

CMPT 354: Database System I

Lecture 9. Design Theory

Design Theory

- Design theory is about how to represent your data to avoid anomalies.

Design 1

Student	Course	Room
Mike	354	AQ3149
Mary	354	AQ3149
Sam	354	AQ3149
..

Design 2

Student	Course
Mike	354
Mary	354
Sam	354
..	..

Course	Room
354	AQ3149
454	T9204

Four Types of Anomalies - 1

- What's wrong?

Student	Course	Room
Mike	354	AQ3149
Mary	354	AQ3149
Sam	354	AQ3149
..

If every course is in only one room, contains
redundant information!

Four Types of Anomalies - 2

- What's wrong?

Student	Course	Room
Mike	354	AQ3149
Mary	354	T9204
Sam	354	AQ3149
..

If we update the room number for one tuple,
we get inconsistent data = an *update* anomaly

Four Types of Anomalies - 3

- What's wrong?

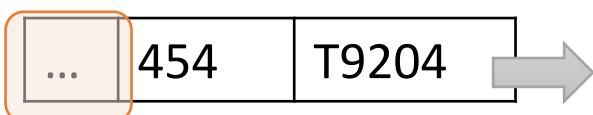
Student	Course	Room
..

If everyone drops the class, we lose what room the class is in! = a *delete* anomaly

Four Types of Anomalies - 4

- What's wrong?

Student	Course	Room
Mike	354	AQ3149
Mary	354	AQ3149
Sam	354	AQ3149
..



Similarly, we can't reserve a room without students = an insert anomaly

Elimination of Anomalies

- Is it better?

Student	Course
Mike	354
Mary	354
Sam	354
..	..

Course	Room
354	AQ3149
454	T9204

- Redundancy?
- Update anomaly?
- Delete anomaly?
- Insert anomaly?

Why this design may be better?
How to find this *decomposition*?

Normal Forms

- 1st Normal Form (1NF) = All tables are flat
- 2nd Normal Form = *disused*
- Boyce-Codd Normal Form (BCNF) = no bad FDs
- 3rd, 4th, and 5th Normal Forms = see text books

1st Normal Form (1NF)

Student	Courses
Mary	{CS145,CS229}
Joe	{CS145,CS106}
...	...

Violates 1NF.

Student	Courses
Mary	CS145
Mary	CS229
Joe	CS145
Joe	CS106

In 1st NF

1NF Constraint: Types must be atomic!

Normal Forms

- 1st Normal Form (1NF) = All tables are flat
- 2nd Normal Form = *disused*
- **Boyce-Codd Normal Form (BCNF)** = no bad FDs
What's this?
- 3rd, 4th, and 5th Normal Forms = see text books

Outline

1. Functional Dependency (FD)

2. Inference Problem

3. Closure Algorithm

Functional Dependency

Def: Let A,B be sets of attributes

We write $A \rightarrow B$ or say A *functionally determines* B if, for any tuples t_1 and t_2 :

$$t_1[A] = t_2[A] \text{ implies } t_1[B] = t_2[B]$$

and we call $A \rightarrow B$ a functional dependency

$A \rightarrow B$ means that
“whenever two tuples agree on A then they agree on B.”

A Picture Of FDs

	A_1	\dots	A_m		B_1	\dots	B_n	

Defn (again):

Given attribute sets $A = \{A_1, \dots, A_m\}$ and $B = \{B_1, \dots, B_n\}$ in R ,

A Picture Of FDs

	A_1	\dots	A_m		B_1	\dots	B_n	
t_i								
t_j								

Defn (again):

Given attribute sets $A = \{A_1, \dots, A_m\}$ and $B = \{B_1, \dots, B_n\}$ in R ,

The *functional dependency* $A \rightarrow B$ on R holds if for *any* t_i, t_j in R :

A Picture Of FDs

	A_1	...	A_m		B_1	...	B_n	
t_i								
t_j								

If t_1, t_2 agree here..

Defn (again):

Given attribute sets $A = \{A_1, \dots, A_m\}$ and $B = \{B_1, \dots, B_n\}$ in R ,

The *functional dependency* $A \rightarrow B$ on R holds if for *any* t_i, t_j in R :

$$t_i[A_1] = t_j[A_1] \text{ AND } t_i[A_2] = t_j[A_2] \text{ AND } \dots \text{ AND } t_i[A_m] = t_j[A_m]$$

A Picture Of FDs

	A_1	...	A_m		B_1	...	B_n	
t_i								
t_j								

If t_1, t_2 agree here.. ...they also agree here!

Defn (again):

Given attribute sets $A = \{A_1, \dots, A_m\}$ and $B = \{B_1, \dots, B_n\}$ in R ,

The *functional dependency* $A \rightarrow B$ on R holds if for *any* t_i, t_j in R :

if $t_i[A_1] = t_j[A_1]$ AND $t_i[A_2] = t_j[A_2]$ AND
... AND $t_i[A_m] = t_j[A_m]$

then $t_i[B_1] = t_j[B_1]$ AND $t_i[B_2] = t_j[B_2]$
AND ... AND $t_i[B_n] = t_j[B_n]$

Example

An FD holds, or does not hold on a table:

EmpID	Name	Phone	Position
E0045	Smith	1234	Clerk
E3542	Mike	9876	Salesrep
E1111	Smith	9876	Salesrep
E9999	Mary	1234	Lawyer

$\text{Position} \rightarrow \text{Phone}$

$\text{Phone} \rightarrow \text{Position}$

$\text{Phone, Name} \rightarrow \text{Position}$

Exercise - 1

An FD holds, or does not hold on a table:

Name	Category	Color	Department	Price
Gizmo	Gadget	Green	Toys	49
Tweaker	Gadget	Green	Toys	49
Gizmo	Stationary	Green	Office-supply	59

Name → Color

Category → Department

Color, Category → Color

Exercise - 2

A	B	C	D	E
1	2	4	3	6
3	2	5	1	8
1	4	4	5	7
1	2	4	3	6
3	2	5	1	8

Find at least *three* FDs which
do not hold on this table:

$$\begin{array}{ccc} \{ & \} & \rightarrow \{ & \} \\ \{ & \} & \rightarrow \{ & \} \\ \{ & \} & \rightarrow \{ & \} \end{array}$$

Outline

1. Functional Dependency (FD)

2. Inference Problem

3. Closure Algorithm

An Interesting Observation

Provided FDs:

1. Name \rightarrow Color
2. Category \rightarrow Department
3. Color, Category \rightarrow Price

Does it always hold? **Name, Category \rightarrow Price**

If we find out from application domain that a relation satisfies some FDs, it doesn't mean that we found all the FDs that it satisfies! There could be more FDs implied by the ones we have

Inference Problem

Whether or not a set of FDs imply another FD?

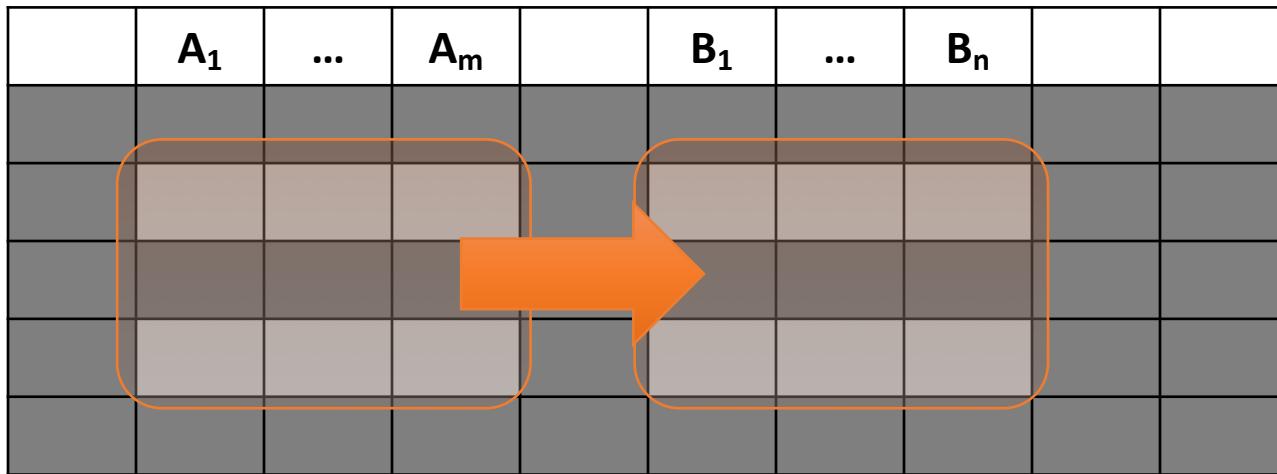
This is called **Inference problem**

Answer: Three simple rules called
Armstrong's Rules.

1. Split/Combine,
2. Reduction, and
3. Transitivity

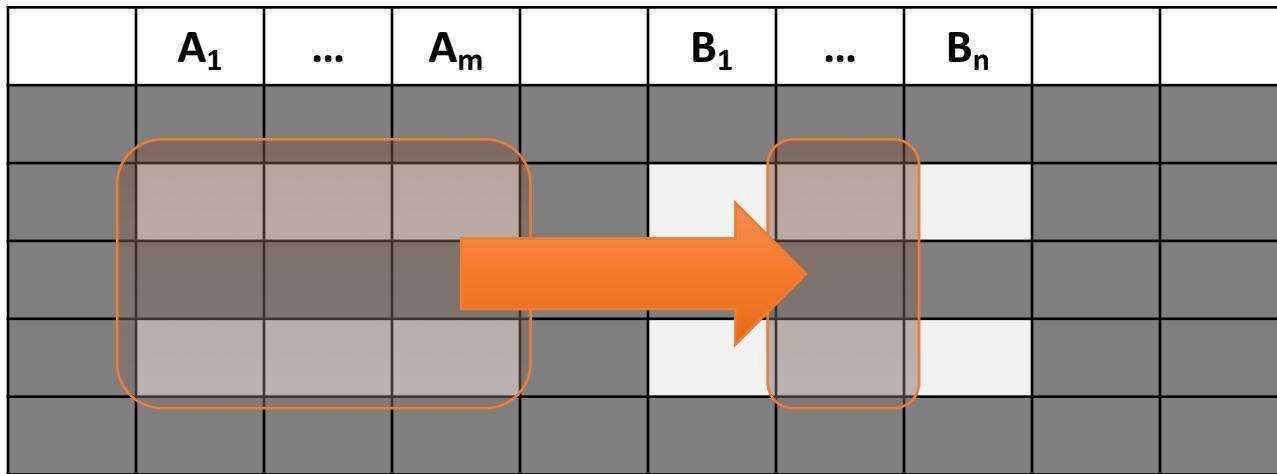
William Ward Armstrong is a Canadian mathematician and computer scientist. He earned his Ph.D. from the [University of British Columbia](#) in 1966 and is most known as the originator [Armstrong's axioms](#) of dependency in a [Relational database](#).^[1]

1. Split/Combine



$$A_1, \dots, A_m \rightarrow B_1, \dots, B_n$$

1. Split/Combine

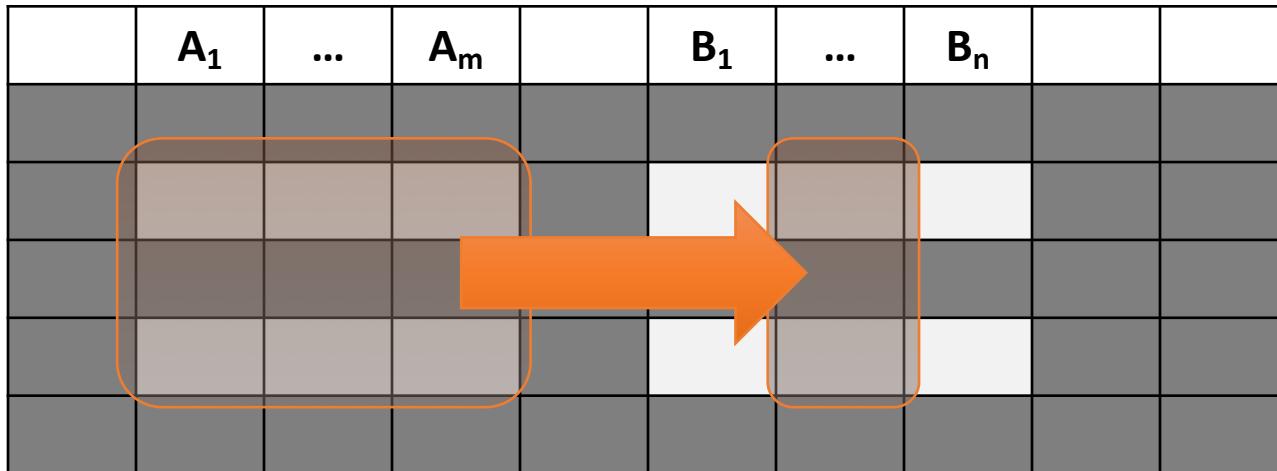


$$A_1, \dots, A_m \rightarrow B_1, \dots, B_n$$

... is equivalent to the following n FDs...

$$A_1, \dots, A_m \rightarrow B_i \text{ for } i=1, \dots, n$$

1. Split/Combine

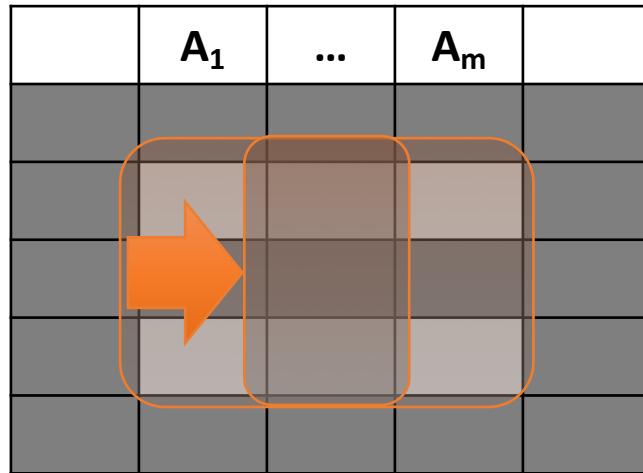


And vice-versa, $A_1, \dots, A_m \rightarrow B_i$ for $i=1, \dots, n$

... is equivalent to ...

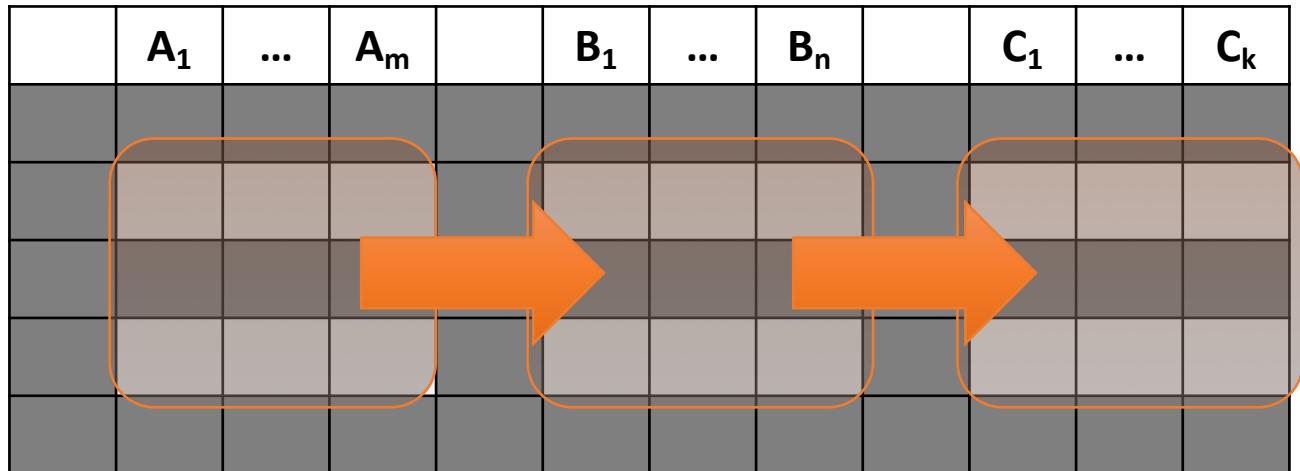
$$A_1, \dots, A_m \rightarrow B_1, \dots, B_n$$

2. Reduction/Trivial



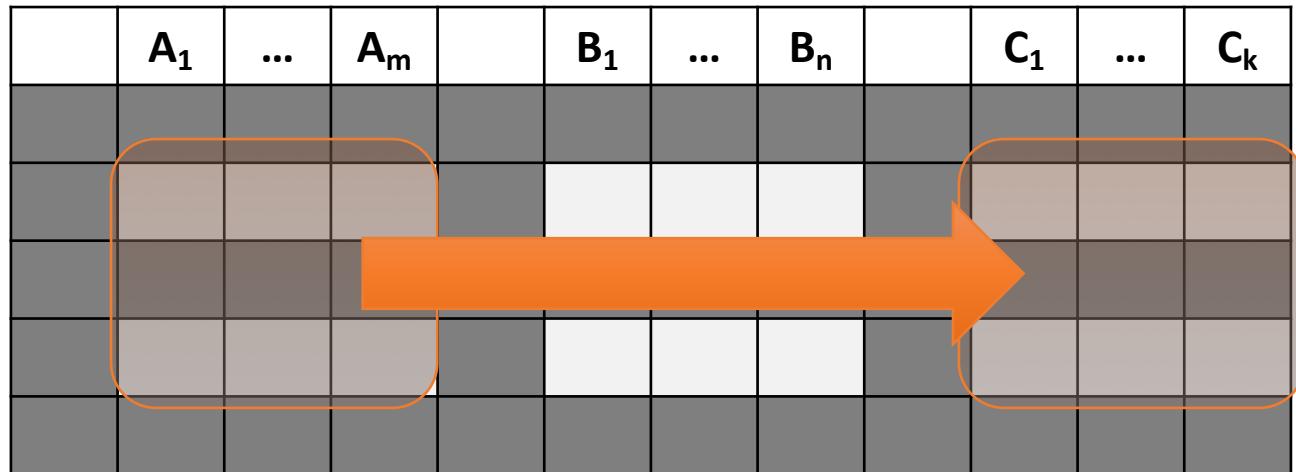
$$A_1, \dots, A_m \rightarrow A_j \text{ for any } j=1, \dots, m$$

3. Transitive



$A_1, \dots, A_m \rightarrow B_1, \dots, B_n$ and
 $B_1, \dots, B_n \rightarrow C_1, \dots, C_k$

3. Transitive



$A_1, \dots, A_m \rightarrow B_1, \dots, B_n$ and
 $B_1, \dots, B_n \rightarrow C_1, \dots, C_k$

implies

$A_1, \dots, A_m \rightarrow C_1, \dots, C_k$

Inferred FDs

Example:

Inferred FDs:

Inferred FD	Rule used
4. Name, Category → Name	?
5. Name, Category → Color	?
6. Name, Category → Category	?
7. Name, Category → Color, Category	?
8. Name, Category → Price	?

Provided FDs:

1. {Name} → {Color}
2. {Category} → {Dept.}
3. {Color, Category} → {Price}

Which / how many other FDs hold?

Inferred FDs

Example:

Inferred FDs:

Inferred FD	Rule used
4. Name, Category → Name	Trivial
5. Name, Category → Color	Transitive (4 -> 1)
6. Name, Category → Category	Trivial
7. Name, Category → Color, Category	Split/combine (5 + 6)
8. Name, Category → Price	Transitive (7 -> 3)

Provided FDs:

1. {Name} → {Color}
2. {Category} → {Dept.}
3. {Color, Category} → {Price}

Can we find an algorithmic way to do this?

Outline

1. Functional Dependency (FD)

2. Inference Problem

3. Closure Algorithm

Closure of a set of Attributes

Given a set of attributes A_1, \dots, A_n and a set of FDs F :

Then the closure, $\{A_1, \dots, A_n\}^+$ is the set of attributes B s.t. $\{A_1, \dots, A_n\} \rightarrow B$

Example: $F =$ $\text{name} \rightarrow \text{color}$
 $\text{category} \rightarrow \text{department}$
 $\text{color, category} \rightarrow \text{price}$

Closures:

$$\{\text{name}\}^+ = \{\text{name, color}\}$$

$$\{\text{name, category}\}^+ = \{\text{name, category, color, dept, price}\}$$

$$\{\text{color}\}^+ = \{\text{color}\}$$

Closure Algorithm

Start with $X = \{A_1, \dots, A_n\}$ and set of FDs F .

Repeat until X doesn't change; do:

if $\{B_1, \dots, B_n\} \rightarrow C$ is in F

and $\{B_1, \dots, B_n\} \subseteq X$

then add C to X .

Return X as X^+

Closure Algorithm

Start with $X = \{A_1, \dots, A_n\}$, FDs F.

Repeat until X doesn't change; do:

if $\{B_1, \dots, B_n\} \rightarrow C$ is in F
and $\{B_1, \dots, B_n\} \subseteq X$:
then add C to X.

Return X as X^+

$\{\text{name, category}\}^+ =$
 $\{\text{name, category}\}$

F =

name \rightarrow color

category \rightarrow dept

color, category \rightarrow price

Closure Algorithm

Start with $X = \{A_1, \dots, A_n\}$, FDs F.

Repeat until X doesn't change; do:

if $\{B_1, \dots, B_n\} \rightarrow C$ is in F
and $\{B_1, \dots, B_n\} \subseteq X$:
then add C to X.

Return X as X^+

$\{\text{name, category}\}^+ =$
 $\{\text{name, category}\}$

$\{\text{name, category}\}^+ =$
 $\{\text{name, category, color}\}$

F =

name \rightarrow color

category \rightarrow dept

color, category \rightarrow price

Closure Algorithm

Start with $X = \{A_1, \dots, A_n\}$, FDs F.

Repeat until X doesn't change; do:

if $\{B_1, \dots, B_n\} \rightarrow C$ is in F
and $\{B_1, \dots, B_n\} \subseteq X$:
then add C to X.

Return X as X^+

F =

name \rightarrow color

category \rightarrow dept

color, category \rightarrow price

$\{\text{name, category}\}^+ =$
 $\{\text{name, category}\}$

$\{\text{name, category}\}^+ =$
 $\{\text{name, category, color}\}$

$\{\text{name, category}\}^+ =$
 $\{\text{name, category, color, dept}\}$

Closure Algorithm

Start with $X = \{A_1, \dots, A_n\}$, FDs F.

Repeat until X doesn't change; do:

if $\{B_1, \dots, B_n\} \rightarrow C$ is in F
and $\{B_1, \dots, B_n\} \subseteq X$:
then add C to X.

Return X as X^+

F =

$\text{name} \rightarrow \text{color}$

$\text{category} \rightarrow \text{dept}$

$\text{color, category} \rightarrow \text{price}$

$\{\text{name, category}\}^+ =$
 $\{\text{name, category}\}$

$\{\text{name, category}\}^+ =$
 $\{\text{name, category, color}\}$

$\{\text{name, category}\}^+ =$
 $\{\text{name, category, color, dept}\}$

$\{\text{name, category}\}^+ =$
 $\{\text{name, category, color, dept, price}\}$

Exercise - 3

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

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

Compute $\{A, B\}^+ = \{A, B, \}$

Compute $\{A, F\}^+ = \{A, F, \}$

Exercise - 3

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

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

Compute $\{A, B\}^+ = \{A, B, C, D\}$ }

Compute $\{A, F\}^+ = \{A, F, B\}$ }

Exercise - 3

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

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

Compute $\{A, B\}^+ = \{A, B, C, D, E\}$

Compute $\{A, F\}^+ = \{A, B, C, D, E, F\}$

Exercise - 4

- Find all FD's implied by

A, B → C
A, D → B
B → D

Requirements

1. **Non-trivial** FD (i.e., no need to return $A, B \rightarrow A$)
2. The right-hand side contains a **single** attribute (i.e., no need to return $A, B \rightarrow C, D$)

Given $F =$

A, B	→	C
A, D	→	B
B	→	D

Exercise - 4

Step 1: Compute X^+ , for every set of attributes X:

$\{A\}^+ = ?$

$\{B\}^+ = ?$

$\{C\}^+ = ?$

$\{D\}^+ = ?$

$\{A, B\}^+ = ?$

$\{A, C\}^+ = ?$

$\{A, D\}^+ = ?$

$\{B, C\}^+ = ?$

$\{B, D\}^+ = ?$

$\{C, D\}^+ = ?$

$\{A, B, C\}^+ = ?$

$\{A, B, D\}^+ = ?$

$\{A, C, D\}^+ = ?$

$\{B, C, D\}^+ = ?$

$\{A, B, C, D\}^+ = ?$

Exercise - 4

Given $F =$

A, B	→	C
A, D	→	B
B	→	D

Step 1: Compute X^+ , for every set of attributes X:

$$\{A\}^+ = \{A\}$$

$$\{B\}^+ = \{B, D\}$$

$$\{C\}^+ = \{C\}$$

$$\{D\}^+ = \{D\}$$

$$\{A, B\}^+ = \{A, B, C, D\}$$

$$\{A, C\}^+ = \{A, C\}$$

$$\{A, D\}^+ = \{A, B, C, D\}$$

$$\{B, C\}^+ = \{B, C, D\}$$

$$\{B, D\}^+ = \{B, D\}$$

$$\{C, D\}^+ = \{C, D\}$$

$$\{A, B, C\}^+ = \{A, B, C, D\}$$

$$\{A, B, D\}^+ = \{A, B, C, D\}$$

$$\{A, C, D\}^+ = \{A, B, C, D\}$$

$$\{B, C, D\}^+ = \{B, C, D\}$$

$$\{A, B, C, D\}^+ = \{A, B, C, D\}$$

Exercise - 4

Given $F =$

A, B	→	C
A, D	→	B
B	→	D

Step 2: Enumerate all FDs $X \rightarrow Y$, s.t. $Y \subseteq X^+$ and $X \cap Y = \emptyset$:

$\{A\}^+ = \{A\}$
 $\{B\}^+ = \{B, D\}$
 $\{C\}^+ = \{C\}$
 $\{D\}^+ = \{D\}$
 $\{A, B\}^+ = \{A, B, C, D\}$
 $\{A, C\}^+ = \{A, C\}$
 $\{A, D\}^+ = \{A, B, C, D\}$
 $\{B, C\}^+ = \{B, C, D\}$
 $\{B, D\}^+ = \{B, D\}$
 $\{C, D\}^+ = \{C, D\}$
 $\{A, B, C\}^+ = \{A, B, C, D\}$
 $\{A, B, D\}^+ = \{A, B, C, D\}$
 $\{A, C, D\}^+ = \{A, B, C, D\}$
 $\{B, C, D\}^+ = \{B, C, D\}$
 $\{A, B, C, D\}^+ = \{A, B, C, D\}$

B → D
A, B → C
A, B → D
A, D → B
A, D → C
A, B, C → D
A, B, D → C
A, C, D → B

Review

1. Functional Dependency (FD)

- What is an FD?

2. Inference Problem

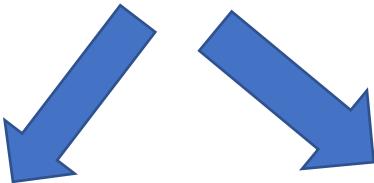
- Whether or not a set of FDs imply another FD?

3. Closure

- How to compute the closure of attributes?

High-level Idea

Student	Course	Room
Mike	354	AQ3149
Mary	354	AQ3149
Sam	354	AQ3149
..



Student	Course
Mike	354
Mary	354
Sam	354
..	..

Course	Room
354	AQ3149
454	T9204

Two Steps

1. Search for “bad” FDs in the table
2. *Keep decomposing the table into sub-tables until no more bad FDs*

Like a debugging process 😊

Outline

- “Good” vs. “Bad” FDs
- Boyce-Codd Normal Form
- Decompositions

“Good” vs. “Bad” FDs

EmpID	Name	Phone	Position
E0045	Smith	1234	Clerk
E3542	Mike	9876	Salesrep
E1111	Smith	9876	Salesrep
E9999	Mary	1234	Lawyer

EmpID → Name, Phone, Position

Good FD since EmpID can determine everything

EmpID is a
Key

Phone → Position

Bad FD since Phone cannot determine everything

Exercise - 1

Student	Course	Room
Mike	354	AQ3149
Mary	354	AQ3149
Sam	354	AQ3149
..

Student, Course → Room Good FD!

Course → Room Bad FD!

What's wrong with “Bad” FDs

- If $X \rightarrow Y$ is a Bad FD, then X functionally determines *some* of the attributes; therefore, those other attributes can be duplicated
 - Recall: this means there is redundancy
 - And redundancy like this can lead to data anomalies!

Student	Course	Room
Mike	354	AQ3149
Mary	354	AQ3149
Sam	354	AQ3149
..

Outline

- “Good” vs. “Bad” FDs
- Boyce-Codd Normal Form
- Decompositions

Boyce-Codd Normal Form (BCNF)

- Main idea is that we define “good” and “bad” FDs as follows:
 - $X \rightarrow A$ is a “*good FD*” if X is a key
 - In other words, if A is the set of all attributes
 - $X \rightarrow A$ is a “*bad FD*” otherwise
- We will try to eliminate the “bad” FDs!

Boyce-Codd Normal Form (BCNF)

A relation R is in BCNF if:
there are no “bad” FDs

A relation R is in BCNF if:
if $\{A_1, \dots, A_n\} \rightarrow B$ is a *non-trivial* FD in R
then $\{A_1, \dots, A_n\}$ is a key for R

Equivalently: \forall sets of attributes X, either $(X^+ = X)$ or $(X^+ = \text{all attributes})$

Example

Is this table in BCNF?

Name	SIN	PhoneNumber	City
Fred	123-45-6789	604-555-1234	Vancouver
Fred	123-45-6789	604-555-6543	Vancouver
Joe	987-65-4321	908-555-2121	Burnaby
Joe	987-65-4321	908-555-1234	Burnaby

$\{SIN\} \rightarrow \{Name, City\}$

This FD is *bad* because it is not a key

⇒ Not in BCNF

What is the key?
 $\{SIN, PhoneNumber\}$

Example

Name	<u>SIN</u>	City
Fred	123-45-6789	Vancouver
Joe	987-65-4321	Burnaby

$\{\text{SIN}\} \rightarrow \{\text{Name}, \text{City}\}$

This FD is now *good* because it is the key

<u>SIN</u>	<u>PhoneNumber</u>
123-45-6789	604-555-1234
123-45-6789	604-555-6543
987-65-4321	908-555-2121
987-65-4321	908-555-1234

Now in BCNF!

BCNF Decomposition Algorithm

BCNFD**e**comp(R):

BCNF Decomposition Algorithm

BCNFDcomp(R):

Find a non-trivial bad FD: $X \rightarrow Y$

X is not a key, i.e.,
 $X^+ \neq [all\ attributes]$

BCNF Decomposition Algorithm

BCNFD**e**comp(R):

Find a non-trivial bad FD: $X \rightarrow Y$

if (not found) then Return R

If no “bad” FDs found, in BCNF!

BCNF Decomposition Algorithm

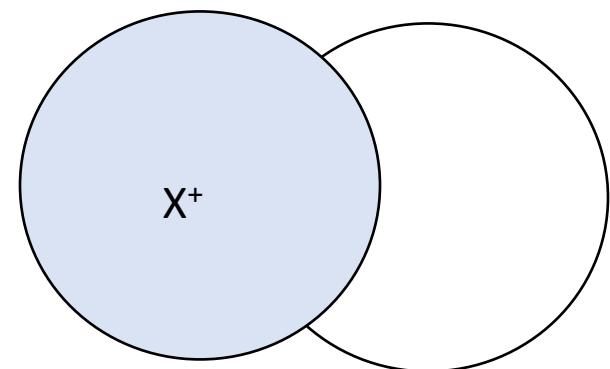
BCNFDcomp(R):

Find a non-trivial bad FD: $X \rightarrow Y$

if (not found) then Return R

Split R into X^+ and $X^+[\text{rest attributes}]$

One table is X^+



BCNF Decomposition Algorithm

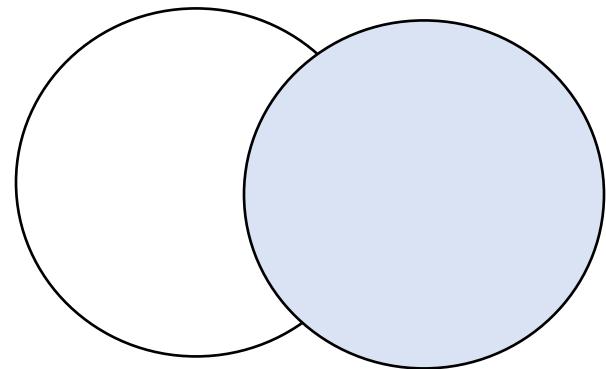
BCNFDcomp(R):

Find a non-trivial bad FD: $X \rightarrow Y$

if (not found) then Return R

Split R into X^+ and $X^+[\text{rest attributes}]$

The other table is
 $X + (R - X^+)$



BCNF Decomposition Algorithm

BCNFD**e**comp(R):

Find a non-trivial bad FD: $X \rightarrow Y$

if (not found) then Return R

Split R into X^+ and $X^+[\text{rest attributes}]$

Return BCNFD**e**comp(R_1), BCNFD**e**comp(R_2)

Proceed recursively until no more “bad” FDs!

BCNF Decomposition Algorithm

BCNFD**e**comp(R):

Find a non-trivial bad FD: $X \rightarrow Y$

Only look at the FD in the given set

if (not found) **then Return** R

Split R into X^+ and $X^+[\text{rest attributes}]$

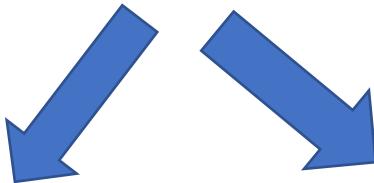
Return BCNFD**e**comp(R_1), BCNFD**e**comp(R_2)

Need to imply all FDs for R_1 and R_2

Example

Student	Course	Room
Mike	354	AQ3149
Mary	354	AQ3149
Sam	354	AQ3149
..

Course → Room



Student	Course
Mike	354
Mary	354
Sam	354
..	..

Course	Room
354	AQ3149
454	T9204

Exercise - 2

BCNFDecomp(R):

Find a non-trivial bad FD: $X \rightarrow Y$

if (not found) then Return R

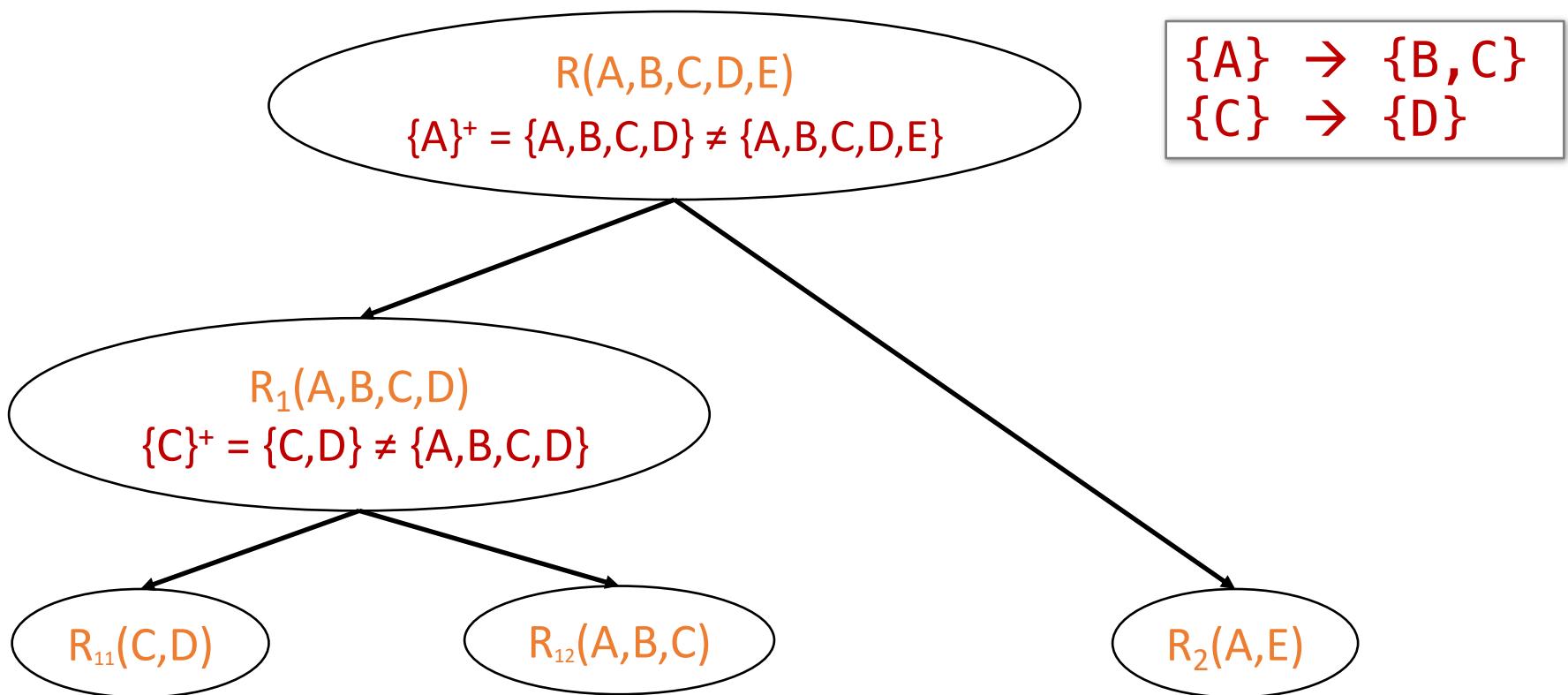
Split R into X^+ and $X^+[\text{rest attributes}]$

Return BCNFDecomp(R_1), BCNFDecomp(R_2)

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

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

Exercise - 2



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

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

$R_1(A, B, C, D)$

$\{C\}^+ = \{C, D\} \neq \{A, B, C, D\}$

$R_{11}(C, D)$

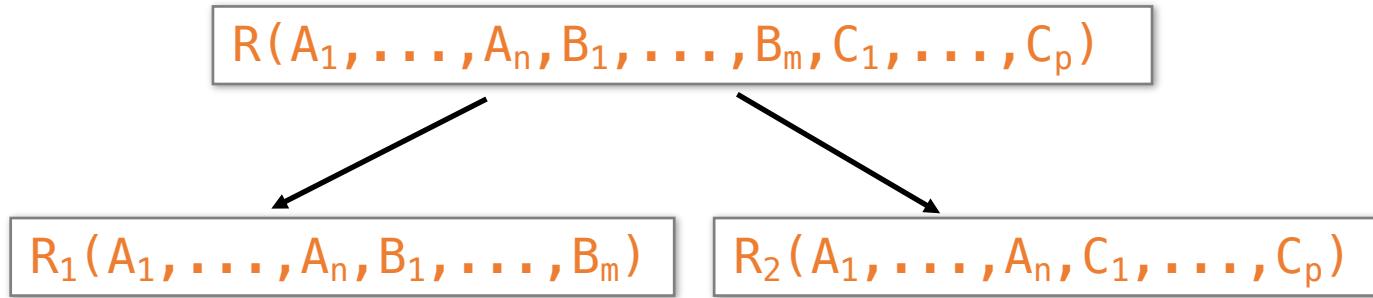
$R_{12}(A, B, C)$

$R_2(A, E)$

Outline

- “Good” vs. “Bad” FDs
- Boyce-Codd Normal Form
- Decompositions

Decompositions in General



R_1 = the *projection* of R on $A_1, \dots, A_n, B_1, \dots, B_m$

R_2 = the *projection* of R on $A_1, \dots, A_n, C_1, \dots, C_p$

Lossless Decompositions

Name	Price	Category
Gizmo	19.99	Gadget
OneClick	24.99	Camera
Gizmo	19.99	Camera

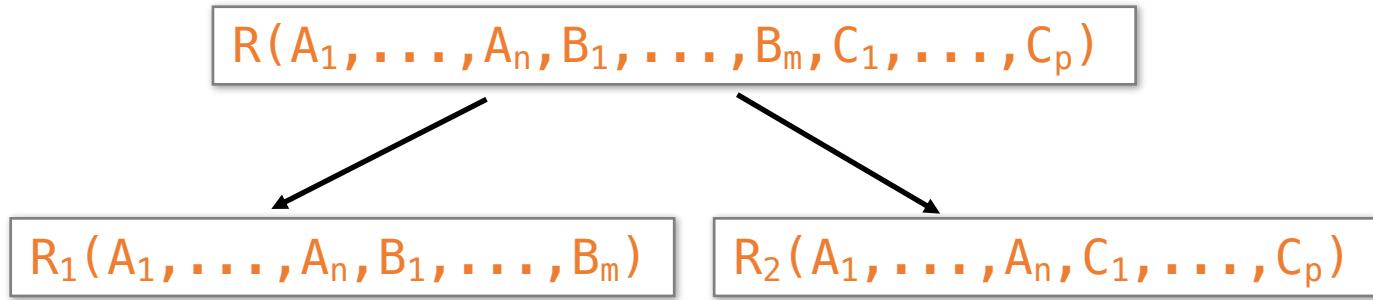
It is a Lossless decomposition



Name	Price
Gizmo	19.99
OneClick	24.99
Gizmo	19.99

Name	Category
Gizmo	Gadget
OneClick	Camera
Gizmo	Camera

Lossless Decompositions



A decomposition R to (R_1, R_2) is lossless if $R = R_1 \text{ Join } R_2$

Lossy Decomposition

Name	Price	Category
Gizmo	19.99	Gadget
OneClick	24.99	Camera
Gizmo	19.99	Camera

However sometimes it isn't

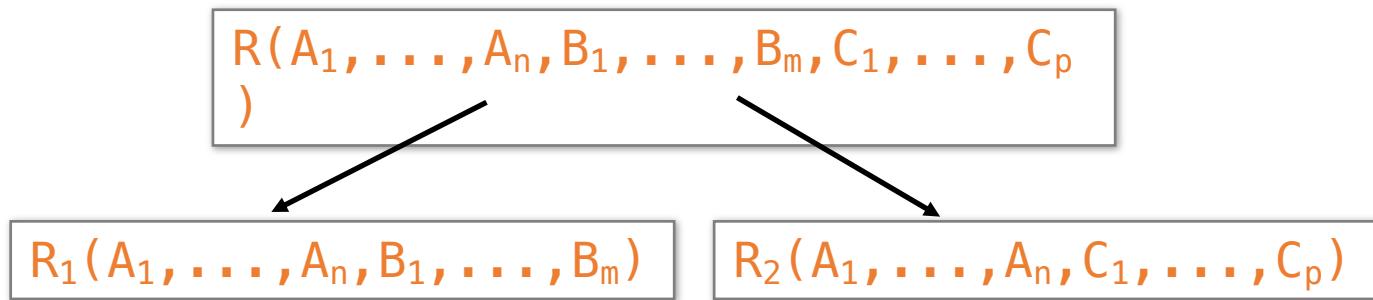
What's wrong here?



Name	Category
Gizmo	Gadget
OneClick	Camera
Gizmo	Camera

Price	Category
19.99	Gadget
24.99	Camera
19.99	Camera

Lossless Decompositions



If $\{A_1, \dots, A_n\} \rightarrow \{B_1, \dots, B_m\}$
Then the decomposition is lossless

Note: don't need
 $\{A_1, \dots, A_n\} \rightarrow \{C_1, \dots, C_p\}$

BCNF decomposition is always lossless. Why?

A Problem with BCNF

Unit	Company	Product
...

$\{Unit\} \rightarrow \{Company\}$
 $\{Company, Product\} \rightarrow \{Unit\}$

Unit	Company
...	...

Unit	Product
...	...

$\{Unit\} \rightarrow \{Company\}$

We do a BCNF decomposition
on a “bad” FD:
 $\{Unit\}^+ = \{Unit, Company\}$

We lose the FD $\{Company, Product\} \rightarrow \{Unit\}!!$

The Problem

- We started with a table R and FDs F
- We decomposed R into BCNF tables R_1, R_2, \dots with their own FDs F_1, F_2, \dots
- We insert some tuples into each of the relations—which satisfy their local FDs but when reconstruct it violates some FD **across** tables!

Practical Problem: To enforce FD, must reconstruct R —*on each insert!*

Trade-offs

- **Different Normal Forms**

Prevent Decomposition Problems

VS

Remove Redundancy

BCNF still most common- with additional steps to
keep track of lost FDs...

Summary

- “Good” vs. “Bad” FDs
- Boyce-Codd Normal Form
- Decompositions

Acknowledge

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 - “CS186: Introduction to Database Systems” by Joe Hellerstein at UC Berkeley
 - “CS145: Introduction to Databases” by Peter Bailis at Stanford
 - “CS 348: Introduction to Database Management” by Grant Weddell at University of Waterloo