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Foundations of Query Languages
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1. Conjunctive Queries

Exercise 1 (NP-Completeness Proof)
Based on the reduction from 3SAT to query answering of Boolean conjunctive queries in the lecture, show the following:

a) The reduction can be done in Logspace.

b) The 3SAT formula F is satisfiable (that is, there is a boolean assignment of all the variables in F such that F true), if and only if $Q(\mathcal{I})$ returns true.

Exercise 2 (NP-Completeness Proof)
Prove that query answering of Boolean conjunctive queries is NP hard by a reduction from 3-Colorability.

Exercise 3 (Conjunctive query containment)
Given the following queries:

$$\begin{array}{lll} Q_1: & q(A,C) & \leftarrow \quad a(A,B), a(B,C), a(B,D). \\ Q_2: & q(X,Z) & \leftarrow \quad a(X,Y), a(Y,Z). \end{array}$$

Decide whether they are contained in each other.

Exercise 4 (Conjunctive query containment)
Find all equivalences and containments among the conjunctive queries given below (give the respective containment mappings).

$$\begin{array}{lll} Q_1: & p(X,Y) & \leftarrow \quad q(X,A), q(A,B), q(B,Y). \\ Q_2: & p(X,Y) & \leftarrow \quad q(X,A), q(A,B), q(B,C), q(C,Y). \\ Q_3: & p(X,Y) & \leftarrow \quad q(X,A), q(B,C), q(D,Y), q(X,B), q(A,C), q(C,Y). \\ Q_4: & p(X,Y) & \leftarrow \quad q(X,A), q(A,c), q(c,B), q(B,Y). \end{array}$$

Minimize each of the above queries. Minimize the set $\{Q_1, Q_2, Q_3, Q_4\}$. Note that the small c in the last query is a constant.

Exercise 5 (Conjunctive query minimization)
Instead of eliminating rows, query minimization can also be achieved by eliminating variables. Write an algorithm which minimizes queries by eliminating each time at least one variable. Prove that your algorithm generates a minimal query.

Exercise 6 (Conjunctive query minimization)
Let conjunctive queries Q_1 and Q_2 be both equivalent and minimal, prove that Q_1 and Q_2 are isomorphic (which means that the queries are equivalent upto renaming the variables). For instance, $Q_1 : q \leftarrow e(X,Y), e(Y,Z)$ and $Q_2 : q \leftarrow e(A,B), e(B,C)$ are isomorphic.