Foundations of Databases

Exercises – Relational Query Languages /2, Query Optimization

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1. Express the queries on the Database schema $\mathbf{C} = \{$ `Account, Movie, Schedule` $\}$, where

   ```
   Account:  number, branch, customerId
   Movie:  title, director, actor
   Schedule:  theater, title
   ```

   in relational calculus:

   (a) Find titles of current movies
   (b) Find theaters showing movies directed by Polanski
   (c) Find theaters showing movies featuring Nicholson
   (d) Find all directors who acted themselves
   (e) Find directors whose movies are playing in all theaters
   (f) Find theaters that only show movies featuring Nicholson

   If a query is domain-independent, the query should be safe-range.

2. Exhibit a relational algebra query which is not monotonic.

3. Exhibit a relational algebra query which is not satisfiable.

4. Prove proposition if a query Q in relational calculus is domain independent, then for each $\mathbf{d} \subseteq \mathbf{dom}$ and database instance $\mathbf{I}$ such that $Q_{\mathbf{d}}(\mathbf{I})$ is defined, $Q_{\mathbf{d}}(\mathbf{I}) = Q_{nat}(\mathbf{I}) = Q_{adom}(\mathbf{I})$

5. Map the relational calculus queries in Ex. (1) to relational algebra.

6. Detail the mapping from relational calculus under Active Domain Semantics to relational algebra (in the named or unnamed setting), such that each $F(x_1, \ldots, x_n)$ in relational calculus is translated into an expression E_F that produces a relation with n attributes.

7. Find all equivalences and containments among the following conjunctive queries:

$$
\begin{aligned}
Q_1(x, y) &\ :- \quad q(x, y), q(y, z), q(z, w) \\
Q_2(x, y) &\ :- \quad q(x, y), q(y, z), q(z, u), q(u, w) \\
Q_3(x, y) &\ :- \quad q(x, y), q(z, u), q(v, w), q(x, z), q(y, u), q(u, w) \\
Q_4(x, y) &\ :- \quad q(x, y), q(y, 3), q(3, z), q(z, w)
\end{aligned}
$$

8. For each conjunctive query Q_i in Ex. 7,

   (a) convert Q_i into a tableau

   (b) minimize Q_i

9. Suppose a finite set S of equality and inequality atoms is given.

   (a) Describe a procedure for inferring all equalities $t_1 = t_2$ and inequalities $t_1 \neq t_2$, where t_1 and t_2 are variables or constants, which logically follow from S.
   For example, $X = Y$ follows from $S = \{X = a,\ a = Y\}$.

   (b) Describe an axiom system for inferring all equalities and inequalities from S, in the style of the Armstrong axiom system for functional dependencies. The axioms should be of the form

   $$\frac{A_1, \ldots, A_n}{B}, \qquad n \geq 0$$

   where the A_i and B are equality and inequality axioms.

   (c) How difficult (in complexity terms) is it to decide whether an (in)quality atom A follows from S, given S and A for input?

10. Let us consider unions of conjunctive queries: $Q_1 = Q_{1,1} \cup Q_{1,2} \cup \cdots \cup Q_{1,n_1}$ and $Q_2 = Q_{2,1} \cup Q_{2,2} \cup \cdots \cup Q_{2,n_2}$, where each $Q_{i,j}$ is of the form

$$Q_{i,j}(x_1, \ldots, x_n) \text{ :- } < \mathit{Body} >$$

and $< \mathit{Body} >$ consists of atoms over a relation R. Then it holds that Q_1 is contained in Q_2 ($Q_1 \subseteq Q_2$), if and only if for each $Q_{1,i}$ $i \in \{1, \ldots, n_1\}$ there exists some $j \in \{1, \ldots, n_2\}$ such that $Q_{1,i} \subseteq Q_{2,j}$ holds.

(a) Argue why this is true

(b) Using this criterion, examine whether $Q_1 \cup Q_3$ is contained in (resp., equivalent to) $Q_2 \cup Q_4$ from Ex. (7)

11. A union of conjunctive queries $Q = Q_1 \cup \cdots \cup Q_n$ might be optimized by removing "redundant" elements Q_i. Describe a procedure for minimization, and apply it to the query $Q_1 \cup Q_2 \cup Q_3 \cup Q_4$ from Ex. (7)

12. Do the same as in Ex. (8), but assume that the relation $R : A, B$ satisfies the functional dependency $A \rightarrow B$.