Answering Queries Using Views

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Discussion: Daniel Long

Slides adapted from Jeffrey Niu, Nalin Munshi, Rachel Pottinger

Introduction

Main Papers:

1. Alon Y. Levy, Anand Rajaraman, Joann J. Ordille: Querying Heterogeneous Information Sources Using Source Descriptions. VLDB 1996: 251-262
2. Alon Y. Halevy, Anand Rajaraman, Joann J. Ordille: Data Integration: The Teenage Years. VLDB 2006: 9-16.

Survey for background:

1. Alon Y. Halevy. 2001. Answering queries using views: A survey. The VLDB 2001: 270–294.

Background – Views

A view is a stored query. It can be saved and reused.

In SQL:

```
Product(Name, Price, Category, Manufacturer)
Company(Cname, StockPrice, Country)
```

```sql
CREATE VIEW JapaneseProducts AS
SELECT Name, Price, Category, Manufacturer
FROM Product, Company
WHERE Product.Manufacturer=Company.Cname
      AND Company.Country = 'Japan'
```

Taken from Jeffrey Niu's, Nalin Munshi's slides

Background – Views

Can rewrite queries using views (datalog):

Query:

```
q(code) :- Airport(code, city), Feature(city, POI)
```

View definition:

```
feature-code(code, POI) :- Airport(code, city),
                           Feature(city, POI)
```

Rewriting using view:

```
q(code) :- feature-code(code, POI)
```

Taken from Jeffrey Niu's, Nalin Munshi's slides

Applications

1. Query Optimization
    - Build query plan using views
2. Data Integration
    - Query from multiple heterogeneous sources

Query Optimization

Goal:

- Use views alongside base relations to answer a query
  - Reuse materialized view
- Rewrite with views should yield same answer as original query
- Maintain physical data independence
  - Only need to work with views
  - Views do not change when modifying storage schema [1]

Taken from Jeffrey Niu's, Nalin Munshi's slides

1. Alon Y. Halevy. 2001. Answering queries using views: A survey. The VLDB Journal 10, 4 (December 2001), 270–294.

Containment

Query Q_1 is contained in Q_2 ($Q_1 \subseteq Q_2$) if for any database D,

$$Q_1(D) \subseteq Q_2(D)$$

In other words, the tuples returned from running Q_1 on D are a subset of running Q_2 on D.

Containment

Query Q_1:

```
q1(code) :- Airport(code, city)
```

Query Q_2:

```
q2(code) :- Airport(code, “New York”)
```

Containment

Query Q_1:

```
q1(code) :- Airport(code, city)
```

$Q_1(D)$:

Code
JFK
LGA
YVR
YYZ
…

Query Q_2:

```
q2(code) :- Airport(code, “New York”)
```

$Q_2(D)$:

Code
JFK
LGA

Hence, we have $Q_2 \subseteq Q_1$

Equivalent Rewriting

Given query Q and views $\mathbf{V} = \{V_1, \ldots, V_m\}$, a query Q' is an **equivalent rewriting** of Q using $\mathbf{V}$ if Q and Q' are contained within each other [1] (return the exact same answers).

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Query:

```
q(code) :- Airport(code, city), Feature(city, POI)
```

View V_1:

```
feature-code(code, POI) :- Airport(code, city),
                           Feature(city, POI)
```

Equivalent rewrite using V_1 :

```
q(code) :- feature-code(code, POI)
```

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Equivalent Rewriting

Given query Q and views $\mathbf{V} = \{V_1, \ldots, V_m\}$, a query Q' is an **equivalent rewriting** of Q using $\mathbf{V}$ if Q and Q' are contained within each other [1] (return the exact same answers).

Query:

```
q(code) :- Airport(code, city), Feature(city, POI)
```

View V_2:

```
Beach-code(code) :- Airport(code, city),
                    Feature(city, "Beach")
```

Non-equivalent rewrite using V_2 :

```
q(code) :- Beach-code(code)
```

Only gets “Beach” results from Feature

1. Alon Y. Halevy. 2001. Answering queries using views: A survey. The VLDB Journal 10, 4 (December 2001), 270–294.

Taken from Jeffrey Niu’s, Nalin Munshi’s slides

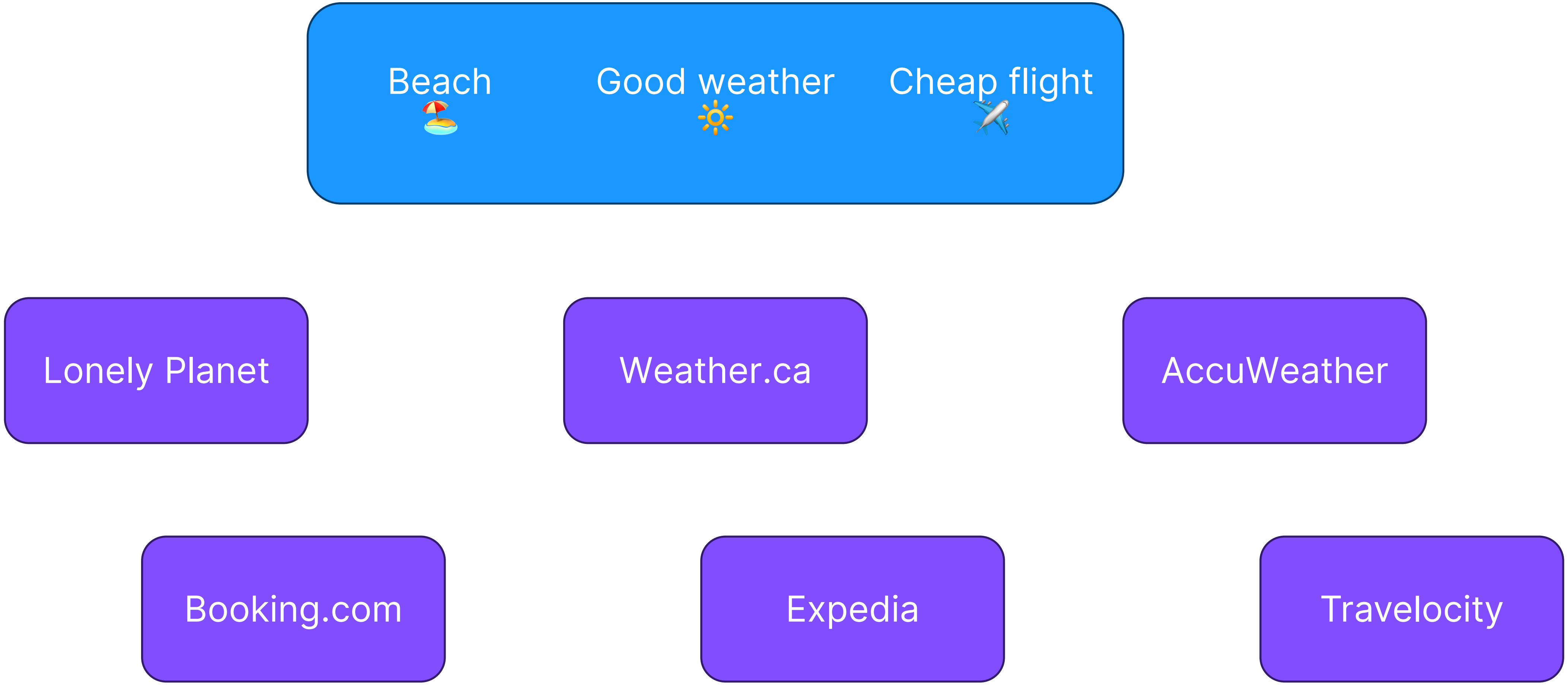
Data Integration

Goal:

- Provide a uniform query interface to many heterogeneous data sources over the internet
- Free the user from having to find the data sources relevant to a query
- Easy to add and delete sources
- Find the **maximal** set of answers available from the sources
  - Each source only has some of the tuples we want

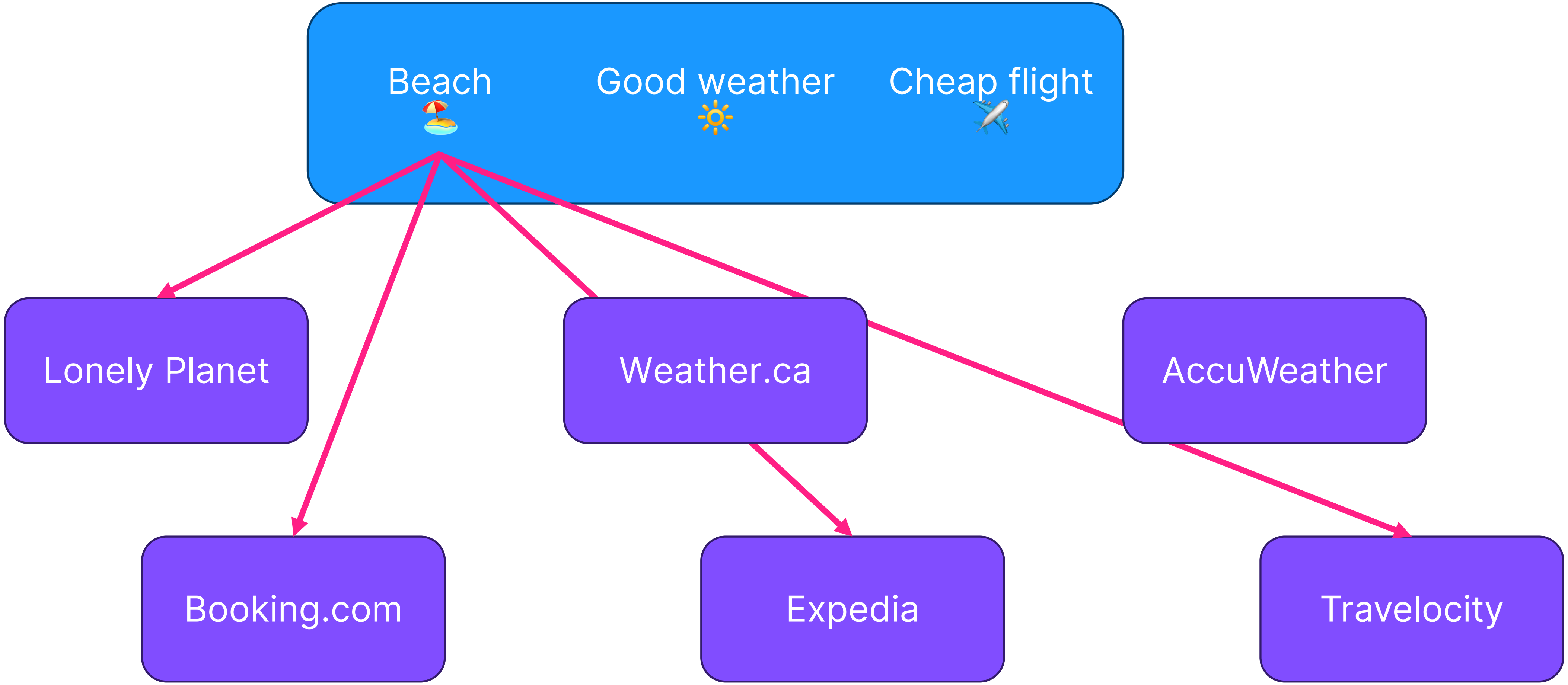
Paper: Information Manifold (IM) provides uniform access to over 100 heterogeneous sources

Example – Data Integration



Taken from Jeffrey Niu's, Nalin Munshi's slides

Example – Data Integration



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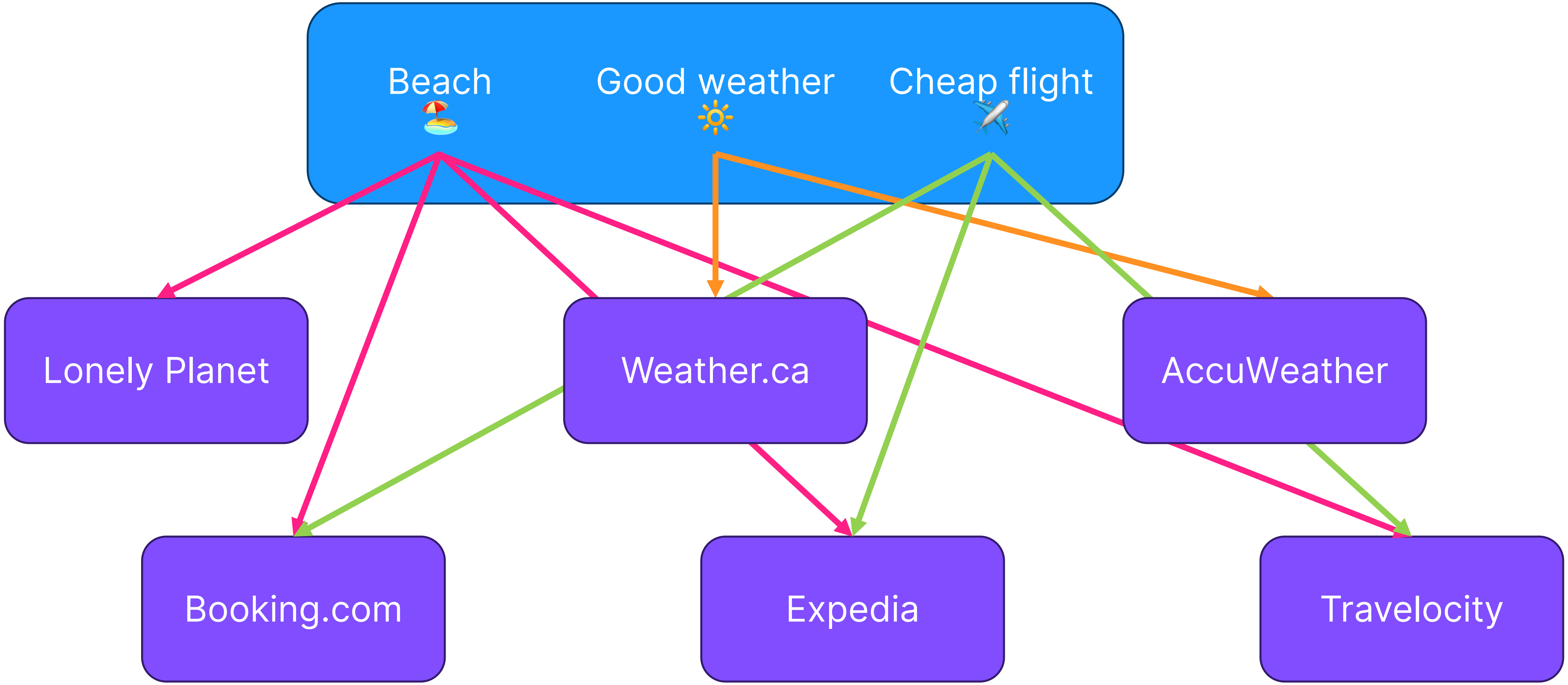
Example – Data Integration



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Discussion (2 people)

Given the example of Data Integration and its use of incomplete sources.

- What are some other modern domains that require the use of incomplete sources?
- Can you think of any real-world scenarios (perhaps in your own research) where assuming complete data from a single source could be advantageous compared to the assumption of incomplete data?

Data Integration

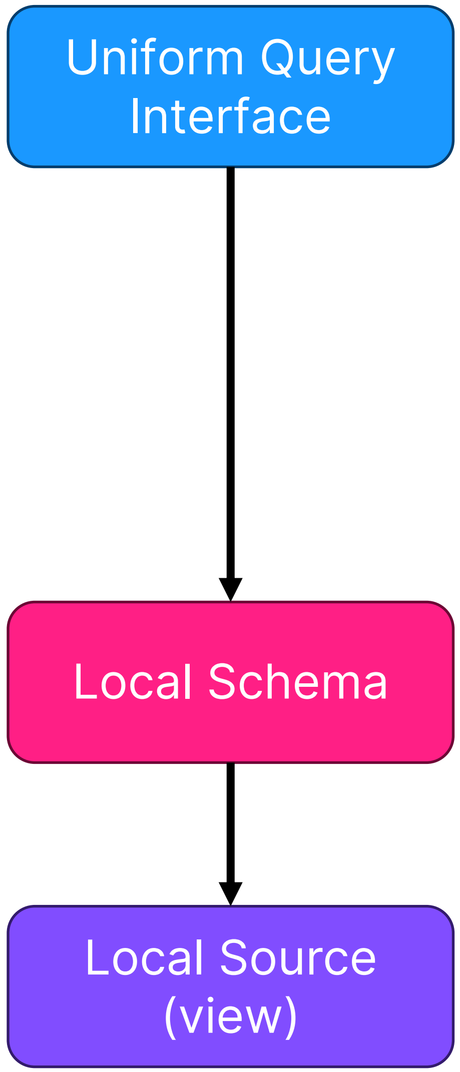
Challenges:

Incomplete data

- View is sound but not complete
- Assume data is correct, but not all data relevant to view is in the view

Different local schemas all over the web

- Need to identify how to bind variables to create execution plans



Discussion (4 People)

Data Integration faces the challenges of different local schemas over the web.

- How important is standardization (data formats, APIs, etc.) in the evolution of data integration?
- Can you identify areas where lack of standardization is still a significant barrier?

Maximally-Contained Rewriting

Given query Q, views $\mathbf{V} = \{V_1, \dots, V_m\}$, a query language $\mathcal{L}$, a query Q' is a **maximally-contained rewriting** of Q using $\mathbf{V}$ with respect to $\mathcal{L}$ if [1]:

- Q' is a query in $\mathcal{L}$ that refers only to views in $\mathbf{V}$
- $Q' \cup \mathbf{V}$ is contained in Q
- Q' is the query that obtains the most answers from $\mathbf{V}$

Finding maximally-contained plan computes all certain answers [2]

1. Alon Y. Halevy. 2001. Answering queries using views: A survey. The VLDB Journal 10, 4 (December 2001), 270–294.
2. Bertossi, L., Bravo, L. 2005. Consistent Query Answers in Virtual Data Integration Systems. In: Bertossi, L., Hunter, A., Schaub, T. (eds) Inconsistency Tolerance. Lecture Notes in Computer Science, vol 3300. Springer, Berlin, Heidelberg.

Maximally-Contained Rewriting

Query:

```
Dest(code) :- Airport(code, city), Feature(city,
                                           "Beach")
```

Views:

```
Expedia-Air(code, city) :- Airport(code, city)
```

```
LonelyPlanet(city, POI) :- Feature(city, POI)
```

Rewriting:

```
Dest(code) :- Expedia-Air(code, city),
                          LonelyPlanet(city, "Beach")
```

At best maximally contained. Rewriting gives as many answers as it can to query given the views.

Taken from Jeffrey Niu's, Nalin Munshi's slides

Bucket Algorithm - CreateBucket

Given a query $Q(\bar{X}) \leftarrow R_1(\bar{X}_1), \ldots, R_m(\bar{X}_m), C_Q$:

CreateBucket:

create an empty bucket for every subgoal R_i

for every subgoal R_i:

  for each view $V(\bar{Y}) \subseteq S_1(\bar{Y}_1), \ldots, S_n(\bar{Y}_n), C_V$

    for every class S_j:

      if R_i and S_j are non-disjoint:

        map variables between R_i and S_j

      if union of Q and the mappings is satisfiable:

        add mapped V to bucket i

do containment check over cartesian product of buckets

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Given a query $Q(\bar{X}) \leftarrow R_1(\bar{X}_1), \ldots, R_m(\bar{X}_m), C_Q$:

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    for every class S_j:
      if R_i and S_j are non-disjoint:
        map variables between R_i and S_j
      if union of Q and the mappings is satisfiable:
        add mapped V to bucket i
do containment check over cartesian product of buckets

Not in paper

Bucket Algorithm - CreateBucket

View definitions:

```
V1(student,number,year) :- Registered(student,course,year),
              Course(course,number),number≥500,year≥1992
```

```
V2(student,dept,course) :-Registered(student,course,year),
                           Enrolled(student,dept)
```

```
V3(student,course) :- Registered(student,course,year),
                   year ≤ 1990
```

Query:

```
q(S,D) :- Enrolled(S,D),Registered(S,C,Y),Course(C,N),
              N≥300,Y≥1995.
```

1. Alon Y. Halevy. 2001. Answering queries using views: A survey. The VLDB Journal 10, 4 (December 2001), 270–294.

Bucket Algorithm - CreateBucket

V1(student,number,year)	Registered(student,course,year),Course(course,number),number≥500,year≥1992
V2(student,dept,course)	Registered(student,course,year),Enrolled(student,dept)
V3(student,course)	Registered(student,course,year),year ≤ 1990
q(S,D)	Enrolled(S,D),Registered(S,C,Y),Course(C,N),N≥300,Y≥1995

V2 has the Enrolled subgoal
S → student
D → dept

Buckets

Enrolled(S,D)	Registered(S,C,Y)	Course(C,N)
V2(S,D,C’)		

1. Alon Y. Halevy. 2001. Answering queries using views: A survey. The VLDB Journal 10, 4 (December 2001), 270–294.

Bucket Algorithm - CreateBucket

V1(student,number,year)	Registered(student,course,year),Course(course,number),number≥500,year≥1992
V2(student,dept,course)	Registered(student,course,year),Enrolled(student,dept)
V3(student,course)	Registered(student,course,year),year ≤ 1990
q(S,D)	Enrolled(S,D),Registered(S,C,Y),Course(C,N),N≥300,Y≥1995

V1,V2,V3 have Registered
S → student
C → course
Y → year

V3 predicate does not match in year so it is not included

Enrolled(S,D)	Registered(S,C,Y)	Course(C,N)
V2(S,D,C')	V1(S,N',Y)	
	V2(S,D',C)	

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Bucket Algorithm - CreateBucket

V1(student,number,year)	Registered(student,course,year),Course(course,number),number≥500,year≥1992
V2(student,dept,course)	Registered(student,course,year),Enrolled(student,dept)
V3(student,course)	Registered(student,course,year),year ≤ 1990
q(S,D)	Enrolled(S,D),Registered(S,C,Y),Course(C,N),N≥300,Y≥1995

V1 has Course
C → course
N → number

Enrolled(S,D)	Registered(S,C,Y)	Course(C,N)
V2(S,D,C’)	V1(S,N’,Y)	V1(S’,N,Y’)
	V2(S,D’,C)	

1. Alon Y. Halevy. 2001. Answering queries using views: A survey. The VLDB Journal 10, 4 (December 2001), 270–294.

Bucket Algorithm - CreateExecutablePlan

- Checks if the plan is executable
- Sets bindings in execution plan
- Adds appropriate inputs to subsequent subgoals
- Removes unnecessary outputs

Time Complexity

Creating executable plan is polynomial in size of Q'

- NP-complete if more than 1 capability record possible per source

NP-complete overall

- Cartesian product over buckets for CreateExecutablePlan

Becomes much worse once we start allowing more predicates

Discussion (2 People)

The Information Manifold works with non-equivalent (contained) rewritings.

- What are other scenarios that you can imagine where you would want to use contained rewritings (maximally contained or otherwise)?

Example:

- Language translations → some words or combinations have different meanings.
- Approximate query → maybe no need to write all information

Impact of the Information Manifold

Information Manifold was highly influential:

- Became known as the Local-as-View approach
  - Easy to accommodate new sources
  - More precise source descriptions
- Sparked research into:
  - Describing sources – expressive power, tractability, binding patterns restrictions, etc.
  - Certain answers – model incomplete information
- Answering queries using views got more attention

Research Directions

- Generating schema mappings automatically
  - Using ML to make mappings
- Reference reconciliation
- Adaptive query processing
- Extension towards XML
- Model management
  - Algebra for manipulating schemas and mappings
- Peer-to-peer

Data Integration Industry

- Enterprise Information Integration (EII)
  - Provide tools for integrating from many sources without central warehouse
- High demand for data integration
  - Research matured
  - More data sharing (XML)

Current/Future Challenges

- Scaling/performance
- Getting people to share data
- Data uncertainty, inconsistency, lineage
- Leveraging human attention

Discussion (4 people)

The "Data Integration: The Teenage Years" was written in response to the the original "Querying Heterogeneous Information Sources using Source Descriptions" paper wining the VLDB 10-years Best Paper Award.

- What are some important things to consider when reading a test-of-time award papers?
- What kinds of things would you **want** the authors to do?
- What kinds of things can you hope to get out of them?

Summary

Two applications/formalisms of answering queries using views:

1. Query Optimization
   - How to build a query plan using views
   - Find equivalent rewriting
2. Data Integration
   - How to integrate multiple data sources into one uniform interface
   - Find maximally-contained rewriting (incomplete sources)
   - Data integration saw significant growth in industry and research