COMP 3311
DATABASE MANAGEMENT SYSTEMS

LECTURE 5 EXERCISES
RELATIONAL MODEL AND RELATIONAL DATA BASE DESIGN

EXERCISE 1

Given relation schema R(X, Y, U, V, W) and F = {X→Y, UV→W, V→X}

a) **Determine the closure of each attribute.**

X^+ = {X, Y} (Look for X on LHS of FDs)

Y^+ = {Y}

U^+ = {U}

V^+ = {V, X, Y}

W^+ = {W}

b) **What are the candidate keys of R?**

The candidate key is UV since UV^+ = {X, Y, U, V, W}.

EXERCISE 2

We want to create the database for a bank that contains accounts (A), branches (B) and customers (C).

a) **What are the functional dependencies implied by the following constraints?**

- An account cannot be shared by multiple customers.

  Account → Customer $A \rightarrow C$

- Two different branches do not have the same account.

  Account → Branch $A \rightarrow B$

- Each customer can have at most one account in a branch (but different accounts in different branches).

  Branch, Customer → Account $BC \rightarrow A$

b) **What are the candidate keys?**

  (Branch, Customer) and Account   BC and A

EXERCISE 3

Given: R(A, B, C, D, E)

F = {A→BC}

Decomposition: R_1(A, B, C) and R_2(A, D, E)

a) **Is the decomposition lossless? Why?** (*iff* $R_1 \cap R_2 \rightarrow R_1$ or $R_1 \cap R_2 \rightarrow R_2$)

Yes The common attribute A is a key for R_1.

b) **Is the decomposition dependency preserving? Why?** (*iff* $(\cup F_i)^+ = F^+$)

Yes A→BC is preserved in R_1.

c) **Is the decomposition** R_1(A, B, C) and R_2(C, D, E) **lossless? Why?**

No C is not a key for any table.

EXERCISE 4

Identify the candidate key(s) and the current highest normal form for each of the following relation schemas given their corresponding FDs.

a) R(A, B, C, D, E) $F = \{A \rightarrow B, C \rightarrow D\} = F^+$

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

Candidate keys: ACE

Normal form: **1NF** (both FDs violate 2NF)

⟹ Both A→B and C→D violate 2NF since A and C are proper subsets of the candidate key ACE.

⟹ Both A→B and C→D violate 2NF since B and D are non-prime attributes of R.

2NF

R is in 2NF *if and only if*

For each FD: X→A in F^+:

- A ∈ X (*trivial FD*) ***or***
- X is not a proper subset of a candidate key for R ***or***
- A is a prime attribute for R.

3NF

R is in 3NF *if and only if*

For each FD: X→A in F^+:

- A ∈ X (*trivial FD*) ***or***
- X is a superkey for R ***or***
- A is a prime attribute for R.

EXERCISE 4 (CONT'D)

b) R(A, B, C) F = {AB→C, C→B} = F^+

AB$^+$={A, B, C} C$^+$={C, B}

Candidate keys: AB, AC

Normal form: 3NF

⟹ For AB→C, AB is a superkey of R.

⟹ For C→B, B is a prime attribute of R.

2NF

R is in 2NF *if and only if*

For each FD: X→A in F^+:

A ∈ X (*trivial FD*) ***or***

X is not a proper subset of a candidate key for R ***or***

A is a prime attribute for R.

3NF

R is in 3NF *if and only if*

For each FD: X→A in F^+:

A ∈ X (*trivial FD*) ***or***

X is a superkey for R ***or***

A is a prime attribute for R.

EXERCISE 4 (CONT'D)

c) R(A, B, C, F) $\qquad F = \{AB \rightarrow C, C \rightarrow F\} = F^+$

$AB^+ = \{A, B, C, F\}$ $\qquad C^+ = \{C, F\}$

Candidate keys: AB

Normal form: **2NF** (C→F violates 3NF)

⟹ For C→F, C is not a proper subset of a candidate key.

⟹ C→F violates 3NF since C is not a superkey of R.

⟹ C→F violates 3NF since F is a non-prime attribute.

2NF

R is in 2NF *if and only if*
For each FD: X→A in F^+:
A ∈ X (*trivial FD*) ***or***
X is not a proper subset of a candidate key for R ***or***
A is a prime attribute for R.

3NF

R is in 3NF *if and only if*
For each FD: X→A in F^+:
A ∈ X (*trivial FD*) ***or***
X is a superkey for R ***or***
A is a prime attribute for R.

EXERCISE 5

Given relation schema R(A, B, C, G, H, I) and

$F = \{A \rightarrow B, \quad A \rightarrow C, \quad CG \rightarrow H, \quad CG \rightarrow I, \quad B \rightarrow H\}$

a) **Determine the closure of each attribute.**

$A^+ = \{A, B, C, H\}$ $\quad B^+ = \{B, H\}$ $\quad C^+ = \{C\}$

$G^+ = \{G\}$ $\quad H^+ = \{H\}$ $\quad I^+ = \{I\}$

b) **What are the candidate keys of R?**

The candidate key is AG.

Compute AG^+

$AG^{(0)} = \{A, G\}$

$AG^{(1)} = \{A, G, B\}$ $\quad (A \rightarrow B \text{ and } A \subseteq \{A, G\})$

$AG^{(2)} = \{A, G, B, C\}$ $\quad (A \rightarrow C \text{ and } A \subseteq \{A, G\})$

$AG^{(3)} = \{A, G, B, C, H\}$ $\quad (CG \rightarrow H \text{ and } CG \subseteq \{A, G, B, C\})$

$AG^{(4)} = \{A, G, B, C, H, I\}$ $\quad (CG \rightarrow I \text{ and } CG \subseteq \{A, G, B, C, H\})$

EXERCISE 6

Given: Sale(customer, store, product, price) and the constraints:

A customer buys from only one store.

There is a unique price for each product in a store, but the same product can have a different price in different stores.

a) **What are the FDs implied by the above description?**

customer → store

store, product → price

b) **What are the candidate keys?**

{customer, product}

Since customer, product → store, product (**IR2**)
and customer, product → price (**IR3**)

Also $\{customer, product\}^+ = \{customer, product, store, price\}$

EXERCISE 6 (CONT'D)

3NF
R is in 3NF *if and only if*
For each FD: $X \rightarrow A$ in F^+:
A $\in$ X (*trivial FD*) ***or***
X is a superkey for R ***or***
A is a prime attribute for R.

Given: Sale(customer, store, product, price)

A customer buys from only one store.

There is a unique price for each product in a store, but the same product can have a different price in different stores.

c) **Explain why Sale is not in 3NF.** candidate key: {customer, product}

F = {customer ⟶ store; store, product ⟶ price}

Both FDs violate 3NF.

The LHS of the FDs are not superkeys; the RHS are not prime attributes of Sale.

d) **Decompose Sale into 3NF relation schemas.**

R_1(<u>customer</u>, store) R_2(<u>store, product</u>, price)

e) **Is the decomposition dependency preserving? Why?**

Yes Each FD is preserved in a relation schema, **BUT** … (next page).

EXERCISE 6 (CONT'D)

The decomposition R_1(customer, store), R_2(store, product, price) is lossy because the common attribute store is not a key of any table.

Sale

customer	product	store	price
c1	p1	s1	pr1
c1	p2	s1	pr2
c2	p1	s1	pr1

decompose

R_1

customer	store
c1	s1
c2	s1

R_2

store	product	price
s1	p1	pr1
s1	p2	pr2

The two decomposed relations do not generate the original one if joined (on the common store attribute). The join result contains 4 records instead of 3 as in the original relation.

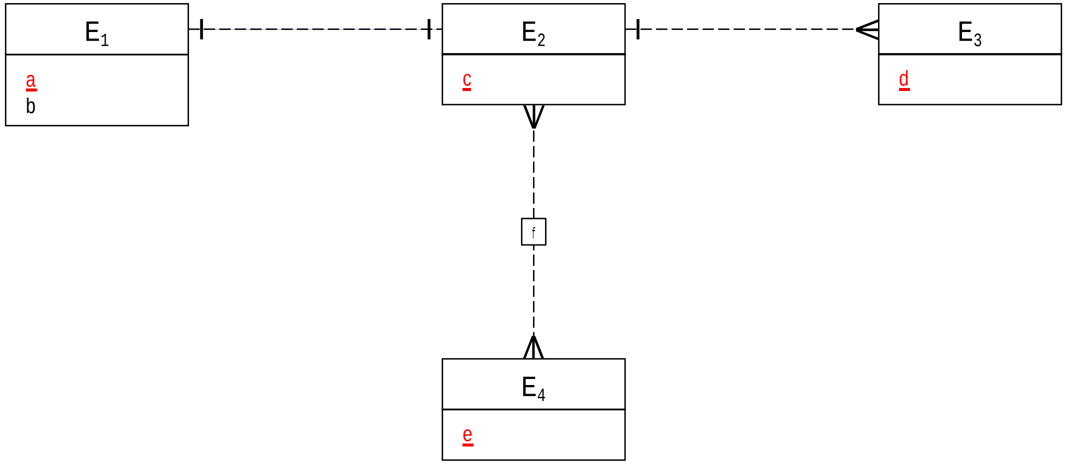
What is the problem? None of the fragments contains the candidate key (customer, product).

Solution? Include an additional table R_3(customer, product) containing the candidate key in the decomposition.

R_3

customer	product
c1	p1
c1	p2
c2	p1

EXERCISE 7



What are the FDs implied by the E-R diagram?

a→b

a→c

c→a

c→b (from c→a and a→b) **IR3**

d→c

d→a (from d→c and c→a) **IR3**

d→b (from d→c and c→b) **IR3**

ce→f