Query Consolidation: Interpreting a Set of Independent Queries Using a Multidatabase Architecture in the Reverse Direction

[Project to be known as Retroplex]

Aybar C. Acar and Amihai Motro

(submitted for publication)

Motivation

- Assume this scenario:
  - Person's *information goal* is satisfied by data stored in different databases.
  - Person submits a set of queries to these databases.
  - Then, off-line, consolidates the answers obtained in some "big answer".
- By extracting this query set from the various logs, and analyzing it, we may be able to discover a *single interpretation* for the entire set, which (it is hoped) will correspond to the original information goal.
- This may suggest how the information should be *re-organized* to facilitate such tasks in the future.
- Recall that the original motivation for virtual databases is provide a single source for a particular task!

Analogy

- Consider a shopping center with multiple stores.
- Analysis of sales records shows that within *a small time interval*, the *same customer* purchased, in *different stores*:
  - A box of candy,
  - Gift-wrapping paper,
  - Greeting card.
- Conclusion: Customer service could be improved if all items were sold in the same store.

Another Possible Motivation

- In the analogy: What if the motivation for the individual purchases is that the customer is trying to *hide* his overall purpose?
- Hence, a possible application of query consolidation is *surveillance* and *security*:
  - A consolidated query discloses the *intentions* of the user posing the queries.

How Do Virtual Databases Fit Here?

- **Query decomposition** in virtual databases:
  - Given a global query Q, find
    - Local queries $Q_1, \ldots, Q_n$
    - Assembly expression E

    Such that $Q = E(Q_1, \ldots, Q_n)$.
- We propose to adopt the same virtual database architecture, but use a process that is the *reverse* of query decomposition.
- **Query consolidation**:
  - Given local queries $Q_1, \ldots, Q_n$, find
    - Global query Q
    - Assembly expression E

    Such that the same query decomposition algorithm will decompose Q into $Q_1, \ldots, Q_n$.
    - Therefore, $Q = E(Q_1, \ldots, Q_n)$.

The Main Obstacle

- Query consolidation is a *function*:
  - Each query is mapped to a *unique* decomposition.
- But it is not *injective*:
  - There could be *multiple* global queries $Q^1, \ldots, Q^m$,
  - And corresponding expressions $E^1, \ldots, E^m$,
  - Such that Q^i will decompose to $Q_1, \ldots, Q_n$ using E^i ($I = 1, \ldots, m$),

Our Approach

- We assume the independent databases to which queries are submitted had been incorporated into a virtual database system.
- We then “reverse” the query decomposition algorithm.
- Two steps could introduce multiple solutions:
  - At one point, the system must infer *equi-joins* for a set of relations.
  - At another point, it must discover the most likely *selection constraints* that would be applied to a relation.
- In each case we develop a procedure that *ranks* solutions according to their perceived likelihood.
- The final result is a *ranked* list of suggested consolidations.

The Virtual Database Architecture

- We adopt the Multiplex model:
  1. A global database scheme D.
  2. A set $D_1, \ldots, D_n$ of local database schemes and their associated instances $d_1, \ldots, d_n$.
  3. A set $(V_1,U_1), \ldots, (V_m,U_m)$ of view pairs where V_i is a view of D and each U_i is a view of some local database.
  4. Each view V_i is materialized by the corresponding view U_j.
- We assume queries and views are relational algebra expression with selections, projections and Cartesian products. These can be written:

$$Q = \pi_A \sigma_C (R_1 \times R_2 \times \ldots \times R_n)$$

A Canonical Decomposition Algorithm

- A query Q is decomposed in 7 steps:
  1. Create a global relation scheme R for the Cartesian product operations in Q.
  2. Determine the views V_j that are relevant to Q (intersect with Q).
  3. Construct queries Q_i to retrieve from the corresponding local views U_j the parts that are relevant to Q.
  4. Evaluate Q_i in the local databases, obtaining answers A_i.
  5. Extend A_i with nulls, creating instances A^*_i of scheme R.
  6. Coalesce the instances A^*_i to a single instance A^*.
  7. Apply Q's selection and projection operators, yielding an answer A to the query Q.

Sufficiency and Necessity Assumptions

- **Sufficiency**: The information in the local queries Q_1, …, Q_n is sufficient to accomplish the user's goal.
  - No outside information is used.
  - Hence, the goal can be approximated by a consolidation.
- **Necessity**: All the information in the local queries Q_1, …, Q_n is necessary to accomplish the user goal.
  - Nothing retrieved is discarded.

Duality

- Consider a global query that retrieves a person's age.
- Its decomposition could involve any of these (and more):
  1. Retrieve just the person's age.
  2. Retrieve the person's entire tuple, and then the expression *E* would project the age.
  3. Retrieve a group of persons (e.g., everybody), and then *E* will select the person's tuple and project the age.
- The guiding principle is to retrieve from the local database *as little as possible*:
  - Take advantage of the local database processing capabilities
  - Reduce costs of all sorts (charges by the local database, transmission).
- An *optimal decomposition* is one that minimizes the data transmitted.
- *Consolidation necessity* is similar to *decomposition optimality*:
  - Both assume that all information extracted from local databases is necessary:
    - Either to answer *Q* (decomposition) or to conclude *Q* (consolidation).

Methodology

- Reverse query decomposition with this procedure:
  1. For each local query Q_i, determine the views U_j that are relevant (intersect with Q_i).
  2. Process each answer A_i to obtain the part A^*_i that is within U_j.
  3. In the virtual database, materialize the corresponding views V_j with the answers A^*_i.
  4. Populate the relations R_k with the materialized views V_j.
  5. The global relations populated by at least one view must now be joined meaningfully.
     - If a view V_j is a join over two or more relations then a join is implied.
     - Hence, we have *clusters* with implied joins, that need to be joined.
  6. In the single relation thus obtained we keep only attributes that are in some view V_j.

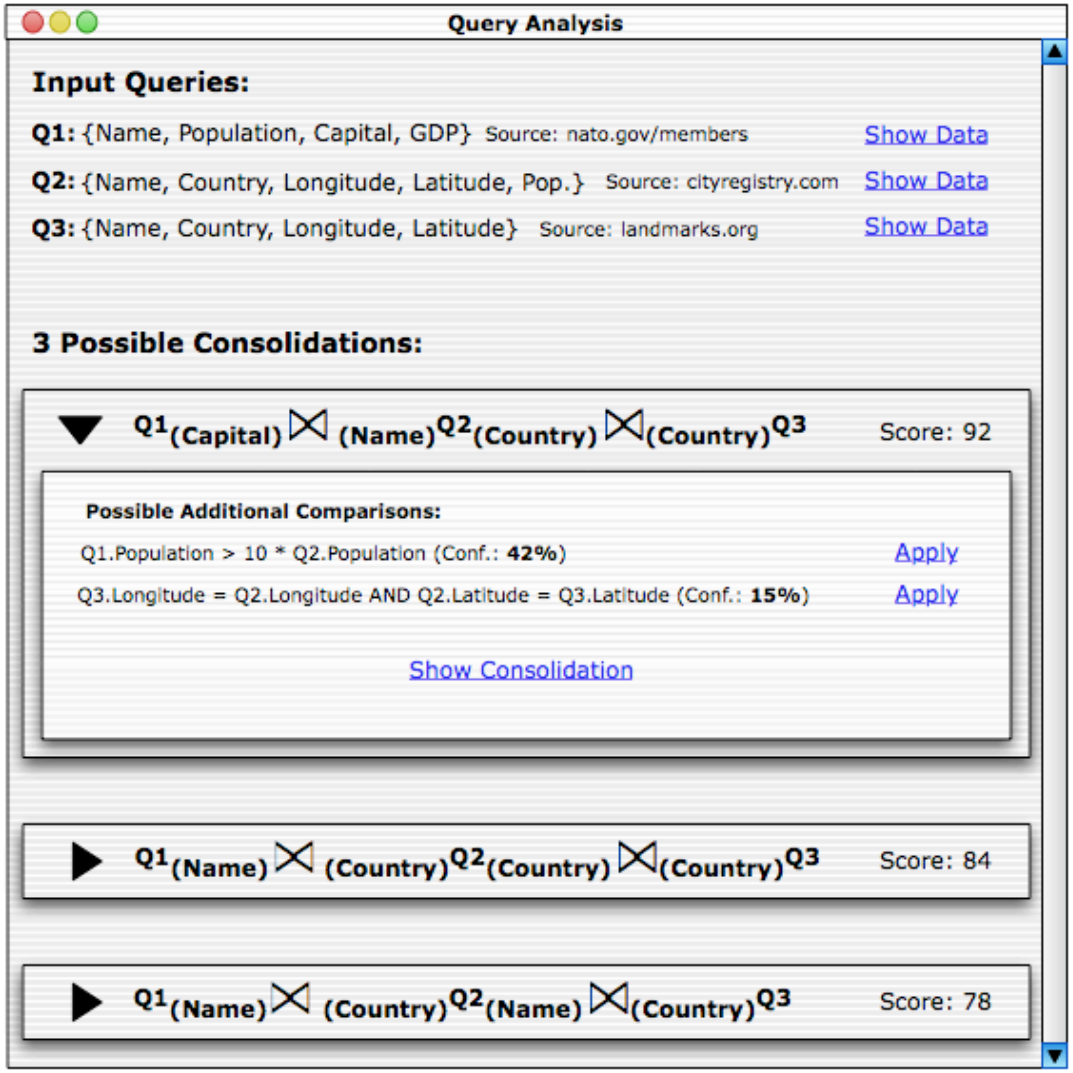
Methodology (*Cont.*)

- We call the resulting relation *R*.
- The global (sought-after) query *Q* is now embedded in *R*.
- We now consider processing *R* by selection and projection.
- The necessity assumption implies that *R* should not be subjected to any selections based on *constants*.
  - These should have been done in local queries!
- It also implies that R should not subjected to any *projections*.
  - These too should have been done in local queries!

Methodology (*Cont.*)

- The multiplicity of possible consolidations has two sources:
  1. The given relations can be joined in different ways.
  2. The relation *R* could be subjected to different *global* selections.
     - Selections that compare attributes retrieved from different local queries.
- We handle these issues consecutively:
  1. First, generate all the possible joins and rank them according to plausibility.
  2. Then for each join plan, suggest global selections, ranking them as well.
- These are explained in the “appendix”.

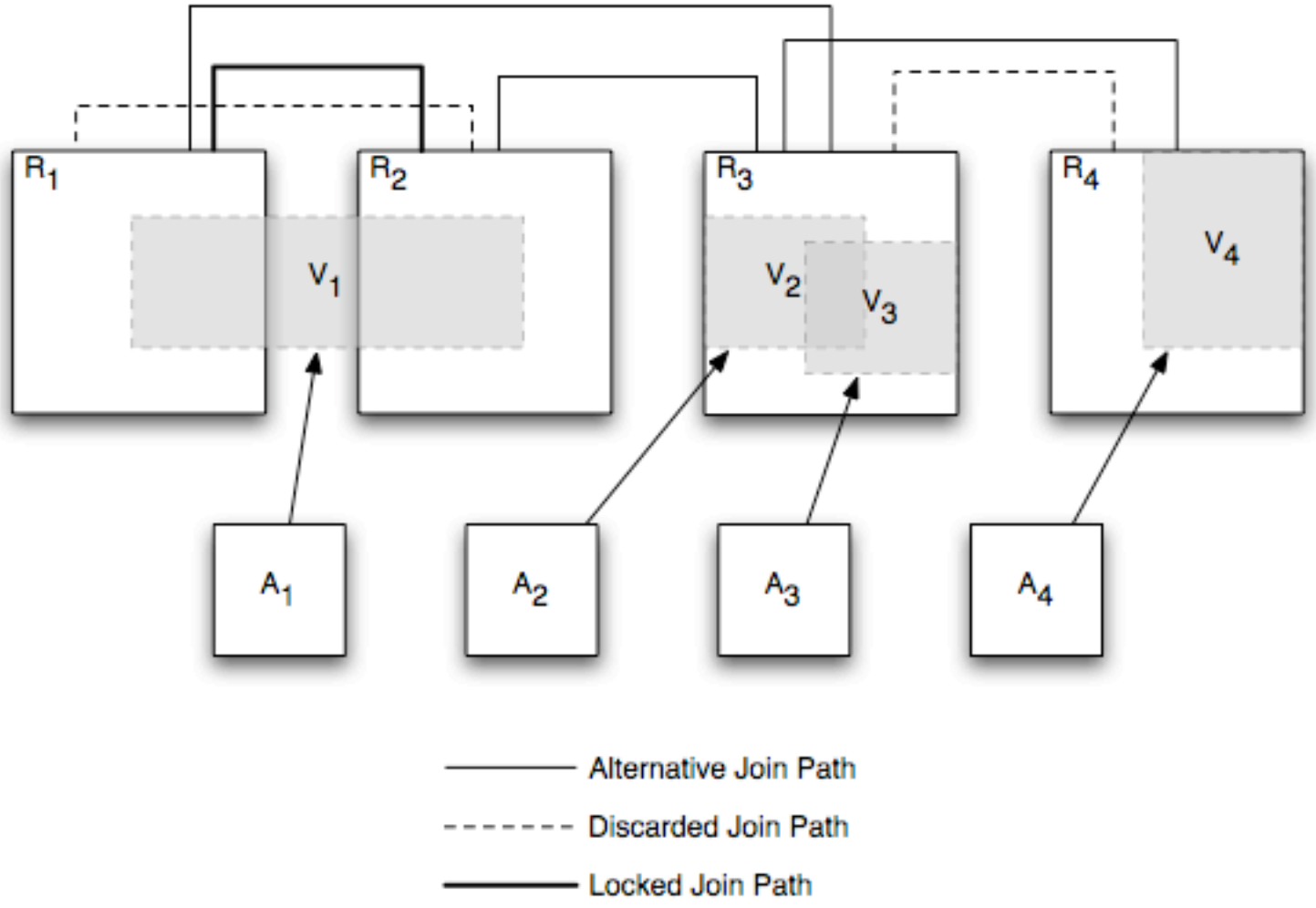
User Interface (mock)



Conclusion

- We described an entirely new problem: *query consolidation*.
- This problem exhibits attractive duality with the well-known problem of *query decomposition*.
- We assumed the independent databases have been integrated into a virtual database system (and a global scheme exists).
  - A more challenging situation is when a global scheme does not exist.
  - The extensions of the given queries must be analyzed to infer their semantic associations (scheme-matching!).
- Other research issues:
  1. Cull from independent logs a set of queries that constitute a single task.
  2. Relax the assumptions of sufficiency and necessity
     - i.e., the information in the queries Q_1, …, Q_n is neither sound no complete.
  3. Prefer *precise-but-complex* precise consolidations or *simple-but-rough*?
  4. Discover interpretations in *real-time*.

Appendix


R1
R2
R3
R4
V1
V2
V3
V4
A1
A2
A3
A4
Alternative Join Path
Discarded Join Path
Locked Join Path

Appendix