CSDS 433 Database Systems
Spring 2022
Assignment 1

The following axioms of functional dependencies are provided for your reference.

[Reflexivity]: If $Y \subseteq X$, then $X \rightarrow Y$

[Augmentation]: If $X \rightarrow Y$, then $XW \rightarrow YW$

[Transitivity]: If $X \rightarrow Y$ and $Y \rightarrow Z$, then $X \rightarrow Z$

[Union]: If $X \rightarrow Y$ and $X \rightarrow Z$, then $X \rightarrow YZ$

[Decomposition]: if $X \rightarrow YZ$, then $X \rightarrow Y$ and $X \rightarrow Z$

[Pesudotransitivity]: if $X \rightarrow Y$ and $WY \rightarrow Z$, then $XW \rightarrow Z$

[Set accumulation]: if $X \rightarrow YZ$ and $Z \rightarrow W$, then $X \rightarrow YZW$.

1. *[Candidate Keys & FDs] (30) Consider* the following schema and FDs that hold on the schema.

   (a) R (A, B, C, D):

   FD1: $A \rightarrow BCD$,
   FD2: $C \rightarrow AB$

   List all the candidate keys of R.

   A/C

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

   FD3: $A \rightarrow BC$

   FD4: $CD \rightarrow E$

   FD5: $B \rightarrow D$

   FD6: $E \rightarrow A$

   Give a candidate key of R.

   A/BC/CD/E

2. *[FDs] (30)* Given the following set of four FDs (FD1 – FD4), derive FD5 and FD6. Label each step with the rules from the above axioms.

   FD1: $C \rightarrow B$,

   FD2: $A \rightarrow B$,

   FD3: $AC \rightarrow D$,

   FD4: $D \rightarrow ABC$

   FD5: $D \rightarrow ABCD$

   FD6: $AC \rightarrow BD$

Example: Derive FD7: AC → BCD:

1. A → B (FD2)
2. AC → BC (Augmentation)
3. AC → D (FD3)
4. AC → BCD (Union, 2, 3)

Derive FD5: D → ABCD

1. D → ABC (FD4)
2. D → ABCD (Augmentation)

Derive FD6: AC → BD

1. A → B (FD2)
2. AC → BC (Augmentation)
3. AC → D (FD3)
4. AC → BCD (Union, 2, 3)
5. AC → BD (Decomposition, 4)

3. *[Relational Algebra]* (40)

(a) Consider the following database schema:

Movies (Title, Director, Actor);

Location (Theater, Address, Phone number);

Schedule (Theater, Title, Time).

Express the following queries in relational algebra (select σ, project ∏, Cartesian product X, join (theta-join))

Q1: Who is the director of the movie "The Matrix Resurrections"?

$\pi_{Director}(\sigma_{Title='The\ Matrix\ Resurrections'}(Movies))$

Q2: List the theaters showing movies directed by "Polanski".

$\pi_{Theater}(\sigma_{Director='Polanski'}(Movies) \bowtie Schedule))$

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Q3: What is the address and phone number of theaters that feature "Frozen 2"?

$\pi_{\text{Address, Phone number}}(\sigma_{\text{Title='Frozen 2'}}(\text{Schedule}) \bowtie \text{Location}))$

Q4: List the pairs of persons such that the first directed the second in a movie and vice versa.

$\pi_{\text{M1.Director, M2.Director}}(\sigma_{\text{M1.Director=M2.Actor}\wedge\text{M1.Actor=M2.Director}\wedge\text{M1.Director>M1.Actor}} (\rho(\text{M1, Movies})\times\rho(\text{M2, Movies})))$

(Using M1.Director>M1.Actor here to eliminate duplicate pairs such as (A, B) and (B, A).)

(b) Consider the following schema:

Books(bid, title, year**)** **Students(**sid, sname, age, major**)** **Authors(**aname, address**)**
borrows(bid, sid, data**)** **writtenBy(**bid, aname**), content(**bid, keyword**)**

Give natural language description for the following relational algebra.

Q5: $\pi_{\text{sname}}(\sigma_{\text{age>35}}(\text{Students})) - \pi_{\text{sname}}(\sigma_{\text{Major='CS'}}(\text{Students}))$

Selecting names of students who are older than 35 years old and not major in CS.

Q6: $\pi_{\text{sname}}(\sigma_{\text{Students.sid=borrows.sid}}(\sigma_{\text{major='CS'}}(\text{Students}) \times \text{borrows}))$

Selecting the names of all students with CS majors who have borrowed a book.

Q7: $\pi_{\text{sname}}(\text{Students}) - \pi_{\text{S1.sname}}(\sigma_{\text{S1.Age>S2.Age}}(\rho(\text{S1, Students})\times\rho(\text{S2, Students})))$

Selecting the youngest students' names.

Q8: $\text{Books} \bowtie (\pi_{\text{bId}}(\sigma_{\text{Keyword='database'}}(\text{content})) \cap \pi_{\text{bId}}(\sigma_{\text{Keyword='programming'}}(\text{content})))$

Selecting the books which have both keywords "database" and "programming".