Optimizing Information Mediators by Selectively Materializing Data

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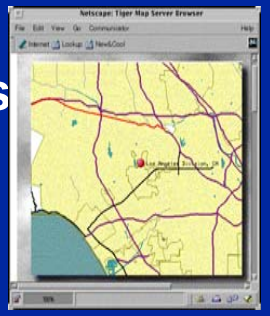
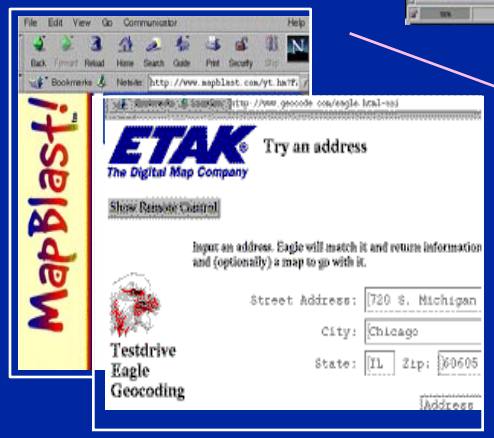
Information Mediators

Map Servers

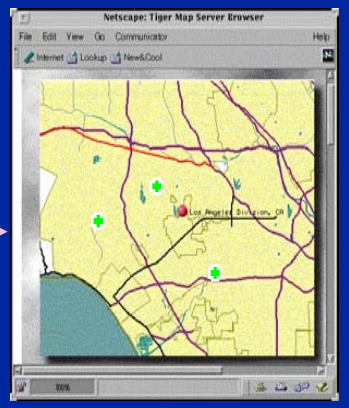


Example: Restaurant and Theatre Info on the Web

Geocoders



Ariadne Mediator



Movies

Zagat

Health Ratings

Talk Outline

- Performance - speed of application dependent on sources
- Approach to performance optimization by local materialization
- Materialization framework for mediators
- Design of materialization system
- Selecting data to materialize
  - Distribution of user queries
  - Structure of sources
  - Updates
- Admission and replacement
- The integrated materialization system
- Experimental results
- Related work, applicability to other mediator systems
- Conclusion and future directions

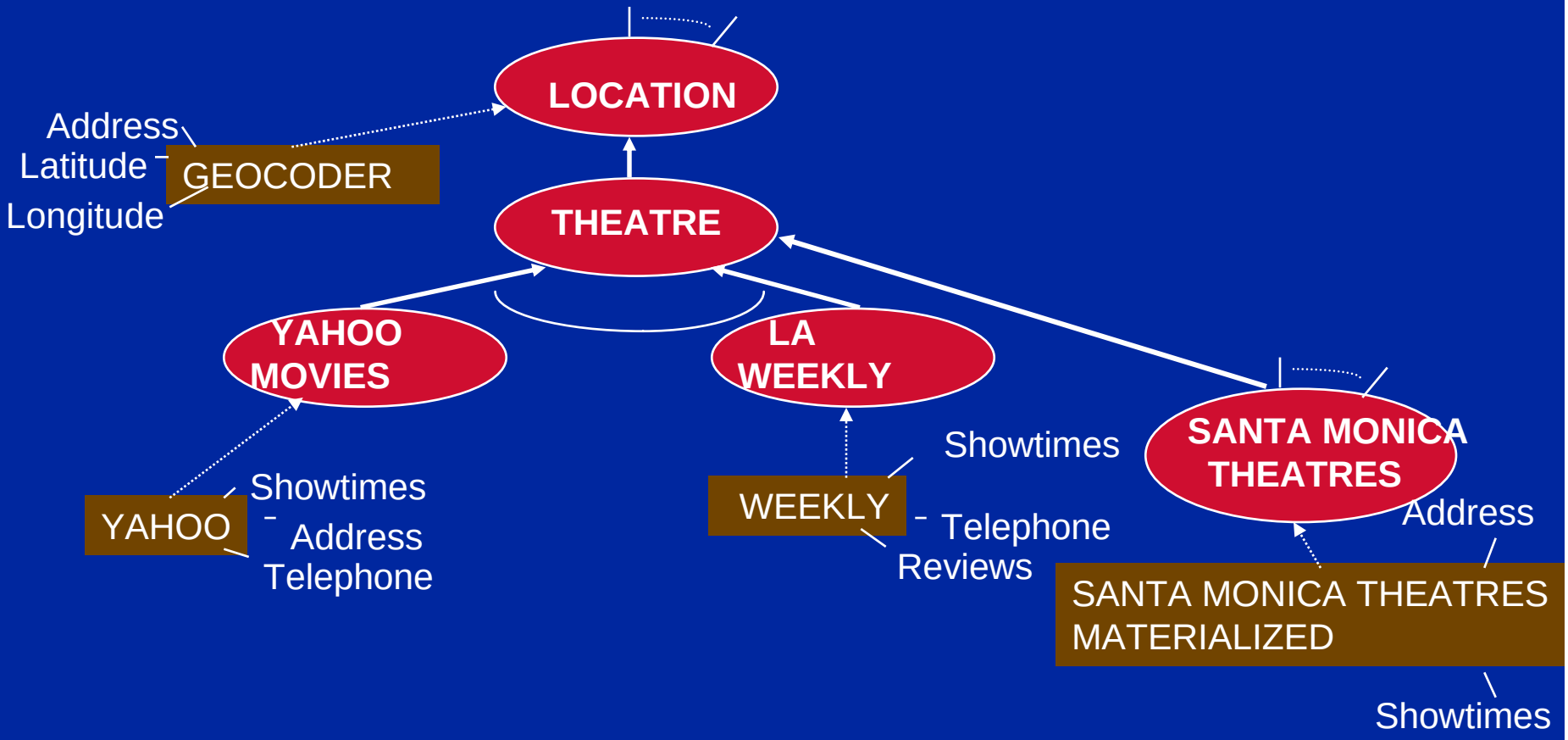
Performance Issue in Information Mediators

- Speed of the application is heavily dependent on sources
- Query response time is high despite having high quality query plans
- Dominant cost is retrieving data from remote sources
  - May have to retrieve a large number of Web pages
  - Source is structured such that retrieving data is time consuming
  - Source may be slow
- Typical Query: *"Find all chinese restaurants in Santa Monica with an excellent food rating"*
- Takes several minutes to return an answer

Solution: Materialize Data Locally

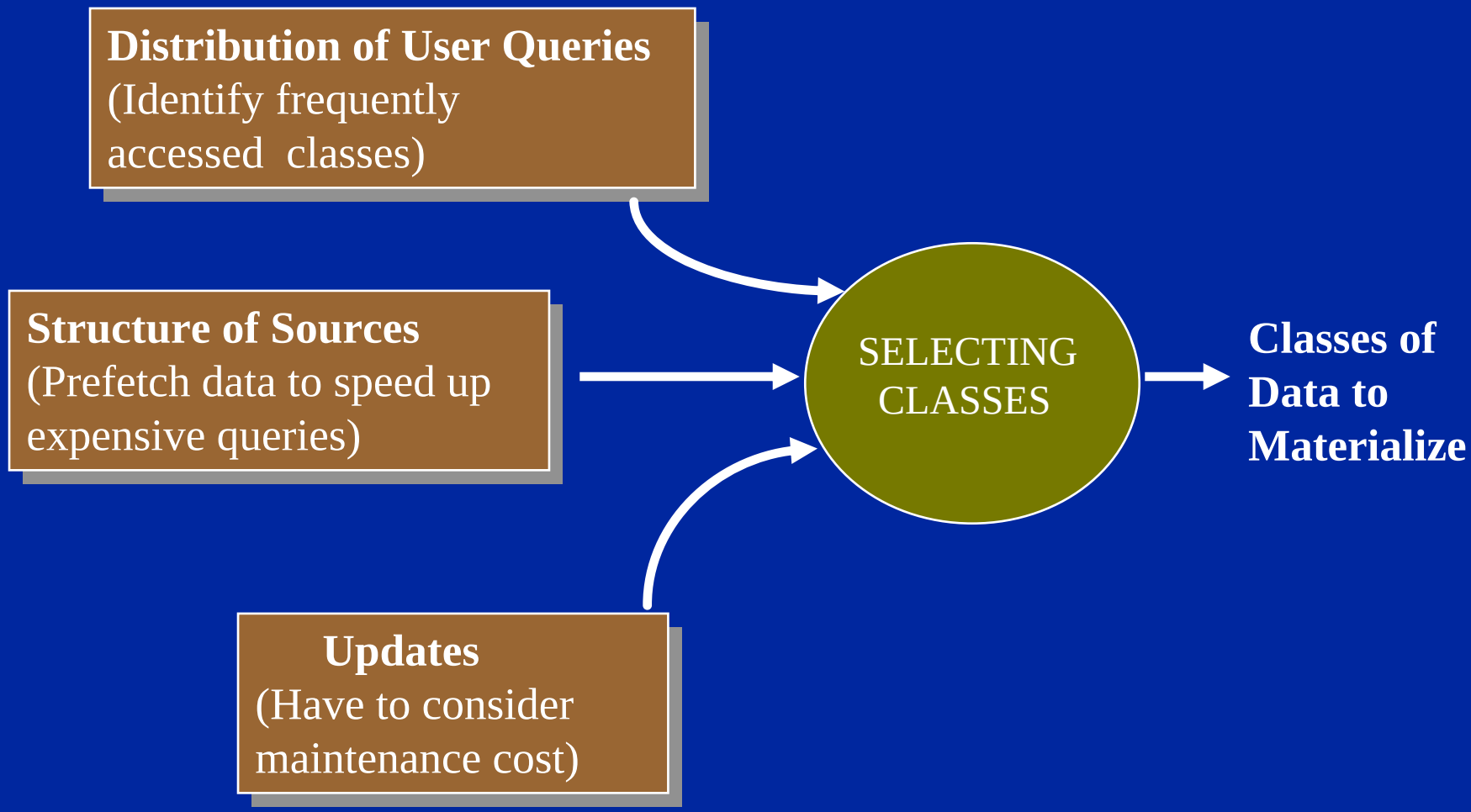
- Materialize data locally
- Materializing all the data is impractical
  - Mediator degenerates into data warehouse
- Significant performance gain can be achieved by materializing small fraction of data
  - Hypotheses that some portions of data queried more frequently
  - Materializing certain portions of data speeds up response time for expensive queries
- Data has to be *selectively* materialized
- Primary Issues
  - How is materialized data represented and used
  - How do we automatically identify what to materialize

Overall Approach: Define Materialized Data as Another Information Source

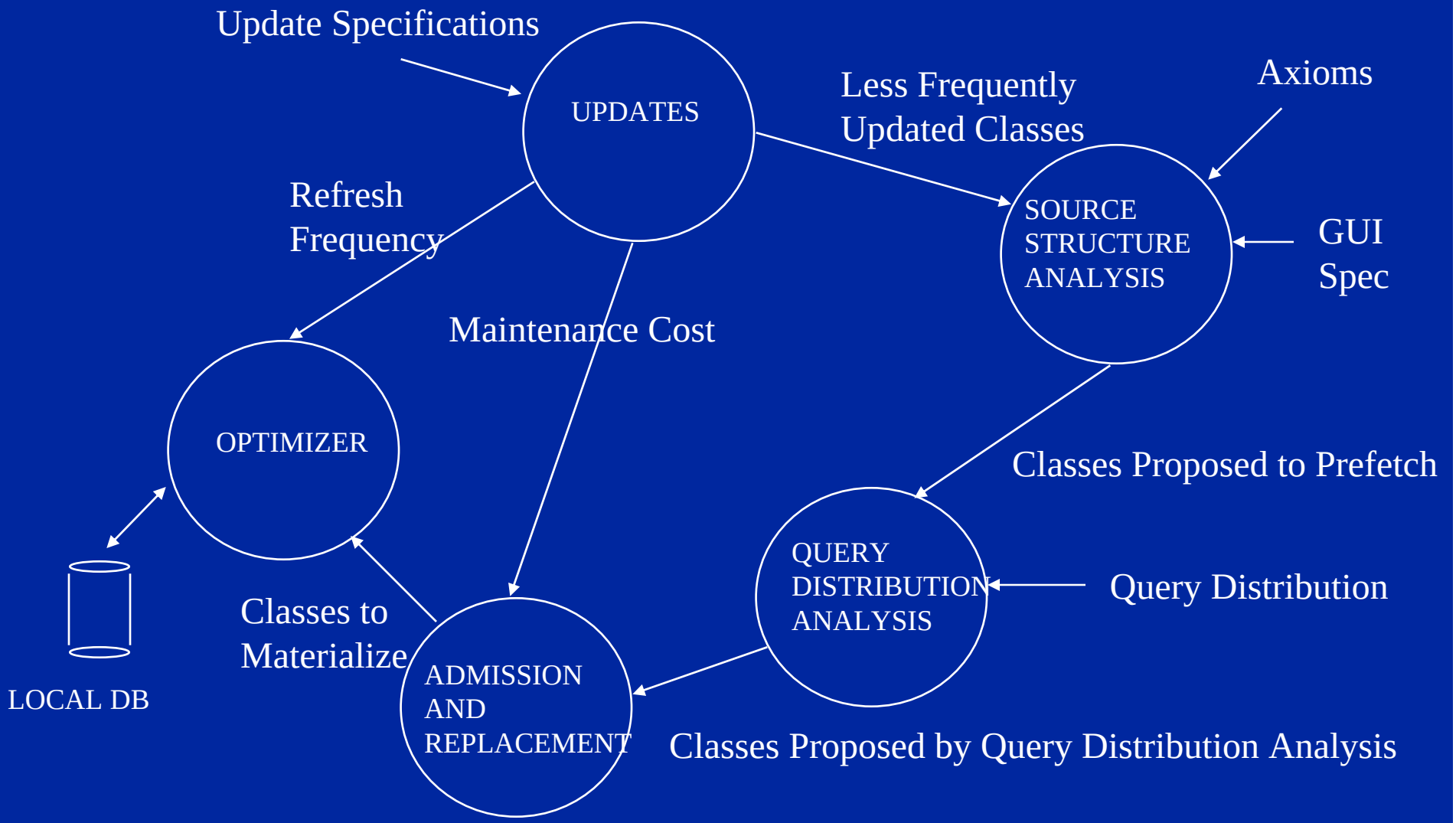


- Existing mediator infrastructure to address two issues
  - Providing semantic description of materialized data contents
  - Query planner can reason with contents of materialized data

Selecting Data to Materialize



Materialization System : Architecture



Distribution of User Queries: Extracting Patterns

```
SELECT name, tel
  FROM restaurant
   WHERE cuisine="Chinese"

      SELECT name, review, address
      FROM restaurant
     WHERE city="Los Angeles"

SELECT name, address
FROM restaurant
 WHERE cuisine="Mexican"

  SELECT name, tel, address
   FROM restaurant
    WHERE cuisine="Chinese"

       SELECT name, review
         FROM restaurant
           WHERE cuisine="Italian"

        SELECT name, address
     FROM restaurant
   WHERE city="Santa Monica"

SELECT name, tel,review
```

EXTRACTING PATTERNS

(name, tel) of chinese_restaurant

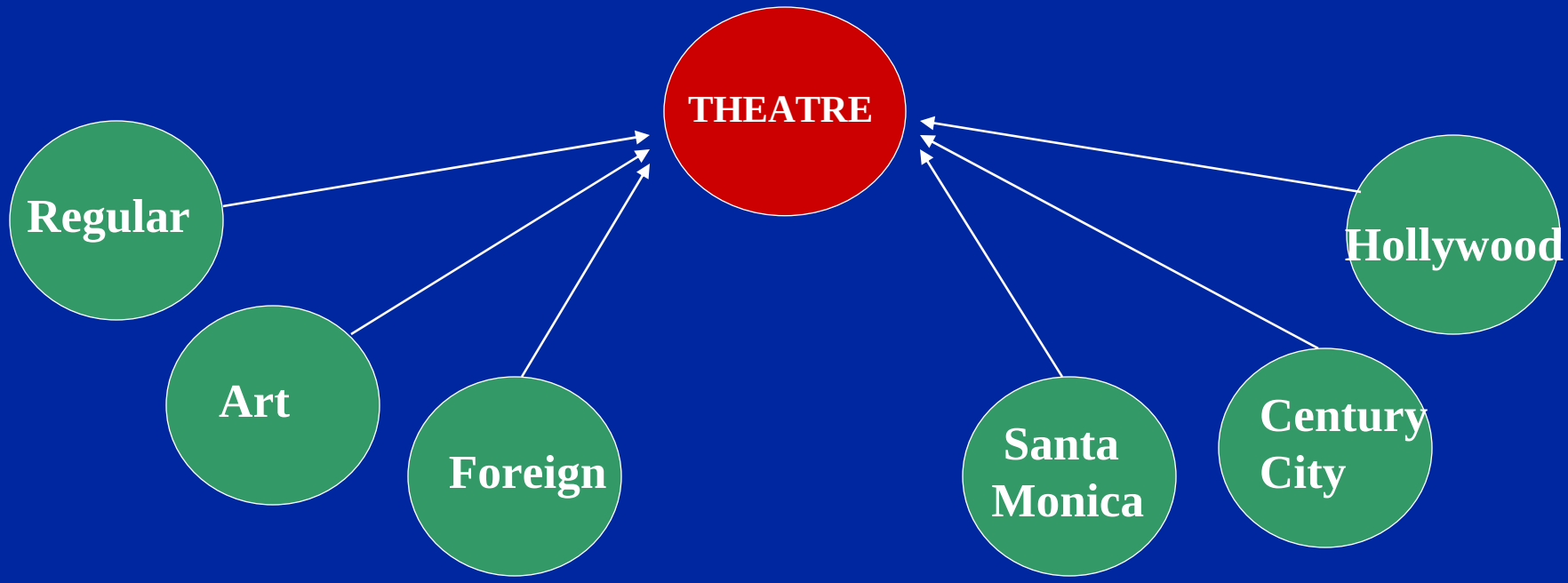
(name, address) of restaurant

(name, reviews, times) of theatre

CM Algorithm for Extracting Patterns

- Too many classes i.e, new information sources create performance problems for query planner
  - Compact description of patterns extracted
- Analyze each query in query distribution
- Create subclasses of interest by analyzing constraints
- For each subclass cluster attribute groups
- Merge across class coverings
- Outputs compact description

Ontology of Subclasses of Interest



- Analyze constraints in each query
- Identify subclasses of information of interest
- Maintain ontology in KR system LOOM
- Record attribute groups queried for each subclass

Clustering Attribute Groups

Santa Monica

(name, address, showtimes) 13
(movieurl, tel) 12
(tel, reviews, name) 5
(name, showtimes) 2
(name, address) 2
(movieurl, tel, reviews) 4
(tel, reviews) 7
(name, showtimes, trailers) 10
(name, showtimes) 8
...

(name, address, showtimes) 13
(name, showtimes) 8
(name, showtimes, trailers) 10

(name, showtimes) 2
(name, address) 2

(tel, reviews, name) 5
(tel, reviews) 7

(movieurl, tel, reviews) 4
(movieurl, tel) 12

...

- Cluster by attribute group similarity and hits
- 2D clustering - optimal clustering NP complete, approximate

Clustering Attribute Groups

Santa Monica

(name, address, showtimes) 13
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(name, showtimes) 2
(name, address) 2
(movieurl, tel, reviews) 10
(tel, reviews) 7
(name, showtimes, trailers) 10
(name, showtimes) 8
...

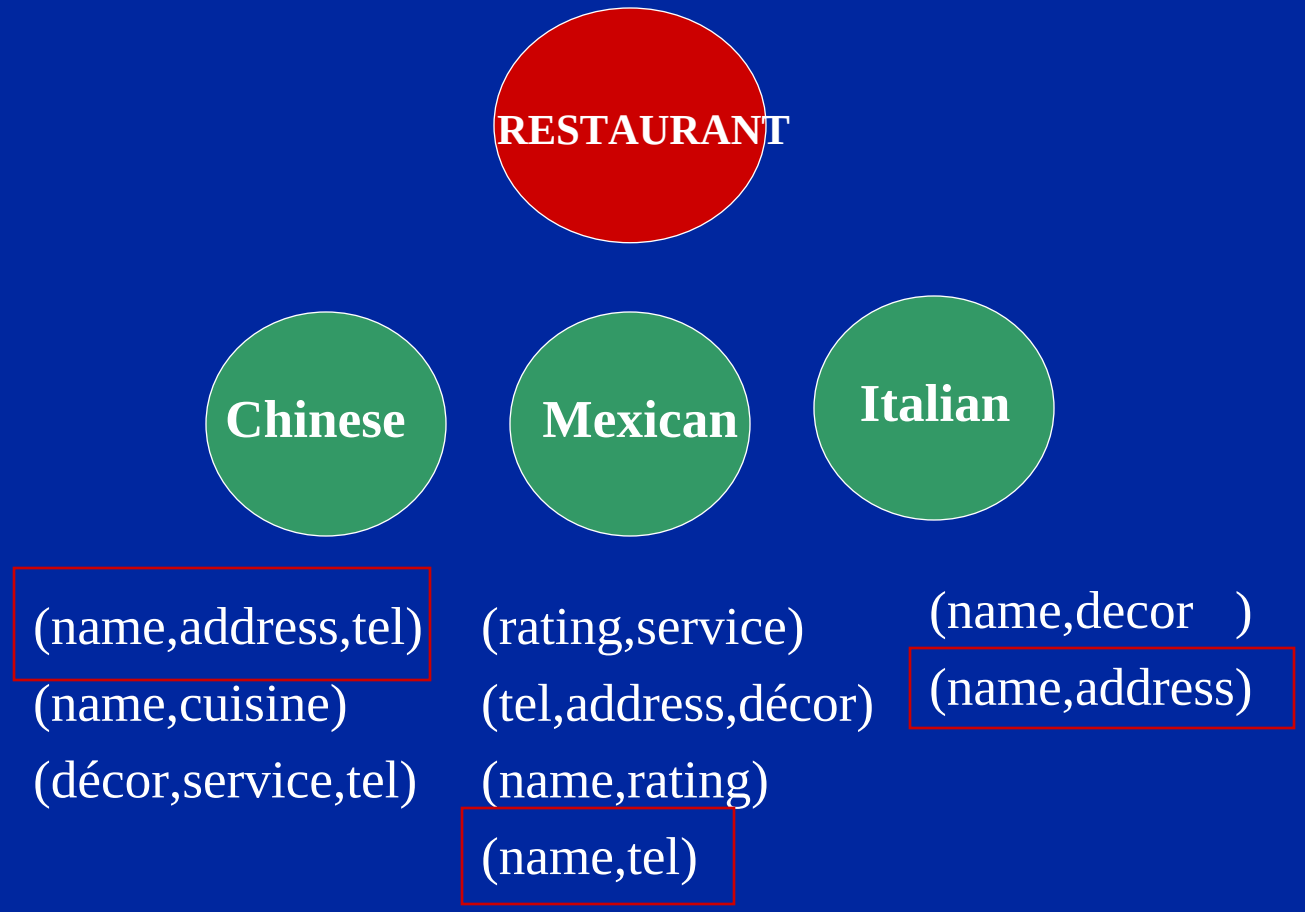
(name, address, showtimes, trailers) 10

(name, address, showtimes) 2

(tel, reviews, name) 6

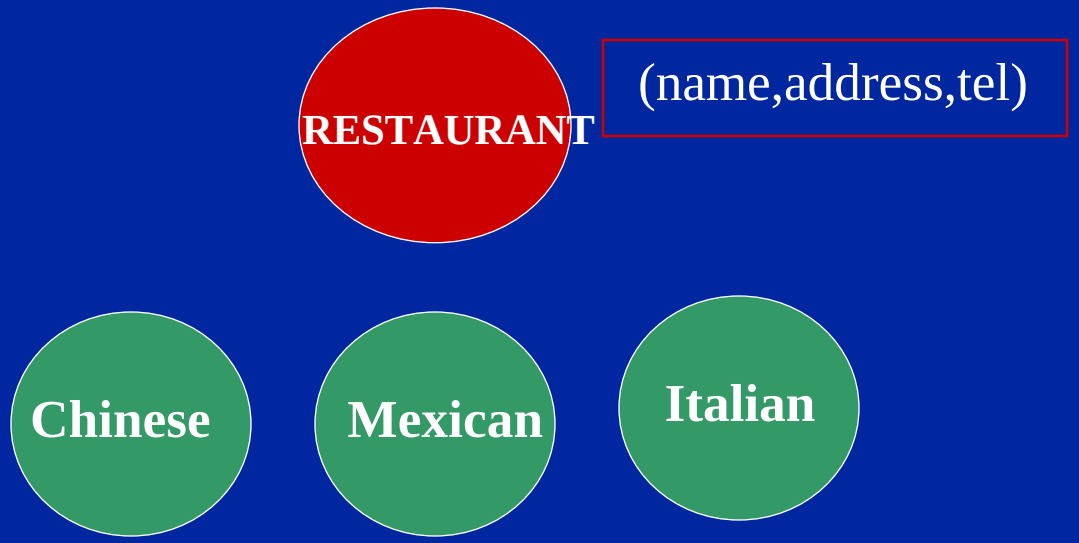
(movieurl, tel, reviews) 11
...

Merging Across Coverings

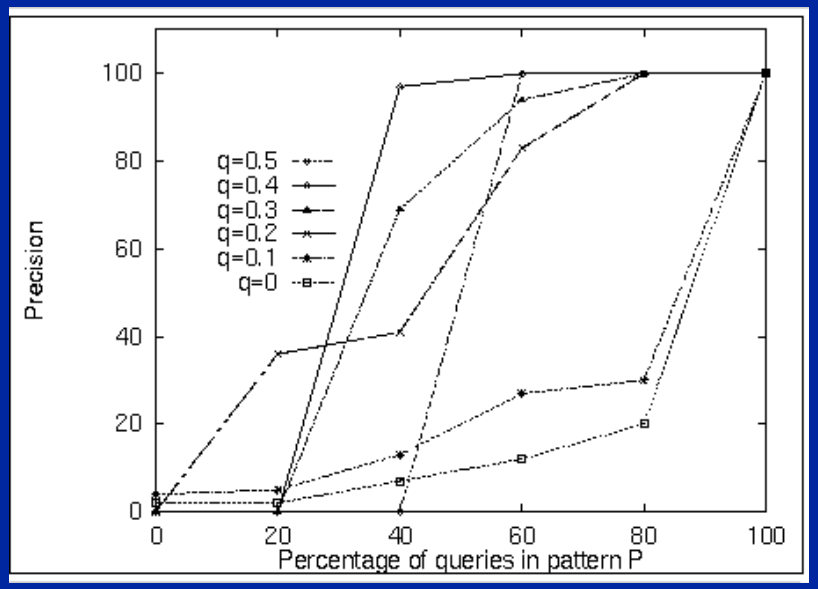


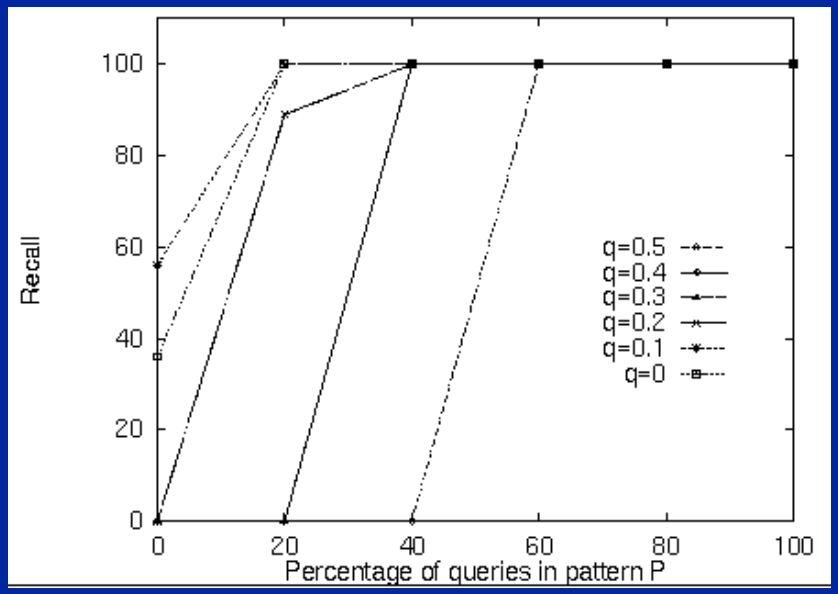
- Covering: (chinese, mexican, italian) --> Restaurant
- (chinese,{A}) U (mexican,{A}) U (italian,{A}) -->(Restaurant,{A})

Merging Across Coverings



Effectiveness, Complexity

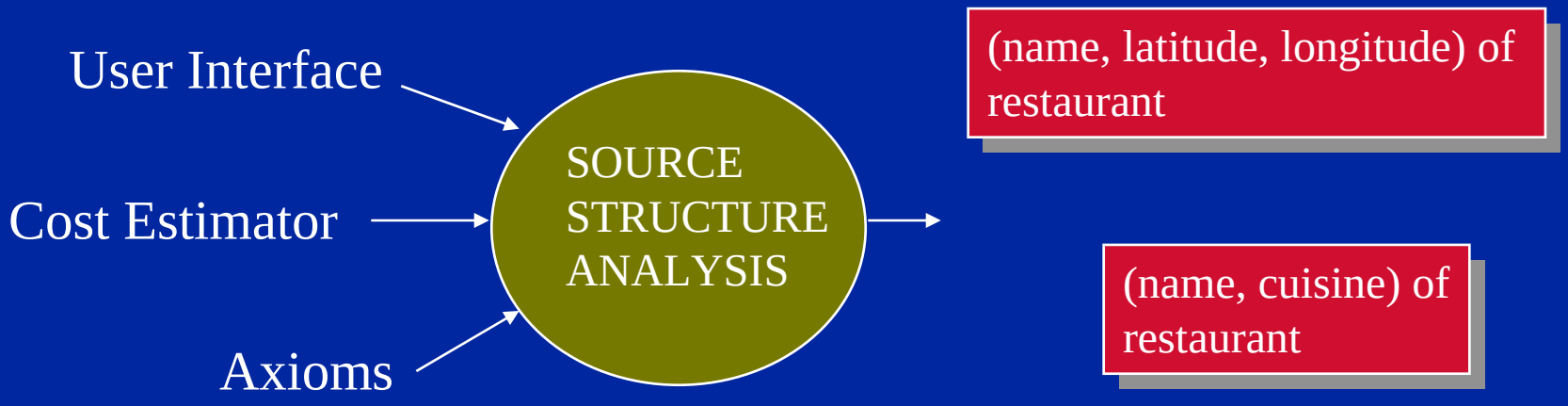




- Measured ‘precision’ and ‘recall’ in extracting patterns
- Pattern P in query distribution
  - Precision is % of patterns extracted that is in P
  - Recall is % of P that is in patterns extracted
- High precision and recall for q=0.2
- Complexity = $O(M^2N^2)$
  - M = number of queries, N = Number of attributes in a class

Source Structure Analysis

- Problem: Certain kinds queries are expensive as wrapped Web sources not originally designed for database like querying
- Solution: Prefetch and materialize data to improve response time
- Such data cannot be identified by analyzing user queries



GUI Specification

- Mediator GUI is typically more restrictive
- Formal specification language
- Data items that can be retrieved
- Details of selection conditions that can be specified
- SELECT {name, tel, address, cuisine, review, city, rating, map}
  FROM ent
  WHERE [city,1,(LA, NYC, Santa Monica ....)] {cuisine,1,(chinese,...)}

Query Processing Axioms

- Precompiled axioms for query processing

restaurant(name,cuisine,address,tel)= zagats(z.name,z.cuisine,z.address,z.tel)

restaurant(name,cuisine,address,tel,lat,long)= zagats(z.name,z.cuisine,z.address,z.tel)
and ent_geocoder($z.address,g.lat,g.long)

- Axioms tell what data operations will be performed on what sources
- Can be used to determine data to prefetch
- Cost Estimator: Costs of queries
- Process of Source Structure Analysis
  - Use GUI specification and axioms to identify queries
  - Use cost estimator to determine expensive queries
  - Use axioms and knowledge of type of query to determine data to prefetch

Source Structure Analysis

- Example :

  GUI specification : selection queries on “cuisine” of restaurant

  Cost estimator : Expensive query

  Query processing axioms:

  restaurant(name,cuisine,address,tel)= zagats(z.name,z.cuisine,z.address,z.tel)

  Heuristic : Prefetch key (name) and selection attribute (cuisine)

  Optimization : selection can now be done locally, thus faster

- Examples of heuristics

  1. selection query - materialize key and selection attribute
  2. join query - materialize join attributes and keys
  3. ordered join - materialize result of ordered join

Updates

- Data materialized can change at original sources
- Strategy
  - Do not materialize very frequently updated data
  - Refresh materialized data at appropriate intervals
- Specifying update characteristics, frequency
- Need not assume that user always absolutely requires the latest data
- Also specify user's requirements for freshness of data

Update Specifications

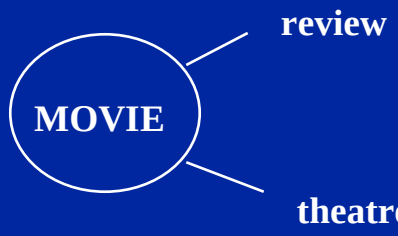
CLASS	MEMBERSHIP	CHANGE	TIME_PERIOD	TIME
MOVIE_SRC	A	Y	1 week	week : friday

ATTRIBUTE	CHANGE	TIME_PERIOD	TIME
actors	N	-	-

CLASS	TOLERANCE
MOVIE	0

ATTRIBUTE	TOLERANCE
theatre	0
actors	0
review	6 weeks

Maintenance Frequency and Cost



- For each attribute:

  maintenance period = max(update period, tolerance)

  = tolerance , if update period unknown

- Example

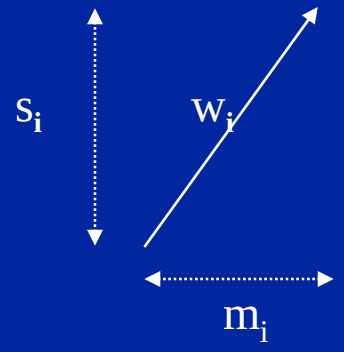
  review = max(1 week, 6 weeks) = 6 weeks

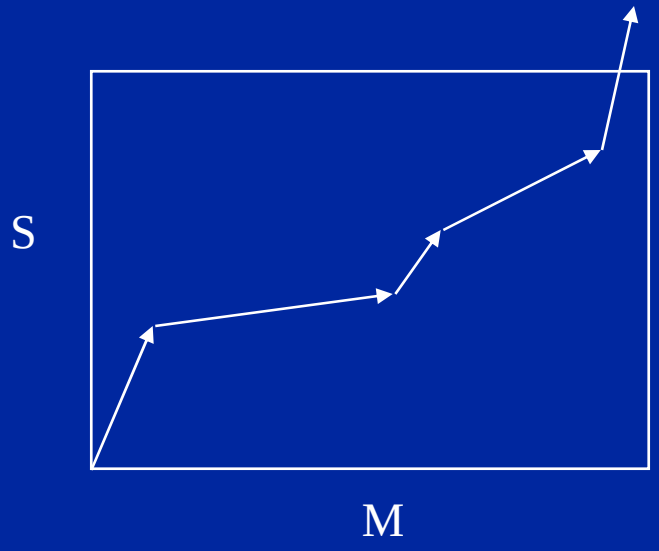
  theatre = max(1 week, 0) = 1 week

- Maintenance frequency and Query cost - > Maintenance cost
- Do not materialize an attribute if maintenance cost too high
- Total maintenance cost must be within limit

Admission and Replacement

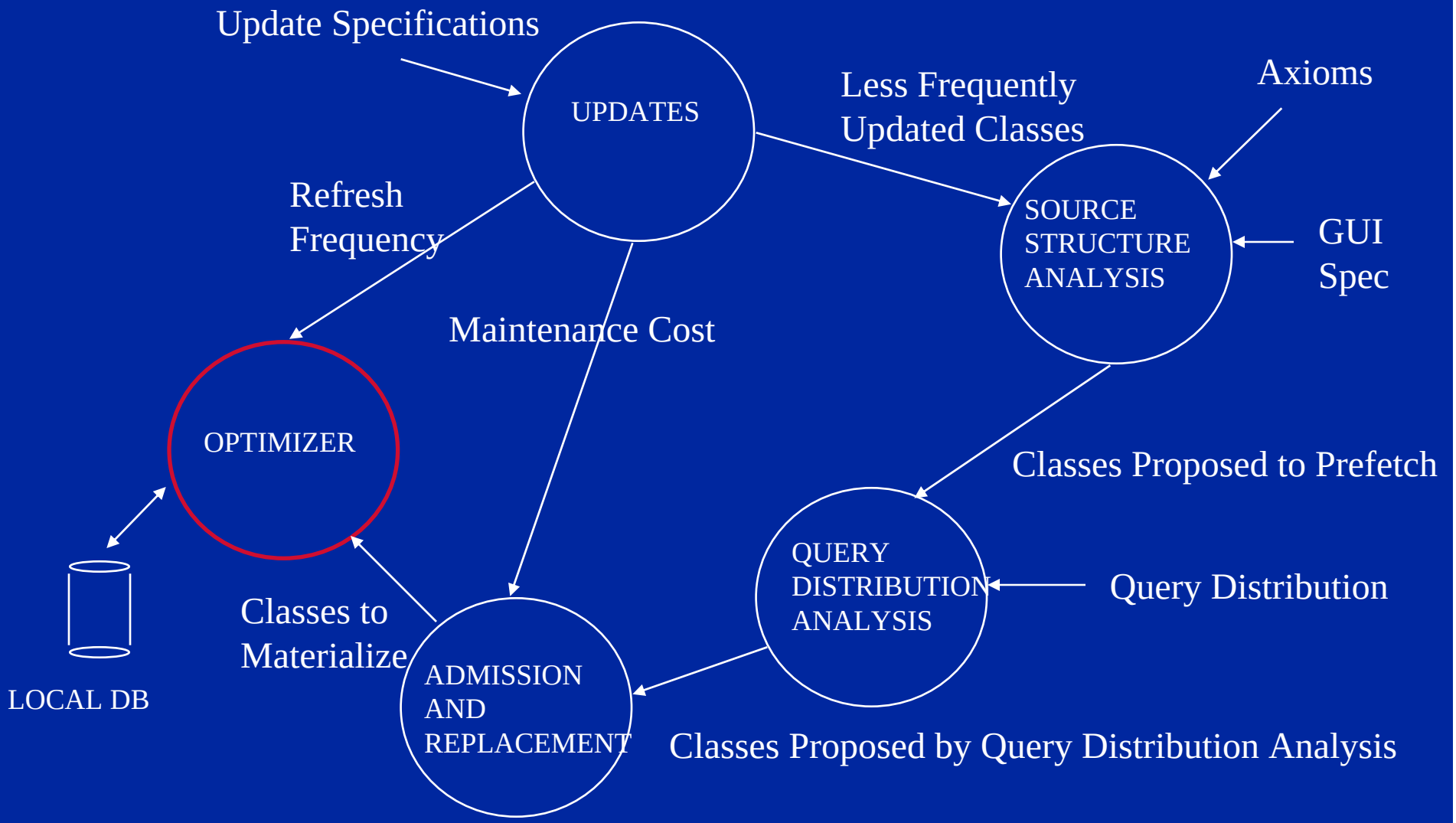
- Choose optimal set of classes to materialize under 2 constraints
  - Space and Maintenance Cost
- Same as fractional knapsack in 2 dimensions
  - Greedy algorithm for multi-dimensional fractional knapsack





- w_i (query response time savings), s_i (space), m_i (maintenance cost)
- Store in order of wi/max(si,mi)
- Guarantees optimal selection, generalizes to n dimensions

Materialization System : Architecture



Optimizer Module

- Gets set of classes of data to materialize
- Retrieves data from original sources
- Populates local database with data
- Makes appropriate changes to domain and source models
- Recompiles axioms
- Periodically refreshes materialized classes
- Periodically reevaluates materialized data classes

Experimental Results

Query Set	Response Time (No optimization)	Response Time (with Optimizer)	%improvement
Q1	38115	9301	75 %
Q2	44186	3775	91 %

(a) Source structure analysis (Countries)

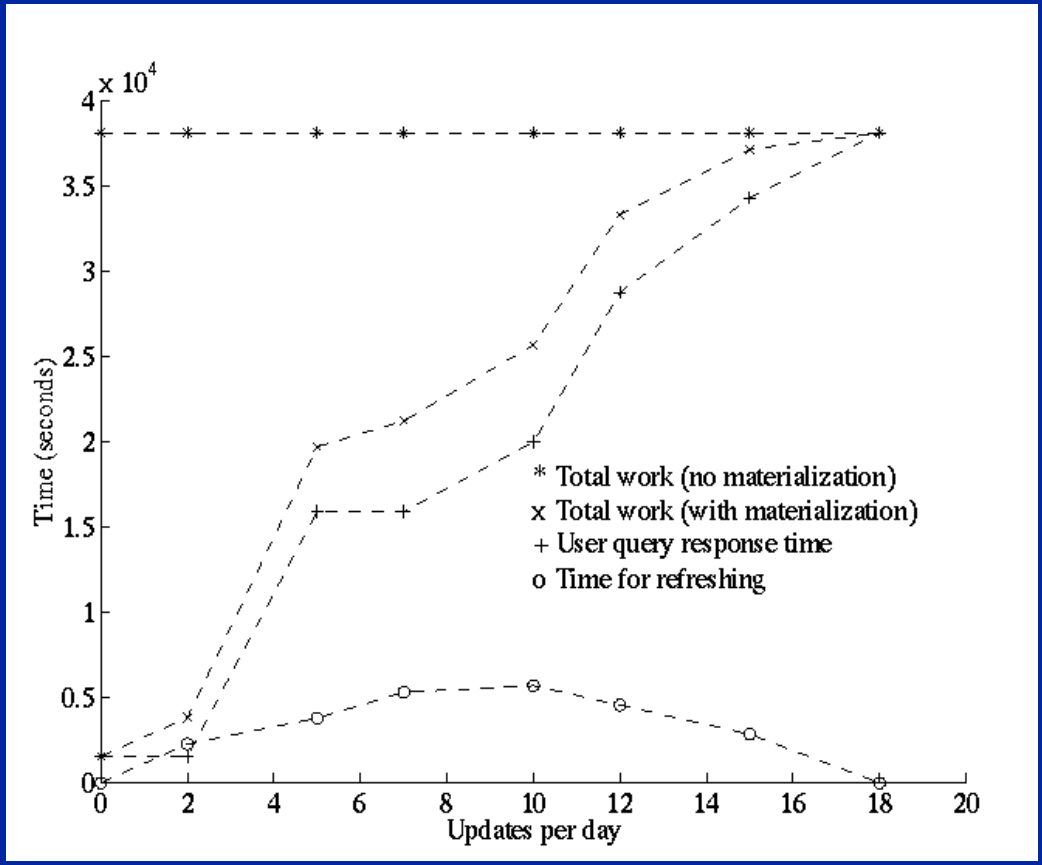
Query Set	Response Time (No optimization)	Response Time (with Optimizer)	Response Time (Page level)	%improvement (Optimizer)	%improvement (Page level)
Q1	38115	1549	34320	96 %	10 %
Q2	44186	2174	37993	95 %	13 %

(b) All factors, comparison with page level (Countries)

Query Set	Response Time (No optimization)	Response Time (with Optimizer)	Response Time (Page level)	%improvement (Optimizer)	%improvement (Page level)
Q1	22013	1644	17832	93 %	19 %

(c) All factors, comparison with page level (TheaterLoc)

Experimental Results



- Total work done with and without materialization
- Varied update frequency

Related Work

- Semantic Caching [Dar 1996, Keller and Basu 1996]
  - Compact description is solution to containment problem
- Caching for Web Proxy Servers [Chankunthod et al., 1995]
  - Significant improvement over page level
- Caching for Federated Databases [Goni et al, 1996]
  - Only fixed classes
- View Selection for materialization in Data Warehousing [Gupta and Mumick 1998]
  - Fixed set of views, minimizing cost of data operations
- Extracting patterns from queries similar to mining association rules [Agrawal, Imielinski & Swami 1993]
  - Differences in language learnt, also we have dynamic ontology

Related Work ....

- Studied applicability of materialization approach in Information Manifold, InfoMaster, TSIMMIS, InfoSleuth, DISCO and Garlic
- Different modeling and query processing approaches
  - views, object-based, datalog based, KR based etc.
- Materialization framework applicable
- Compact description needed in all
- Can be extended for source structure analysis
- Approach for updating data will also apply

Conclusion

- Contributions
  - Approach for performance optimization by materialization
  - Identifying what to materialize
    - Query distribution analysis
    - Source structure analysis
    - Update issue
- Future Work
  - Support for multimedia data
  - Tighter integration with query planner
  - Automating collection of statistics about sources
- Extending contributions to other data management areas
  - Query mining
  - Semantic caching in databases
  - Semi-structured data management