UNIVERSITAS INDONESIA

FAKULTAS ILMU KOMPUTER

Slide 11

Database Design Theory & Normalization (part 1)

CSF2600700 - BASIS DATA

SEMESTER GENAP 2019/2020

Tujuan Pemelajaran

- Mengevaluasi model database relasional yang telah dibuat berdasarkan teori desain database relasional sehingga dapat menghasilkan skema database yang “baik” dalam level conceptual maupun physical.

Outline

1. Panduan Informal dalam Merancang Basis Data Relasional
2. *Functional Dependency*
3. Normalisasi Berdasarkan *Primary Key*
4. *General Normal Form*
5. *Boyce Codd Normal Form*

Panduan Informal dalam Merancang Basis Data Relasional

Panduan Informal

Panduan secara umum berkaitan dengan:

- Semantik atribut-atribut relasi
- Data yang berulang dan kaitannya dengan *update anomaly*
- Nilai null
- *Spurious tuples*

Panduan 1: Terkait Semantik Atribut-Atribut Relasi

Panduan 1: Setiap tuple pada relasi seharusnya **merepresentasikan satu entity** atau **relationship instance**.

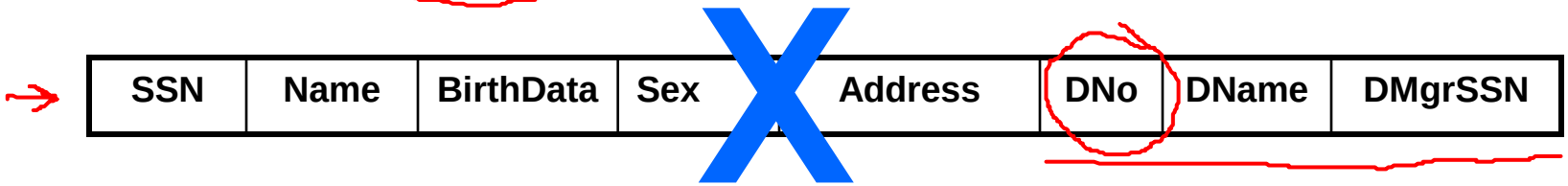
Skema perlu dirancang agar mudah dijelaskan relasi demi relasi.

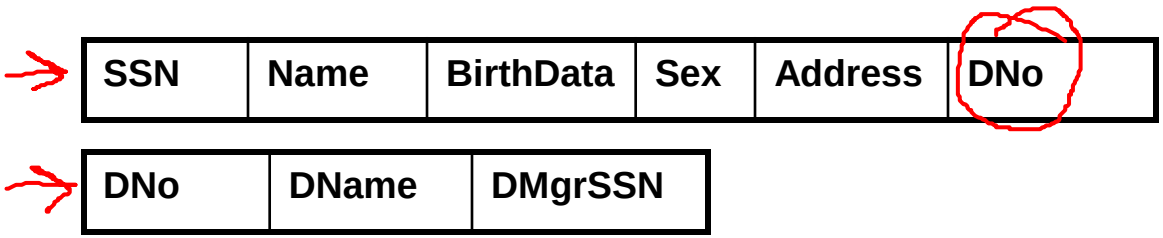
Semantik dari atribut sebaiknya mudah diinterpretasikan

Atribut-atribut dari entity yang berbeda-beda seharusnya tidak bergabung dalam satu relasi

Hanya foreign key yang digunakan untuk mengacu ke relasi lain

Atribut-atribut entity dan relationship sebaiknya dipisahkan





Panduan 2: Terkait Data Berulang dan *Update Anomaly*

- Informasi yang disimpan berulang (*redundant*) menyebabkan pemborosan ruang penyimpanan dan berpotensi menyebabkan *update anomaly*.

Panduan 2: Terkait Data Berulang dan *Update Anomaly*

- Contoh:

Redundancy

EMP_DEPT

Ename	Ssn	Bdate	Address	Dnumber	Dname	Dmgr_ssn
Smith, John B.	123456789	1965-01-09	731 Fondren, Houston, TX	5	Research	333445555
Wong, Franklin T.	333445555	1955-12-08	638 Voss, Houston, TX	5	Research	333445555
Zelaya, Alicia J.	999887777	1968-07-19	3321 Castle, Spring, TX	4	Administration	987654321
Wallace, Jennifer S.	987654321	1941-06-20	291 Berry, Bellaire, TX	4	Administration	987654321
Narayan, Ramesh K.	666884444	1962-09-15	975 FireOak, Humble, TX	5	Research	333445555
English, Joyce A.	453453453	1972-07-31	5631 Rice, Houston, TX	5	Research	333445555
Jabbar, Ahmad V.	987987987	1969-03-29	980 Dallas, Houston, TX	4	Administration	987654321
Borg, James E.	888665555	1937-11-10	450 Stone, Houston, TX	1	Headquarters	888665555

- Relation EMP_DEPT berasal dari natural join antara 2 buah relation: EMPLOYEE dan DEPARTMENT.
- Menyimpan relasi hasil join ini dapat menyebabkan *update anomaly*

Panduan 2: Terkait Data Berulang dan *Update Anomaly*

- *Update anomaly* meliputi:
  - *Insertion anomaly*
  - *Deletion anomaly*
  - *Modification anomaly*

- Panduan 2: **Rancanglah skema yang bebas dari anomali**. Jika terpaksa ada anomali, perlu dicatat dan ditangani oleh aplikasi

Panduan 2: Terkait Data Berulang dan *Update Anomaly*

- *Insertion Anomaly*

Redundancy

EMP_DEPT

Ename	Ssn	Bdate	Address	Dnumber	Dname	Dmgr_ssn
Smith, John B.	123456789	1965-01-09	731 Fondren, Houston, TX	5	Research	333445555
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Narayan, Ramesh K.	666884444	1962-09-15	975 FireOak, Humble, TX	5	Research	333445555
English, Joyce A.	453453453	1972-07-31	5631 Rice, Houston, TX	5	Research	333445555
Jabbar, Ahmad V.	987987987	1969-03-29	980 Dallas, Houston, TX	4	Administration	987654321
Borg, James E.	888665555	1937-11-10	450 Stone, Houston, TX	1	Headquarters	888665555

- Contoh: *Insert new tuple of employee*

Manning, Chris	246879135	1970-02-19	3324 Abcd, Spring, TX			

Harus ikut ditambahkan atau NULL

- Demikian halnya ketika dilakukan penambahan departemen baru

Panduan 2: Terkait Data Berulang dan *Update Anomaly*

- *Deletion Anomaly*

Contoh:

Redundancy

EMP_DEPT

Ename	Ssn	Bdate	Address	Dnumber	Dname	Dmgr_ssn
Smith, John B.	123456789	1965-01-09	731 Fondren, Houston, TX	5	Research	333445555
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Borg, James E.	888665555	1937-11-10	450 Stone, Houston, TX	1	Headquarters	888665555

Jika *tuple* ini dihapus, maka departemen "*Headquarters*" akan ikut terhapus

Panduan 2: Terkait Data Berulang dan *Update Anomaly*

- *Modification Anomaly*

Redundancy

EMP_DEPT

Ename	Ssn	Bdate	Address	Dnumber	Dname	Dmgr_ssn
Smith, John B.	123456789	1965-01-09	731 Fondren, Houston, TX	5	Research	333445555
Wong, Franklin T.	333445555	1955-12-08	638 Voss, Houston, TX	5	Research	333445555
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- Mengubah nilai atribut departemen "*Research*" pada *tuple* di baris ini harus diikuti dengan pengubahan pada *tuple* pada baris lain yang menyimpan informasi departemen "Research" (baris 1,2, dan 5)

Panduan 3: Terkait Nilai *NULL*

- Nilai NULL pada suatu atribut:
  - Pemborosan *storage* di *physical level*
  - Terjadi masalah ketika dijalankan dilakukan JOIN atau fungsi *aggregate* (misalnya SUM, COUNT)
  - Tidak dapat dibedakan dengan jelas penyebab nilai NULL *(does not apply, unknown, or known but absent ?)*

- Panduan 3: *Relations* harus dirancang agar **nilai *null* yang ada pada baris-barisnya sesedikit mungkin**

Panduan 4: Terkait *Spurious Tuples*

- Dalam merancang, kadang-kadang kita melakukan dekomposisi relasi maupun penggabungan beberapa relasi. Ada 2 hal yang perlu diperhatikan:
  - Apakah dekomposisi (pemecahan) sebuah relasi menjadi dua/lebih relasi baru akan menyebabkan **adanya data yang hilang?**
  - Apakah penggabungan dua/lebih relasi menjadi sebuah relation baru akan menghasilkan **kelebihan data (yang sebenarnya tidak ada)?**

Panduan 4: Terkait *Spurious Tuples*

- Contoh:

Redundancy Redundancy

EMP_PROJ

Ssn	Pnumber	Hours	Ename	Pname	Plocation
123456789	1	32.5	Smith, John B.	ProductX	Bellaire
123456789	2	7.5	Smith, John B.	ProductY	Sugarland
666884444	3	40.0	Narayan, Ramesh K.	ProductZ	Houston
453453453	1	20.0	English, Joyce A.	ProductX	Bellaire
453453453	2	20.0	English, Joyce A.	ProductY	Sugarland

EMP_LOCS

Ename	Plocation
Smith, John B.	Bellaire
Smith, John B.	Sugarland
Narayan, Ramesh K.	Houston
English, Joyce A.	Bellaire
English, Joyce A.	Sugarland

EMP_PROJ1

Ssn	Pnumber	Hours	Pname	Plocation
123456789	1	32.5	ProductX	Bellaire
123456789	2	7.5	ProductY	Sugarland
666884444	3	40.0	ProductZ	Houston
453453453	1	20.0	ProductX	Bellaire
453453453	2	20.0	ProductY	Sugarland

Panduan 4: Terkait *Spurious Tuples*

- Contoh: Hasil Natural Join antara EMP_LOCS dengan EMP_PROJ1

	Ssn	Pnumber	Hours	Pname	Plocation	Ename
	123456789	1	32.5	ProductX	Bellaire	Smith, John B.
*	123456789	1	32.5	ProductX	Bellaire	English, Joyce A.
	123456789	2	7.5	ProductY	Sugarland	Smith, John B.
*	123456789	2	7.5	ProductY	Sugarland	English, Joyce A.
*	123456789	2	7.5	ProductY	Sugarland	Wong, Franklin T.
	666884444	3	40.0	ProductZ	Houston	Narayan, Ramesh K.
*	666884444	3	40.0	ProductZ	Houston	Wong, Franklin T.
*	453453453	1	20.0	ProductX	Bellaire	Smith, John B.
	453453453	1	20.0	ProductX	Bellaire	English, Joyce A.
*	453453453	2	20.0	ProductY	Sugarland	Smith, John B.
	453453453	2	20.0	ProductY	Sugarland	English, Joyce A.
*	453453453	2	20.0	ProductY	Sugarland	Wong, Franklin T.

Panduan 4: Terkait *Spurious Tuples*

- **Panduan 4**:
  - Relasi harus dirancang agar **memenuhi *lossless join condition***
    - **Tidak ada *spurious tuples*** yang dihasilkan oleh *natural join* antar relasi
      - Hindari relasi yang memiliki *matching attribute* selain kombinasi PK dan FK.

EMP_LOCS

Ename	Plocation
Smith, John B.	Bellaire
Smith, John B.	Sugarland
Narayan, Ramesh K.	Houston
English, Joyce A.	Bellaire
English, Joyce A.	Sugarland

EMP_PROJ1

Ssn	Pnumber	Hours	Pname	Plocation
123456789	1	32.5	ProductX	Bellaire
123456789	2	7.5	ProductY	Sugarland
666884444	3	40.0	ProductZ	Houston
453453453	1	20.0	ProductX	Bellaire
453453453	2	20.0	ProductY	Sugarland

Panduan Informal - Summary

- Akibat yang ditimbulkan karena kesalahan mendefinisikan suatu relasi:
  - *Redundancy* → *Update Anomalies*
  - Munculnya nilai NULL → Pemborosan storage / kesulitan dalam melakukan JOIN/*aggregate function*
  - Kesalahan proses dekomposisi → *Spurious tuples*

Functional Dependency

Definisi

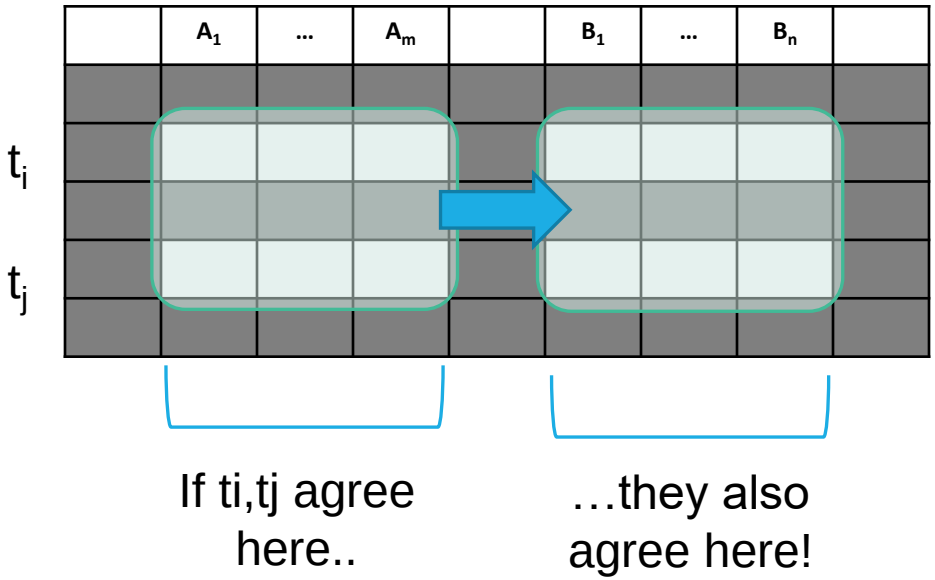
Def: Let A,B be *sets* of attributes
We write A → B or say A ***functionally determines*** B if, for any tuples t_1 and t_2:

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

and we call A → B a **functional dependency**

A→B means that
"whenever two tuples agree on A then they agree on B."

A Picture Of FDs



Defn (again):

Given attribute sets $A=\{A_1,\ldots,A_m\}$ and $B = \{B_1,\ldots B_n\}$ 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 $t_i[B_n] = t_j[B_n]$

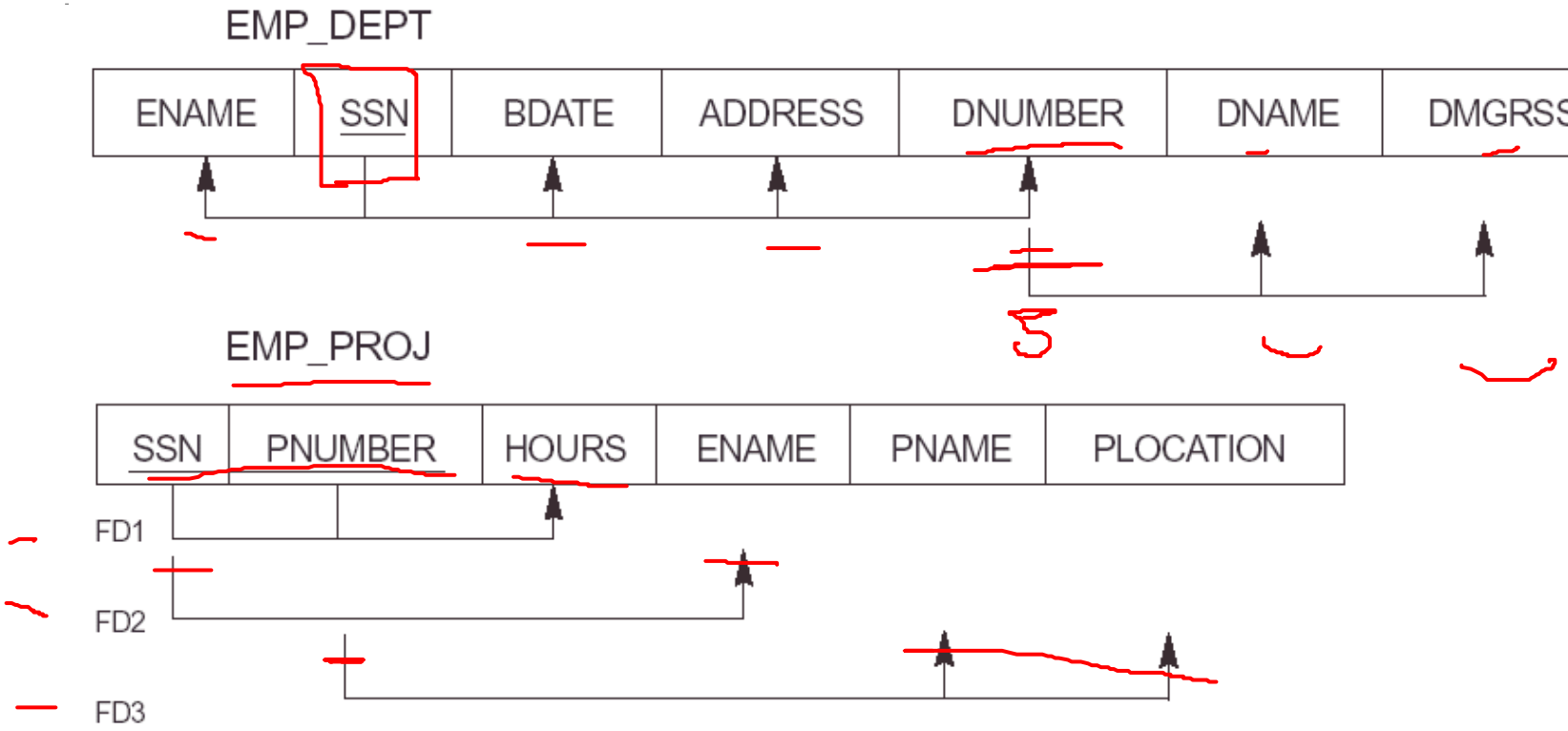
Contoh *Functional Dependency*

TEACH

Teacher	Course	Text
Smith	Data Structures	Bartram
Smith	Data Management	Martin
Hall	Compilers	Hoffman
Brown	Data Structures	Horowitz

Tentukan FD untuk tabel di atas

Contoh *Functional Dependency*



Pada relasi EMP_PROJ terdapat 3 FD:

- **{SSN, PNUMBER} → HOURS**
- **SSN → ENAME**
- **PNUMBER → {PNAME, PLOCATION}**

Bagaimana menemukan FD lainnya?

Contoh:

Products

Name	Color	Category	Dep	Price
Gizmo	Green	Gadget	Toys	49
Widget	Black	Gadget	Toys	59
Gizmo	Green	Whatsit	Garden	99

Provided FDs:

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

Given the provided FDs, we can see that {Name, Category} → {Price} must also hold on **any instance**…

Which / how many other FDs do?!?

Bagaimana menemukan FD lainnya?

Sama saja bertanya: *Given a set of* FDs, F = $\{f_1,\ldots f_n\}$, *does an* FD *x hold*?

Inference problem: *How do we decide*?

Answer: Three simple rules called
Armstrong's Rules.

1. Reflexive
2. Augmentation
3. Transitive

Inference Rule untuk FD

- *Amstrong's Inference Rule*

  1. ***Reflexive* (IR1)**: If {X ⊇ Y} then X → Y.
  2. ***Augmentation* (IR2)**: If {X → Y} |= XZ → YZ.
  3. ***Transitive* (IR3)**: If {X→ Y, Y→ Z} |= X → Z.

- *Derived Inference Rule*

  4. ***Decomposition***: If {X→ YZ} |= X → Y.
  5. ***Additive (Union)***: If {X→ Y, X→ Z} |= X → YZ.
  6. ***Pseudotransitive***: If {X→ Y, WY→ Z} |= WX → Z.

Inference Rule untuk FD

Provided FDs:

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

- *Amstrong's Inference Rule*
  1. ***Reflexive* (IR1):** If {X ⊇ Y} then X → Y.
  2. ***Augmentation* (IR2):** If {X → Y} |= XZ → YZ.
  3. ***Transitive* (IR3):** If {X→ Y, Y→ Z} |= X → Z.
- *Derived Inference Rule*
  4. ***Decomposition*:** If {X→ YZ} |= X → Y.
  5. ***Additive (Union)*:** If {X→ Y, X→ Z} |= X → YZ.
  6. ***Pseudotransitive*:** If {X→ Y, WY→ Z} |= WX → Z.

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}	?

Inference Rule untuk FD

- *Amstrong's Inference Rule*
  1. ***Reflexive* (IR1):** If {X ⊇ Y} then X → Y.
  2. ***Augmentation* (IR2):** If {X → Y} |= XZ → YZ.
  3. ***Transitive* (IR3):** If {X→ Y, Y→ Z} |= X → Z.
- *Derived Inference Rule*
  4. ***Decomposition*:** If {X→ YZ} |= X → Y.
  5. ***Additive (Union)*:** If {X→ Y, X→ Z} |= X → YZ.
  6. ***Pseudotransitive*:** If {X→ Y, WY→ Z} |= WX → Z.

Manakah FD yang didapatkan jika diberikan FD sbb.

F = {SSN → {EName, BDate, Address, DNumber},
{SSN, ProjNo} → Hours }

- SSN → Ename
- SSN → Bdate
- SSN → Address
- SSN → Dnumber
- SSN → SSN
- {SSN, ProjNo} → ProjNo .....dst

Closure (Penutup)

- **Closure** dari himpunan **functional dependency F** adalah himpunan F^+ yang beranggotakan F dan semua FD yang dapat diturunkan dari F

- **Closure** dari himpunan **attribute X** yang berkaitan dengan F adalah himpunan X^+ yang beranggotakan semua attribute yang ditentukan secara fungsional oleh X

- X^+ dapat dicari dengan menerapkan secara berulang IR1, IR2, IR3 dengan menggunakan FD yang ada pada F

Closure Algorithm

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

Repeat until X doesn't change; **do**:

if $\{B_1, \ldots, B_n\} \rightarrow C$ is entailed by F

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

then add C to X.

Return X as X^+

Closure Algorithm

Start with X = $\{A_1, \ldots, A_n\}$, FDs F.
Repeat until X doesn't change; **do**:
  if $\{B_1, \ldots, B_n\} \rightarrow C$ is in F **and** $\{B_1, \ldots, B_n\} \subseteq X$:
    then add C to X.
Return X as X^+

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

F =

{{name} → {color},

{category} → {dept},

{color, category} → {price}}

Closure Algorithm

Start with X = $\{A_1, \ldots, A_n\}$, FDs F.
Repeat until X doesn't change; **do**:
  if $\{B_1, \ldots, B_n\} \rightarrow C$ is in F **and** $\{B_1, \ldots, B_n\} \subseteq X$:
    then add C to X.
Return X as X^+

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

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

F =

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

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

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

Closure Algorithm

Start with X = $\{A_1, \ldots, A_n\}$, FDs F.
Repeat until X doesn't change; **do**:
  if $\{B_1, \ldots, B_n\} \rightarrow C$ is in F **and** $\{B_1, \ldots, B_n\} \subseteq X$:
    then add C to X.
Return X as X^+

F =

{name} → {color}

{category} → {dept}

{color, category} → {price}

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

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

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

Closure Algorithm

Start with X = $\{A_1, \ldots, A_n\}$, FDs F.
Repeat until X doesn't change; **do**:
  if $\{B_1, \ldots, B_n\} \rightarrow C$ is in F **and** $\{B_1, \ldots, B_n\} \subseteq X$:
    then add C to X.
Return X as X^+

F =

{name} → {color}

{category} → {dept}

{color, category} → {price}

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

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

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

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

Contoh Closure

Diberikan F = {
SSN → ENAME,
PNUMBER → {PNAME, PLOCATION},
{SSN, PNUMBER} → HOURS
}

- **$\{SSN\}^+ = \{SSN, ENAME\}$**
- **$\{PNUMBER\}^+ = \{PNUMBER, PNAME, PLOCATION\}$**
- **$\{SSN, PNUMBER\}^+ =$**
  {SSN, PNUMBER, ENAME, PNAME, PLOCATION, HOURS}

Cara lain menentukan *Closure*

Menentukan {SSN, PNUMBER}+

Apakah {SSN, PNUMBER} ⊇ SSN?

Ya – Tambahkan ENAME

Apakah {SSN, PNUMBER, ENAME} ⊇ PNUMBER?

Ya – Tambahkan PNAME, PLOCATION

Apakah {SSN, PNUMBER, ENAME, PNAME, PLOCATION} ⊇ {SSN, PNUMBER}?

Ya – Tambahkan HOURS

Sehingga {SSN, PNUMBER}+ =

{SSN, PNUMBER, ENAME, PNAME, PLOCATION, HOURS}

Contoh Closure

Diketahui G = {
SSN → {ENAME, BDATE, ADDRESS, DNUMBER},
DNUMBER → {DNAME, DMGRSSN}
}

Carilah $\{DNUMBER\}^+$

Carilah $\{SSN\}^+$

Contoh Closure

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

{A,B} → {C}
{A,D} → {E}
{B} → {D}
{A,F} → {B}

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

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

Menginterpretasikan Himpunan Closure

Apa yang ekuivalen dengan $\{SSN\}^+ = \{SSN, ENAME\}$?

SSN → ENAME, SSN → SSN, SSN → SSN, ENAME

Bagaimana dengan

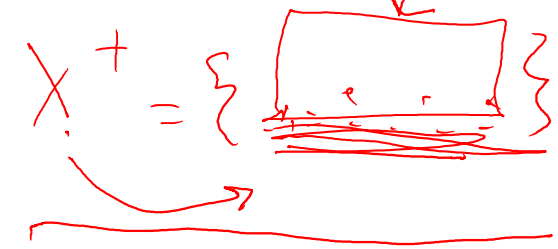
$\{PNUMBER\}^+ = \{PNUMBER, PNAME, PLOCATION\}$?

PNUMBER → PNAME
PNUMBER → PLOCATION
PNUMBER → PNUMBER
PNUMBER → {PNAME, PLOCATION}
PNUMBER → {PNUMBER, PLOCATION}
PNUMBER → {PNAME, PNUMBER}
PNUMBER → {PNUMBER, PNAME, PLOCATION}

Bagaimana dengan $\{SSN, PNUMBER\}^+ =$
$\{SSN, PNUMBER, ENAME, PNAME, PLOCATION, HOURS\}$?

Kenapa kita membutuhkan *closure*?

- With closure we can find all FD's easily
- To check if $X \rightarrow A$
  1. Compute X^+
  2. Check if $A \in X^+$



Note here that **X** is a *set* of attributes, but **A** is a *single* attribute. Why does considering FDs of this form suffice?

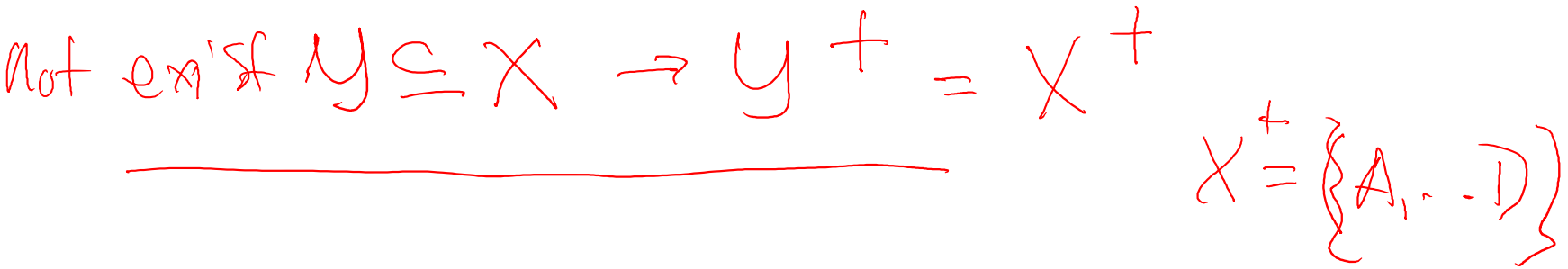
Recall the Split (Decomposition) / combine (Union/Additive) rule:

Decomposition:	**If {X→ YZ} then X → Y.**
Additive (Union):	**If {X→ Y, X→ Z} then X → YZ.**

Kenapa kita membutuhkan *closure*?

- For each set of attributes X

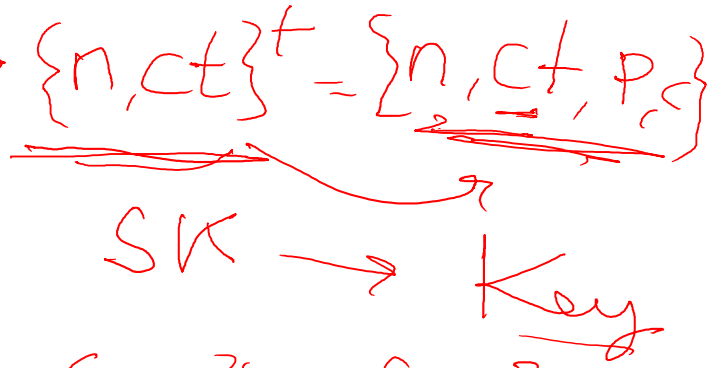
  1. Compute X^+
  2. If X^+ = set of all attributes then X is a **superkey**
  3. If X is minimal, then it is a **key**



Temukan *key*-nya

Product(name, price, category, color)

{name, category} → price
{category} → color



What is a key?

{n}+ = {n}

{ct}+ = {ct,c}

Summary

- Panduan informal untuk Relational DB
- Functional Dependency
- Closure
- Next? DB Normalization

- Latihan tersedia di SCELE: Latihan FD