The exercise is based on the *Mondial* database. Its schema can be accessed at [https://files.ifi.uzh.ch/dbtg/dbs/mondial/schema.pdf](https://files.ifi.uzh.ch/dbtg/dbs/mondial/schema.pdf). Note, there are no restrictions on the operators you can use in your relational algebra (RA) expressions and SQL queries.

1 RA to DRC and SQL

Consider the following RA expression:

\[
\pi_{\text{Country}} \left( \sigma_{\text{Country}=\text{Country1} \land \text{Code2}=\text{Country2} \lor \text{Country}=\text{Country2} \land \text{Code2}=\text{Country1}} \land \text{River}=\text{River2} \left( \text{geoSource} \times \text{borders} \right) \right) \]

1. Explain briefly but precisely in natural language what this RA expression returns independently of the actual data stored in the Mondial database.

2. Convert the RA expression into a DRC expression and a SQL query. Write down the number of rows returned by the SQL query.

3. Consider a database instance in which there exists a country for which all rivers that originate in the country also have their estuary in the same country. Is it possible according to the relational schema that the RA expression returns this country? Explain.

2 DRC to RA and SQL

Consider the following DRC expression:

\[
\{ \text{Code} | \text{country} = \text{Code, Country, Code, Country, River} \}
\land \forall \text{Prov} \left( \text{province} = \text{Prov, Code, Code, Prov} \Rightarrow \text{geoMountain} \right) \]

1. Explain briefly but precisely in natural language what this DRC expression returns independently of the actual data stored in the Mondial database.

2. Convert the DRC expression into an RA expression and a SQL query. Write down the number of rows returned by the SQL query.

3. Explain briefly but precisely in natural language what a modified DRC expression that contains a conjunction instead of an implication returns independently of the actual data stored in the Mondial database.

3 SQL to RA and DRC

1. Consider the following SQL query:
SELECT b.Country1, SUM(b.Length) 
FROM (SELECT Country1, Length FROM borders 
UNION ALL 
SELECT Country2, Length FROM borders 
) b 
GROUP BY b.Country1;

(a) Explain briefly but precisely in natural language what this SQL query returns independently of the actual data stored in the Mondial database. Assume that a country cannot be a neighboring country to itself.

(b) Can the SQL query be converted into a DRC expression? If yes, give the expression, if no, explain why not.

(c) Convert the SQL query into an RA expression.

2. Consider the following SQL query:

SELECT c.Name, c.Code 
FROM country c, geoSource g 
WHERE c.Code = g.Country;

(a) Explain briefly but precisely in natural language what this SQL query returns independently of the actual data stored in the Mondial database.

(b) Is it possible to convert the SQL query into an equivalent RA and/or DRC expression? Equivalent means that the result is the same on all possible database instances. If yes, give the expression(s). If no, explain why not.