CompSci 516
Data Intensive Computing Systems

Lecture 23
Data Integration

Instructor: Sudeepa Roy

Announcements

- No class next week
  - thanksgiving recess!
  - We meet again on 11/30 (Wed)
- Final report first draft due on 11/28 (Mon) night
  - but can update until Friday 12/2 night
  - send me an email if you update
- I will post a message on piazza looking for three groups who will present on 11/30 (Wed)
  - the remaining seven groups present on 12/2 (Fri)
  - 10 minutes talk/demo for each group (8 mins talk + 2 mins questions)

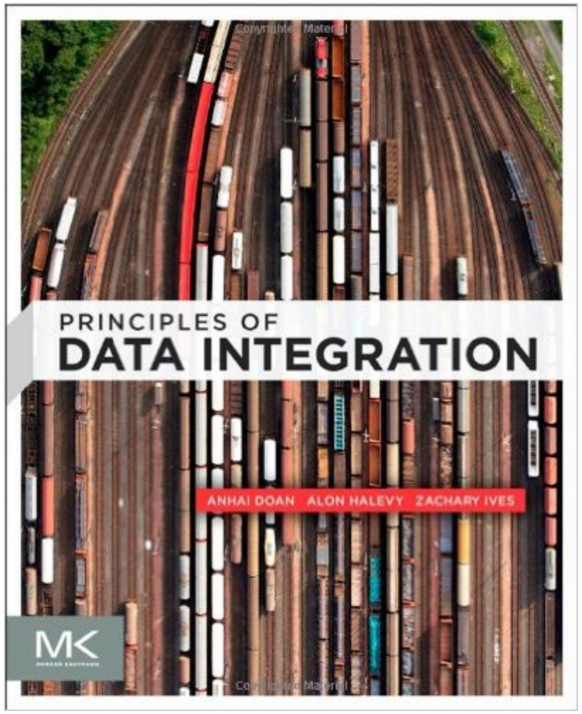
Today's topic

- An overview of data integration
- Some optional additional slides at the end

Reading Material

Optional Reading:

- The "Principles of Data Integration" book by
AnHai Doan, Alon Halevy, Zack Ives
The lecture slides are based on Ch. 1, 3, 5 of this book



- Data integration PODS 2005 tutorial by
Phokion Kolaitis
(more on the theoretical aspects)

What is Data Integration? 1/2

- Internet and WWW have revolutionized people’s access to digital data
- We take it for granted that a search query into a browser taps into millions on documents and databases and returns what we are looking for
- Systems on the Internet must efficiently and accurately process and serve a large amount pf data

What is Data Integration? 2/2

- Unlike traditional RDBMS, the new services need the ability to
  - Share data among multiple organizations
  - Integrate data on a flexible and efficient fashion

- Data integration:
  - A set of techniques that enable building systems geared for flexible sharing and integration of data across multiple autonomous data providers.

Why data integration? 1/2

- With issues like normalizations, and trade-offs in design choices, different people design different schemas for the same data
- Sometimes different needs as well
  – not all attributes are needed by all people
- Sometimes people want to share their data
  – collaborators
  – researchers who want to publish data for others' use

Why data integration? 2/2

- In the Web,
  - Many websites posting job applications, hotel or flight deals, movie information
  - To keep up with new information and for new need, you may have to look at all of them
  - But now there are websites where you can access all
  - e.g. TripAdvisor helps you see the price of the same hotel on the hotel website, hotels.com, booking.com, expedia, ….
- But this type of data integration has its challenges too

Why data integration? 2/2

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- But this type of data integration has its challenges too

Challenges in Data Integration: 1. Query

- Offer uniform access to a set of autonomous and heterogeneous data sources

- Query:
  – query disparate data sources, sometimes update them

Challenges in Data Integration: 2. Number of sources

- Number of sources:
  - challenging even for 10 or 2 data sources
  - amplified for hundreds of sources say in Web-scale

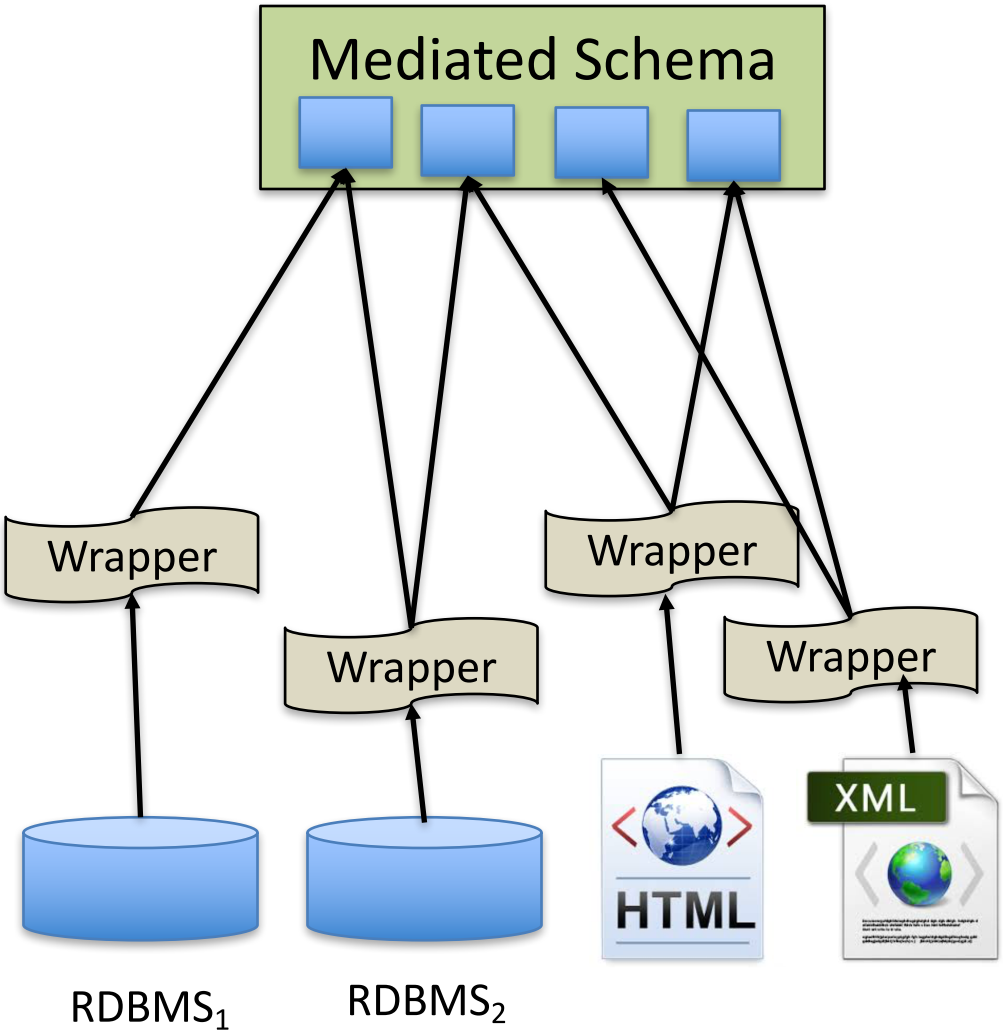
Challenges in Data Integration: 3. Heterogeneity

- Heterogeneity:
  - data sources were developed independently of each other
  - databases, files, html
  - different schema and references
  - some structured some unstructured

Challenges in Data Integration: 4. Autonomy

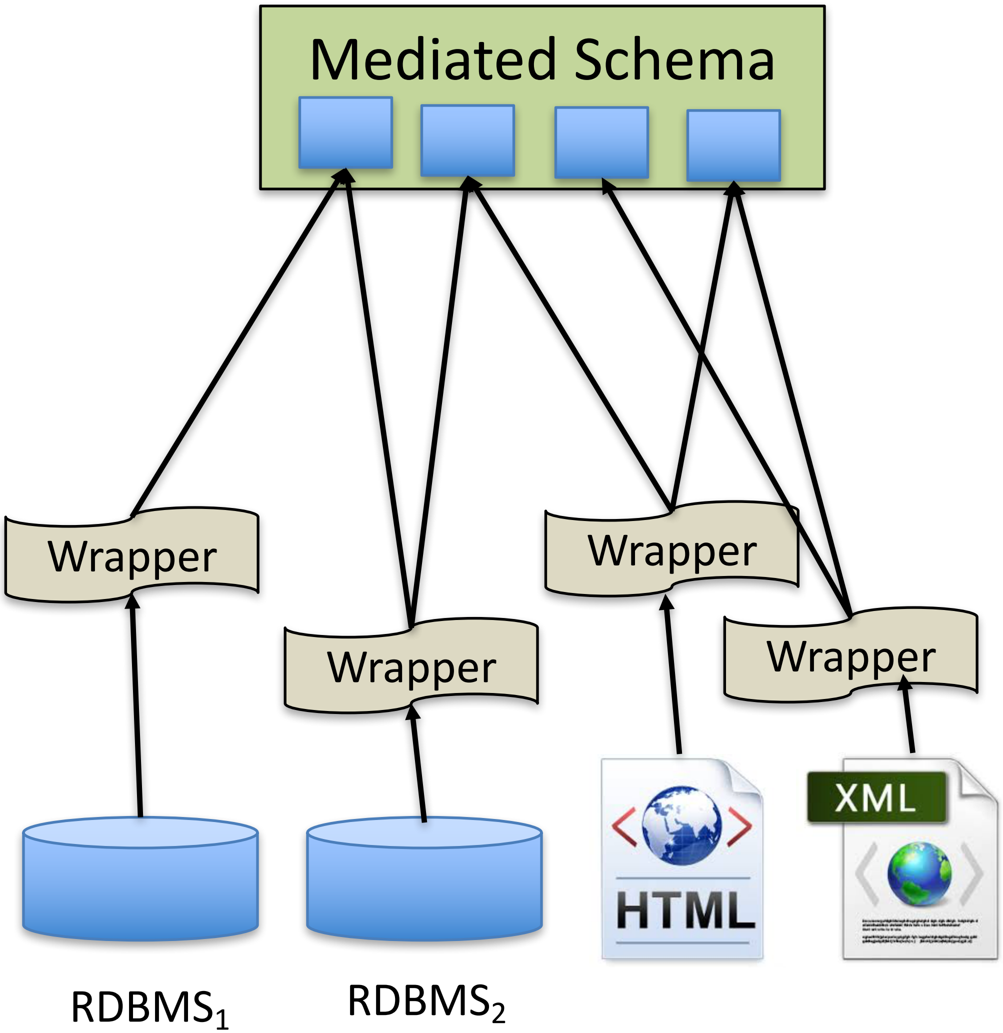
- Autonomy:
  - the sources may not belong to the same administrative entity
  - even then may be run by different organizations
  - may not have full access to the data
  - there may be privacy concerns
  - the sources may change their formats and access patterns at any time without notifying

Virtual Data Integration Architecture



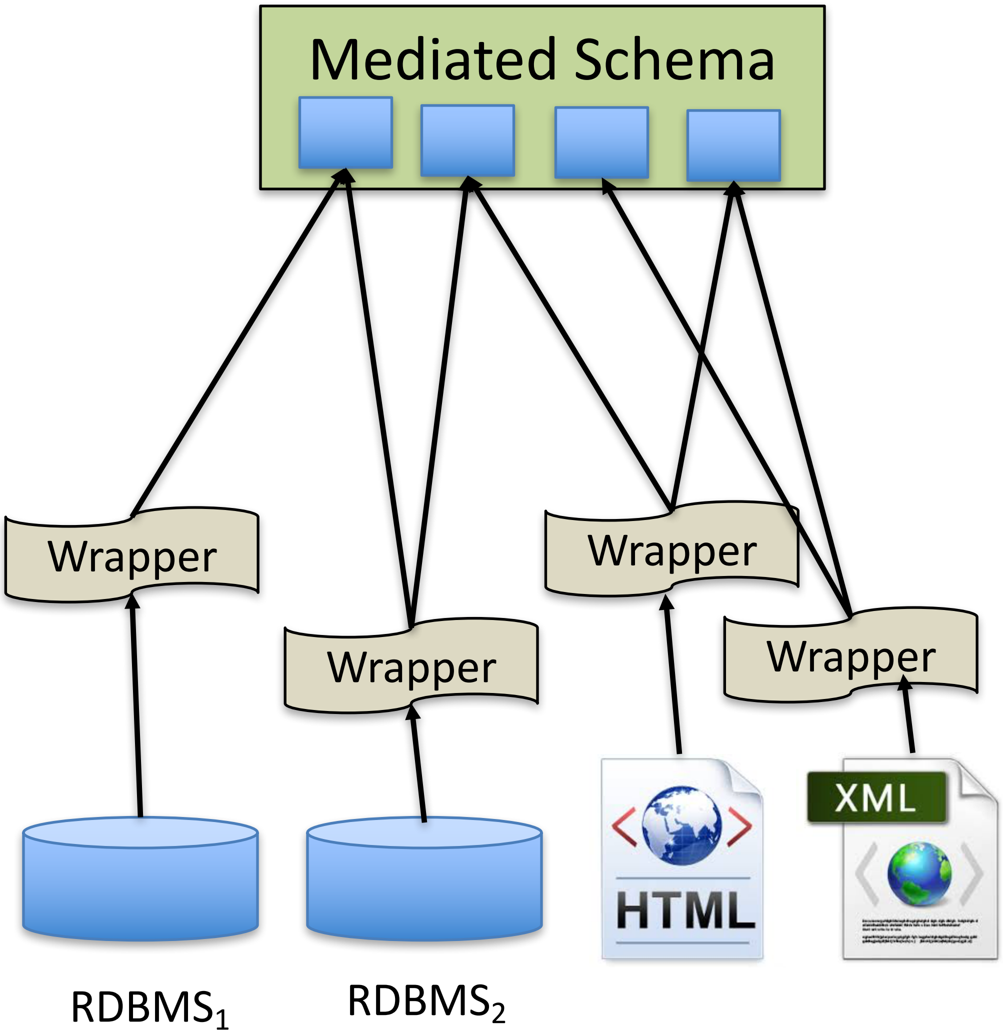
- Three components
  - Data sources
  - Wrappers
  - Mediated Schema

Virtual Data Integration Architecture



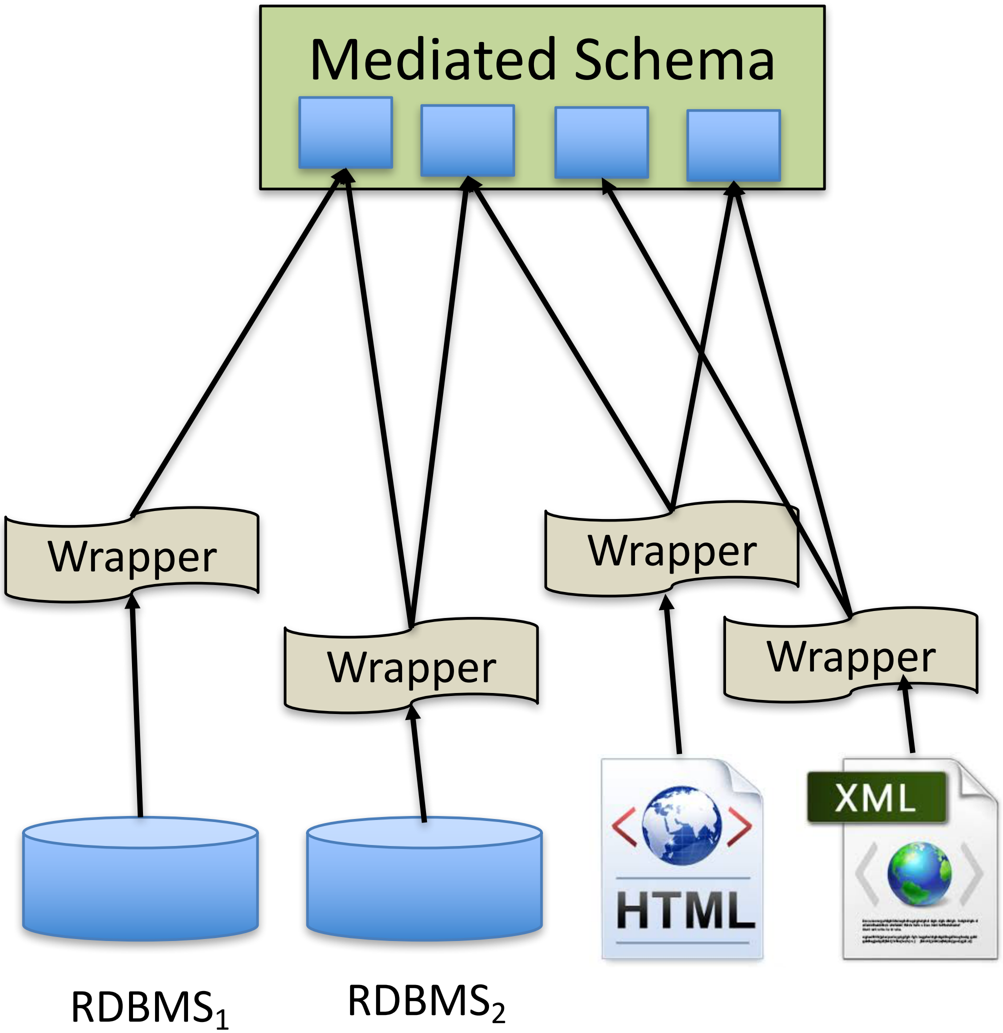
- Data sources
  - can be any data model like relational dbms with SQL interface
  - XML with Xquery interface
  - HTML

Virtual Data Integration Architecture



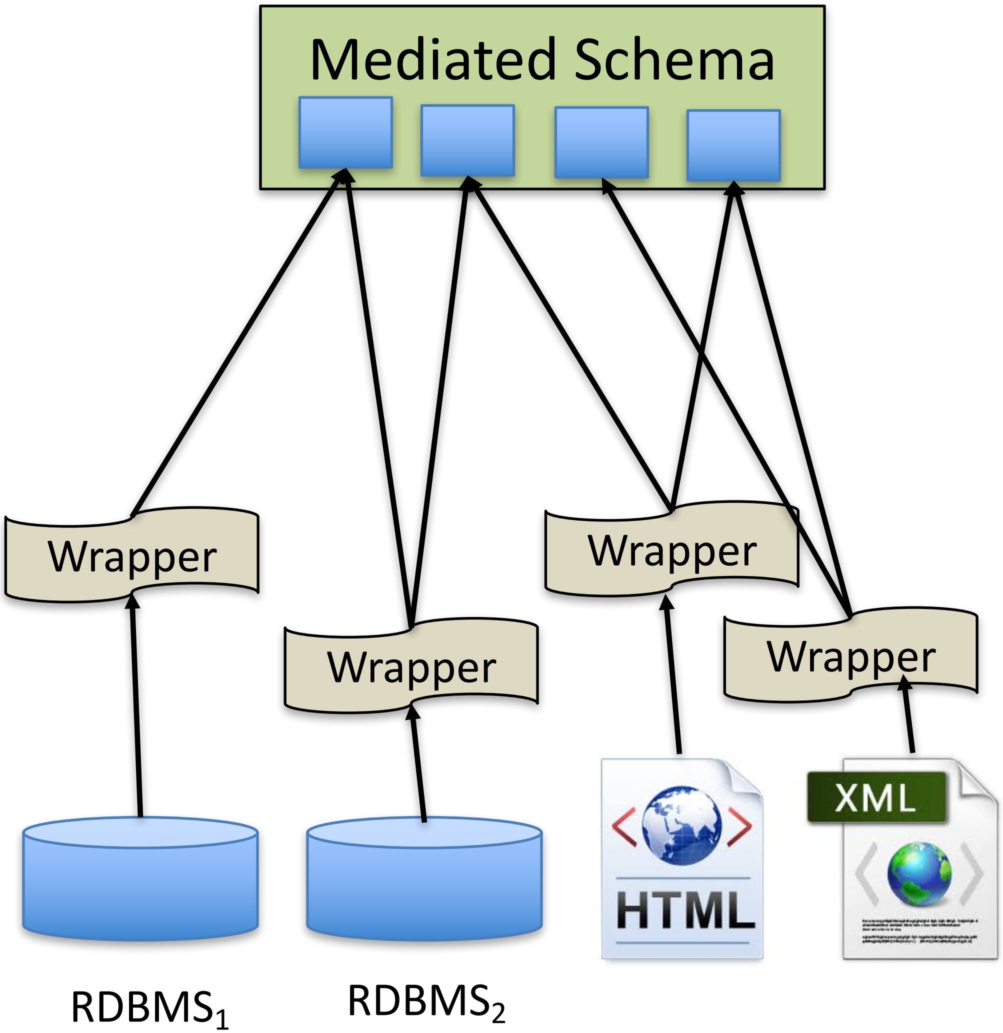
- Wrappers
  - programs that send queries to a data source
  - receives answers
  - apply some basic transformations
- e.g. to a web form source
  - translate query to a http request with a url
  - when the answer comes back as an html file, extract tuples

Virtual Data Integration Architecture



- Mediated schema
  - built for the data integration application
  - contains only the aspects that are relevant
  - may not contain all attrbutes
  - does not store any data typically
  - logical schema for posing queries by the users

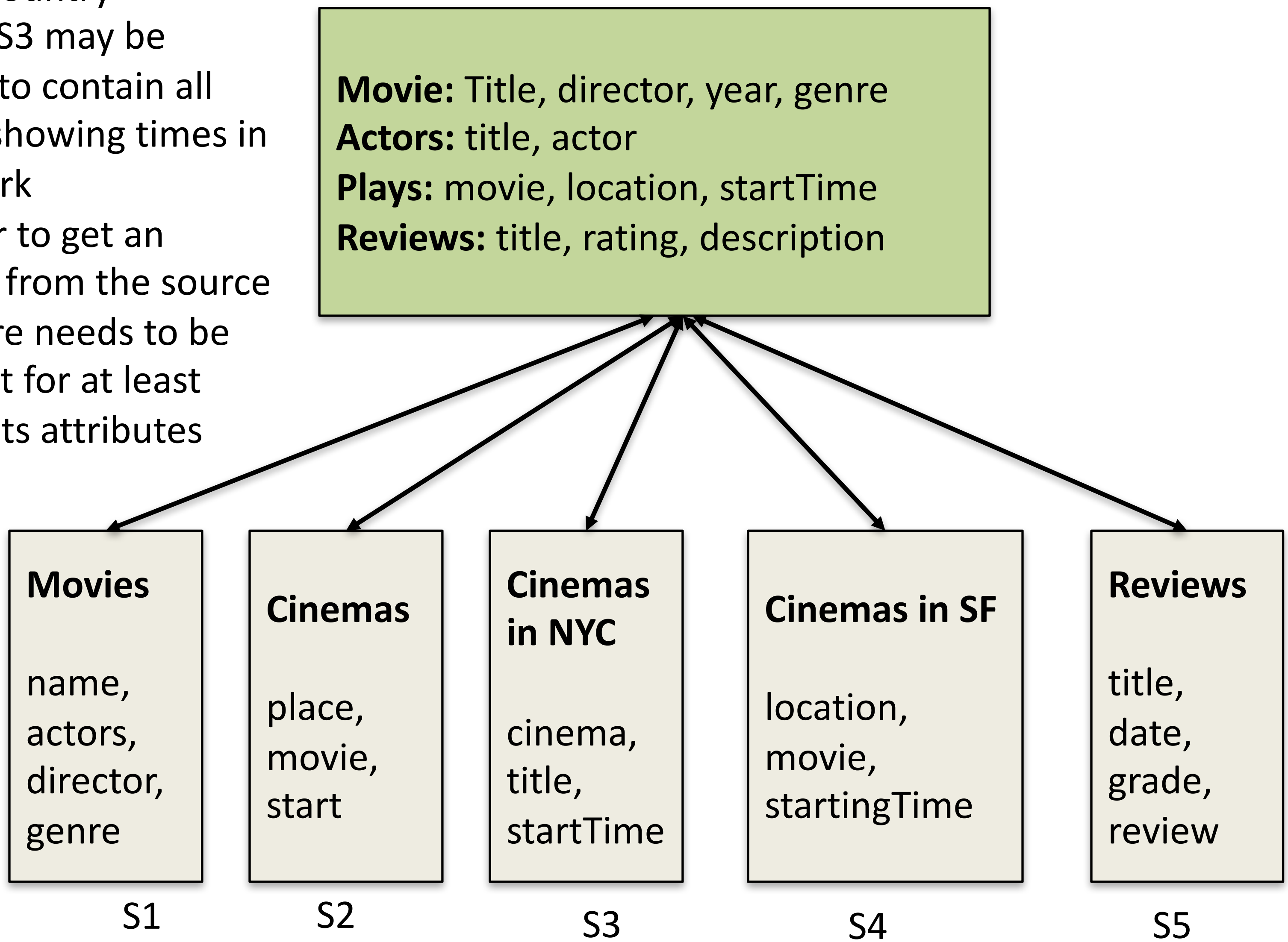
Source Descriptions



- Specify the property of the sources that the system needs to know
- main components are semantic mappings
  - relate the schema of the sources to the attributes in the mediated schema
- specified declaratively
- between data sources and mediated schema
  - not between two sources
- also specifies
  - whether sources are complete or not
  - limited access patterns to sources

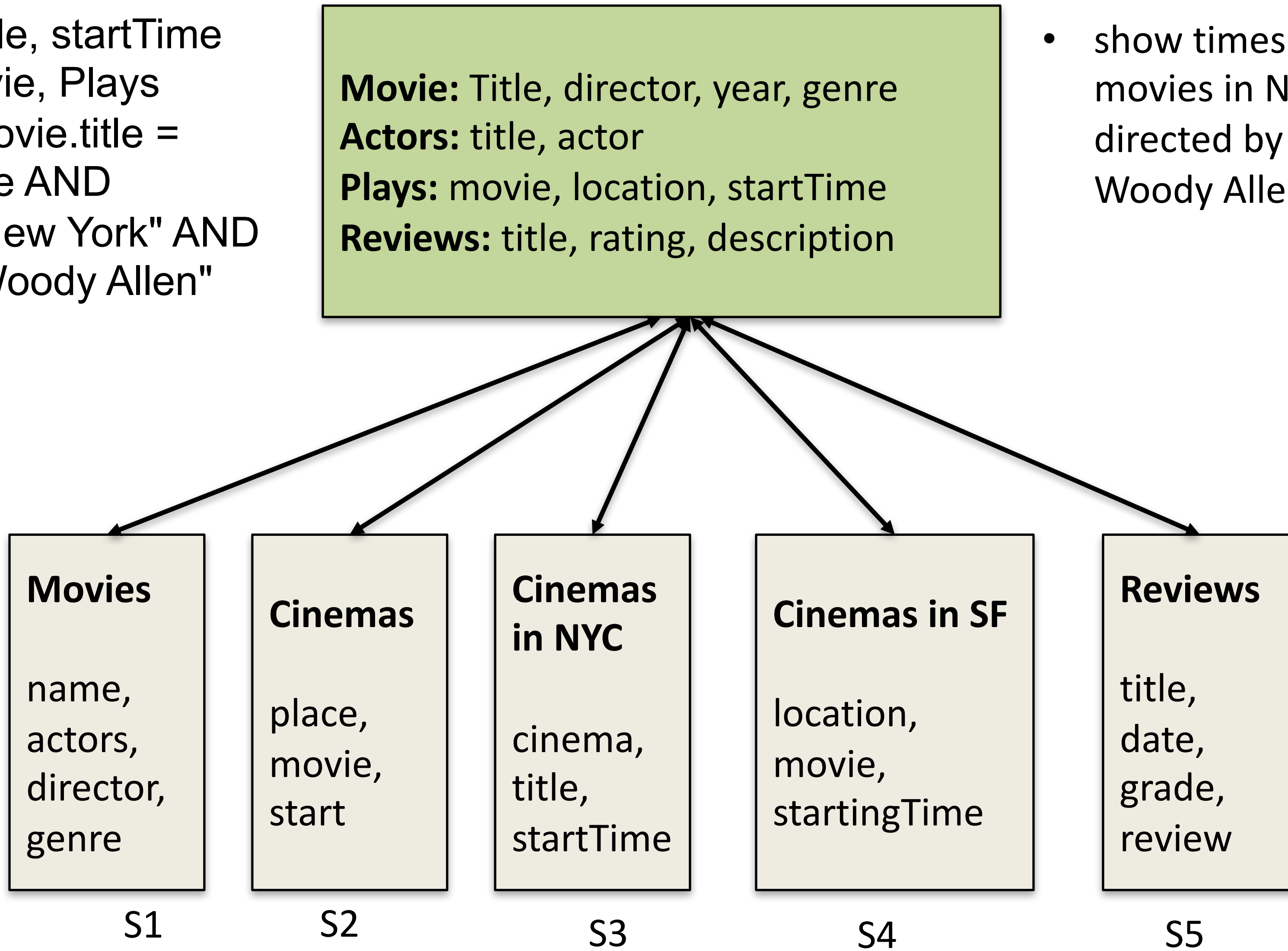
Example

- source S2 may not contain all the movie showing times in the entire country
- source S3 may be known to contain all movie showing times in New York
- in order to get an answer from the source S1, there needs to be an input for at least one of its attributes



Example: Query on the Mediated Schema

SELECT title, startTime
FROM Movie, Plays
WHERE Movie.title =
Plays.movie AND
location="New York" AND
director="Woody Allen"



- show times of movies in NYC directed by Woody Allen

Example: Reformulation on source databases: 1/5

- S2: may not contain all the movie showing times in the entire country
- S3: known to contain all movie times in NYC
- S1: to get an answer there needs to be an input for at least one of its attributes

```
SELECT title, startTime
FROM Movie, Plays
WHERE Movie.title =
Plays.movie AND
location="New York" AND
director="Woody Allen"
```

Movie: Title, director, year, genre
Actors: title, actor
Plays: movie, location, startTime
Reviews: title, rating, description

- Tuples for Movie can be obtained from source S1
  - but the attribute title needs to be reformulated to name

S1	S2	S3	S4	S5
Movies	**Cinemas**	**Cinemas in NYC**	**Cinemas in SF**	**Reviews**
name, actors, director, genre	place, movie, start	cinema, title, startTime	location, movie, startingTime	title, date, grade, review

Example: Reformulation on source databases: 2/5

- S2: may not contain all the movie showing times in the entire country
- S3: known to contain all movie times in NYC
- S1: to get an answer there needs to be an input for at least one of its attributes

- Tuples for Plays can be obtained from either source S2 or S3
  - Since the latter is complete for showings in NYC, we choose it over S2

```
SELECT title, startTime
FROM Movie, Plays
WHERE Movie.title =
Plays.movie AND
location="New York" AND
director="Woody Allen"
```

Movie: Title, director, year, genre
Actors: title, actor
Plays: movie, location, startTime
Reviews: title, rating, description

S1	S2	S3	S4	S5
Movies	**Cinemas**	**Cinemas in NYC**	**Cinemas in SF**	**Reviews**
name, actors, director, genre	place, movie, start	cinema, title, startTime	location, movie, startingTime	title, date, grade, review

- S2: may not contain all the movie showing times in the entire country
- S3: known to contain all movie times in NYC
- S1: to get an answer there needs to be an input for at least one of its attributes

Example: Reformulation on source databases: 3/5

- Source S3 requires the title of a movie as input
  - but such a title is not specified in the query
  - the query plan must first access source S1
  - then feed the movie titles returned from S1 as inputs to S3

```
SELECT title, startTime
FROM Movie, Plays
WHERE Movie.title =
Plays.movie AND
location="New York" AND
director="Woody Allen"
```

Movie: Title, director, year, genre
Actors: title, actor
Plays: movie, location, startTime
Reviews: title, rating, description

S1	S2	S3	S4	S5
Movies	**Cinemas**	**Cinemas in NYC**	**Cinemas in SF**	**Reviews**
name, actors, director, genre	place, movie, start	cinema, title, startTime	location, movie, startingTime	title, date, grade, review

Example: Reformulation on source databases: 4/5

- S2: may not contain all the movie showing times in the entire country
- S3: known to contain all movie times in NYC
- S1: to get an answer there needs to be an input for at least one of its attributes

- Options of logical query plan:
  - access S1, S3
  - could access S1 then S2 as well (possibly not complete)
- Then query optimization
  - as in traditional database system
  - take a logical plan output a physical plan

```
SELECT title, startTime
FROM Movie, Plays
WHERE Movie.title =
Plays.movie AND
location="New York" AND
director="Woody Allen"
```

Movie: Title, director, year, genre
Actors: title, actor
Plays: movie, location, startTime
Reviews: title, rating, description

S1	S2	S3	S4	S5
Movies name, actors, director, genre	**Cinemas** place, movie, start	**Cinemas in NYC** cinema, title, startTime	**Cinemas in SF** location, movie, startingTime	**Reviews** title, date, grade, review

Example: Reformulation on source databases: 5/5

- S2: may not contain all the movie showing times in the entire country
- S3: known to contain all movie times in NYC
- S1: to get an answer there needs to be an input for at least one of its attributes

- Then query execution
  - execute the physical query plan
  - May ask the optimizer to reconsider the plan (unlike RDBMS), e.g. if S3 is too slow
- sometimes contingencies are included in original plan
  - tradeoff between complexity of plan and ability to respond to unexpected events

```
SELECT title, startTime
FROM Movie, Plays
WHERE Movie.title =
Plays.movie AND
location="New York" AND
director="Woody Allen"
```

Movie: Title, director, year, genre
Actors: title, actor
Plays: movie, location, startTime
Reviews: title, rating, description

S1	S2	S3	S4	S5
Movies	**Cinemas**	**Cinemas in NYC**	**Cinemas in SF**	**Reviews**
name, actors, director, genre	place, movie, start	cinema, title, startTime	location, movie, startingTime	title, date, grade, review

Schema Mapping should handle the discrepancies between source and the mediated schema: 1/4

- Relation and attribute names
  - "description" in the mediated schema (MS) the same as "review" in S5
  - "name" of Actors in MS and is S3 in NYCCinemas are not the same

Movie: Title, director, year, genre
Actor: title, name
Plays: movie, location, startTime
Reviews: title, rating, description

Mediated schema

S1:
Actor (AID, firstName, lastName, nationality, yearof Birth)
Movie (MID, title), **AcrtorPlays**(AID, MID)
MovieDetail (MID, directorm genre, year)

S2:
Cinemas(place, movie, start)

S3:
NYCCinemas(name, title, startTime)

S4:
Reviews(title, date, grade, review)

S5:
MovieGenres(title, genre)

S6:
MovieDirectors(title, dir)

S7:
MovieYears(title, year)

Schema Mapping should handle the discrepancies between source and the mediated schema: 2/4

- Tabular organization
  - In MS, Actor stores movie title and actor name
  - In S1, a join is needed that has to be specified by the mapping

S1:
Actor (AID, firstName, lastName, nationality, yearof Birth)
Movie (MID, title), **AcrtorPlays**(AID, MID)
MovieDetail (MID, directorm genre, year)

Movie: Title, director, year, genre
Actor: title, name
Plays: movie, location, startTime
Reviews: title, rating, description

Mediated schema

S2:
Cinemas(place, movie, start)

S3:
NYCCinemas(name, title, startTime)

S4:
Reviews(title, date, grade, review)

S5:
MovieGenres(title, genre)

S6:
MovieDirectors(title, dir)

S7:
MovieYears(title, year)

Schema Mapping should handle the discrepancies between source and the mediated schema: 3/4

- Domain coverage
  - the coverage and level of detail may differ
  - S1 stores more info about actors than in MS

Movie: Title, director, year, genre
Actor: title, name
Plays: movie, location, startTime
Reviews: title, rating, description

Mediated schema

S1:
Actor (AID, firstName, lastName, nationality, yearof Birth)
Movie (MID, title), **AcrtorPlays**(AID, MID)
MovieDetail (MID, directorm genre, year)

S2:
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Reviews(title, date, grade, review)

S5:
MovieGenres(title, genre)

S6:
MovieDirectors(title, dir)

S7:
MovieYears(title, year)

Schema Mapping should handle the discrepancies between source and the mediated schema: 3/4

- Data level variations
  - GPA as a letter grade vs. a numeric score of 4.0 scale
  - S1 stores actor names in two columns, MS stores in one

Movie: Title, director, year, genre
Actor: title, name
Plays: movie, location, startTime
Reviews: title, rating, description

Mediated schema

S1:
Actor (AID, firstName, lastName, nationality, yearof Birth)
Movie (MID, title), **AcrtorPlays**(AID, MID)
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S2:
Cinemas(place, movie, start)

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Three Desired Properties of Schema Mapping Languages 1/3

- Flexibility
  - significant differences between disparate schemas
  - the languages should be very flexible
  - should be able to express a wide variety of relationships between schemas

Three Desired Properties of Schema Mapping Languages 2/3

- Efficient reformulation
  - our goal is to use the schema mapping to reformulate queries
  - we should be able to develop reformulation algorithms whose properties are well understood and are efficient in practice
  - often competes with flexibility, because more expressive languages are typically harder to reason about

Three Desired Properties of Schema Mapping Languages 3/3

- Easy update
  - for a formalism to be useful in practice, it needs to be easy to add and remove sources
  - If adding a new data source potentially requires inspecting all other sources, the resulting system will be hard to manage for a large number of sources

Three standard schema mapping languages

1. Global-as-View (GAV)
2. Local-as-View (LAV)
3. Global-Local-as-View (GLAV)

Global-as-View (GAV)

- GAV defines the mediated schema (MS) as a set of views over the data sources
  - Mediated Schema = Global schema
  - An intuitive approach

- Mediated schema (MS) G
  - G_i = some relation in G
  - X_i denotes attributes in G_i
- Source schema $S_1, S_2, \ldots, S_n$

GAV Definition

- A GAV schema mapping M is a set of expressions of the form:

- $G_i(X_i) \supseteq Q(S_1, S_2, \ldots, S_n)$
  - open world assumption
  - instances computed for MS are assumed to be incomplete

- or, $G_i(X_i) = Q(S_1, S_2, \ldots, S_n)$
  - closed world assumption
  - instances computed for MS are assumed to be complete

GAV Example

- Movie(title, director, year, genre) ⊇ S1.Movie(MID, title), S1.MovieDetail(MID, director, genre, year)
- Movie(title, director, year, genre) ⊇ S5.MovieGenres(title, genre), S6.MovieDirectors(title, director), S7.MovieYears(title, year)
- Plays(movie, location, startTime) ⊇ S2.Cinemas(location, movie, startTime)
- Plays(movie, location, startTime) ⊇ S3.NYCCinemas(location, movie, startTime)

Movie: Title, director, year, genre
Actor: title, name
Plays: movie, location, startTime
Reviews: title, rating, description

Mediated schema

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Actor (AID, firstName, lastName, nationality, yearof Birth)
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MovieYears(title, year)

Discussions: GAV 1/2

- Suppose we have a data source S8 that stored pairs of (actor, director) who worked together on movies.
- The only way to model this source in GAV is with the following two descriptions that use NULL:
  - Actors(NULL, actor) $\supseteq$ S8(actor, director)
  - Movie(NULL, director, NULL, NULL) $\supseteq$ S8(actor, director)
- These descriptions create tuples in the mediated schema that include NULLs in all columns except one

S8:
ActTogether(actor, director)

Movie: Title, director, year, genre
Actor: title, name
Plays: movie, location, startTime
Reviews: title, rating, description

Discussions: GAV 2/2

- If the source S8 includes the tuples (Keaton, Allen) and (Pacino, Coppolag), then the tuples computed for the mediated schema would be:
  - Actors(NULL, Keaton), Actors(NULL, Pacino)
  - Movie(NULL, Allen, NULL, NULL), Movie(NULL, Coppola, NULL, NULL)
- Now suppose we have the following query that recreates S8:
  - Q(actor, director) :- Actors(title, actor), Movie(title, director, genre, year)
- We would not be able to retrieve the tuples from S8 because the source descriptions lost the relationship between actor and director.

S8:
ActTogether(actor, director)

Movie: Title, director, year, genre
Actor: title, name
Plays: movie, location, startTime
Reviews: title, rating, description

Local As View (LAV)

- describes each data source as precisely as possible and independently of any other sources
  – opposite approach to GAV
- Mediated schema (MS) G
- Source schema S_1, S_2, …, S_n
  – X_i denotes attributes in S_i

LAV Definition

- A LAV schema mapping M is a set of expressions of the form:

- $S_i(X_i) \subseteq Q_i(G)$
  - open world assumption

- or, $S_i(X_i) = Q_i(G)$
  - closed world assumption
  - but completeness about data sources, not about the MS

LAV Example

- S5.MovieGenres(title, genre) $\subseteq$ Movie(title, director, year, genre)
- S6.MovieDirectors(title, director) $\subseteq$ Movie(title, director, year, genre)
- S7.MovieYears(title, year) $\subseteq$ Movie(title, director, year, genre)
- S8(actor, dir) $\subseteq$ Movie(title, director, year, genre), Actors(title, actor)
- Can also specify constraints on the contents
- S9(title, year, “comedy”) $\subseteq$ Movie(title, director, year, “comedy”), year $\geq$ 1970

Movie: Title, director, year, genre
Actor: title, name
Plays: movie, location, startTime
Reviews: title, rating, description

Mediated schema

S1:
Actor (AID, firstName, lastName, nationality, yearof Birth)
Movie (MID, title), **ActorPlays**(AID, MID)
MovieDetail (MID, directorm genre, year)

S2:
Cinemas(place, movie, start)

S3:
NYCCinemas(name, title, startTime)

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S5:
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S7:
MovieYears(title, year)

Global-Local-As-View (GLAV)

- GAV and LAV can be combined into GLAV
- Has the expressive power of both
- The expressions in the schema mapping include
  - a query over the data sources on the left hand side
  - a query on the mediated schema on the right-hand side
- Mediated schema (MS) G
- Source schema $S_1, S_2, \ldots, S_n$

GLAV Definition

- A GLAV schema mapping M is a set of expressions of the form:

- $Q^S(X) \subseteq Q^G(X)$
  - open world assumption

- or, $Q^S(X) = Q^G(X)$
  - closed world assumption

- Q^G is a query over G whose head variables are X
- Q^S is a query over data sources S_1, S_2, …, S_n where the head variables are also S

GLAV Example

- Suppose S1 is known to have comedies produced after 1970 only
- S1.Movie(MID, title), S1.MovieDetail(MID, director, genre, year) $\subseteq$
  Movie(title, director, “comedy", year), year ≥ 1970

S1:
Actor (AID, firstName, lastName, nationality, yearof Birth)
Movie (MID, title), **AcrtorPlays**(AID, MID)
MovieDetail (MID, directorm genre, year)

Movie: Title, director, year, genre
Actor: title, name
Plays: movie, location, startTime
Reviews: title, rating, description

Mediated schema

S2:
Cinemas(place, movie, start)

S3:
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Reviews(title, date, grade, review)

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Optional/Additional Slides

optional slide

Schema Matchings and Mappings

- Specify "matches", e.g.
  - attribute "name" in one source corresponds to attribute "title" in another
  - "location" is a concatenation of "city, state, zipcode"
- Elaborate matches into semantic "mappings"
  - using queries like SQL

optional slide

Challenges

- The tasks of creating the matches and mappings are often difficult
  - they require a deep understanding of the semantics of the schemas of the data sources and ofthe mediated schema
  - This knowledge is typically distributed among multiple people
  - these people are not necessarily database experts and may need help
- There is no algorithm that will take two arbitrary database schemas and flawlessly produce correct matches and mappings
  - goal is to create tools that educe the time by giving suggestions to the designer

optional slide

Two database schemas

DVD-VENDOR

Movies(id, title, year)
Products(mid, releaseDate, releaseCompany, basePrice, rating, saleLocID)
Locations(lid, name, taxRate)

AGGREGATOR

Items(name, releaseInfo, classification, price)

- Attributes and tables in a schema are called its elements
- The aggregator is not interested in all the details of the product, but only in the attributes that are shown to its customers
- Schema DVD-VENDOR has 14 elements
  - 11 attributes (e.g., id, title, and year) and three tables (e.g., Movies)
- Schema AGGREGATOR has five elements
  - four attributes and one table.

optional slide

Semantic mapping

DVD-VENDOR

Movies(id, title, year)
Products(mid, releaseDate, releaseCompany, basePrice, rating, saleLocID)
Locations(lid, name, taxRate)

AGGREGATOR

Items(name, releaseInfo, classification, price)

- A query expression that relates a schema S with a schema T
  - recall GAV, LAV, GLAV

optional slide

Semantic mapping - Example 1

DVD-VENDOR

Movies(id, title, year)
Products(mid, releaseDate, releaseCompany, basePrice, rating, saleLocID)
Locations(lid, name, taxRate)

AGGREGATOR

Items(name, releaseInfo, classification, price)

- "the title of Movies in the DVD-VENDOR schema is the name attribute in Items in the AGGREGATOR schema."

- SELECT name as title
- FROM Items

DVD-VENDOR FROM AGGREGATOR

optional slide

Semantic mapping - Example 2

DVD-VENDOR

Movies(id, title, year)
Products(mid, releaseDate, releaseCompany, basePrice, rating, saleLocID)
Locations(lid, name, taxRate)

AGGREGATOR

Items(name, releaseInfo, classification, price)

- "get the price attribute of the Items relation in the AGGREGATOR schema by joining the Products and Locations tables in the DVD-VENDOR schema.."

- SELECT (basePrice * (1 + taxRate)) AS price
- FROM Products , Locations
- WHERE Products . saleLocID = Locations .lid

AGGREGATOR FROM DVD-VENDOR

optional slide

Semantic mapping - Example 3

DVD-VENDOR

Movies(id, title, year)
Products(mid, releaseDate, releaseCompany, basePrice, rating, saleLocID)
Locations(lid, name, taxRate)

AGGREGATOR

Items(name, releaseInfo, classification, price)

- "Get the entire tuple in Items table from DVD-VENDOR"

- SELECT title AS name , releaseDate AS releaseInfo , rating AS
- classification , basePrice * (1 + taxRate) AS price
- FROM Movies , Products , Locations
- WHERE Movies .id = Products .mid AND Products . saleLocID =
- Locations .lid

AGGREGATOR FROM DVD-VENDOR

optional slide

Semantic Matches

- Relates a set of elements in schema S to a set of elements in schema T
  - without specifying the details of the nature of relationship (as SQL queries)

Why are matching and mapping difficult?

optional slide

- The semantics may not be fully captured in the schemas
  - "rating" may imply movie rating, customer rating, etc
  - sometimes accompanied by English text, hard for systems to parse and understand
- Schema clues can be unreliable
  - two elements may have the same name but different meaning, like "name" or "title"
- Semantics can be subjective
  - what "plot-summary" means
  - sometimes a committee of experts vote
- Combining data may be difficult
  - need to figure out a join path
  - full/left/right outer join or inner join
  - may need filter conditions
  - the designer has figure these out inspecting a large amount of data
  - erroneous and labor prone

Components in a schema matching system

optional slide

- Matchers
- Combiners
- Constraint Enforcers
- Match Selectors

optional slide

1. Matchers

- schemas → similarity matrix
- takes two schemas S and T as input
- outputs a similarity matrix
- assigns to each element pair s of S and t of T a number between 0 and 1
  - higher the number, s and t are more similar
- e.g.
  - name ≈ <name: 1, title : 0:5>
  - releaseInfo ≈ <releaseDate : 0:6, releaseCompany: 0.4>
  - price ≈ <basePrice : 0:5>

optional slide

Types of Matchers

- Name-based matchers
  - compares the names of elements
  - but almost never written the same way
  - uses techniques for string matching as edit distance, Jaccard measure etc.; synonyms; normalization (capital letters); hyphens; etc
- Instance-based matchers
  - Look at data instances, builds recognizers (dictionaries), computes overlaps, classification

optional slide

2. Combiners

- matrix × …. × matrix → matrix
- merges the similarity matrices output by the matchers into a single one
- can take the average, minimum, maximum, or a weighted sum of the similarity scores

optional slide

Types of Combiners

- Average combiners:
  - Suppose k matchers to predict the scores between the element s_i of schema S and the element t_j of schema T
  - then an average combiner will compute the score between these two elements as the average from these k matchers
- Hand-crafted scripts
  - e.g. if s_i = address, return score of naïve-bayes classifer, else average
- Weighted combiner
  - gives weights to each matcher

optional slide

3. Constraint Enforcers

- matrix $\times$ constraints $\rightarrow$ matrix

- In addition to clues and heuristics, domain knowledge plays an important role in pruning candidate matches
  - e.g. knowing that many movie titles contain four words or more, but most location names do not, can help us guess that Items.name is more likely to match Movies.title than Locations.name
- an enforcer enforces such constraints on the candidate matches
  - it transforms the similarity matrix produced by the combiner into another one that better reflects the true similarities

optional slide

Types of Constraint Enforcers : 1/2

- There may be hard or soft domain integrity constraints
- Hard constraints must be applied
  - The enforcer will not output any match combination that violates them
- Soft constraints are of more heuristic nature, and may actually be violated in correct match combinations
  - the enforcer will try to minimize the number (and weight) of the soft constraints being violated
  - but may still output a match combination that violates one or more of them
- Formally, we attach a cost to each constraint
  - For hard constraints, the cost is 1
  - for soft constraints, the cost can be any positive number.

optional slide

Types of Constraint Enforcers : 2/2

- e.g.
  - c1: If A Items.code, then A is a key (weight = infinity)
  - c2 If A Items.desc, then any random sample of 100 data instances of A must have an average length of at least 20 words (weight = 1.5)
  - c3: If more than half of the attributes of Table U matches those of Table V , then U is similar to V (weight = 1)

optional slide

4. Match Selectors

- matrix → matches

- Produces matches from the similarity matrix output by the constraint enforcer

- name ≈ <title : 0:5>
- releaseInfo ≈ <releaseDate : 0:6>
- classication ≈ <rating : 0:3>
- price ≈ <basePrice : 0:5>
- Given the threshold 0.5, the match selector produces matches:
  - name ≈ title, releaseInfo ≈ releaseDate, and price ≈ basePrice

optional slide

Types of Match Selectors

- The simplest selection strategy is thresholding
  - all pairs of schema elements with similarity score exceeding a given threshold are returned as matches
- More complex strategies include formulating the selection as an optimization problem over a weighted bipartite graph