Name:

Section (315/415):

MIDTERM EXAM - 600.315/415 - Databases

Date: November 8, 2016, 3:00 PM

The total number of points in this exam is 74 for 600.315 students, and 79 for 600.415 students. If you work at approximately 1 minute per point, you should finish on time.

Some questions should only be done by 600.415 or 600.315 students and are marked so.

Question 1 - Relational Algebra (5 points)

Express the following query in the Relational Algebra. The tables that are used in this (and following) questions are found on your supplementary handout.

• (5 points - 600.315 only) List the country in the database where all of the senators are women.

result ← Π_{CName} (Country) − Π_{CName}(σ_{Gender = "Male" ∧ Office = "Senator" } Country ⊲ ⊳ Politician)

• (5 points - 600.415 only) List the country in the database where all of the senators are women but the head of government is not a woman.

all_female_senators ← Π_{CName} (Country) − Π_{CName}(σ_{Gender = "Male" ∧ Office = "Senator" } Country ⊲ ⊳ Politician)

not_female_head ← Π_{CName}(σ_{Gender = "Male" } Country ⊲ ⊳ Politician ⊲ ⊳ Head_of_Government)

result ← all_female_senators ∧ not_female_head
Question 2 - Relational Algebra (5 points)

• (5 points - 600.315 only) List the countries in the database that are in NATO but do not have a female head of government.

\[
\text{NatoCountries} ← \Pi_{CName}(σ_{Alliance = "NATO"} \text{ Country} \bowtie \text{ AllianceMembership})
\]
\[
\text{not\_female\_head} ← \Pi_{CName}(σ_{Gender = "Male"} \text{ Country} \bowtie \text{ Politician} \bowtie \text{ HeadOfGovernment})
\]
\[
\text{result} ← \text{NatoCountries} \land \text{not\_female\_head}
\]

• (5 points - 600.415 only) List the countries in the database that are in NATO but do not border another NATO country.

\[
\text{NatoCountries} ← \Pi_{CName}(σ_{Alliance = "NATO"} \text{ Country} \bowtie \text{ AllianceMembership})
\]
\[
\text{NatoBorder} ← \Pi_{CName}(\text{NatoCountries} \bowtie \text{Country1=Name} \text{ Borders} \bowtie \text{Country2=Name} \text{ NatoCountries})
\]
\[
\text{result} ← \text{NatoCountries} \setminus \text{NatoBorder}
\]
Question 3 - Tuple Relational Calculus (5 points)

Express the following query in Tuple Relational Calculus:

- (5 points) Print the name and GDP of all countries that border Austria or have a female head of government but not both.

\[
\left\{ t \mid \exists c \in \text{COUNTRY} \ (t[CName] = c[CName] \land t[GDP]=c[GDP] \land (\exists b \in \text{BORDERS} \ (b[country1]=c[CName] \land b[country2]='Austria') ) \right\} \\
\bigcup \\
\left\{ t \mid \exists h \in \text{HEAD_OF_GOVERNMENT} \ (h[CName] = c[CName] \land \exists p \in \text{POLITICIAN} \ (p[country]=c[Cname] \land h[Office] = p[Office] \land P[gender] = 'female' \land t[Cname] = c[CName]) ) \right\} \\
\bigcap \\
\left\{ t \mid \neg \exists b1 \in \text{BORDERS} \land \neg \exists h1 \in \text{HEAD_OF_GOVERNMENT} \land \neg \exists p1 \in \text{POLITICIAN} \ (b1[country] = c[cname] \land b1[country2]=’Austria’ \land h1[CName] = c[CName] \land p1[country]=c[cname] \land h1[Office] = p1[Office] \land p1[gender] = ’female’ \land t[Cname] = c[CName]) \right\}
\]

Question 4 - Relational Algebra (5 points)

Express the following query in the relational algebra.

(a) (5 points) List the full names of all people who are either (a) a president, (b) directly related to a president, or (c) directly related to someone who is directly related to a president.

\[
\text{President} \leftarrow \Pi_{\text{pname}} (\sigma_{\text{Office} = ‘President’} \text{ Politician} ) \\
\text{D\_PresidentInit} \leftarrow \Pi_{\text{politician2}} (\text{IsRelated} \land \sigma_{\text{politician1}=\text{pname}} \text{ President} ) \\
\text{D\_President} \leftarrow \rho_{\text{pname}=\text{politician2}} (\text{D\_PresidentInit} ) \\
\text{D2\_PresidentInit} \leftarrow \Pi_{\text{politician2}} (\text{IsRelated} \land \sigma_{\text{politician1}=\text{pname}} \text{ D\_President} ) \\
\text{D2\_President} \leftarrow \rho_{\text{pname}=\text{politician2}} (\text{D2\_PresidentInit} ) \\
\text{Result} \leftarrow \text{President} \cup \text{D\_President} \cup \text{D2\_President}
\]
Question 5 - Relational Algebra (5 points)

Express the following query in the relational algebra:

(a) (5 points - 600.415 only) List the names and populations of all countries that have a smaller GDP than every country that they border.

\[
\text{Bordering} \leftarrow \Pi_{\text{country1}, \text{GDP1}, \text{population1}, \text{country2}, \text{GDP2}} \left( \text{Country} \bowtie \sigma_{\text{cname} = \text{country1}} \text{Borders} \bowtie \sigma_{\text{country2} = \text{cname}} \text{Country} \right) \\
\text{LessThanAtLeastOne} \leftarrow \Pi_{\text{country1}, \text{population1}, \text{country2}} \left( \sigma_{\text{GDP1} < \text{GDP2}} \left( \text{Bordering} \right) \right) \\
\text{Result} \leftarrow \Pi_{\text{country1}, \text{population}} \left( \text{LessThanAtLeastOne} \div \text{Bordering} \right)
\]

SKIP THIS QUESTION - DO NOT ANSWER

Question 6 - Relational Algebra (6 points)

Express the following query in the relational algebra:

List the full names of all politicians in the database who have a mother who also is a politician in the same country.

\[
\text{AreSis} \leftarrow \Pi_{\text{politician1}, \text{politician2}} \left( \sigma_{\text{Type} = \text{'mother'}} \left( \text{IsRelated} \right) \right) \\
\text{OfficeSis} \leftarrow \Pi_{\text{politician1}, \text{country}} \left( \text{Politician} \bowtie \sigma_{\text{pname} = \text{politician2}} \text{AreSis} \right) \\
\text{Result} \leftarrow \Pi_{\text{pname}} \left( \text{Politician} \bowtie \sigma_{\text{country} = \text{country}\land \text{pname} = \text{politician1}} \left( \text{OfficeSis} \right) \right)
\]
Question 7 - SQL (25 points)

Express the following queries in SQL:

(a1 - 5 points) - **600.315 only** List the name, GDP and population of the country with the youngest head of government in the database.

```sql
SELECT CName, GDP, Population
FROM COUNTRY AS c, POLITICAN AS p, HEAD_OF_GOVERNMENT AS h
WHERE c.CName = p.country
AND p.office = h.office
AND p.country = h.country
AND p.age = (SELECT min(p1.age)
FROM POLITICAN AS p1, HEAD_OF_GOVERNMENT AS h1
WHERE p1.office = h1.office
AND p1.country = h1.country)
```

(a2 - 5 points) - **600.415 only** List the name, GDP and population of the NATO country with the youngest head of government in the database.

```sql
SELECT CName, GDP, Population
FROM COUNTRY, ALLIANCE_MEMBERSHIP, POLITICIAN, HEAD_OF_GOVERNMENT
WHERE COUNTRY.CNAME = ALLIANCE_MEMBERSHIP.Country
AND ALLIANCE_MEMBERSHIP = 'NATO'
AND COUNTRY.CNAME = POLITICIAN.coutry
AND POLITICIAN.office = HEAD_OF_GOVERNMENT.office
AND POLITICIAN.country = HEAD_OF_GOVERNMENT.country
AND POLITICIAN.age = (SELECT min(p1.age)
FROM POLITICAN AS p1, HEAD_OF_GOVERNMENT AS h1
WHERE p1.office = h1.office
AND p1.country = h1.country)
```
(b - 5 points) List the names of all countries that do not border Russia directly, but border a country that borders Russia.

```
(SELECT country1
 FROM BORDERS
 WHERE country2 IN
   (SELECT country1
    FROM BORDERS
    WHERE country2 = "Russia")
)
MINUS
(SELECT country1
 FROM BORDERS
 WHERE country2 = "Russia");
```
(c - 5 points) For each continent, list the name of the country with the lowest literacy rate in the continent (along with the name of the continent).

Your output should be a single table and not use multiple queries.

```
SELECT COUNTRY.CName, COUNTRY Continent
FROM COUNTRY,
(  
    SELECT Contient, Min(Litrate) AS min_value
    FROM COUNTRY GROUP BY Contient
  ) AS c
WHERE COUNTRY.Contient = c. Contient
AND c.min_value = COUNTRY.Litrate;
```

(d - 5 points) List the pair of bordering countries with the greatest absolute difference in life expectancy (give both names and do not repeat them).

```
SELECT Country1, Country2
FROM BORDERS, COUNTRY AS c1, COUNTRY AS c2
WHERE Country1 = c1.CName
AND Country2 = c2.CName
AND Country1 < Country2
AND ABS(c1.LifeExp - c2.LifeExp) >=
ALL (  
    SELECT ABS(c3.LifeExp - c4.LifeExp)
    FROM BORDERS, COUNTRY AS c3, COUNTRY AS c4
    WHERE Country1 = c3.CName
    AND Country2 = c4.CName
  )
)
List the country in the database where the highest percentage of listed politicians are women.

SELECT c.CName
FROM COUNTRY AS c,
  (  
    SELECT CName, COUNT(*) AS num
    FROM POLITICIAN
    WHERE Gender = "Female"
    GROUP BY CName
  ) AS f,
  (  
    SELECT CName, COUNT(*) AS num
    FROM POLITICIAN
    GROUP BY CName
  ) AS t,
WHERE f.CName = t.CName
AND f.num / t.num >=
ALL(  
    SELECT f1.num / t1.num
    FROM COUNTRY AS c1,
      (  
        SELECT CName, COUNT(*) AS num
        FROM POLITICIAN
        WHERE Gender = "Female"
        GROUP BY CName
      ) AS f1,
    (  
        SELECT CName, COUNT(*) AS num
        FROM POLITICIAN
        GROUP BY CName
    ) AS t1,
WHERE f1.CName = t1.CName  
)
List the country in the database where the highest percentage of listed politicians are women but do not have a female head of government.

```
(SELECT c.CName
 FROM COUNTRY AS c,
    (SELECT CName, COUNT(*) AS num
     FROM POLITICIAN
     WHERE Gender = "Female"
     GROUP BY CName
    ) AS f,
    (SELECT CName, COUNT(*) AS num
     FROM POLITICIAN
     GROUP BY CName
    ) AS t,
WHERE f.CName = t.CName
AND f.num / t.num >=
 ALL(
 SELECT f1.num / t1.num
 FROM COUNTRY AS c1,
    (SELECT CName, COUNT(*) AS num
     FROM POLITICIAN
     WHERE Gender = "Female"
     GROUP BY CName
    ) AS f1,
    (SELECT CName, COUNT(*) AS num
     FROM POLITICIAN
     GROUP BY CName
    ) AS t1,
WHERE f1.CName = t1.CName
)
)
EXCEPT

(SELECT c.CName
 FROM COUNTRY AS c, POLITICIAN AS p, HEAD_OF_GOVERNMENT AS h
WHERE c.CName = p.country
AND p.office = h.office
AND p.country = h.country
AND p.gender = "Female"
)
Question 8 - QBE (10-15 points)

Express the following queries in QBE. To simplify your work, table shells have been provided. Just fill in the appropriate cells with variables/values.

(a) (5 points) List the name and continent of every country that borders a country that borders a country that borders a country that has a female prime minister.

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>CName</th>
<th>Continent</th>
<th>GDP</th>
<th>Population</th>
<th>LitRate</th>
<th>LifeExp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P.α</td>
<td>P.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BORDERS</th>
<th>Country1</th>
<th>Country2</th>
</tr>
</thead>
<tbody>
<tr>
<td>α</td>
<td>β</td>
<td></td>
</tr>
<tr>
<td>β</td>
<td>γ</td>
<td></td>
</tr>
<tr>
<td>γ</td>
<td>δ</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>POLITICIAN</th>
<th>PName</th>
<th>Gender</th>
<th>Office</th>
<th>Country</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P.δ</td>
<td>&quot;Female&quot;</td>
<td>&quot;Prime Minister&quot;</td>
<td>δ</td>
<td></td>
</tr>
</tbody>
</table>

Condition

α ≠ γ and α ≠ δ and β ≠ δ
(b) (5 points) List the name and gender of all politicians who are prime ministers of a country and older than the prime minister or president of at least one country that they border.

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>CName</th>
<th>Continent</th>
<th>GDP</th>
<th>Population</th>
<th>LitRate</th>
<th>LifeExp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BORDERS</th>
<th>Country1</th>
<th>Country2</th>
</tr>
</thead>
<tbody>
<tr>
<td>c1</td>
<td>c2</td>
<td>c3</td>
</tr>
<tr>
<td>c1</td>
<td>c3</td>
<td>c3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>POLITICIAN</th>
<th>PName</th>
<th>Gender</th>
<th>Office</th>
<th>Country</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>P.</td>
<td>P.</td>
<td></td>
<td>&quot;Prime Minister&quot;</td>
<td>c1</td>
<td>a1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&quot;Prime Minister&quot;</td>
<td>c2</td>
<td>a2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&quot;President&quot;</td>
<td>c3</td>
<td>a3</td>
</tr>
</tbody>
</table>

Condition

\[ a_1 > a_2 \text{ or } a_1 > a_3 \]
(c) (5 points - 600.415 only) List the name of all continents that contain at least two countries that do not border each other. (600.415 only)

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>CName</th>
<th>Continent</th>
<th>GDP</th>
<th>Population</th>
<th>LitRate</th>
<th>LifeExp</th>
</tr>
</thead>
<tbody>
<tr>
<td>c1</td>
<td>P.</td>
<td>con</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BORDERS</th>
<th>Country1</th>
<th>Country2</th>
</tr>
</thead>
<tbody>
<tr>
<td>¬</td>
<td>c1</td>
<td>c2</td>
</tr>
</tbody>
</table>

Condition

\[ c_1 \neq c_2 \]
Question 10 - Functional Dependencies (14 points)

(a) List at least 10 additional non-trivial functional dependencies that hold for schema \( R = (A, B, C, D, E) \) if the following list hold for \( R \) (i.e. a subset of the closure). For extra credit, list as many additional non-trivial FD’s as possible. It is recommended that you focus on additional FD’s that will help you answer (b) below.

\[
\begin{align*}
C & \rightarrow AE \\
E & \rightarrow D \\
B & \rightarrow C \\
AD & \rightarrow B
\end{align*}
\]

\textit{Solution:}

\[
\begin{align*}
B & \rightarrow AE, AD \rightarrow C \\
AE & \rightarrow AD, AE \rightarrow B \\
C & \rightarrow AD, C \rightarrow B \\
C & \rightarrow A, D \rightarrow E \\
B & \rightarrow D, B \rightarrow A \\
DB & \rightarrow C, C \rightarrow AB \\
C & \rightarrow BE, \\
C & \rightarrow ABDE, B \rightarrow ACDE \\
C & \rightarrow ABCDE, B \rightarrow ABCDE \\
AE & \rightarrow ABCDE, AD \rightarrow ABCDE
\end{align*}
\]

(b) List the candidate keys for \( R \).

\textit{Candidate Keys} : \( B, C, AD, AE \)

(c) Show that the decomposition of the schema \( R \) above into \( (A, C, E) \) and \( (B, C, D) \) is a lossless-join decomposition if the set of functional dependencies above hold on \( R \).

Let \( R_1 = (A, C, E) \) and \( R_2 = (B, C, D) \)

The decomposition is a lossless-join decomposition of \( R \) if at least one of the following functional dependencies are in \( F^+ \),

\[
\begin{align*}
R_1 \cap R_2 & \rightarrow R_1 \\
R_1 \cap R_2 & \rightarrow R_2
\end{align*}
\]

where \( F \) is the given set of functional dependencies.

In our case \( R_1 \cap R_2 = C \)

Since \( C \rightarrow CAE \) is is in \( F^+ \), the decomposition is a lossless-join decomposition.
CERTIFICATION PAGE

By signing below, I promise that my answers on this exam are entirely my own work. I have not looked at the answers written by others and I have not allowed others to look at my answers.

My Signature: