Name

CWID

Exam
1

October 26th, 2022

CS425 - Database Organization
Fall 2022
Solutions

Please leave this empty! 1 2 3 Sum

Instructions

- Try to answer all the questions using what you have learned in class. Keep hard questions until the end.
- **When writing a query, write the query in a way that it would work over all possible database instances and not just for the given example instance!**
- The exam is closed book and closed notes!
- **For relational algebra questions assume set semantics!**

Consider the following database schema and example instance for a Booking Flight database:

passenger

pID	name	nationality	age	city
P100	Peter	British	20	London
P200	Alice	US	35	Chicago
P300	Bob	French	49	Paris

Airport

airportID	name	city
LHR	Heathrow	London
LGW	Gatwick	London
CDG	Charles de Gaulle	Paris
ORY	Orly	Paris

Flight

flightNo	flightCompany	depAirport	arrAirport
AF1231	Air France	LHR	CDG
AF1232	Air France	CDG	LHR
AF1234	Air France	LGW	CDG
AF1235	Air France	CDG	LGW
BA2943	British Airways	LGW	ORY
BA2944	British Airways	ORY	LGW
BA4059	British Airways	LHR	CDG
BA4060	British Airways	CDG	LHR

Booking

ticketNo	pID	flightNo	seatNo
EAG129489	P100	AF1232	12D
EAF123456	P200	AF1232	30E
ABS958332	P300	BA2944	10A
EAG348595	P400	BA2944	30D

Seat

seatNo	flightNo	class
12D	AF1232	Business
30E	AF1232	Economy
10A	BA2944	Business
5D	BA4060	Business
14B	BA4059	Economy
30D	BA2944	Economy

Hints:

- Attributes with black background form the primary key of a relation (.e.g, `airportID` for relation `Airport`)
- The attribute `depAirport` of relation `Flight` is a foreign key to `airportID` of relation `Airport`.
- The attribute `arrAirport` of relation `Flight` is a foreign key to `airportID` of relation `Airport`.
- The attribute `flightNo` of relation `Booking` is a foreign key to `flightNo` of relation `Flight`.
- The attribute `seatNo` of relation `Booking` is a foreign key to `seatNo` of relation `Seat`.
- The attribute `flightNo` of relation `Seat` is a foreign key to `flightNo` of relation `Flight`.

Part 1 Relational Algebra (Total: 24 Points)

Write a **relational algebra** expression that:

Question 1.1 (3 Points)

Returns the *name* and *nationality* of all passengers that are 30 years or older and live in London.

Solution

$$\pi_{name,nationality}(\sigma_{age \geq 30 \vee city = `London`}(\text{ passenger }))$$

Question 1.2 (3 Points)

Retrieve details of all bookings by British and French passengers.

Solution

$$\pi_{Booking.*}(\sigma_{nationality='British' \vee nationality='French'}(\text{ Booking} \bowtie \text{passenger }))$$

```
-- or use UNION
```

Question 1.3 (3 Points)

Retrieve the flight number, Departure and Arrival airports of all British Airways flights.

Solution

$$q_1 \leftarrow \pi_{flightNo,name\ as\ depAirport}(\sigma_{flightCompany='BritishAirways'}(\text{ Flight } \bowtie_{depAirport=airportID} \text{ Airport }))$$
$$q_2 \leftarrow \pi_{flightNo,name\ as\ arrAirport}(\sigma_{flightCompany='BritishAirways'}(\text{ Flight } \bowtie_{arrAirport=airportID} \text{ Airport }))$$
$$q \leftarrow q_1 \bowtie q_2$$

Question 1.4 (3 Points)

Increases the *age* of each passenger by 3 years.

Solution

$$passenger \leftarrow \pi_{pID,name,nationality,age+3,city}(\text{ passenger })$$

Question 1.5 (3 Points)

Find the total number of passengers and total number of Business class on each flight.

Solution

$$\begin{aligned} q_1 &\leftarrow {}_{flightNo}\mathcal{G}_{count(pID)\rightarrow totalPassengers}(\text{ Booking }) \\ q_2 &\leftarrow {}_{flightNo}\mathcal{G}_{count(pID)\rightarrow totalBusiness}\big(\sigma_{class='Business'}(\text{ Seat })\big) \\ q &\leftarrow q_1 \bowtie q_2 \end{aligned}$$

Question 1.6 (3 Points)

Retrieve full details of all flights from Chicago to London.

Solution

$$\begin{aligned} q_1 &\leftarrow \sigma_{city='Chicago'}(\text{ Airport }) \bowtie_{airportID=depAirport} \text{ Flight} \\ q_2 &\leftarrow \sigma_{city='London'}(\text{ Airport }) \bowtie_{airportID=arrAirport} \text{ Flight} \\ q &\leftarrow q_1 \ \bowtie_{q_1.flightNo=q_2.flightNo} \ q_2 \end{aligned}$$

Question 1.7 (3 Points)

Retrieve the passenger IDs and names for passengers who have bookings on at least one flight.

Solution

$$\pi_{pID,name}(\text{ passenger} \bowtie \text{Booking })$$

Question 1.8 (3 Points)

Retrieve the passenger IDs and names for passengers who do not have any bookings

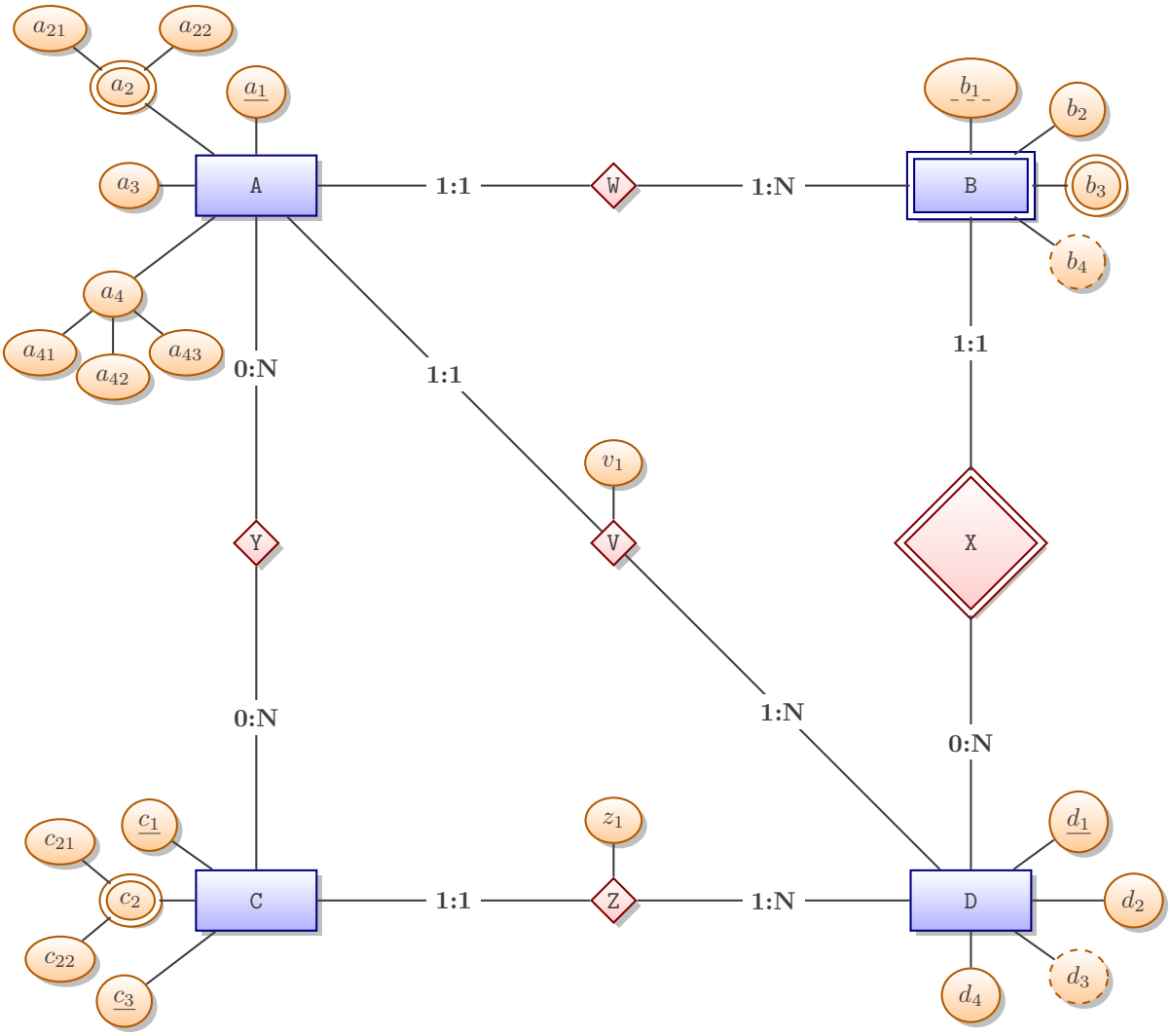
Solution

$$q_1 \leftarrow \pi_{pID}(\text{ passenger }) - \pi_{pID}(\text{ Booking })$$
$$q \leftarrow \pi_{q_1.pID,name}(\ q_1 \bowtie \text{passenger })$$

Part 2 ER Design (Total: 15 Points)

Question 2.1 (15 Points)

Take the following ER-model and translate it into a relational schema using the rules presented in class. Present the relational schema using the notation from the slides. For example, a relation R with attributes a_1 and a_2 where a_1 is the primary key is written as $R(\underline{a_1}, a_2)$. You do not need to specify foreign key constraints.



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Solution

1st Step (strong entities)

```
A(a1,a3, a41, a42, a43)
C(c1,c3)
D(d1,d2,d4)
```

2nd Step (weak entities)

```
A(a1,a3,a41,a42,a43)
B(d1,b1,b2)
C(c1,c3)
D(d1,d2,d4)
```

Solution

3rd Step (multivalued attributes)

```
A(a1,a3,a41,a42,a43)
A2(a1,a21,a22)
B(d1,b1,b2)
B3(d1,b1,b3)
C(c1,c3)
C2(c1,c3,c21,c22)
D(d1,d2,d4)
```

Solution

4th Step (relationships)

```
A(a1,a3,a41,a42,a43,d1,b1,v1)
A2(a1,a21,a22)
B(d1,b1,b2)
B3(d1,b1,b3)
C(c1,c3,d1,z1)
C2(c1,c3,c21,c22)
D(d1,d2,d4)
Y(a1,c1,c3)
```

Part 3 Normalization and Functional Dependencies (Total: 15 Points)

Consider the following relation $R(A, B, C, D, E)$ and functional dependencies $\mathcal{F}$ that hold over this relation.

$$\begin{aligned}\mathcal{F} =& B \to A \\ & AD \to C \\ & C \to ABD\end{aligned}$$

Question 3.1 (3 Points)

Determine all candidate keys of R.

Solution

$$\{CE\}^+ = \{ABCDE\}, \qquad \{ADE\}^+ = \{ABCDE\}, \qquad \{BDE\}^+ = \{ABCDE\}$$

Candidate Keys are:

$$\{CE\} \qquad \{ADE\} \qquad \{BDE\}$$

Question 3.2 (12 Points)

Compute the canonical cover of F. Show each step of the generation according to the algorithm shown in class.

Solution

$$\begin{aligned}\mathcal{F}_c =& B \to A \\ & AD \to C \\ & C \to ABD\end{aligned}$$

1^{st} iteration: 1) Apply union rule to combine right-hand sides:
no changes
1^{st} iteration: 2) Find extraneous attribute:
A is extraneous in $C \to ABD$

$$\begin{gathered}Compute\ C^+\ under\ \mathcal{F'}_c = B \to A, AD \to C, C \to BD \\ \{C\}^+ = \{ABDC\} \Rightarrow it\ includes\ A\end{gathered}$$

$$\begin{aligned}\mathcal{F}_c =& B \to A \\ & AD \to C \\ & C \to BD\end{aligned}$$

2^{nd} iteration: 1) Apply union rule to combine right-hand sides:
no changes
2^{nd} iteration: 2) Find extraneous attribute:
no changes

$$\begin{aligned}\therefore\ \ \mathcal{F}_c =& B \to A \\ & AD \to C \\ & C \to BD\end{aligned}$$