo	Red	8
Polo	Yellow	2
T-shirt	Black	9
S-shirt	Blue	12
S-shirt	Black	2

$(S\#, C\#, W\#)^+ \rightarrow S\#, C\#, W\#, SName, SArea, CName, WLoc, SAmount$

$CK = \{ (S\#, C\#, W\#) \}$

L	B	R
S#		SName SArea
C#		CName
W#		WLoc SAmount

$R1 (\underline{S\#}, \underline{C\#}, \underline{W\#}, SName, SArea, CName, WLoc, SAmount)$

$R1$ is in 1-NF

$S\#^+ \rightarrow S\#, SName, SArea$

$C\#^+ \rightarrow C\#, CName$

$W\#^+ \rightarrow W\#, WLoc$

$S\#, C\#^+ \rightarrow S\#, C\#, SName, SArea, CName$

$C\#, W\#^+ \rightarrow C\#, SName, SArea, W\#, WLoc$

$C\#, W\#^+ \rightarrow C\#, W\#, CName, WLoc$

P.A. = $\{ S\#, C\#, W\# \}$

N.P.A. = $\{ \cancel{SName}, \cancel{SArea}, \cancel{CName}, \cancel{WLoc}, \cancel{SAmount} \}$

$R2 (\underline{S\#}, SName, SArea)$

$R3 (\underline{C\#}, CName)$

$R4 (\underline{W\#}, WLoc)$

$R5 (S\#, C\#, W\#, SAmount)$

2NF

3NF

$R2 (\underline{S\#}, SName, SArea) \checkmark$

$R3 (\underline{C\#}, CName) \checkmark$

$R4 (\underline{W\#}, WLoc) \checkmark$

$R5 (\underline{S\#}, \underline{C\#}, \underline{W\#}, SAmount) \checkmark$

$(\underline{S\#}, \underline{C\#}, SName, SArea, CName)$
$S\# \rightarrow S\#, SName, SArea$
$C\# \rightarrow C\#, CName$

$R2, R3, R4 \& R5$ are in

3-NF

2nd NF

$R(\underline{X} \ Y \ Z)$

$X \rightarrow Y$
 $Y \rightarrow Z$

$X^+ \rightarrow XYZ$

$R(\underline{X} \ Y \ Z)$

$R_1(\underline{X}, Y)$
 $R_2(\underline{Y}, Z)$ } 3NF

L	B	R
X		
X	Z	Z
	Y	

$PC \rightarrow PT, PM, PB$

$E\# \rightarrow EN, D\#$

$D\# \rightarrow DN$

$E\#, PC \rightarrow HR$

L	B	R
PC	D#	PT
E#		PM
		PB
		EN
		DN
		HR

$PC, E\# \rightarrow PC, E\#, PT, PB, PM, EN, D\#, DN, HR$

$R_1(\underline{PC}, \underline{E\#}, PT, PB, PM, EN, D\#, DN, HR) \rightarrow$ 1st NF

$PC\# \rightarrow PC, PT, PB, PM$

$E\# \rightarrow E\#, EN, D\#, DN$

$R_2(\underline{PC}, PT, PB, PM)$
 $R_3(\underline{E\#}, EN, D\#, DN)$
 $R_4(\underline{PC}, E\#, HR)$ } 2NF

$R_2(\underline{PC}, \underline{PT}, \underline{PB}, \underline{PM})$ ✓

$R_3(\underline{E\#}, \underline{EN}, \underline{D\#}, \underline{DN})$

$R_5(\underline{E\#}, EN, D\#)$

$R_6(\underline{D\#}, DN)$

$R_4(\underline{PC}, \underline{E\#}, HR)$ ✓

R_2, R_4, R_5, R_6
3NF

Identification of Normal Form

$$\alpha \rightarrow \beta$$

(R.H.S has single attribute)

$$B: \{PA, NPA\}$$

$$\alpha: \{SK, CK, P, PC, NP, NPC\}$$

$$\underline{AB \rightarrow CD}$$

$$AB \rightarrow C$$

$$AB \rightarrow D$$

	3rd NF	2nd NF	1st NF	
$\alpha \rightarrow \beta$				$AB \rightarrow D$
$SK \rightarrow P$	✓	✓	✓	$AC \rightarrow E$
$SK \rightarrow NP$	✓	✓	✓	$ABC \rightarrow F$
$CK \rightarrow P$	✓	✓	✓	$A \rightarrow G$
$CK \rightarrow NP$	✓	✓	✓	$ABCD \rightarrow H$
$P \rightarrow P$	✓	✓	✓	
$P \rightarrow NP$	x	x	✓	
$PC \rightarrow P$	✓	✓	✓	
$PC \rightarrow NP$	x	x	✓	
$NP \rightarrow P$				
$NP \rightarrow NP$	x	✓	✓	
$NPC \rightarrow P$	✓	✓	✓	
$NPC \rightarrow NP$	x	✓	✓	

α is a SK

or

β is Prime

α is SK

or

α, β is Prime

or

$\alpha\beta$ is non prime

Relation should have FD

R(A B C D E)

$AB \rightarrow CD$

$D \rightarrow A$

$BC \rightarrow DE$

L	B	R
B	A	E
	C	
	D	

$BA^+ \rightarrow BACDE$ ✓

$BC^+ \rightarrow BCDEA$ ✓

$BD^+ \rightarrow BDACE$ ✓

$CK = \{AB, BC, BD\}$

$P.A. = \{A, B, C, D\}$

$N.P.A. = \{E\}$

	3NF
$AB \rightarrow C$	✓
$AB \rightarrow D$	✓
$D \rightarrow A$	✓
$BC \rightarrow D$	✓
$BC \rightarrow E$	✓

3NF

R(A B C D E F G H)

$AB \rightarrow CD$

$A \rightarrow DE$

$B \rightarrow F$

$F \rightarrow GH$

$CK = \{AB\}$

$P.A. = \{A, B\}$

$N.P.A. = \{C, D, E, F, G, H\}$

	3NF	2NF	1NF
$AB \rightarrow C$	✓	✓	✓
$AB \rightarrow D$	✓	✓	✓
$A \rightarrow D$	X	X	✓
$A \rightarrow E$			✓
$B \rightarrow F$			✓
$F \rightarrow G$			✓
$F \rightarrow H$			✓

1NF